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# THE CARLSBERG FOUNDATION'S <br> OCEANOGRAPHICAL EXPEDITION ROUND THE WORLD 1928-30 AND PREVIOUS "DANA"-EXPEDITIONS 

UNDER THE LEADERSHIP OF THE LATE PROFESSOR JOHANNES SCHMIDT

# FURTHER STUDIES ON THE NON-NUCLEATED ERYTHROCYTES OF MAUROLICUS MÜLLERI, AND COMPARISONS WITH THE BLOOD CELLS OF RELATED FISHES 

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## WITH 3 PLATES

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# FURTHER STUDIES ON THE NON-NUCLEATED ERYTHROCYTES OF MAUROLICUS MÜLLERI, AND COMPARISONS WITH THE BLOOD CELLS OF RELATED FISHES 

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## INTRODUCTION

As reported in a preliminary paper by Wingstrand (1956), the erythrocytes of the fish Maurolicus mülleri (Gmelin) differ from those of other fishes in three important respects: 1) They have no nuclei 2) They are exceptionally small, measuring approximately $5 \times 2.5 \mu$, and 3) They do not seem to be flattened.

Predominance of non-nucleated crythrocytes was previously known only in mammals and in the urodelan genus Batrachoseps. As far as size is concerned, the erythrocytes of Maurolicus appear to be unique among non-mammalian vertebrates. Only a few mammals have equally small or even smaller erythrocytes. Nonflattened erythrocytes do not seem to be known in any other vertebrates.

Since the preliminary report was written, the present authors have examined more material and have been able to confirm and amplify the statements cited above. Moreover, we have tried to find an answer to three definite questions which were raised by the preliminary work:

1. How do the erythrocytes of Maurolicus loose their nuclei during cytogenesis? This problem was approached through a study of the hematopoesis.
2. Are the non-nucleated erythrocytes restricted to the species Maurolicus mülleri, or do they occur also in other fish species which are related to Maurolicus systematically or biologically? This required a comparative investigation of the blood in related fishes.
3. What is the functional significance of the exceptional erythrocytes in Maurolicus?

## MATERIAL AND METHODS

Erythropoesis in Maurolicus was studied in paraffin sections of some well preserved specimens, which were fixed in Bouin by Vagn Kr. Hansen on the research vessel "Dana" during the trips to Greenland and Jeeland in $1956-1959.8 \mu$ scetions were used for orientation, but $4 \mu$ sections proved necessary for detailed studies of the ceils. Ehrlich's hematoxylin and eosin was used as a routine stain. A few slides were stained by the Feulgen technique, with light green as a counterstain for safe identification of nuclear structures, and some additional slides were stained with the gallocyanine-chrome-alum according to the method proposed by Einarson (1932) for studies of basophilic substances in general.

The species used in the comparative studies of erythrocyte morphology are listed in the Table 1. Most of the material consisted of Bouir material, cut into $8 \mu$ sections and stained in Ehrlich's hematoxylin and cosin, a procedure which proved sufficient for a study of the gross morphology of the erythrocytes. As a control we have also used blood smears from a number of species. These slides were dried, fixed in $100 \%$ methanol and stained in Giemsa's stain.

Most of the Bouin material and all of the blood smears were collected by Vagn Kr. Havsen. We have also used some Bouin and formalin material of previous "Dana"-collections, and Bouin-fixed specimens preserved by dr. Th. Vilstrup during the Galathea expedition in $1950-1952$. Finally, we have had acces to some existing slides made from interesting species, which were placed at our disposal by dr. E. Bertelsen and Mr. U. Holmgren ${ }^{1}$
${ }^{1}$ The authors want to express their sincere thanks to Dr. A. Bricin, the leader of the Galathea expedition, to Dr. A. Vedel Tixing (t) and Dr. E. Bertelsen, former and present directors of the Danish Institute for Fishery and Marine Research (Charlottenlund), for placing material of the respective collections at our disposal, and to Dr. Th. Vilstrup, Copenhagen, and Mr. U. Holmgres, Sweden, for additional material. We are also greatly indebted to Dr. J. Jorgensen, Copenhagen, for valuable help, to Mr. Magntsson, chemist at Tórshavn, the Faroes, who kindly put his Beckman D. L'.-spectrophotometer at our disposal, and to Dr. G. Mfad, Harvard. U.S.A. for reviewing for the English text.
has eliminated its nucleus. This conclusion is valid, even if the hemoglobin bodies in our Maurolicus pre. parations should turn out to be artefacts.

Among the non-mammalian vertebrates, the amphibian genus Batrachoseps was previously the only ont known to have predominantly non-nucleated erythrocytes in the blood (Eisen 1897, Giglo-Tos 1899, Emmie 1920-1924, Matrer 1920, Комоскi 1930, 1939, Slonimski 1938, Dcrax-Jonda 1951). According to Emmei (1924) the non-nucleated dises in this species are formed by plasmotomy of ordinary, nucleated erythrocytes This would explain why they are so variable in size ( $3,4--30 \mu$ ). Other interpretations of the origin of thes dises have been published by Komocki (1930, 1932), Slonimski (1938) and Duran-Jorda (1951). At any rate it is obvious that the non-nucleated discs in Batrachoseps arise in a way quite different from the erythro. poesis in Maurolicus.

Although the erythropoesis in Maurolicus agrees in some respects with that of mammals, some phylogenetica! considerations leave no doubt about the independent evolution of the non-nucleated blood corpuscles in th. three groups mentioned: Mammals, Batrachoseps and Maurolicus.

## ERYTHROCYTE MORPHOLOGY IN FiShes RELATED TO MaUROLICUS SYSTEMATICALLY OR BIOLOGICALLY

Taxonomists place Maurolicus within the family Gonostomidae of the suborder Stomiatoidei among th clupeiform (isospondylous) fishes (Regan 1923, Parr 1930, Norman 1931, Berg 1940, Bertin and Aram botrg 1958). We therefore tried to study a representative sample of this suborder for a comparison witl Maurolicus. We also included representatives of the suborders Opisthoproctoidei and Myctophoidei (Iniomi). which contain many species similar to Maurolicus in their habits although less closely related to this genus taxonomically (see Berg 1940, Bertin and Arambourg 1958), and a few species from more distantly related groups (see Table 1).

Non-nucleated erythrocytes were found only in the gonostomid species Valenciennellus tripunctulatus: and Vinciguerria lucetia. All the other species were found to have nucleated crythrocytes, but they presented some hematological features of considerable interest for the present problem and will therefore be dealt with in some detail. In many species, particularly within the Stomiatoidei and Myctophoidei, crystallization: of the hemoglobin completely alters the appearance of the erythrocytes soon after the death of the animal This feature has to be considered when the morphology of the cells is discussed.

## Non-nucleated Erythrocytes in Vinciguerria and Valenciennellus.

Two section series of Vinciguerria lucetia show that this species is similar in blood morphology to Maurolicus. The erythrocytes are non-nucleated blunt rods, measuring about $5.5 \times 2.5 \mu$. They are not flattened but look circular in an optical cross section. As in Maurolicus, very few nuclei are found in the blood (less than 1 pel cent). They are probably all situated in lymphocytes or leucocytes. A blood smear and a section series of Valenciennellus tripunctulatus show that this species too has non-nucleated erythrocytes, whereas its lymphoeytes and leucorytes contain distinct and well-stained nuclei. The erythrocytes of Valenciennellus are non flattened glohules, which measure $7 \times 7 \mu$ in the Bouin-fixed sections (Fig. 20). They are thus very different from the small, rod-shaped erythrocytes found in Maurolicus and Vinciguerria. In the sections of Valenciennellus, non-erystallized erythrocytes with even contours were found only in the superficial vessels of the gills. together with cells in which erystallization had resulted in the formation of numerous small hemoglohin bodies (Fig. 20). In the internal vessels the shape of the erythrocytes is distorted by the formation of larger hemoglobin bodies. Such crystallization of the hemoglobin was never seen in Maurolicus and Vinciguerria.

## Nucleated Erythrocytes.

All the other fishes in our material have typical compact nuclei in their oval, disc-like erythrocytes. In fresh and well-fixed cells the position of the nucleus is strictly central. This is also true for the nucleated erythrocytes of stomiatoids (Figs. 10, 23), but many blood preparations of these and other species may show an entirely different picture because of postmortal crystallization of the hemoglobin. When one single hemoglobin body is formed in each erythrocyte (e.g. in Argyropelecus, Stomias and Gonostoma) the nucleus is pushed to the side and may appear as a kind of appendix to the blood corpuscle, sometimes lying at the end of the hemoglobin body, sometimes attached to its side (Figs. 13-15, 24). When two or more hemoglobin bodies are formed within each cell as in Lampanyctus, Myctophum, Bathylagus and Ipnops, the nucleus remains approximately central, surrounded by the hemoglobin bodies (Figs. 16, 19, 22).

Exceptional, non-nucleated erytirocytes have been found among the normal, nucleated ones in a number of non-mammalian vertebrates and also in some teleosts (Babldideri 1930, Oria 1933, Cattov 1951). They appear to be very rare in teleosts. Oria never found more than 0.5 per cent in his material which included 23 different species. A few such "erythroplastids" were found also in our smear preparations of Pleuronectes and Anguilla. They usually look like the normal erythrocytes except for the absence of the nucleus and are thus a poor parallel to the erythrocytes in Maurolicus, which also differ considerably in size and shape from the normal fish erythrocytes.

Size and shape of the erythrocytes. The small size of the erythrocytes in Maurolicus and Vinciguerria appears to be unique among fishes. All the other species investigated by us, including other stomiatoids, have erythrocytes which fall within the limits of variation published by previous investigators of teleosts or even exceed the known maximum. The size measured for the different species is recorded in table 1 . It should be noted, however, that we have not attempted very accurate measurements, because it is known that the size is strongly influenced by shrinkage during the fixation (Catrox 1951). Two abyssal fishes in our material have exceptionally large erythrocytes, viz. Ipnops murrayi $(19 \times 12 \mu)$ and Bathypterois longipes $(20 \times 15 \mu)$ (Figs. 11, 16). This is definitely above the maximum size known for teleosts, as will appear from the Table 2.

With the exception of Maurolicus, Vinciguerria, and Valenciennellus all the fishes investigated by us have flattened erythrocytes of the common teleost type, n. b. before crystallization has taken place. As seen from the surface, such erythrocytes are oval or nearly round (Fig. $9-11,18,23$ ), and as seen from the margin in sections, they are flat discs which are about $2-3 \mu$ thick in the majority of species but reach $5-6 \mu$ in Ipnops and Bathypterois. The discs are usually somewhat narrower in the centre, where the nucleus is located (Fig. 23).

Formation of hemoglobin crystals. Intracellular crystallization of hemoglobin has been described in teleosts by Yoffey (1929, in gadids) and Dawson (1932, in Syngnathus). Dawson concluded that crystallization is indueed by slow drying of the blood smears, particularly if the smear is thick and the humidity is high. Preceeding the appearance of crystalline bodies, the cells assume a triangular or rhomboidal shape. Then clefts appear in the hemoglobin, which soon contracts to form definite bodies. In the species investigated by Dawsox, two to four bodies were formed in the majority of cells.

Crystallization of the hemoglobin takes place very rapidly and is a characteristic feature in many species included in the present investigation (Table 1). Large and distinct hemoglobin bodies of different types were seen in all the stomiatoids except Chuuliodus and Idiacanthus, in all the myetophoids except M. arcticum, in Bathylagus, Neoscopelarcus, Gadus, Motella, and in the smallest fish known, Schindleria. The negative finds in Chauliodus, Idiacunthus and Myctophum arcticum are hardly significant, for only one specimen of each species was investigated.

The other fishes included in the investigation do not show crystallization or the bodies formed are so small that they appear as a diffuse granulation of the plasm. Recalling that Dawsor has described beautiful hemoglobin bodies in Syngnathus fuscus (order Syngnathiformes), we may conclude that the phenomenon

Table 1. The teleost species investigated.
The table shows the number of blood smears (b), the number of specimens sectioned in paraffin (p), the presence ( + ) or absence ( - ) of nuclei in the erythrocytes, the approximate size of the erythrocytes ( $\pm 1-2 \mu$ ), and the number of hemoglobin bodies formed in each erythrocyte, in case crystallization has been observed. System according to Bertin and Arambourg (1958).

|  | Number of specimens | Nucleus | Size in $\mu$ | Number of hemoglobin bodies |
| :---: | :---: | :---: | :---: | :---: |
| Order Clupeiformes |  |  |  |  |
| Suborder Clupeoidei |  |  |  |  |
| Family Clupeidae |  |  |  |  |
| Clupea harengus L . | 1p | $\dagger$ | $?$ | - |
| Suborder Salmonoidei |  |  |  |  |
| Family Salmonidae |  |  |  |  |
| Salmo irideus Gibbons | 4b | + | $14 \times 9$ | - |
| Suborder Opisthoproctoidei |  |  |  |  |
| Family Bathylagidae |  |  |  |  |
| Bathylagus sp. | 3p | $+$ | $17 \times 12 \times 5$ | several |
| Suborder Stomiatoidei |  |  |  |  |
| Family Gonostomidae |  |  |  |  |
| Gonostoma elongatum Günther | 2p | $+$ | $12 \times 7 \times 2$ | 1(-2) |
| Cyclothone signata Bracer... | 5p | + | $15 \times 10 \times 3$ | 1-2 |
| -- microdon (Günther). | 2 p | $+$ | $(9 \times 7)$ | 1 |
| Vinciguerria lucetia Garman | 2p | - | $5 \times 2.5 \times 2.5$ | ? |
| Photichthys argenteus Hutton | 1p | $+$ | $11 \times 7 \times 3$ | 1(-2) |
| Diplophos taenia Günther | 1p | $+$ | $8 \times 5 \times 2$ | 1-2(-4) |
| Maurolicus mülleri (Gmelin) | 3b, 9p | - | $5 \times 2.5 \times 2.5$ | ? |
| Valenciennellus tripunclulatus (Esmark) | 1b, 1p | -- | $7 \times 7$ | several |
| Family Sternoptychidae |  |  |  |  |
| Argyropelecus hemigymnus Cocco | 12b, 2p | $+$ | $15 \times 6 \times 5$ | 1 |
| - olfersi (Cuvier) | 2p | $+$ | $15 \times 6 \times 5$ | 1 |
| Sternoplyx diaphana Hermann | 3p | + | $11 \times 10 \times 3$ | $1(-\infty)$ |
| Family Astronesthidae |  |  |  |  |
| Astronesthes indicus Braver | 1p | $+$ | $11 \times 8 \times 3$ | 1-3 |
| Family Melanostomiatidae |  |  |  |  |
| Bathophilus pawneei Parr | 1p | $+$ | $11 \times 7 \times 2$ | $1-\infty$ |
| Family Idiacanthidae |  |  |  |  |
| Idiacanthus niger Regan | 1p | $+$ | $(7 \times 5)$ | $?$ |
| Family Stomiatidae |  |  |  |  |
| Stomias boa ferox Reinhardt | 4b, 5p | $+$ | $16 \times 8 \times 5$ | 1 |
| Family Chauliodontidae |  |  |  |  |
| Chauliodus sloanei Schneider | 2p | $+$ | $15 \times 11 \times 3$ | - |
| Suborder Esocoidei |  |  |  |  |
| Family Esocidae |  |  |  |  |
| Esox lucius L. | 1p | $+$ | $?$ | - |
| Suborder Alepisauroidei |  |  |  |  |
| Family Scopelarchidae |  |  |  |  |
| Neoscopelarchas dana | 3b, 2p | + | $12 \times 8 \times 2$ | 1 |
| Suborder Myctophoidei |  |  |  |  |
| Family Bathypteroidae |  |  |  |  |
| Bathyplerois longipes Günther | 1p | $+$ | $20 \times 15 \times 6$ | several |
| Ipnops murrayi Günther. . | 2 p | $+$ | $19 \times 14 \times 6$ | several |
| Family Myctophidae |  |  |  |  |
| Myctophum glaciale (Reinhard) | 5b, 2p | $+$ | $16 \times 9 \times 4$ | $(1-) 2-4$ |
| - arcticum (Lëtken) | 1b | $+$ | $10 \times 7$ | - |
| - punctatum (Rafinesque). | 3b | $+$ | $11 \times 8$ | $2(-4)$ |
| Lampanyctus crocodilus Risso | 7b, 4p | $+$ | $13 \times 8 \times 4$ | $2(-3)$ |
| Order Tetraodontitormes |  |  |  |  |
| Suborder Tetraodontoidei |  |  |  |  |
| Family Tetraodontidae |  |  |  |  |
| Tetraodon sp. . . . . . | 1p | $+$ | $8 \times 5 \times 2$ | - |

Table 1 (continued).

|  | Number of specimens | Nucleus | Size in $\mu$ | Number of hemoglobin bodies |
| :---: | :---: | :---: | :---: | :---: |
| Order Cypriniformes |  |  |  |  |
| Suborder Cyprinoidei |  |  |  |  |
| Family Cyprinidae |  |  |  |  |
| Carassius auratus (L.). | 2b | + | $13 \times 8$ | - |
| Order Anguilliformes |  |  |  |  |
| Suborder Anguilloidei |  |  |  |  |
| Family Anguillidae |  |  |  |  |
| Anguilla vulgaris Turton. | 2b, 4p | $+$ | $12 \times 9 \times 3$ | 一 |
| Order Cyprinodontiformes |  |  |  |  |
| Family Cyprinodontidae |  |  |  |  |
| L.ebistes reticulatus (Peters).... | 4b | $+$ | $8 \times 6$ | - |
| Order Gadiformes |  |  |  |  |
|  |  |  |  |  |
| Macrurus fabrici Sundevall. | 1b | + | $11 \times 7$ | - |
| - rupestris Gunnerus. | 3b | + | $13 \times 11$ | -- |
| Family Gadidae |  |  |  |  |
| Gadus callarias L. | 4b, 1p | + | $9 \times 5 \times 2$ | 2-4 |
| Onos maculatus Risso | 1b | + | $10 \times 8$ | - |
| - sp. | 2b | + | $10 \times 5$ | 1-3 |
| Order Stephanoberychiformes |  |  |  |  |
| Family Malamphaeidae Melamphaes sp....... | 1b, 2p | + | $15 \times 12 \times 6$ | - |
| Order Percitormes |  |  |  |  |
| Suborder Blennoidei |  |  |  |  |
| Family Anarhichidae |  |  |  |  |
| Anarhichas latifrons Steenstrup | 2b | + | $10 \times 7$ | - |
| Family Schindlerildae |  |  |  |  |
| Schindleria sp. | 2p | + | $10 \times 5 \times 3$ | several |
| Suborder Echeneoidei |  |  |  |  |
| Family Echeneidae |  |  |  |  |
| Remora remora L. | 1 p | + | $9 \times 6 \times 3$ | - |
| Suborder Cottoidei |  |  |  |  |
| Family Cottidae |  |  |  |  |
| Cottunculus sp. | 1b | + | $15 \times 11$ | - |
| Orde:: Pleuronectiformes |  |  |  |  |
| Suborder Pleuronectoidei |  |  |  |  |
| Family Cynoglossidae |  |  |  |  |
| Pleuronectes platessa L | 2b | + | $11 \times 8$ | - |

is not restricted to a particular taxonomical group but has been observed in members of four different orders (see Table 1). It is difficult to find biological features common to all the fishes which show this crystallization, except for the fact that they are all marine.

The general course of the crystallization in our material is as described by Dawsox (1932). First, a slight angularity of the erythrocytes can be seen, then clefts appear in the hemoglobin, which finally contracts to form definite rods or lumps. The final phase is often accompanied by a complete alteration of the shape of the blood corpuscle (Figs. 12-24). The number and shape of the bodies in each erythrocyte is essentially characteristic of the different species but may be somewhat modified by the conditions under which the process takes place.

When critisizing Kranz' (1928) descriptions of hemoglobin crystals in mammals, Tschachmachtschian (1932) suggested that they are remnants of inconpletely dissolved paraffin crystals, which for some reason or other have been left in the sections. This is not true in the fishes investigated by us. Bodies of similar shape are present both in sections of Bouin-fixed material and in smears. The latter have never been in contact with parafin. They were also seen in iresh, untreated 'blood spread under a corersitp, e. g. in hivod from a specimen of Myctophum glaciale which had been dead for 11 hours.

Table 2. The size of the erythrocytes in teleosts recorded by different investigators.

| Author | Number of species investigated | Size limits in $\mu$ |
| :---: | :---: | :---: |
| Gulliver [1875] | 73 | $9.5-16.7 \times 7.2-10.3$ |
| Schlicher [1927] | 17 | $9-16 \times 6.5-9$ |
| Oria [1933] | 23 | $8--15 \times 7-12$ |
| Dichavid [1950] | 32 | $7.0-14.6 \times 5.5-11.3$ |
| For comparison: |  |  |
| Bathyplerois longipes. |  | $20 \times 15$ |
| Maurolicus mülleri |  | $5 \times 2.5$ |
| Valenciennellus tripunctulatus |  | $7 \times 7$ |

The very frequent appearance of erystals both in smears and section preparations of some species indicatethat they form very rapidly after the death of the animal. This was confirmed in 1958 by some systematical experiments with fishes of the genus Myctophum. Two smears of blood from living specimens of M. glacial, and M. arcticum do not show any hemoglobin bodies in the mature erythrocytes, but some small ones have formed in the immature erythroeytes. A smear from a specimen of M. glaciale which had been dead for 30 minutes, shows clefts and beginning of crystallization in most erythrocytes (Fig. 18), and in a specimen whicl: had been dead for 11 hours there are hemoglobin bodies in all erythrocytes in the smear. When fresh blood samples from the latter specimen were spread under a coverslip, the hemoglobin bodies could be seen directly: in the microscope. This shows that crystallization takes place in the vessels of the dead animal.

On the other hand, it is obvious that the crystallization is accelerated and accentuated by the drying of blood smears, for erystals are often distinet in the stained preparations although only a slight angularity of the cells could be seen in the fresh blood. In paraffin sections of Bouin material, crystallization is usually: complete in the internal vessels and the heart, probably because of the slow penetration of the fluids, whereas the blood in the superficial vessels of the gills may be little changed (Figs. 21-24).

In general, the shape and the number of the bodies formed in each erythrocyte is characteristic of the species concerned. In Argyropelecus, Gonostoma, Photichthys, Stomias and Neoscopelarchus, there is usually one single rod-like body in each cell (Figs. 13-15, 17, 24). It is often cresent-shaped with blunt ends, and the nucleus of the cell is pushed to the side or adheres to the end of the hemoglobin body. The rest of the cytoplasm tends to shrink up and may be difficult to see.

One or two hemoglobin bodies in each cell is the rule in Cyclothone and Diplophos. In Myctophum and Lampanyctus there are usually two cresentic bodies which encircle the nucleus from each side (Fig. 19), but one, three or four are occasionally found. Sometimes the number is more variable as in Astronesthes, Motella and Gadus which have between one and four (Fig. 12). Sternoptyx, Bathylagus and Bathophilus are still more variable, the number of borlies found within each erythrocete ranging from one or a few to several. In Bathypterois and Ipnops the hemoglobin either forms small diffuse granules or is concentrated in small lumps or threads (Figs. 11, 16). Schindleria also has several lump-like bodies in each ersthrocyte.

Although used by previous authors the term erystal is hardly justified for the bodies formed in the erythrocytes. The bodies have no distinct angles, and even surfaces are never seen. They do not show birefringence between crossed nicols. The bodies formed are therefore hardly regular crystals, although they are probably composed of smaller, crystalline units.

The shape of the hemoglobin bodies is different from one species to another. In most fishes investigated they are elongate, cresentic or rod-shaped with blunt ends, but rounded or more irregular forms are found in Bathylagus and Schindleria (Figs. 21, 22). In Ipnops and Bathypterois the hemoglobin often condenses to form thread-like structures (Figs. 16, 11). The single body found in the erythrocytes of Neoscopelarchus can be seen to consist of a bundle of thin needles which, perhaps, represent true paracrystalline units (Fig. 17).

The effect of environmental factors on the number and size of the bodies can sometimes be distinctly seen. In sections of Bathylagus there are many small bodies in the erythrocytes lying in the gill vessels, where
precipitation has been rapid, whereas a few larger bodies are present in the cells lying in the heart and the internal vessels, where precipitation is slow (Figs. 21-22). Similar differences can be seen in blood smears when the drying has been uneven.

## Some Observations on the Hemoglobin.

The rapid crystallization of the blood pigment in most stomiatoids and myctophoids, and the tendency of the bodies formed to take a bluish or blackish colour in the Giemsa-stained blood smears, made us uncertain about the kind of pigment involved. It was therefore decided to make a spectrophotometric analysis of the blood of the said fishes during the "Dana"'s cruise to the Faroe-Island area in 1959 . The only relevant species caught in time for the investigation was Myctophum glaciale, four specimens of which wre cbtained. The blood was pipetted into test tubes, prepared with heparin, and kept cold. When the ship arrived at Tórshavn, the sample was analyzed in a Beckman DL spectrophotometer according to the technique described by Hunter (1951, pp. 106-107 and 110-111).

The absorption curves obtained are the ones typical of oxyhemoglobin and reduced hemoglobin:
Oxyhemcglobin: Absorbtion minima at about $490 \mathrm{~m} \mu, 560 \mathrm{~m} \mu$, and from $590 \mathrm{~m} / \mu$ on ; maxima at $540-550 \mathrm{~m} \mu$ and $.70 \mathrm{~m} \mu$.

Reduced hemoglobin: Absorption minimum at $460-500 \mathrm{~m} \mu$, and a single minimum at $550-560 \mathrm{~m} \mu$.
Blood from Hippoglossus hippoglossus, Microstomus kilt, Melanogrammus aeglefinus, Merlangus merlangus, and Argentina silus was analysed in the same way for comparison, and an identical result was obtained.

Consequently, the blood pigment of Myctophum is a true hemoglobin, and its abnormal blackish staining in many preparations is probably explained by the notorius sensitivity of this method to impurities. When blood smears are made of these small fishes on the ship it is very dif ficult to avoid contamination with small droplets of sea water or salt crystals, which may influence the result of the staining. Actually, a normal reddish staining of the hemoglobin bodies was obtained in some preparations. The tinctorial affinities of the hemoglobin in Bouin-fixed sections of these fishes are normal. Thus there is no reason to attach significance to the blackish colour of the hemoglobin obtained in blood smears of Myctophum and some related species.

## Discussion.

The survey of the erythrocyte morphology in different fishes has shown that the small, non-flattened and non-nucleated erythrocytes found in Maurolicus also occur in the stomiatoid fishes Vinciguerria lucetia and Velenciennellus tripunctulatus. The presence of non-nucleated erythrocytes in Valenciennellus is expected, for this genus is regarded as closely related to Maurolicus and has been placed together with this genus in a separate subfamily, the Maurolicinae (Norman 1931). The occurrence of this same type of erythrocytes in Vinciguerris is more unexpected, for this genus is said to be closely allied to Gonostoma (Normax, 1. e.), which has large, nucleated erythrocytes (Fig. 14).

All the other stomatoids have large dise-like erythrocytes with a distinct nucleus like the majority of teleosts, and no important deviations from this type were found in our specimens of other species. Considering also the extensive investigations on fish erythrocytes published by previous authors (Gulliver 187\%, Scmicmer 1927, Babidideri 1930, Dawsox 1933, Oria 1933, Deraxd 1950) we may safely conclude that Maurolicus, linciguerria and Valenciennellus are rare exceptions anong the teleosts. Out of several hundred species examined by these and other investigators all have erythroeytes of the normal type except for the interesting chaenichthyids, which have neither erythrocytes nor hemoglobin (Recd 1954).

Attention is drawn to the rapid postmortal crystallization of the hemoglobin in the majority of stomiatoids and myetophoids and in some other fish. This indicates a very low solubility of the hemoglobin in these species. In other fish species, e. g. Clupea, such crystallization is never observed, not even in specimens which have been dead for days. It is not possible to correlate these differences with definite taxonomical or biological facts, but differences in solubility of the hemoglobin are known also within other vertebrate classes, for instance in mammals (Wyman 1948). Our observations in Myctophum and other species suggest that ervstallization is induced in the vessels of the untreated animal very soon after death. The sclubility of the hemoglobin in these normal fishes is thus almost as low as in human beings suffering from siekle-cell disease (Pacting
1954). On the whole, the formation of hemoglobin bodies in the fish erythrocytes is very similar to that taking place in sickle-cell homozygotes as soon as the blood becomes venous.

The single, rod-shaped body formed in each erythrocyte of Gonostoma and Argyropelecus may be compares with the entire rod-shaped erythrocyte in the blood of Vinciguerria and Maurolicus. The latter is smaller bu has a similar shape, which is the same both in dried blood smears and Bouin-fixed sections. The close syste matical relationship between Vinciguerria and Gonostoma makes such a similarity more reasonable. Th non-mucleated erythrocytes of Maurolicus could, then, be looked upon as bodies of crystallized hemoglobin probably surrounded by a thin plasmatic membrane which represents the original cell membrane. Thi interpretation looks more probable when the structure of the immature erythrocytes of Maurolicus is studied In these cells, there is a distinct hemoglobin body of the same shape as that of mature erythrocytes, but it isurrounded by an unmistakable coat of normal, basophilic plasm (Figs. 1, 7).

If the hemoglobin is present in a crystallized state in our preparations of Maurolicus, it is probably st also in the living animal. Changes in the blood corpuscles were ever observed, in spite of the fact that some animals were living when fixed. Then the blood corpuscles must be supposed to be fairly rigid, but this wil hardly cause any mechanical complications because of the minute dimensions. The small dimensions may also help to make the oxygen metabolism efficient in spite of the condensed state of the hemoglobin. Thest problems obviously require physiological corroboration.

## FUNCTIONAL ADVANTAGE OF THE SMALL, NON-NUCLEATED ERYTHROCYTES

The functional advantage of small, non-nucleated erythrocytes may, in general, be: 1) a large surface in relation to volume and therefore rapid exchange of gases, 2) a high content of hemoglobin without the nucleus as an extra ballast. This means increased efficiency of the oxygen-carrying mechanism of the blood. As far as Maurolicus, Vinciguerria and Valenciennellus are concerned, this is rather hypothetical, so long as the oxygen tension curves and the absolute concentration of the hemoglobin is unknown. Nor is it possible to give a biological reason for a more efficient oxygen transport in Maurolicus, Vinciguerria and Valenciennellus than in the other stomiatoids. Maurolicus is known to occur as a pelagic species in the Atlantic, the Mediterranean, the Indian Ocean, and waters near New Zealand and Japan. It is caught at moderate depths down to 400 500 m , often together with Argyropelecus hemigymnus, Lampanyctus and other related species which have normal blood corpuscles.

Emmel (1924) suggests that the non-nucleated erythrocytes in the urodelan genus Batrachoseps are necessary to compensate for the unfavourable respiratory conditions in the larva, caused by the poorly developed gills. There is little reason to suggest a similar explanation for Maurolicus. The gills are well developed in the young and adult specimens, although the larval stages have not been examined.

When section series of whole fishes were examined, we discovered an anatomical feature for which the small non-nucleated erythrocytes may be advantageous. It was noticed that the organs responsible for the gas secretion into the swimbladder have a structure which is possible only due to the small erythrocytes. These organs will therefore be described in some detail.

Maurolicus has an entirely closed (physoclist) swimbladder of considerable dimensions. A large paired gas gland is situated in the ventral wall (Fig. 27). It consists of large epitheloid cells separated by a rich net of small capillaries. The gas gland is supplied with blood from a rete mirabile of unusual dimensions. It extends as a separate organ in the body cavity below and behind the swimbladder (Fig. 27) and has the usual structure with numerous parallel vessels which carry arterial blood to, and venous blood from, the gas gland. The most striking feature is the minute dimension of these vessels. The venous ones measure ca. $5-7 \mu$ in diameter, but the arterial ones are only about $2 \mu$ (Fig. 26). Allowing for some collaps of the
walls during the fixation and post-treatment of the specimen, the arterial vessels are so small that only one erythrocyte can pass at a time, and it probably can pass only if oriented lengthwise because it measures about $2.5 \times 5 \mu$. In fact, the erythrocytes seen in the sections of the rete were oriented that way (Fig. 26). There are about 1600 vessels of each kind in the rete of a 2.5 cm . specimen of Maurolicus, or a total of about 3200 . This is a very high figure. For comparison it may be mentioned that the rete of a $\mathbf{5}-\mathbf{6} \mathbf{~ c m}$. specimen of Ca rassius vulgaris contains only $60-100$ vessels (Fänge and Mattisson 1956). However it can be seen in the figures published by Scholander (1954) that many deep sea fishes have very numerous vessels in their rete, and Marshall (1954) points out that fishes which go down to great depths in the ocean have a very large rete if they have preserved a functional swimbladder. This is hardly astonishing for fishes living deep in the ocean need it to secrete gas against a pressure corresponding to over a hundred atmospheres.

The mechanism involved in gas secretion has been vividly discussed (cf. Fänge 1953, Scholander 1954, Ball, Strittmatter and Cooper 1955). It is supposed that the gas gland secretes substances (lactic acid?) into the blood which increase the tension of oxygen and carbon dioxide, so that these gases diffuse into the swimbladder. The blood coming from the gas gland will be rich in dissolved gases and will contain also the substances which cause the liberation of gas. When passing back through the rete venules, the blood is "standardized" again, delivering the said substances and gases to the blood passing to the gas gland in the arterioles. The rete would thus function as a counter-current washing unit, standardizing the blood before it re-enters the circulation and keeping up a high concentration of gases and secretory substances in the gas gland. In deep sea fishes, both the tension of the gas and the activity of the splitting agents must be high in the gas gland, since gas must be secreted against a very high pressure. An efficient rete, which isolates the gas gland from the rest of the circulation, is thus needed.

The rete of Maurolicus must be a particularly efficient washing mechanism because of the numerous and small vessels, and this efficient construction is dependent on small erythrocytes which are able to pass the small ressels. This is obvious if we compare with the conditions in a specimen of Lampanyctus crocodilus of approximately the same size (Figs. 25, 26). This species has a paired rete of considerable dimensions, which lies in a loop on each side of the swimbladder. But since the erythrocytes are large ( $15 \times 8 \mu$ ) there are fairly wide vessels ( $7-15 \mu$ ) and there is only place for about 600 of them in the rete, both sides included. In Maurolicus with the small erythrocytes ( $2.5 \times 5 \mu$ ) there are about 3200 vessels in a rete of approximately the same absolute size.

It is thus obvious that the small, non-nucleated erythrocytes of Marolicus are advantageous for the construction of the very efficient rete mirabile and thus help to increase the capacity of the secretory mechanism of the swimbladder. The biological implications of this can only be guessed at present. Perhaps it allows the fish to make greater and more rapid vertical movements.

On the other hand it is admitted that a similar advantage of small erythrocytes could be found also in other organs, e.g. the gills, but the swimbladder is probably the most obvious example. The discussion in this chapter should therefore be regarded only as a tentative hypothesis, and we do not claim to have explained the functional advantages of the small erythrocytes.

## SUMMARY

1. The stomiatoid fish Maurolicus mülleri has exceptionally small ( $2.5 \times 5 \mu$ ), non-nucleated and nonflattened, rod-shaped erythrocytes. They are formed in the spleen. The hemoglobin is accumulated in erythroblasts, which subsequently loose their basophilia. The nucleus of the erythroblast is pushed to the side and finally disappears by caryolysis. In young specimens a few nueleated erythroblasts are found in the circulating blood but they disappear in older specimens. Immature erythrocytes with a distinct, basophilic plasm around the hemoglobin body are particularly common in young specimens but are rare in adult ones. The aduft
erythrocytes are rod-like with blunt ends, consisting of a single hemoglobin mass, possibly covered by a cytiplasmic membranc, but the latter remains uncertain.
2. Erythrocytes of the Maurolicus type are present in Vinciguerria lucetia. Non-nucleated erythrocyls were found also in Valenciennellus tripunctulatus, but in this species the corpuscles are spherical, not ro..shaped. All the other teleosts investigated have larger, dise-like erythrocytes with a central nucleus, the typ. usually described in text-books. Attention is drawn to the rapid and remarkable kind of intracellular cr:stallization of the hemoglobin in stomiatoids, myctophoids and some other teleosts. In some, e.g. Argyropelect s and Gonostoma, the single hemoglobin body formed in each cell resembles the hemoglobin body which forns the erythroeyte in Marolicus. It is therefore suggested that the hemoglobin is present in a crystallized stat: in the latter species.
3. An attempt is made to find a functional advantage of the remarkable erythrocytes in Maurolicus. I is suggested that the smallness of the erythrocytes is a prerequisite for the construction of the very elaborat. secretory mechanism of the swimbladder in this species.

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PLATES

## PLATE 1.

Fig. 1. Development of erythrocytes in Maurolicus mülleri. $\mathrm{A}-\mathrm{F}=$ cells in the spleen of an adult specimen.
$\mathrm{A}=$ presumed pro-erythrocytes
$B=$ erythroblasts with small hemoglobin bodies
$\mathrm{C}=$ erythroblasts with large hemoglobin bodies
$\mathrm{D}=$ erythroblasts with degenerating nuclei
$\mathrm{E}=$ immature erythrocytes with a sheath of basophilic plasm
$\mathrm{F}=$ one immature (top) and one mature (bottom) erythrocyte as seen in the sinusoids of the spleen
$G=$ types of cells found in the liver vessels of a 25 mm . specimen. Four nucleated erythroblasts, one immature and one mature erythrocyte are drawn.
All figures are drawn from $4 \mu$ paraffin sections.-Bouin, hematoxylineosin, except $D$ which is from a slide stained in Feulgen-light green.

Fig. 2-5. Microphotographs, showing stages of development of erythrocytes in the spleen of the adult Maurolicus.
Fig. 2 = pro-erythroblast and early erythroblasts, compare Fig. 1 IB
Fig. $3=$ pro-erythroblast and late erythroblast, compare Fig. 1 C
Fig. $4=$ immature and mature erythrocytes, the former with a dark coat of basophilic plasm. Compare Fig. 1 E
Fig. $5=$ late erythroblast with the disintegrating nucleus like a girdle around the hemoglobin body. Compare Fig. 1D All figures from $4 \mu$ sections, fixed in Bouin, stained in hematoxy-lin-eosin, and photographed with a Zeiss Neofluoar, N. A. 1.30.

Fig. 6. Cross section of the vena lienalis in a 25 mm . specimen, with many nucleated erythroblasts. Some normal blood has been added through a pancreatic vein.-Bouin, hematoxylineosin, $8 \mu$.
Fig. 7. Heart blood of a 25 mm . specimen, with nucleated erythrocytes (top, right) and immature erythrocytes with a dark coat of plasm (bottom, left).-Bouin, hematoxylin-eosin. Scale as Fig. 8. Neofluoar, N. A. 1.30.

Fig. 8. Blood of adult Maurolicus.-Bouin, hematoxylin-eosin. Neofluoar, N. A. 1.30 .
 (24) (60) (2x) (a) C D

 $\longrightarrow$

E


F


## PLATE 2.

Appearance of fish erythrocytes in preparations. The magnification of all figures is the same as shown in Fig. 19. Microphotographs with a Zeiss Neofluoar, N. A. 1.30.
Fig. 9. Salmo irideus. Normal fish erythrocytes. Blood smear.
Fig. 10. Chauliodus sloanei. Non-crystallized. Section.
Fig. 11. Bathypterois longipes. Several irregular, rod-shaped hemoglobin bodies. Section.
Fig. 12. Onos sp. Complete crystallization. Blood smear.
Fig. 13. Argyropelecus olfersi. Complete crystallization. Section.
Fig. 14. Gonostoma elongatum. Complete crystallization. Section.
Fig. 15. Photichthys argenteus. Complete crystallization. Section.
Fig. 16. Ipnops murrayi. Several small bodies and bands. Section.
Fig. 17. Neoscopelarchus dana. A bundle of hemoglobin needles in the erythrocyte. Section.
Fig. 18. Myctophum arcticum. Blood smear made 30 minutes after death. Crystallization is distinct in the immature erythrocytes with dark plasm and has just begun in the mature erythrocytes.
Fig. 19. Myctophum arcticum. Complete crystallization. Section.


## PLATE 3.

Fig. 20. Valenciennellus tripunctulatus. Erythrocytes in a superficial gill vessel. Crystallization has begun in three of the corpuscles. Section. Magnification as Fig. 24.
Fig. 21. Bathylagus sp. Erythrocyte with small crystals in a gill vessel. Section. Magnification as Fig. 24.
Fig. 22. Bathylagus sp. Erythrocyte in the heart, with a few large hemoglobin bodies. Section. The same specimen as Fig. 21. Magnification as Fig. 24.
Fig. 23. Stomias boa ferox. Erythrocytes in gill vessels. No distinct crystallization. The two erythrocytes to the left are seen from the margin. Section. Magnification as Fig. 24.
Fig. 24. Stomias boa ferox. Erythrocytes in the heart. Crystallization is complete. One big hemoglobin body is formed in each cell. The nucleus is pushed to the side. Section. The same specimen as Fig. 23.
Fig. 25. Lampanyctus crocodilus. Cross section through the rete mirabile. Note the big erythrocytes in the vessels. Bouin, hema-toxylin-eosin.
Fig. 26. Maurolicus mülleri. Cross section of the rete mirabile, showing arterial (e) and venous (f) vessels, containing the small erythrocytes (g). Bouin, hematoxylin-eosin.
Fig. 27. Cross section of the viscera of Maurolicus mülleri, showing the intestine (a), the ovaries (b), the large rete mirabile (c), and the large, paired gas gland (d).-Bouin, hematoxylineosin.


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# IDENTIFICATION OF LARVAE of FOUR SPECIES OF TUNA FROM THE INDO-PACIFIC REGION I. 

BY

WALTER M. MATSUMOTO<br>FISHERY RESEARCH BIOLOGIST U.S. BUREAU OF COMMERCIAL FISHERIES BIOLOGICAL LABORATORY, HONOLULU, HAWAII

WITH 5 FIGURES IN THE TEXT

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# IDENTIFICATION OF LARVAE of FOUR SPECIES OF TUNA FROM THE INDO-PACIFIC REGION I. 

BY

WALTER M. MATSUMOTO<br>FISHERY RESEARCH BIOLOG IST<br>U.S. BUREAU OF COMMERCIAL FISHERIES bIOLOGICAL LABORATORY, HONOLULU, HAWAII

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## INTRODUCTION

There has been increasing interest concerning the early life history of the tunas in recent years throughout various parts of the world, particularly in those countries directly concerned with commercial exploitation of these fish. As a result a number of papers dealing with the identification of larvae and postlarvae of the tunas and closely related fishes have appeared in the literature. To date, identifications of at least six species [Neothunnus macropterus (Temminck and Schlegel), Katsuwonus pelamis (Linnaecs), Euthynnus yaito (Kishinouye), E. lineatus (Kishinouye), E. alletteratus (Rafinesque), and Auxis thazard (Lacépède)] have been published. The identification of $A$. thazard remains doubtful, since there is no way to separate the young of this species below 200 mm . fork length ${ }^{1}$ from that of another species, A. thynnoides (Bleeker), belonging to this genus (Матscmoto, 1960).

In addition to these, Sella (1924) has described the early stages of Orcynus thynnus (Lëtren) [= Thunnus thynnus (Linvaeus)] and O. alalonga (Risso) [=T. alalunga (Gmeliv)] from specimens collected in plankton net hauls and at night-light stations, generally from the Strait of Messina. Saszo (1932, 1933) also has described the earlier stages of T. thynnus and 0 . germo (Lëtien) [ $=$ ? T. alalunga (Gmelin)] based on specimens that had hatched from eggs taken in plankton net hauls in the Strait of Messina, and which he kept alive up to 7 days after hatching. The identifications of these larvae are somewhat dubious, however, since the spawning seasons for both species, as well as for other species of tuna, are known to overlap with respect to time and duration, and although the plankton hauls were made during specific migratory runs through the Strait, there is no definite assurance that the eggs of one species were taken exclusive of the other.

In the Pacific, there has been no success until recently in identifying larvae of thunnids, except that of N. macropterus (Schaffer and Marr, 1948a; Wade, 1951; Mead, 1951; Matscmoto, 1958). The primary reason for this has been the failure to catch juveniles of various sizes, especially those inmediately following the postlarval stages, and adequate numbers of larvae and postlarvae from varied localities.

The term "thunnid", as used hereafter, refers to tunas possessing a completely scaled body.
Recently I was able to identify tertatively four species of thunnids, Parathunnus sibi (Temmince and Schlegel), Thunnus germo (Lacépède), T. orientalis (Temminck and Schlegel), and Kishinoella tonggol (Bleeker) [ $=N$. rarus (Kishinouye)], among the larval tunas collected by the "Dana" during the 1928-30 round-the-world oceanographical expedition. In order not to get involved with the taxonomic relationships of Atlantic and Indo-Pacific tunas, I decided to study the larvae from these two areas separately, concentrating initially on larval specimens taken in the East Indies and Formosan waters because of the availability of adequate published records of adult tunas taken in these and adjacent areas. Because of unexpected success in identification and the importance of these findings, I decided to publish the results immediately, so that other investigators could benefit from them. Consequently, this report is limited to species identifications and to a general description of each species. A subsequent report will include detailed descriptions of developmental changes for each of these species, as well as for other species not covered here or in my previous report (1959), and discussions of distribution and other aspects related to the larvae.

[^0]In order to avoid digressions concerning the nomenclature of the tunas found in different oceans and in different parts of the world, I have used the earliest accredited generic and specific names I could find for the Indo-Pacific tunas.

I wish to express my gratitude to the late Dr. A. Vedel Tining, who allowed me to examine the collection of scombrid larvae taken by the "Dana" and other Danish vessels, and his successor, Dr. E. Bertelsen, who permitted me to continue using this material. I wish to thank also Vernon E. Brock and John C. Marr, for their timely encouragement; Tamotse Nakata, for the chart and illustrations; and staff members of the United States Bureau of Commercial Fisheries Biological Laboratory, Honolulu, Hawaii, who carefully reviewed and criticized the manuscript.

## METHOD

Except for artificial fertilization of ova and rearing of larvae of definitely known species in either shipboard or shore laboratories, a method that has proven extremely difficult and unsuccessful, the best method of studying species identification of larval tunas is to identify a series of juveniles and to trace their descriptions through smaller and smaller individuals, seeking and using larval characters as those of the adult gradually become less usable. This method has been used with some success in the past in identifying larvae of $K$. pelamis, N. macropterus, E. alletteratus, E. lineatus, E. yaito, and Auxis sp. (Ehrenbacm, 1924; Schaefer and Marr, $1948 \mathrm{a}, 1948 \mathrm{~b}$; Wade, 1951; Mead, 1951; Matsumoto, 1958, 1959). In the absence of known juveniles of various sizes, however, such a method cannot be used.

There is an alternative method that can be used in studying some of the presently unidentified species, and that is by comparing the species of adults taken by fishing gear and the "types" of larvae taken in plankton net hauls within the same area. Obviously, the occurrence of adult tuna in any area is not of itself a sufficient reason for assuming that spawning of that species takes place. The adult must be known either to spawn in an area (excellent evidence for this is the taking of fish whose gonads are in advanced stages of maturity or show signs of recent spawning), or be present in the area throughout the year or throughout the spawning months. Since juveniles of appropriate sizes were not available for any of the species, except $N$. macropterus, this method was used in identifying the thunnid larvae.

## DESCRIPTION OF AREA AND OCCURRENCE OF ADULT TUNAS

Of the numerous "Dana" stations in the East Indies and Western Pacific at which plankton nets were used, larval thunnids were caught at only a few scattered stations which clustered about four general areas (fig. 1). Area I consists of the Celebes Sea, Sulu Sea, and the southern half of the South China Sea, where larval thunnids were taken in April and July; Area II is in the Indian Ocean immediately west of Sumatra, where larvae were taken during September and October; Area III consists of waters around Formosa and between Formosa and the Ryukyu Islands, where larvae were taken during May; and Area IV takes in waters near the northwestern coast of New Guinea, where larvae were taken in July.

Judging from Japanese longline fishing records (Nakamcra, 1943; Nankal Regional Fisheries Research Laboratory, 1954, 1959), it may be assumed that T. germo is either extremely scarce or completely absent from Area I. T. orientalis also may be absent, since the fishery for the adults, according to Nakamura, begins in the northern part of the South China Sea and moves northeastward. Warfel (1950) also states that in the Philippine Islands this species is taken only off northern Luzon. The only species of thunnid, other than $N$. macropterus, which is recorded in Japanese longline reports from this area is $P$. sibi.

Regarding $P$. sibi, Yces (1955) indicates that fish in near spawning condition have been taken in the western Pacific (Marshall and Caroline lslands) and the central Pacific from April through October. He gives the size of fish at the time of initial spawning as $14-20 \mathrm{~kg}$., which is equivalent to $87-98 \mathrm{~cm}$. total


Figure 1. Areas and positions where larval thunnids were captured by the "Dana" and the "Spencer F. Baird".
length ${ }^{2}$. Kıkawa (1953) gives a similar range of $90-100 \mathrm{~cm}$. for $P$. mebachi $(=P$. sibi) from the Marshall Islands. On the basis of these reports it can be assumed that the months of the year when plankton hauls were made by the "Dana" (April and July) in Area I coincided with the spawning season of the species. Furthermore, from length-frequency data of P. sibi taken in Philippine waters in March, May and November, 1954; March, 1957; and March, 1958 (Investigative Society of Tuna Fishery, 1954-1959) ${ }^{3}$ it is known that about 95 per cent of the total catch consisted of fish capable of spawning, i.e., over 90 cm . total length. Consequently, although data from observation of gonads are lacking, the presence of adults throughout the known spawning months makes it highly probable that $P$. sibi spawns in this Area.

[^1]A species which is not taken on longline, but which is known to occur in Area I is $K$. tonggol (northern bluefin). Although the geographical distribution of this species is quite extensive, as is shown by records from southern Japan (Kishnotye, 1923), throughout the Indo-Malayan region to southern Australia, westward to the Maldive Islands, and eastward to Papua and New Britain (Slervexty, 1942), it is interesting to note that its occurrence is restricted to inshore waters. It is generally taken by surface trolling within the 100 -fathom line (Simventy, 1956). Servexty (1942) reports that adults of this species weighing 11 to 42 lbs . are common in southern Australia and that (1956) fish with spent gonads have been caught during the summer and early fall (December to May) in the vicinity of New South Wales. Adults of this species are also present in southern Japan, where 13 lbs . is regarded as the average weight and 26 lbs . as the maximum (Kisminouye, 1923).

In the Philippine Islands, Warfel, (1950) reports a large specimen weighing 11.5 lbs ., which, according to Serventy's data, must be considered an adult. He also reports that the average weight of this species taken there is less than $\overline{\mathrm{j}}$ lbs. and that it is not abundant. On the basis of these various reports it appears as though K. tonggol generally spawns in the higher latitudes and does so only to a limited extent in equatorial waters. Moreover, because its distribution is restricted to inshore waters, it is very likely that larvae of this species would be absent from the offshore positions at which plankton net hauls were made by the "Dana" in Area I.

In Area II, adults of three species of thunnids taken on longline are recorded (Nakamera, Vabta and Mmera, 1955; Nanka Labobatory, 1954, 1959). They are N. macropterus, P. sibi, and T. germo. N. macropterus is not discussed here, except to mention that those taken on longline are predominantly large fish. Insofar as $P$. sibi is concerned, fish of spawning sizes (those larger than 90 cm .) comprised 96 percent of the total catch for August, September, and October 195t, September 1956, and August 1957 (Investigative Society of Ticat Fishery, 1954-59) ${ }^{4}$, comparable in season with the months (September and October) when plankton hauls were made by the "Dana" and within the known spawning season of this species. Hence the probable spawning of $P$. sibi in this Area is clearly indicated.

Concerning the size at maturity and the spawning season of T. germo, \exasagi (1957) and Otse and Ucmids (1959) report that the size at maturity of females in the western and central Pacific is about 90 cm . White they do not define the extent of the spawning season, not having gonad samples for all months of the year, they present some evidence that this species is a summer spawner. Otse and Havsen (MS.), who examined gonad samples from the South Pacific, also present similar results. If T. germo in the Indian Ocean mature and spawn like those of the Pacific, it is highly probable that larvae of this species would be present in the plankton net hauls taken by the "Dana" in waters west of Sumatra, since September and October, the months when the plankton hauls were made, roughly represent the summer months at or near the Equator and adults are known to occur in Sumatran waters during these two months, as well as in other months of the year (Investigative Society of Texa Fishery, 1954-59) ${ }^{5}$.
K. tonggol is not listed among the species represented in the Japanese longline catches, but because of its wide distribution throughout the archipelago and of its occurrence as far west as the Maldive Islands in the Indian Ocean, the possible presence of this species in Sumatra cannot be overlooked. As explained in the discussion for Area I, however, it is not likely that this species would be present in the larval samples from Area 1I, since thunnid larvae other than those of $N$. macropterus were found only in hauls taken well beyond the 800 -fathom line.

Another species, T. maccoyii (Castilxat) or southern bluefin, is found in waters adjacent to this Area, but it is known that the fishery for this species begins south of Java between $110^{\circ}$ and $120^{\circ}$ E. longitude in September and October, moves westward to about $100^{\circ} \mathrm{E}$. longitude by February, and then moves back east of $110^{\circ} \mathrm{E}$. longitude by March and April, after which the fish migrate south along the west coast of Australia (Mimera, 1958). None are taken as far north as $5^{\circ}$ S. latitude west of Sumatra until March, when only incidental catches are made. Since the thunnid larvae taken west of Sumatra were collected during the months of September and October, when adult $T$. maccoyii are generally caught to the east of $110^{\circ} \mathrm{E}$. longitude and south of $8^{\circ} \mathrm{S}$. latitude, it may be assumed that larvae of this species are not present in the "Dana" collection from this Area. Further-

[^2]more, there is little likelihood that eggs and larvae of this species drift northwestward along the coast of Sumatra, since the surface current in this region is to the southeast throughout most of the year (Nakamera, 1943).

In Area III, four species of thunnids, N. macropterus, P. sibi, T. germo, and T. orientalis, are generally present during April-June (Investigative Society of Tuna Fishery, 1954-59; Nanka Laboratohy, 1954, 1959), comparable with the month (May) when thunnid larvac were taken by the "Dana" and with the spawning season of the first three species. $K$. tonggol is also known to occur here, and Nakamera (1943) reports that all of these species, except $T$. orientalis, which appears from $A$ pril to June, are present in Formosan waters throughout the year. Insofar as $T$. orientalis is concerned, the size at maturity has not been determined. For T, thynnus, however, Frade (1937) reports a female 126 cm . in total length from Tunisian waters as having gonads containing predominantly ripe eggs, an indication of sexual maturity. Moreover, T. thynnus has been known to spawn in early summer, May-June, in the Atlantic and Mediterranean (Frade, 1937; Rivas, 19.54). If $T$. orientalis is synonymous with $T$. thynnus, as many believe, then it should spawn in Fornosan waters during the summer, since most of the fish caught there on longline during April-June are larger than 140 cm . (lneestigative Society of Tina Fishery, $1954-59)^{6}$, well beyond the size of the mature female reported by Frade (1937).

Area IV is not included in the discussion because no longline catch recorl is available for the month of July from the vicinity where plankton net hauls were made. Thus, insofar as the occurrence of probable spawners, exclusive of $N$. macropterus, in these waters is concerned the following situation prevails:

| Area | Probable spawners |
| :---: | :--- |
| I | P.sibi |
| II | P.sibi; T. germo |
| III | P.sibi; T. germo ; T. orientalis; K. tonggol |

## IDENTIFICATION OF SPECIES

In the following sections larvae of $N$. macropterus are neither discussed nor described in detail because they have already been identified by a number of authors (Schaefer and Marr, 1948a; Wade, 1951; Mead, 19.51 ; Matscmoto, 1958). In order to avoid any misunderstanding concerning the presence or absence of this species, because of its exclusion from the discussion, it is here emphasized that yellowfin larvae were found in large numbers throughout all of the Areas described above.

Matscmoto ( 1958,1959 ) has shown that larval tunas can be diagnosed successfully by characteristic pigmentation in certain parts of the body. Preliminary examination of all probable thunnid larvae collected by the "Dana" from Indo-Pacific waters indicated that this method would be quite applicable to segregating the various forms represented in the catches. Detailed examinations, therefore, were made of the specimens, and the numbers and positions of chromatophores on the dorsal and ventral edges of the body, exclusive of the caudal fin, were noted as accurately as possible. They were symbolized as $\frac{0}{1}, \frac{1}{2}$, $\frac{2}{3}$, etc., the upper figure representing the number of chromatophores along the dorsal edge and the lower figure representing the number of chromatophores along the ventral edge. The number of different forms or "types" of larvat obtained in this way (2S) far exceeted the number of species represented in the adult catches (4). Exidently there was considerable variation in the number of chromatophores on either the dorsal or ventral edge, and a grouping of the types was necessary. By using the dorsal chromatophores as the basis for this grouping, since they exhibited less variation than those located ventrally, the following six types were obtained: $\begin{array}{ccc}0 & 1 & 2 \\ 1-5 & 1-7 & 1-7\end{array}$

[^3]
## Parathunnus sibi and Thunnus germo

In Area I, where only adults of $P$. sibi are known to occur in the vicinity where thunnid larvae were taken, all the larvae examined were of the type represented by $1-\overline{5}$. In order to determine how this compared with samples taken from the same area in other years, I examined the larvae collected during 1947-49 by the "Spencer F. Baird" ${ }^{7}$ of the C.S. Fish and Wildlife Service. Thunnids other than $N$. macropterus were found at 11 stations (fig. 1), but only one type of larva, similar to that collected by the "Dana", was found. In Area II, where adults of $P$. sibi and $T$. germo are known to occur, the larvae fell into two types, $\frac{0}{1-5}$ and $\frac{1}{1-7}$. Thus, type $\frac{0}{1-5}$, which was found in Areas I and II, was tentatively assigned to $P$. sibi, since adults of this species occur in both areas, and type $\frac{1}{1-7}$, which was found only in Area II, was tentatively designated as T. germo. As expected, larvae of both types were also found in Area III. Of the remaining four types, 261 out of 311 specimens examined were of type $\frac{2}{1-7}, 41$ were of type $\frac{3}{1-5}, 5$ were of type $\frac{4}{2-4}$, and 4 were of type ${ }_{2}^{5}-3$. The small numbers of the last two types seemed to indicate that they might be variations of the preceeding two types, which were taken as representing T. orientalis and $K$. longgol. For the time being these were grouped together as bluefins, on the basis of two or more chromatophores on the dorsal edge of the body.

In order to verify these designations, the following hypothesis was set up: If the species designations are correct, then plankton samples from the central Pacific should contain larvae resembling those identified as P. sibi and T. germo, but not those of the bluefins, since one species of bluefin is absent from the area and the other is so rarely recorded that it could be regarded as being absent. Examination of thunnid larvae taken from the central Pacific from 1950 to 1958 by the Bureau of Commercial Fisheries Biological Laboratory, Honolulu, in 11 cruises across the Equator between $180^{\circ}$ and $130^{\circ} \mathrm{W}$ longitude showed the presence of only two types of larvae, which were similar to those designated as P. sibi and T. germo. No larva with two or more chromatophores on the dorsal edge of the body, as in the types designated as bluefins, was found. On this basis the species designations of P. sibi and T. germo ascribed to larvae from Areas I, II and III seem warranted. The result also confirms the tentative designation of the bluefins.

## Thunnus orientalis and Kishinoella tonggol

The bluefins presented some difficulty, since larvae designated as such occurred only in one area. Consequently, species designations could not be made on the basis of areal comparison, as it was done with $P$. sibi and $T$. germo. It was necessary, therefore, to search for morphological characters showing species differences in the adults which would be usable also in separating the larvae. Tuna larvae do not possess completely developed morphological characters, except in the number of myomeres, until they are well over 10 to 12 mm . fork length; however, the initial stages of development of a few of these characters, such as the origins of the first and second dorsal fins, are quite noticeable on specimens as small as $6.0-6.5 \mathrm{~mm}$. Consequently, the morphological character which seemed most promising in larval identification involved the dorsal fins and their relationship with the myomeres.

In many fishes, the number of spines and rays in the first and second dorsal fins, as well as the rays in the anal fin, can be used in species identification. The number of spines in the first dorsal fin, however, is usually expressed in figures representing either the total or most usual range of variations observed, so that even when a significant difference of one or two spines might exist between two species, the reported counts would not show this owing to overlapping of the ranges. In some species the range may represent actual variations, but in certain instances, such as that often encountered among the large tunas, where there is a tendency for the last spine to become imbedded beneath the skin so that it is not noticed by the observer, the range could also represent variations that may only be apparent.

[^4]An example of this may be seen in the spine counts of 214 N . macropterus from the central Pacific made by the staff of the Bureau of Commercial Fisheries Biological Laboratory, Honolulu. Of this number, 118 fish had 13 spines and 95 had 14 spines in the first dorsal fin. On the basis of this, one would consider 13-14 as the spine count for this species. If these fish are arranged by size groups, however, as is done below, it is clearly seen that the number of fish with 14 spines is greater than those with 13 spines in the two smaller size groups, but is much smaller in the two larger size groups. This is seen more conclusively in the results obtained from 43 juveniles, $10-386 \mathrm{~mm}$. fork length, and by counts obtained by Wade (1950) from 18

| Size group (mm.) | Number of spines |  |  |
| :---: | :---: | :---: | :---: |
|  | 12 | 13 | 14 |
| 400-800 | 1 | 19 | 24 |
| 801-1200 |  | 11 | 27 |
| 1201-1600 |  | 50 | 32 |
| Over 1601 |  | 38 | 12 |
| Tota | 1 | 118 | 95 |

juveniles $9.8-35 \mathrm{~mm}$. fork length. In all of these juveniles there were 14 spines in the first dorsal fin, and in several instances specimens as small as 18 mm . were found with the last spine in a subcutaneous position. Therefore, although the spine count for adult N. macropterus may be given as 13-14 in many taxonomic reports, 14 must be considered the more accurate number for this species. This point is dealt with at length because part of the following discussion depends upon the number of spines in the first dorsal fin.

As for the bluefins, Rivas (1951) notes 14 or 15 as the number of spines in the first dorsal fin of $T$. thynnus. If $T$. orientalis is synonymous with T. thynnus, it should also have 14 or 15 spines. Kishivouye (1923) gives a range of $13-15$ for $T$. orientalis, but the lower end of the range is suspect for the same reason cited above for $N$. macropterus. A count of $14-15$ would be more likely for this species. This is attested to by the fact that Kishivocye illustrates a young $T$. orientalis, about 95 cm . in length, with 14 spines in the first dorsal fin. In contrast, the spine count for $K$. longgol given by Serventy ( 1942,1956 ) is quite consistent. He found 216 out of 237 fish (or 91.1 percent) with 13 spines in the first dorsal fin and only 9 fish with 14 spines. The validity of his count is enhanced by the fact that $K$. tonggol is a relatively small species, as tunas go, and therefore error in counting the last spine should be minimal. Kishinotye (1923) illustrates a specimen of N. rarus ( $=$ K. tonggol) with 13 spines in the first dorsal fin. Thus, for the purpose of separating T. orientalis and K. tonggol, the difference in number of first dorsal spines can be regarded as a reliable character.

Since the first dorsal fin is not completely developed on the larvae, however, the difference in the number of first dorsal spines noted in the adults of these species has to be interpreted through some other character closely related to it. The most obvious one is the position of the origin of the second dorsal fin, but before this character is used it is first necessary to establish the relationship between the last spine of the first dorsal fin and the origin of the second dorsal fin in terms of myomere number. Since neither juveniles nor adults of bluefin were available for examination, other species of tunas were examined, on the premise that if this relationship is consistent for other tunas, it should be consistent for the bluefins as well. The juveniles examined included 10 K . pelamis, 10 N . macropterus, 10 E . yaito, 5 E . alletleratus, and $\overline{5} \mathrm{E}$. lineatus, all of which possessed completely developed dorsal fins.

On all of the juveniles the last spine and corresponding pterygiophore of the first dorsal fin were on the myomere which was one greater than the total number of spines, and the first ray and corresponding pterygiophore, or the origin of the second dorsal fin, were located on the myomere following that which contained the pterygiophore of the last spine of the first dorsal fin. For example, in K. pelamis, a species having 16 spines in the first dorsal fin, the last spine and pterygiophore were located on the 17th myomere and the origin of the second dorsal fin was on the 18th myomere; in $N$. macropterus, a species having 14 spines in the first dorsal fin, the last spine and pterygiophore were located on the 15 th myomere and the origin of the second dorsal
fin was on the 16 th myomere. Consequently, the position of the origin of the second dorsal fin can be expressed as being on the myomere which is two greater than the number of spines in the first dorsal fin. Since this was true for all the species examined, it was assumed that it would be true also for the two species of bluefins. On this basis the origin of the second dorsal fin of $k$. tonggol, which predominantly has 13 spines in the first dorsal fin, and of 7 . orientalis, which has $14-15$ spines, should be located on the 15 th and 16 th -17 th myomeres, respectively.

In the larvae, neither the ray nor its corresponding plerygiophore, representing the origin of the second dorsal fin, develops until the growth of the larva is fairly well advanced. At a body length of about $6.0-6.5 \mathrm{~mm}$. , however, there begins along the base of the median membrane an accretion of tissue representing the incipient second dorsal fin. The anterior end of this accretion, which later becomes the origin of the fin, is clearly defined, so that specimens larger than $6.0-6.5 \mathrm{~mm}$. can be separated by its position relative to myomere number, as discussed above.

In order to determine whether the bluefin larvae separated on this basis possessed significantly different pigment patterns, 50 K . tonggol and 22 T. orientalis were examined in detail. In all specimens of K . tonggol the initial or anteriormost chromatophore along the dorsal edge of the body was located anterior to the origin of the second dorsal fin, whereas on the 22 T. orientalis, the anteriormost chromatophore was located posterior to the origin of the second dorsal fin. On the basis of these observations regarding pigmentation, it was tentatively concluded that larvae having two or more chromatophores along the dorsal edge of the body, the anteriormost chromatophore being anterior to the origin of the second dorsal fin or the 15 th myomere, are $K$. tonggol; and larvae having two or more chromatophores along the dorsal edge of the body, the anteriormost chromatophore being posterior to the origin of the second dorsal fin or the 16 th-17th myomere, are T. orientalis. Larvae smaller than 6.0 mm . were thus identified by the location of the first chromatophore.

Of interest concerning the pigmentation along the dorsal edge of the body in both species is the occasional unusually large size of one chromatophore, which is found either at the base of the second dorsal fin or at one of the anterior dorsal finlets. This, however, is not true for all of the specimens examined, for in numerous instances all the chromatophores were of uniform size.

## DISCUSSION

It might be well to point out that in the larvae it is often difficult to determine clearly the number of myomeres in the anterior and posterior extremities of the trunk. This problem was partially solved by examining juveniles cleared and stained in alizarin. The initial spine of the first dorsal fin of juveniles measuring 19 to 294 mm . fork length always occurred on the third myomere (this situation does not apply to adults, in which the initial spine is shifted posteriorly while the initial pterygiophore is elongated anteriorly into the second myomere), so that in instances where the anterior myomeres in the larvae were difficult to discern, the count was started at the third myomere or the origin of the first dorsal fin.

Regarding Slala's (1924) report, the description he gives of A. bisus (Bonaparte) [=A. thazard (Lacépène). appears reliable, and my description of Auxis sp. (Matscmoto, 1958, 1959) generally agrees with his. Selda, however, fails to mention any pigment spot either at the symphysis of the pectoral girdle or at the anterior edge of the anal opening, which is of major importance in identifying this genus. It seems that Savzo (1932) also failed to recognize this, for his figures 13 and 14 representing $T$. thynnus, plainly show a pigment spot anterior to the anal opening, indicative of the genus Auris. It is very likely that eggs of this species were taken in the plankton hauls from which Saxzo obtained the eggs of T. thynnus, and that they were not distinguished.

Concerning T. thynnus, both Saxzo's description and figures 11 and 12 agree with the description given for this species by Sella in that generally two or more chromatophores are present along the dorsal edge of the body: In this respect, the description of T. orientalis presented herein also agrees with their descriptions.

As for the albacore, however, the description given by Savzo (1933) contradicts that given by Sella (1924). Since both descriptions are rather sketchy, it is impossible to confirm either identification.

As a point of interest, Sella (1924) refers to the pigmentation on the caudal fin in describing 0 . alalonga $(=T$. alalunga $=$ germo?). He states that there are one to three chromatophores located dorsally or ventrally on the caudal fin. (This pigmentation is not to be confused with the chromatophores "along the dorsal edge of the body" mentioned previously). During the formation of the caudal fin, when the incipient urostyle is still in a horizontal position, this pigment is generally found near the tip of but ventral to the urostyle. After the urostyle has turned upward and the hypural fan is being formed, this pigment is generally found in the dorsal half of the posterior margin of the hypural fan (fig. 1-4). In the specimens I examined, during this and in my previous studies, usually one and often two or three chromatophores were found on the caudal fin in all species. Whenever there were two or three chromatophores, one of them was sometimes found dorsal to the incipient urostyle. In a check made on the larvae of $K$. pelamis, N. macropterus, and the four species tentatively identified herein, 14 out of 16 K . pelamis, 2 out of 6 N . macropterus, 31 out of 58 P . sibi, 26 out of 118 T. germu, 11 out of 60 K . tonggol, and 5 out of 18 T . orientalis were found to have this pigmentation. Because of such widespread occurrence in all of the species examined, and also because of variation in the number of spots, this pigmentation was not considered adequate for diagnostic purposes.

## DESCRIPTIONS OF SPECIES

The descriptions presented here include those characters which I helieve to be of importance for identifying the various species and some which are common to the thunnids, as represented in $N$. macropterus. Since only one illustration is presented for each species, it must be understood that all the variations noted on the larvae are not shown. These variations are, however, noted in the text. Furthermore, since the $6.0-7.0 \mathrm{~mm}$. group represented the bulk of the catch, thus providing the best source of material for comparative purposes among all the species, all of the specimens illustrated are of this size.

## Parathunnus sibi (Temminck and Schlegel)

This species (fig. 2) has several characters in common with $N$. macropterus. There are 40 myomeres in the trunk; the origin of the second dorsal fin is on the 16 th myomere; there is no pigmentation over the forebrain, at the symphysis of the pectoral girdle, or along the dorsal margin of the trunk exclusive of the caudal fin. Pigmentation in the first dorsal fin appears quite early, after the development of the first 3 to 5 spines, and in instances where the first dorsal fin is well developed, with more than 7 or 8 spines, it is heavily pigmented.


Figure 2. Parathunnus sibi, 6.05 mm .

The only noticeable difference between it and $N$. macropterus is in the presence of pigmentation along the ventral edge of the trunk, which in $N$. macropterus is unpigmented. Although the figure shows two chromatophores, one on the 34th myomere, the other near the origin of the caudal fin on the 37th myomere, in other specimens the chromatophores may vary from one to eight and they may be located anywhere between the origins of the anal and caudal fins. Generally, however, the number of chromatophores is one to four. The only other tuna with similar pigmentation on the trunk is $K$. pelamis, but the number of myomeres, absence of pigmentation over the forebrain, and heavier pigmentation in the first dorsal fin distinguish $P$. sibi from this species.

## Thunnus germo (Lacépède)

This species (fig. 3) is similar to $N$. macropterus and $P$. sibi in many ways. There are 40 myomeres in the trunk and the origin of the second dorsal fin is on the 16 th myomere. There are no chromatophores over the forebrain in specimens less than about 9 mm . fork length, and none at the symphysis of the pectoral girdle. Pigmentation in the first dorsal fin appears early and is quite heavy when the fin is well developed. It differs


Figure 3. Thunnus germo, 6.47 mm .
from $\lambda$. macropterus in having two chromathophores along the ventral edge of the body on the 28th and 33rd myomeres. As in $P$. sibi, the position and number of chromatophores on the ventral edge of the body vary considerably, there being generally one to five, and in rare instances up to seven.

The distinctive character which sets this species apart from $P$. sibi and $N$. macropterus is the single chromatophore on the dorsal edge of the trunk. On the figured specimen, it is located on the 27th myomere, at the base of about the third dorsal finlet. In other specimens, however, it may be found anywhere between the origins of the second dorsal and caudal fins.

## Thunnus orientalis (Temminck and Schlegel)

This species (fig. 4) has 40 myomeres, and the origin of the second dorsal fin is on the 16 th myomere. There are no chromatophores over the forebrain in specimens less than about 9 mm . fork length, and none at the symphysis of the pectoral girdle. Pigmentation in the first dorsal fin appears early and is quite heavy whenever the fin is well developed. In the specimen figured there are three chromatophores along the ventral edge of the body on the 27th, 30th, and 36th myomeres. As in P. sibi and T. germo the number and location of the ventral chromatophores vary among specimens. Generally there are one to six chromatophores situated between the origins of the anal and caudal fins. Unlike $N$. macropterus and $P$. sibi, this species generally has two or three chromatophores along the dorsal edge of the body between the origins of the second dorsal and caudal fins. In the figured specimen the two dorsal chromatophores are on the 28 th and 31 st myomeres.


Figure 4. Thunnus orientalis, 6.51 mm .

Kishinoella tonggol (Bleeker)
This species (fig. 5) also has 40 myomeres. The forebrain of specimens less than about 9 mm . fork length and the symphysis of the pectoral girdle are unpigmented. Pigmentation in the first dorsal fin appears early and is quite heavy when the fin is well developed. Although the figure shows two chromatophores along the ventral edge of the body on the 27 th and 36 th myomeres, in other specimens the number may vary from one to


Figure 5. Kishinoella tonggol, 6.94 mm .
five and the position of each chromatophore may also vary as in the three species already discussed. There are two chromatophores along the dorsal edge of the body on the 13th and 28th myomeres in the figured specimen. The usual number of chromatophores in other specimens is two or three, but quite often there may be as many as five. In all specimens the initial chromatophore is found anterior to the origin of the second dorsal fin, along the base of the first dorsal fin, but the succeeding ones may be found anywhere between the origins of the second dorsal and caudal fins. This species differs from the three just described in having the origin of the second dorsal on the 15 th myomere.

## SUMMARY

Examination of larval thunnids collected from Indo-Pacific waters by the "Dana" during the 1928-30 round-the-world oceanographical expedition resulted in the tentative identification of larvae of four species of thunnids, Parathunnus sibi (Temminck and Schlegel), Thunnus germo (Lacépède), T. orientalis (Temminck and Schlegel) and Kishinoella tonggol (Bleeker), which have hitherto been unidentified. Inasmuch as another of the thunnids, Neothunnus macropterus (Temmince and Scmegel), has been identified and described by numerous authors, it was not included in this discussion. In order to a void digressions concerning
the nomenclature of the tunas found in different parts of the world, the earliest generic and specific names given to tunas from this region were used.

Species identification was done by segregating the larvae from three localized areas into various "types" on the basis of number and position of chromatophores on the body, particularly the chromatophores along the dorsal edge of the trunk. The number of larval types in each area was then compared with the species composition of adult thunnids caught on longline fishing gear, including also a species ( K . tonggol) which is known to be present in the areas, but which is not commonly taken on this gear.

All specimens examined had 40 myomeres and had little or no pigmentation over the forebrain. Larvac with no pigmentation along the dorsal edge of the trunk, exclusive of the caudal fin, but with one to five chromatophores along its ventral margin were designated as P. sibi. Larvae similar to P. sibi but having one chromatophore along the dorsal margin of the trunk, at the base of either the second dorsal fin or one of the dorsal finlets, were diagnosed at T. germo. Larvae similar to $P$. sibi but having two or three chromatophores along the dorsal edge of the body, the initial chromatophore being at the base of either the second dorsal fin or one of the dorsal finlets, were identified as T. orientalis. On all these three species, the origin of the second dorsal fin was located on the 16 th myomere. Larvae similar to $T$. orientalis but having the initial dorsal chromatophore anterior to the 15 th myomere or the origin of the second dorsal fin were designated $K$. tonggol.

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# THE CARLSBERG FOUNDATION'S 

# MELAMPHAIDAE II <br> a NEW MELAMPHAID GENUS, SIO, WITH A REDESCRIPTION OF SIO NORDENSKJÖLDII (LÖNNBERG) 

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WITH 4 FIGURES IN THE TEXT
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## INTRODUCTION AND ACKNOWLEDGEMENT

Recent examinations of Melamphaidae from all oceans indicate that this bathypelagic family requires extensive revision. Although formerly all melamphaids were placed in the single genus. Melamphaes, it is now evident that the family comprises at least five distinct genera (Ebeling, 1962) ${ }^{1}$. Taxonomically, the present account describes for the first time one of these genera, Sio, and redescribes its single included species, Sio nordenskjöldii (Lövvberg). The distribution of $S$. nordenshjöldii is analyzed with respect to physicochemically defined water masses, which may play an important role as isolating mechanisms associated with the remarkable radiation of the Melamphaidae. Indeed, according to Ebeling, intraspecific variation between populations inhabiting slightly different water masses is not uncommon.

Specimens for this study were graciously supplied by the Carlsberg Foundation (Denmark) from the R/V "Dana" collections (designated "D" in the "Specimens Examined" section); the British Museum (Natural History) ("BM (NH)"); the Institute of Oceanology, Academy of Sciences of the L.S.S.R. ("Y"); and the University of California, Scripps Institution of Oceanography ("SIO"). To Drs. E. Bertelsen and the late A. Vedel Tiving, of Charlottenlund Slot; Mr. Denys Tlcker and Mr. N. B. Marshall, London; Dr. Theodor S. Rass, Moscow; and Drs. Carl L. Hebbs and Richard H. Rosevblatt, La Jolla, goes my deepest appreciation for the loan of these specimens. The work was done at the Bingham Oceanographic Laboratory and leabody Museum, Yale Cniversity, which provided every needed facility. Special acknowledgements go to Dr. Alfred W. Ebeling for help and encouragement, to Dr. Daniel Merrinan for reading the manuscript, and to Mrs. Sarah IV. Richards for her helpful ideas.

## MATERIALS AND METHODS

The 34 specimens of Sio nordenskjöldii examined represent most of the known specimens of this genus collected thus far. Of these, 19 specimens were borrowed from the Danish "Dana" collections (1928-1930) made in the Tasman Sea and extreme southwestern lndian Ocean, 8 from the British Museum (Natural History) "Discovery" collections (1930) made in the southeast Atlantic Ocean, 1 from the Danish "Galathea" collections (1951) made in the southwest Indian Ocean, 1 from the Russian "Vitiaz" collections (1958) made in the subarctic North Pacific, and 5 from the Scripps Institution of Oceanography Monsoon Expedition collections from the Indian Ocean made in 1960.

The collecting gear used by the R/V "Dana" and "Discovery" consisted of conical ring stramin nets, while the "Galathea" employed deep water otter trawls and deep sea dredges. The R/V "Vitiaz" and Monsoon Expedition used $\mathbf{1 0}$-foot beam Isaacs-Kidd midwater trawls. The "greatest depth" of trawl was calculated as half of the length of cable out. The depth attained by the shallowest trawl that captured Sio nordenshjöldii was taken as the upper distributional limit for this species. This upper limit was used in constructing the temperature - salinity capture diagrams which are explained below. Unfortunately, because self closing devices were not employed in the trawls used, more exact determinations for the vertical depth range of capture could not be made.

[^5]All specimens were preserved in formalin or isopropyl alcohol and were in generally good condition except that, rubbed ofl by the capture nets, most of the body scales were usually missing.

For each fish all counts and measurements were made on the left side only and recorded to the nearest 0.1 mm . Needlepoint dividers were used for larger measurements and a binocular microscope fitted with an ocular micrometer for those measurements under 5 mm . All counts and measurements used are defined in Ebeling (196 ) except body depth which was measured vertically from the dorsal origin. A General Electric soft X -ray machine was used to take X -ray photographs of all specimens for vertebral counts.

Temperature - salinity capture diagrams consisting of temperature versus salinity plots were made after the method of Ebeling (196) for all localities of capture. Hydrographic data was taken from Thomsen (1937), Discovery Comm. (1929:27), and Rakestraw, et al. (1960:234, 291).

The paucity of midwater collections made thus far in some areas of the southern oceans limits an adequate diseussion of the distribution of Sio. Further, determination of the variation between possibly discrete populations of Sio was hindered by the small sample available (34) which did not lend itself to rigorous statistical examination. The lack of an adequate ontogenetic series of specimens also limited such a discussion.

## Sio, new genus

Type species. - Melamphaes nordenskjöldii Lönvberg, 1905, by monotypy.
Distribution. - Recorded from the Tasman Sea, southern Indian Ocean, and southern South Atlantic, monotypic Sio in the Southern Hemisphere is apparently associated with southern regions of the central water masses. One large adult, however, was taken in the subarctic North Pacific (fig. 2). With the young occurring shallowest, all specimens were trawled below 150 meters.

Diagnosis. - Melamphaids with 12 dorsal rays (soft rays plus spines), 2 or possibly 3 cheek scales, teeth in upper jaw uniserial ( $1-2$ rows in lower jaw), 7 branchiostegal rays, head ridges smooth, preopercular margin weakly serrate, posttemporal spineless, and maxillary extending to vertical from posterior edge of eve.

Body and head. - Typical of most melamphaids, but with snout noticeably squared resembling that of Melamphaes. Slit-like posterior nostril curved with convexity nearest antorbital ridge. Diameter of eye greater than suborbital width. Head ridges smooth with no clearly defined serrations. Preopercular margins weakly serrate, especially around angle. Embossed lines on fragile head epidermis widely spaced.

Jaws and teeth. - Lower jaw with distinct symphyseal knob protruding bevond upper jaw. Gape extends to vertical from mid-anterior half of eye, with posterior edge of relatively short maxillary reaching to vertical from posterior border of eye. Minute conical teeth uniserial in upper jaw, but in 1-2 rows in Iower jaw.

Gill rakers and branchiostegal rays. - First arch with numerous long, well-developed gill rakers. Those of the fourth arch more widely spaced, fewer in number, and reduced to spiny nubbins. Branchiostegals 7 .

Scales. - Body scales medium sized, numbering $25-30$ in horizontal series from end of posttemporal to caudal. Scales easily lost, most specimens examined retaining few or none. Cheek scales 2 or possibly 3, including one at end of maxillary. Opercular scales 4 .

Fins. - Dorsal III, 9. Anal I, 8-9, originating under end of dorsal base. Pectorals 14-15, Iong. Pelvics I, 7, inserting under base of first pectoral ray; large.

Internal characters. -- Pyloric caeca 7. Downward projecting spur on first haemal arch (on first precaudal vertebra) reduced or absent in most specimens.

Color. - In formalin adults dark brown to black, darker on operculum and caudal base. Young specimens lighter, possibly faded.

Derivation of name. - Sio, an arbitrary combination of letters, neuter in gender.

Table I. Comparison of the Melamphaid genera. Proportions are in thousandths of standard length. For Scopelogadus, Scopeloberyx, and Poromilra listed values are highly tentative (especially dubious values are queried).

|  | Sio new genus | Melamphaes GÜлther, 1864 | Scopelogadus <br> Vaillait, 1888 | Scopeloberyx <br> Zcgatyer, 1911 | Poromitra <br> Goode and bean 1883 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Hranchiostegal rays | 7 | 8 | 8 | 8 | ' |
| Horsal spines. . . . . . . . . . . . . | 3 | 3 | 1-2 | 2-3 | 3 |
| \| m msel rays. . . . . . . . . . . . . . | 9 | 14-18 | 10-11 | 10-12 | 10-14 |
| S ye diameter (in S.L.). . . . . . | 43-59 | 40-62 | 43-65 | 24-40 | 32-90 |
| I.ength of upper jaw. . . . . . . | 133-140 | 155-203 | 130-188 | 150-230 | 148-222 |
| f'recandal vertebrae. | 10 | 11-12 | 10 | 10 ? | 9-10 |
| Caudal vertebrae. | 16-17 | 14-18 | 13-17 | 14-17? | 15-20 |
| Total gill rakers 1 st. arch). .. | 24-29 | $14-25$ | 22-29 | 13-24 | 23-31 |
| reopercle serrations | weak | O -few spines | weak | none | strong |
| theek scales. . . . . . . . . . . . . | 2 or 3 | 2 | 0 | more than 2 | 3-4 |
|  | 7 | $7-8$ | $5$ | $6-7$ ? | $2-8$ |
| scale rows (series from posttemporal to caudal) | 25-30 | 28-31 | fewer than 15 | 25-45 | 23-29? |
| ural tooth rows in premaxillary | 1 | $2-8$ | 1 | $1 ?-5$ | 1 |

## Sio nordenskjöldii ( Lönnberg, 1905)

 length 76 mm . D. III, 9 ; eye $5^{1 / 2}$ in head: gape extending to vertical from middle of eye). Bracer, $1906: 279$ (in key). Corman, 1929: 155, 1.59 (captures in South Atlantic; descr.: in key): 1930: 345 (captures repeated). Parr, 1931: $3!9$ (in key); 1933: 14 (in key). Mcnoo, 1938: 77-78 (short desct. after Lönnberg). Alblquerqlé, 1954-50: 587 (possible Ynonomy with M. anthrax).

Counts. - Dorsal III, 9; anal I, 8-9; caudaI $4+(9-11)-(9-10)+4$; pectoral $14-15$; pelvic I, 7 ; scale rows $6-7+25-30$ : scales in diagonal series $10-11$; vertebrae $10 \div 17$; gill rakers on first arch (6-9) (18-20); gill rakers on lower fourth arch 10-12.
Proportions. - The holotype was unavailable for study. Proportions are given in thousandths of standard length and are presented as the mean of 29 specimens ( $11.4-115.4 \mathrm{~mm}$. standard length ), followed ly the range in parentheses.

Body depth at origin of dorsal 272 (249-302); predorsal 485 (452-525); head length 367 (339-418); snout to preopercle $245(219-260)$; prepectoral $368(342-402)$; length of caudal peduncle 298 ( $254-318$ );


Fig. 1. Sio nordenskjöldii (LöNBERG). Adult or near adult specimen, BM(NH) 1930.1.12.983-7, traced and modified from photograph (standard length 68.3 mm .). Part of the epidernis on the cheek has been removed, revealing the cheek scales.
depth of caudal peduncle 111 (98-126); length of upper jaw $133(110-184)$; snout length $80(63-100)$; suborbital width 29 (24-52); eve 57 ( $45-77$ ).

The following proportions, indicated by range only, are from four adults ( $60.3-115.4 \mathrm{~mm}$. standard length) : postdorsal ( $528-564$ ); orbit to cheek ridge ( $60-66$ ); head depth (263-273); head width (179-201); posterior head length ( $231-244$ ); interorbital ( $108-126$ ); length of frontal fossa ( $69-76$ ); prepelvic (388 -410 ) ; isthmus to pelvic ( $354-369$ ); pelvic to anal (243-314); pectoral (299-324); pelvic (167-253); preanal ( $654-683$ ); anal to caudal (337-371) ; orbit to cheek angle (111-123).

Body and head form. - Dorsal body contour descends abruptly under dorsal fin, then more gently to caudal. Ventral body contour almost straight from preopercular angle to anus but gently rises under anal. Point of greatest body depth at pelvic insertion (ripe females excepted). Caudal peduncle more than twice as long as deep, only slightly tapered. Predorsal profite straight to dip at nape; angular forehead marks upper margin of steep, occasionally slightly decurved snout. Ventral head contour slopes gently to angular isthmus, then sharply to mandibular symphysis. Diameter of eye noticeably greater than suborbital width; about 0.7 snout length.

Head ridges and epidermis. - Frontal fossa twice as long as wide; expands twice before squared posterior half, then only slightly constricts at its back margin. Lateral margins of frontal bone over eves even, so that interorbital not marked by angles in these margins; interorbital defined, therefore, as the distance between frontal margins at mid-level of lenses, which distance exceeds by eye diameter distance from orbit to preopercular ridge. Spine-like ridges at cheek angle weak. Head epidermis usually intact in young, easily lost in older specimens, exposing smooth, flange-line ridges; cheek epidermis especially fragile and usually lost. Epidermal embossed lines very widely spaced; cover most of head. Epidermal prickles noticeable on lips and around mouth in large specimens.

Sensory pores. - Group of pores in suprateniporal canal directly above preoperculum (suprapreopercular pores) 3 in one adult, 4 in another; most other specimens too extensively damaged to make any pore counts. In fig. 1 an attempt was made to reconstruct other pore groups.

Operculum. -- Without salient spines, ridges, or reticulate bone; very pliant and fragile. Preopercular margin weakly serrate, most noticeably around angle. Anterodorsal margin of posttemporal without antrose spine.

Jaws and teeth. - Maxillary relatively short, just reaching vertical from posterior margin of eve: 0.38 in head. Gape reaches vertical from mid-anterior half of eve. Tecth in upper jaw conical, small, and uniserial. Mandibular symphyseal knob distinct. Teeth in lower jaw usually uniserial but occasionally biserial in arlults. Pharyngeal teeth in 4 adults $21-27$ on second pharyngobranchial, $49-61$ on third pharyngobranchial, 28-50 on third epibranchial (groups illustrated in Ebelivg (196:fig. 13)). Younger specimens have fewer teeth in each group.

Gill rakers. - On first arch usually $8+19$, long, slender, and closely packed; longest near angle slightly exceeds eye diameter. Rakers on lower fourth arch usually 11 or 12 , reduced to small spinous nubbins.

Scales. - Body scales usually represented by pockets; horizontal series from nape to end of posttemporal usually 6 or $\mathbf{7}$; scales in horizontal series from posttemporal to caudal usually $\mathbf{2 6}$ or 27 . Diagonal rows usually 10 or 11 . Cheek scales usually lost but 2 or 3 probably present. Circuli on body scales closely spaced, grooves between about 0.03 mm . wide; absent on posterior field.

Fins. - Dorsal diagnostically III, 9, second soft ray longest. Anal generally 1,8 , usually originates under or slightly behind last dorsal ray. Pectoral usually 15 ; long, reaching slightly beyond end of dorsal base: last ray finely filamentous. Pelvic inserts slightly behind pectoral insertion.

Internal characters. -- Vertebrae usually $10+17$. Swim bladder, including gas gland and rete mirable well developed in young, $3-4$ times length of stomach; may be either large or greatly reduced in larger specimens.

Size at maturity. - The three specimens sexed, $115.4,79.5$ and 78.0 mm , are gravid females.

## SPECIMENS EXAMINED

The collections are listed as follows: collection or museum number (e.g., D $3620(2)$ ); locality; depth, given either in number of meters of wire out (e.g., 600 w ) or as the trigonometrically calculated "actual depth" (e.g., 1878 m ); number of specimens, followed, in parentheses, by the range of standard lengths (e.g., $3(30-33)$ ).

Tasman Sea and southwest Pacific. - D 3620(2), $24^{\circ} 46^{\prime} \mathrm{S} / 170^{\circ} 18^{\prime} \mathrm{E} ., 600 \mathrm{w}, 1(13) ;$ D 3624(2), 2817'S. $177^{\circ} 01^{\prime}$ W., $4000 \mathrm{w}, 1(19)$; D $3624(3), 28^{\circ} 18^{\prime}$ S. $/ 177^{\circ} 01^{\prime}$ E., $3000 \mathrm{w}, 1(25)$; D $3627(1), 30^{\circ} 08$ S. $/ 176^{\circ} 50^{\prime}$ W., $5(h) 0 \mathrm{w}, 3(30$ -33 ) ; D $3627(3), 30^{\circ} 08^{\prime}$ S. $/ 176^{\circ} 50^{\prime}$ W., 3000 w, $1(25)$; D $3727(7), 30^{\circ} 08^{\prime}$ S. $176^{\circ} 50^{\prime}$ W., $600 \mathrm{w}, 1(32)$; D $3630(1), 34^{\circ} 24^{\prime}$ S. $178^{\circ} 42^{\prime}$ E., $3000 \mathrm{w}, 1(35)$; D $3630(4), 34^{\circ} 24^{\prime}$ S. $/ 178^{\circ} 42^{\prime}$ E., $1000 \mathrm{w}, 1(30)$; D $3637(1), 36^{\circ} 24^{\prime} \mathrm{S} .165^{\circ} 53^{\prime} \mathrm{E} ., 1000 \mathrm{w}, 1(32)$ : i) $3653(1), 33^{\circ} 31^{\prime} \mathrm{S} .165^{\circ} 53^{\prime} \mathrm{E} ., 1000 \mathrm{w}, 1(33)$; D $3653(6), 33^{\circ} 31^{\prime} \mathrm{S} .165^{\circ} 53^{\prime} \mathrm{E} ., 4000 \mathrm{w}, 2(27-33)$; D) $3653(8)$, $33^{\circ} 31^{\prime} \mathrm{S}$. $165^{\circ} 53^{\prime}$ E., $3000 \mathrm{w}, 1(24)$ : D $3654(1), 33^{\circ} 28^{\prime} \mathrm{S} . / 161^{\circ} 45^{\prime} \mathrm{E} ., 1000 \mathrm{w}, 1(34)$; D $3656(3), 33^{\circ} 26^{\prime} \mathrm{S} .157^{\circ} 02^{\prime} \mathrm{E} ., 3000 \mathrm{w}, 1(35)$.

Indian Ocean. - D $3969(3), 37^{\circ} 33^{\prime} \mathrm{S} . / 30^{\circ} 07^{\prime} \mathrm{E}$., $300 \mathrm{w}, 1(18)$; D 3971, $35^{\circ} 49^{\prime} \mathrm{S} . / 29^{\circ} 09^{\prime} \mathrm{E}$., $1000 \mathrm{w}, 1$ (299); G 1866, :212 $33^{\prime} \mathrm{S} . / 3^{\circ} 01^{\prime} \mathrm{E} ., 1(80)$ : SIO $61-37,33^{\circ} 19^{\prime} 18^{\prime \prime} \mathrm{S} . / 72^{\circ} 34^{\prime} 24^{\prime \prime} \mathrm{E} ., 1878 \mathrm{~m}, 4(21-30)$; SIO $61-38,42^{\circ} 03^{\prime} 48^{\prime \prime} \mathrm{S}$. $70^{\circ} 39^{\prime} 54^{\prime \prime} \mathrm{E}$, $2060 \mathrm{~m}, 1$ (78).

Southeast Atlantic. - BM(NH) 1930.1.12.984, $34^{\circ} \mathrm{S} .9^{\circ} \mathrm{E}$., $1(21)$; BM(NH) 1930.1.12.985, $34^{\circ} \mathrm{S} .9^{\circ} \mathrm{E}$., 1 (11): BM(NH) 1930.1.12.988, $35^{\circ} \mathrm{S} .7^{\circ} \mathrm{E}$., $1(26)$; BM(NH) 1930.1.12.989, 35${ }^{\circ} \mathrm{S} .7^{\circ} \mathrm{E}$., 1(25); BM(NH) 1930.1.12.990, $35^{\circ} \mathrm{S}$.
 1930.1.12.98ㅇ, $33^{\circ} 23^{\prime} \mathrm{S} . / 8^{\circ} 31^{\prime} \mathrm{E} ., 1(60.3)$.

North Pacific. - V $2830-068,41^{\circ} 19^{\prime}$ N. $/ 177^{\circ} 44^{\prime} \mathrm{E} ., 3000 \mathrm{w}, 1(115.4)$.

## DISTRIBUTION AND VARIATION

Most of the specimens of Sio nordenskjöldii examined were captured in two geographically widely separated areas (fig. 2). The first is east of Australia in and northeast of the Tasman Sea; the second is in the southeastern Atlantic Ocean west of the Cape of Good Hope (three fish captured just east of the Cape in the Indian Ocean


[^6]may be considered with the Atlantic group). Single specimens are reported in the literature from the southwest Atlantic east of the Falkland Islands (Lönnberg, 1905: Holotype, 76 mm .) and from near Port Hacking, Australia, 76 mm . (Munko, 1938). Five specimens were recently taken during the University of California, Scripps Institution of Oceanography Monsoon Expedition in the southern Indian Ocean: four young about 7 degrees north of the Subtropical Convergence, one adult near or within this convergence. One large specimen ( 115 mm .), here examined, was taken about $41^{\circ} \mathrm{N}$. in the western North Pacific. Most captures of large adults (over 70 mm .) were made in water possibly associated with the Subtropical Convergence (about $40^{\circ} \mathrm{S}$.), while young were taken only in the warmer central water masses. Because of this distribution, which is analogous to that of Melamphaes lugubris Gilbert in the northern North Pacific Ocean (Ebfling, 196 ), it is suggested that the breeding areas of Sio may be confined to southern central waters. Older fish, however, may stray into colder subantarctic water. Breeding areas, therefore, may exist in the southern parts of these warm central water masses in the vicinity of the Tasman Sea, eastern South Atlantic, and southern Indian Ocean. This speculation remains highly tentative, howerer, because of the scarcity of available collections from intermediate localities. The great distances separating these areas raises a question as to the similarity of the bathypelagic environments. Therefore, temperature - salinity curves were constructed for each capture locality (fig. 3). As might be expected, these curves are similar and all fall within the water mass envelope characteristic of both western South Pacific Central and South Atlantic Central waters. This suggests the similarity of the environments and implies the localization of at least young Sio nordenskjöldii in central water


Fig. 3. Temperature-salinity capture diagram for Sio nordenshiöldii. The broad lines enclose combined water mass envelopes, adapted from Sverdrep et al. (1942), for South Atlantic Central Water and Western South Pacific Central Water. The thinner lines are temperature. salinity curves through the maximum possible depth range of each capture; solid lines for the Tasman Sea and western South Pacificdashed lines for the eastern South Atlantic and Indian Ocean. The presumed upper depth limit for S. nordenskjöldii is $\mathbf{1 5 0}$ meters.


Hig. 4. Scatter diagrams for body proportions relative to standard length of specimens. A, head length and snout length plotted as per cent of standard length; B, length of caudal peduncle and eye diameter plotted as per cent of standard length.
masses of the Southern Hemishere. Of course, other physicochemical (e.g., current structure and oxygen distribution) or biological (e.g., productivity) factors may influence the distribution of this species.

The spatial isolation between the two statistically analyzed populations suggested intraspecific variation between them. A Students' " $t$ " test of statistical differences in numbers of gill rakers on the lower first arch, however, was non-significant at the 0.05 level ( $\mathrm{P}=0.8$ ). Plots of body proportions (snout length, length of caudal peduncle, eve diameter, and head depth) as functions of standard length revealed possible differences between these two populations (fig. 4). Unfortunately, however, satisfactory ontogenetic series were unavailable for study.

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BY

ALFRED W. EBELING

UNIVERSITY OF CALIFORNIA, SCRIPPS INSTITUTION OF OCEANOGRAPHY AND Yale university

WITH 73 FIGURES IN THE TEXT

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## INTRODUCTION AND ACKNOWLEDGMENTS

Bathypelagic fishes inhabit the cold, poorly lighted mid-depths of the oceans. For the earlier ichthyologists the technical problems of sampling these great depths were nearly insurmountable and only after the pioneering Challenger Expedition were even a few specimens of the important groups available for study. Consequently, without the benefit of modern ships and trawls these ichthyologists could know little about the distributions of deep-sea fishes. Uncritical studies of inadequate material forced many of them to assume most species to be cosmopolitan. This opinion was reinforced by the lack of any then obvious barriers to the dispersal of these species. In the introduction to a Challenger Report Albert Gǜther (1887) remarked that "this uniformity of the physical characters of the lowermost strata of the ocean is . . the cause of the almost unlimited horizontal distribution of deep sea fishes." And, further, that ". . . the physical conditions of the abyss are of a very uniform character, and therefore cannot have given rise to the development of numerous specific and generic forms." Even in the 1930 's competent ichthyologists such as J. R. Norman (1949) wholeheartedly shared this opinion, which was not proved incorrect until many large expeditions had accumulated huge collections from all oceans.

Based on large series of specimens from many localities, studies like those in the "Dana-Reports" now thow that several species of a single genus may be localized singly or in groups in particular regions or water masses. Realizing this, Marshali. (1955) noted that ". . the widespread nature of the deep-sea fauna may have been overstressed." For example, critical studies of the Myctophidae by Rolf L. Bolis (personal communication), and of the Cauliodontidae by Ege (1948), Haffser (1952), and James E. Morrow, Jr. (personal communication), have shown that the many species of these two families have discrete distributions, none of which is world-wide.

With the ever-increasing store of specimens of bathypelagic fishes, along with accumulated data on their distributions and environment, it is now possible to discuss their zoogeography profitably; that is, to inrestigate not only what species are present and where they are, but also why they are there and how they tot there. Pertinent questions to be examined are: first, what constitute the boundaries in the open oceans, and where are they located? Are the distributions of different bathypelagic fishes limited by these boundaries io as to conform with distinct faunal regions? Do the boundaries limit both shallow and deep species, or only -ertain ontogenetic stages? And finally, what isolating mechanisms, biological as well as physico-chemical, may be involved? Though subtle and fluctuating, these boundaries may be of utmost importance in the ipeciation of bathypelagic fishes. Furthermore, it is interesting to speculate whether certain morphological raits of a species may be directly associated with biological of physical characteristics of a particular water nass.

One of the more interesting aspects of this study of the species of the bathypelagic fish genus Melamphaes s their distributions relative to physico-chemically defined water masses. But a study of this type would be mpossible without, first, a strict accounting of the species. Fortunately, sufficiently abundant material was nade available for an extensive revision of this cosmopolitan genus. Because it contains many geographically eparated species, Melamphores proved to be an excellent subject for a distributional study of this sort. In his study the data involve not only systematies, but also the distributions and the biological and physico'hemical characteristics of the environment. Armed with such data, I have been able to show that the distriutions of the included species are not haphazard, but follow definite, predictable patterns.

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For this investigation specimens were borrowed from 20 museums and other institutions. The bulk of material was supplied by the Danish Carlsberg Foundation. l commend the kindness and cooperative spirit shown by the curators and other investigators in loaning material and helping out and in many other ways. My sincere gratitude goes to all concerned. During various trips to examine collections, and in dealings by correspondence, l have always been treated with hospitality, and all collections have been placed at my disposal. The following is a list of the museums and institutions, together with their code-abbreviations, and of the persons who provided material and information:

AMNH, American Museum of Natural History: Charles M. Breder, Vladimir Walters.
AZM, Zoological Museum of Amsterdam: L. F. de Bfatfort, J. J. Hoedeman.
BM(NH), British Museum (Natural History): Denys W. Tecker.
BOC, Bingham Oceanographic Collections, Yale University: Daniel Merriman, James E. Morrow, Jr., Yygre H. Olsen.
BZM, University of Bergen Zoological Museum: Hans Brattström, Johan Fr. Willgohs.
CNHM, Chicago Natural History Museum: Marion Grey, Pearl Sonada.
CZM, University of Copenhagen Zoological Museum: Anton F. Brece, J. R. Pfaff.
D, R/V "Dana" Collections of the Danish Carlsberg Foundation at Charlottenlund Slot: A. Veder. Tining, Erik Bertelsen, Vita Holm, Esther Hansen.
G, Collections of the R/V"Galathea": Anton F. BricN, J. R. Praff.
GNM, Natural History Museum of Göteborg: Orvar Nybelin.
MCZ, Museum of Comparative Zoology, Harv. University: Widiam C. Schroeder, Myvanwy M. Dick.
MMF, Municipal Museum of Funchal, Madeira: G. E. Maul.
Ob , Collections of the $\mathrm{R} / \mathrm{V}^{\prime \prime} \mathrm{Ob}^{\prime \prime}$, Zoological Institute at the I'S.S.R. Academy of Sciences, Leningrad: A. P. Andriashev, O. $\mathrm{I}^{\circ}$. Lindberg.
POFI, L.S. Fish and Wildife Service, Pacific Oceanic Fisheries Investigations (now L.S. Bureau of Commercial Fisheries, Biological Laboratory, Honolulu): Donald W. Strasburg.
SIO, Scripps Institution of Oceanography, University of California, La Jolla: Carl. L. Hibbs, Richard H. Rosenblatt.
SLi, Natural History Museum, Stanford Cniversity: George S. Meyers, Mahgabet H. Stobey, Danifi M. Cohen.
ESNM, United States National Museum: Leonard P. Scheltz, Ehiest A. Lachner, Gifes W. Mead.
UW, Department of Oceanography, University of Washington: Whifam Aron, Peter McCrery. V, Collections of the R/V "Vitiaz": Institute of Oceanology, L.S.S.R. Academy of Sciences, Moscow: Theodor S. Rass, N. V. Pabin.
WhOI Woods Hole Oceanographic Institution: John Kanwisim:r, Richard H. Backus.
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My special thanks go to my wife, dan, who not only typed hundreds of pages of manuscript, but sorted collections, helped with statistical analyses, and drafted many of the figures and graphs. Most of all, however. I acknowledge her encouragement in completing this work.

## SYSTEMATICS

In the order Stephanoberyciformes (Xenoberyces), the Melamphaidae comprise spiny-rayed deep-sea fishes, which are, like the beryciform fishes, morphologically intermediate between the generalized clupeiform and the more specialized perciform types. Within this family the genus Melamphaes, even as here restricted, is the largest. The constituent species occur generally below $100-300$ meters in all oceans except the Aretic Ocean and the Mediterranean Sea.

The latest published worldwide revision of the group, that of Norman (1929), was based on inadequate material and information. He treated the Melamphaidae as comprising a single genus, Melamphaes, with 14 included species. Only 3 of these are in Melamphaes, as here restricted. Adding two new species, Parr (1931, 1933) expanded and revised Norman's key. Later studies by Cuapman (1939) and Koffoed (1953) added 3 more, bringing the total number of species recognized in the family to 18, and those in Melamphaes as here restricted to 5 . These few described species are only a fraction of the actual number and constitute a vast underestimation of the size and diversity of the group. The Melamphaidac, as I now interpret the family, comprise 5 genera and over 30 species. The genus Melamphaes alone contains 19 species, 13 of which are here described as new; these, in turn, can be alloted to 6 in part poorly defined species groups, one of which contains only "dwarf species".

This study is largely confined to the species of the single genus Melamphaes, as here restricted. During the course of the investigation 3003 specimens from 905 collections were examined and, of these, 857 specimens, representing most growth stages, were counted and measured. Geographical differentiation was statistically analyzed whenever possible.

## MATERIALS AND METHODS

In this section are listed or described expeditions and trawling gear, methods of depth determination, preservation and condition of specimens, explanations of counts and measurements, determination of sex, and the presentation of data. Inder this last heading are included the format for the species accounts, a means for division of specimens into growth stages for a more meaningful presentation of allometric proportions, statistical methods used in descriptions and variational studies, the format for listing of material, and listing and deposition of type specimens. Descriptions of methods used in the zoogeographical studies, including the water mass analyses, are given in the section, "Zoogeography and Speciation".

## Collections.

Expeditions:--In Table 1 are given relevant data on the expeditions and cruises that obtained the specimens used in the present study. Most of the pertinent stations are plotted in fig. 11. From the "dates" column, it is evident that most of the stations were occupied during the spring and summer months.

Gear.-For some years the Isaacs-Kidd Midwater Trawl has been by far the most eflective mechanism yet invented for capturing bathypelagic fishes. It has been built for a 15 -foot, 10 -foot, 6 -foot, or 3 -foot $V$ shaped beam depressor. The mesh size of the long, tapered net decreases from the mouth, which is held open

Table 1. Expeditions and cruises supplying Melamphaidae examined in the present study.

| Institution | Dates | Ship | Expeditions and/or stations | Area covered |
| :---: | :---: | :---: | :---: | :---: |
| U. S. Fish Commission ... | $\begin{array}{ll} \text { IlI: } & 1883- \\ \text { IX: } & 1887 \end{array}$ | "Albatross" | Stations 2001-2749 | Western North Atlantic |
| - .................. | $\begin{aligned} & \text { III: } 1888- \\ & \text { VII: } 1896 \end{aligned}$ | - | Stations 2792-3640 | Eastern tropical Pacific to Bering Sea |
| --- | III-VI: 1904 | - | Stations 4303-4566 | Southern California coastal |
| - | $\begin{array}{ll} \mathrm{X}: & 1904 \\ \mathrm{ll:} & 1905 \end{array}$ |  | Stations 4567-4743 | Eastern tropical Pacific, Calif. to Peru, Easter Island. |
| U.S. Bureau of Fisheries. | $\begin{aligned} & \text { X11: } 1907 \\ & \text { XII: } 1909 \end{aligned}$ |  | Stations 5096---5672 | Philippine Islands and vicinity |
| - .................. | III-IV: 1911 | - | Stations 5673-5699 | Off Southern California and Baja California, Gulf of California |
| Norwegian Government, University of Bergen..... | IV-VIII: 1910 | "Michael Sars" | North Atlantic Deep Sea | North Atlantic |
| Carlsberg Foundation. | IV゙-VIII: 1920 | "Dana II" | I, stations 823-900 | Central North Atlantic, Caribbean, Gulf of Mexico. Panama Bay |
| - .................. | $\begin{array}{ll} \text { VI: } & 1928 \\ \text { VI: } & 1930 \end{array}$ | -- | Round the world; stations 3501-4167 | Circumtropical, N. Atlantic |
| Discovery Committee. | $\begin{aligned} & \text { XII: } 1925- \\ & \text { VIII: } 1927 \end{aligned}$ | "Discovery" | Stations 1-297 | South Atlantic, Antarctic |
| New York Zoological Society | 1II- - $\mathbf{N}$ : 1929 | "Gladisfen" | NII | Off Bermuda |
| - .......... | IV-X: 1930 | - | XIII | - |
| - | V-XI: 1931 | - | 8-mi. cylinder | - |
| Woods Hole Oceanographic Institution | 1928-1940 | "Chance" <br> "Atlantis" | Columbus Iselin explorations of the Gulf Stream; stations 1004000 | Western North Atlantic |
| Scripps Institution of Oceanography | 1949-1959 | "Horizon," "S. F. Baird," <br> "Paolina T.," "Stranger" | Mise. trawlings | Eastern tropical, central, and South Pacific; California and vicinity |
| --.................. | VII-IX: 1951 | "Horizon" | Northern Holiday | Nortli Pacific, southern Calif., Aleutian Ids. |
| - .................. | V-VIII: 1952 | - | Shellback | Eastern tropical Paciflc |
| - | VII-XI: 1953 | 'S. F. Baird' | Transpac | Subarctic North Pacific, Japan; San Diego |
| - | 1949-1959 | "Horizon" | Eastropic | Eastern tropical Pacific |
| University of Copenhagen. | 1950-1952 | "Galathea' | Trench study | Circumtropical |
| L.S.S.R. Institute of Oceanology | $\begin{aligned} & 1950 ; 1953 ; \\ & 1954 ; 1955 \end{aligned}$ | "Vitiaz" | North Pacific; <br> stations 618-3535 | Western subarctic North Pacific |
| - . . . . . . . . . . . . . . . | $\begin{aligned} & \text { XI: } 1957- \\ & \mathrm{l}: 1958 \end{aligned}$ | - | Stations 3571-3998 | Western Pacific: $172^{\circ} \mathrm{W}, 40^{\circ} \mathrm{N}-40^{\circ} \mathrm{S}$ |
| - | III-VI: 1958 | "Ob" | Third Soviet Antarctic Expedition; stations 342-457 | South Pacific and Antarctic, Tasman Sea |
| Pacific Oceanic Fisheries Investigations | $\begin{aligned} & \text { 1952; 1953; } \\ & \text { VII-IX: } 1955 \end{aligned}$ | "J. R. Manning," <br> "Hugh M. Smith" | Cruises 15, 16, 30, 31 | Central North Pacific |
| University of Washington, Dept. of Oceanography.... | VII-IX: 1957 | "Brown Bear" | Cruise 176 | Gulf of Alaska, Aleutian Ids. |
| - | VII-VIII: 1958 | "Brown Bear" | Cruise 199 | Alaska-California |
|  | 1958 | --- | Cruise 202 | Gulf of Alaska |
| L.. S. Fish and Wildlife Service. | 1948--1955 | "Oregon" <br> "Caryn" | Miscellaneous explorations | Atlantic, Caribbean, Gulf of Mexico |
| Yale University, Bingham Oceanographic collection.. | 1926-1927 | "Pawnee" | Second Oceanographic | Eastern tropical Pacific |
| - |  | - | Third Oceanographic | Caribbean |

by the beam, a spreader bar, and 4 bridles, to the terminal plankton net (Isaacs and Kidd, 1953). It is towed at speeds of two and a half to six knots. Used extensively by the Scripps Institution of Oceanography, where it was developed ( 6 -foot, 10 -foot, and 15 -foot beam), it also serves the Russian Institute of Oceanology ( $10-$ foot beam), the Lniversity of Washington Department of Oceanography ( 6 -foot and 3 -foot beam), and the Pacific Oceanic Fisheries Investigations (6-foot beam).

The "Albatross" and "Galathea" expeditions employed heavy bottom trawls with rigid, rectangular openings. Even though these coarse-netted structures fished at relatively slow speeds, they were often effective collectors. During the "Galathea" Expedition midwater otter trawls, with the wide, non-rigid mouth held open by otter boards, successfully caught bathypelagic fishes and invertebrates.

Gently tapered, conical-ring, stramin nets were most universally used. The "Dana" and "Discovery" expeditions, for example, used these nets exclusively. Resembling butterfly nets, these nets usually carried weights to sink them. Those of the "Discovery" frequently contained opening-closing devices. The "Dana" Expedition used several sizes; the largest had an opening 3 meters in diameter. Parr, Tceker, and others have built variations of this net with triangular or square openings.

Depth determinations:-Most specimens were captured in trawl-hauls to below 100-200 meters. In general, the greatest depths of haul was determined trigonometrically from shiphoard. Unfortunately, few expeditions or cruises had nets with opening-closing devices. Therefore, depth ranges for the species in this study could be determined only by comparisons and evaluations of vertical series of net hauls or of many captures from several localities.

Condition of specimens:-Almost all the specimens were initially preserved in 10 per cent formalin; some were later transferred to 75 per cent ethanol or 40 per cent isopropynol. Most of the specimens are in poor condition. Because melamphaids have delicate skins, soft skeletons, fragile fins, and caducous scales, most specimens during capture were twisted, torn, scaled, and otherwise damaged. The counts and measurements of these specimens, therefore, are not only difficult to make, but are occasionally abnormally variable. Normally poorly ossified, the skeletons of many specimens were further decalcified during lengthy preservation in formalin. Most radiographs of these specimens, however, revealed the true vertebral counts.

## Counts and Measurements.

Counts and measurements were made on the left side of a specimen whenever possible. Measurements longer than $80-100 \mathrm{~mm}$. usually were taken with dial calipers, those between 10 and 80 mm . with needlepoint dividers, and those about 10 mm . or less with a stage-calibrated ocular micrometer. Although measurements less than $5-.-6 \mathrm{~mm}$. were recorded to the nearest 0.01 mm ., most were listed to the nearest 0.1 mm . All were calculated to thousandths of the standard length.

Most vertebral counts and structural observations were made from radiographs. Some small or poorly ossified specimens were dissected so that more accurate counts could be made.

Because of the structure and condition of the specimens, many new reference points or techniques were used in taking the counts and measurements. All counts and measurements except those already described in Hubbs and lagien (1949) are explained below. Since a large part of the squamation is often missing. scale counts are usually of the remaining pockets.

Counts:-Counts were made as follows: caudal rays, all procurrent and principal rays (usually $4+10-9+4$ ); pectoral rays, all except the small bony splint just before first (umbranched) ray (see account of family); scale rows, scales from and including mid-dorsal scale at nape, through all oblique rows, to, but not including, mid-lateral triangular scale that anteriorly slightly overlaps edge of hypural plate (the deviation from the usual initial point was adopted because the relation of the scale pockets to the shoulder girdle was often obscure); scales in diagonal series, all scales in an oblique series from and including the modified mid-dorsal scale immediately before the first dorsal spine to and including a scale of the midventral row near the anus (on the mid-sides of the body it is easier to count horizontal rows); vertebrae, all centra including the urostyle (the atlas has a slightly shorter centrum than the second precaudal vertebra and has associated with it an casily visible neural spine). The first caudal vertebra has a complete
arch and haemal spine. The arch frequently bears 2 antrorse spurs; the spine is more inclined than the one immediately following; gill rakers on lower limb of fourth arch, all rudiments and stumps, even patches of spines, but excluding those at or above angle; mandibular pores, all pores aligned near the outer margin of the mandible from and including the small, single pore just behind the angle to and including the large pore under the symphysis.

Accounting for the number of teeth in the jaws, the "tooth formula" in each species description gives the range of the number of tooth-rows through the widest part of the tooth-band in the right side of the upper jaw followed, after a diagonal, by that for the mandible (e.g. $6-7 / 2-4$ ). In the upper jaw the tooth-band is widest between the middle and end of the premaxillary; in the mandible it is widest immediately behind the symphysis.

Measurements.-Measurements were taken as follows: standard length, mid-line of upper lip tw caudal base (the edge of hypural usually subtends the anterior third of a large, triangular scale); body depth, insertion of pelvic, vertically upward; postdorsal, base of first dorsal spine to caudal base; end of dorsal to caudal, base of last dorsal ray to caudal base; snout to preopercle, mid-line of upper lip horizontally to edge of preopercle; orbit to cheek ridge, posterior edge of bony orbit on line with middle of eye, posteriorly, to edge of check ridge (ridge between bony orbit and preopercular edge); head depth, occiput directly over preopercle vertically downward to ventral edge of proopercle; interorbital, apex of one frontal angle (angle in wide margin of frontal bone over eye) directly across to its fellow; length of frontal fossa, anterior ridge of frontal knob, posteriorly, to line between posterior extremities of paired ridges on top of head; width of frontal fossa, edge of one of these paired ridges, perpendicularly, over greatest width of frontal fossa to the other; prepectoral, mid-line of upper lip to base of first pectoral ray; prepelvic, mid-line of upper lip to base of pelvic spine; isthmus to pelvic, midpoint of the ridge that ventrally crosses mandibles under nostrils to base of pelvic spine; pelvic to anal, base of pelvic spine to base of anal spine; preanal, mid-line of upper lip to base of anal spine; anal to caudal, base of first anal spine to caudal base; orbit to angle of cheek, posteroventral margin of fleshy orbit to recess between two spinelets at angle of cheek ridge (with dividers lightly pressed against the fleshy orbit; the slight reduction in measurement caused by pressing the dividers was taken into account when an ocular micrometer was used).

## Determination of Sex.

Every specimen that was counted and measured was also sexed. Females were considered ripe only if their abdomens were swollen with large organish eggs. Males were listed as ripe if their testes were milky white, occupied a sizable part of the posterior body cavity, and had within them easily visible convolutions. To inspect the gonads, a small, oblique slit was made in the body wall from the anal region obliquely forward.

## Presentation of Data.

Descriptions of the family, genus, and species groups complement descriptions of the included species. Characters of the family Melamphaidae usually are not repeated in the account of the genus Melamphaes and those differentiating the included species are omitted from this generic account. Descriptive experts that are common to all species within a species group are presented only once, following the diagnosis of the group. Because each species is carefully delineated in the key, no diagnoses have been prepared for the species accounts. The distribution section is placed near the beginning of each species account (immediately following the synonymy), because frequently the range is among the most useful criteria for species identification. Next, data on counts and measurements introduce the description proper, which is presented by morphological systems. Unless otherwise stated, this description is of adult and halfgrown specimens. After this are sections on sex ratio and size at maturity, geographical variation (if data are sufficient), distinctions from other species, remarks on nomenclature and synonymy (where necessary), derivation of the names of new species, and list of specimens examined.

Counts:--Lnder the "Counts" section of "Counts and Measurements" are given the ranges, followed
by the means, in parentheses, for the counts of 11 characters. The means are omitted if these counts have extraordinarily wide ranges and exhibit significant geographical variation. Unusual variation in counts is further analyzed in the body of the descriptions.

Measurements:-All measurements are presented as proportions in thousands of the standard length. The ranges, each followed in parentheses by means, are listed for 28 or 29 proportions in the "Counts and Measurements" section under "Proportions".

Because, for most of the species, collections contain relatively few adults, proportions of young and halfgrown specimens must also be listed. Furthermore, a method must be used whereby allometric proportions from different growth stages can be compared between all species. For each species, therefore, : or 4 allometric proportions, usually including head length and eve diameter, were plotted against the standard length. Two growth inflections frequently could be discerned on the resulting curves. After a rapid period of intensely allometric juvenile growth, there is a leveling off at the onset of adolescence; further on, the second, indistinct inflection probably represents the onset of sexual maturity. Therefore, these inflections normally separate 3 growth stages comprising the young, halfgrown, and adults. A fourth, postlarval, stage is analyzed for 2 characters for M. typhlops only. With sufficient data, the ranges and means of allometric characters for each species were apportioned into 2,3 , or 4 growth stages, although the allocation of the proportions into non-allometric or allometric categories is only an indication and is sometimes arbitrary, expecially when the total number of specimens is small, or when a particular growth stage is poorly represented in the collections.

Variational studies:-Analyses of geographical variation were made only for species that contained statistical series of specimens from 3 or 4 localities. These analyses follow the graphical method described by Hubbs and Hubss (1953). In each figure, the base line indicates the range; the small vertical line, the mean; the black-centered bar, two standard deviations, one on either side of the mean; and the dark bar, 4 standard crors, 2 on either side of the mean. The number of specimens can be calculated from the relative length of one white bar to the whole black bar, as shown in a graph in the paper by Hebrs and Hubrs; within the limits of specimens here employed, the number can be approximated by multiplying by 40 the ratio between the length of one white bar to the length of the whole black bar.

Statistical reliability of samples:-Because of the type of net used, track of the ship, depth trawled, cle., the collections were not taken randomly. Furthermore, it was sometimes difficult to make accurate counts and measurements due to the usual poor condition of the specimens. Both these sources of error could cause vome statistics to be misleading. Inasmuch as it is impossible to evaluate the errors involved, however, the means and ranges are presented as the hest approximations of valid statistics. The number of specimens available for study and therefore the sample number ( $n$ ) varied considerably from species to species; also because of the damaged specimens, $n$ varied within a single species from count to count or measurement to measurement. Ranges and means, therefore, are not always completely comparable. Nevertheless, even with $n$ less than $5-10$, the sample range and mean are the best estimates of the corresponding population parameters and should be of some value.

Subjective bias is omnipresent. At the onset of compilations for a particular species, an opinion is soon formed as to the range of values certain counts and measurements should include. Furthermore, if this error is recognized, it is often subjectively over-compensated. In the present study, damaged specimens occasioned considerable latitude in making some counts and measurements. Consequently, this source of error has been especially dangerous. It is assumed, however, that constant re-evaluations and rechecking of data have kept it minimal.

Listing of material:-For each species, specimens other than the holotype are listed under each broad locality in order by collection. Abbreviations of institutions preceding collection numbers are identified under "Acknowledgments". The data for each collection are presented in the following order: eollection number (e.g., D $2417(6)=$ sixth net from bottom, in "Dana" collection 2417) ; locality (e.g., $4^{*} 00^{\prime}$ ' $120^{\circ} 00^{\prime} \mathrm{E}$ ), represented by "do." when there is no change ; greatest depth trawled and time of capture (explained below); and number of specimens, followed in parentheses by size range in mm. of standard length (e.g.,

7(13-42)-if postlarvae are included they are so identified, e.g., $7 \mathrm{PL}-\mathrm{HG}(13-42)$ ). In the account of M. pumilus some of these data are condensed.

All depths are in meters, but if the number is followed by w. (e.g., 300 w .) it indicates the meters of wire out on the particular haul. For the Dana collections this value should be halved to obtain an estimate of the greatest depth trawled. The time of the haul immediately follows and is given simply as night (n), day (d) or, more rarely, both (dn or nd).

Types:--There usually is no specific treatment of holotype in the species descriptions. Instead, complete counts and measurements for each type specimen are given in the appendix. All holotypes and paratypes if the new species will be deposited in the institutions whose abbreviations precede the collection numbers.

## Melamphaidae

Melamphaidae. Regan, 1911: 2,8,9, (diagnosis; comprises with the Stephanoberycidae the order Xenoberyces; includes Caulclepis [ = Anoplogaster] and Anoplogaster. Jordan, 1923: 172 (in Xenoberyces; includes Anoplogaster). Bal:nard, 1925: 367-368 (diagnosis). Norman, 1929: 154-155 (includes Anoplogaster and Malacosarcus as related genera: aligned with the Stephanoberycidae). Weber and de Beaufort, 1929: (diagnosis, in part after Regan). Fowler, 1936a: 533 (diagnosis, after Barnard; key to genera; includes Platyberyx). Fowler, 1936b: 1263 (additional species listed; subfamilies Melamphainae introduced for Melamphaes, and Anoplogastrinae for Anoplogaster). Schultz and Stern, 1948: 237 (listed under Berycomorphoidea; aligned with the Stephanoberycidae, Rondeletidae, and Caulolepididae [Anoplogastridae]. Madl, 1949: 148 (subfamily Melamphainae recognized). Berg, 1947: 468 (includes Melamphaes and "other doubtful genera" in Beryciformes; order Stephanoberyciformes ( $=$ Xenoberyces) restricted to Stephan", berycidae). Madl, 1954: 39 (diagnosed in key). Fowler, 1956: 209 (key to species; "no orbitosphenoid").

## Classification.

In the classification of the Melamphaidae most investigators (e.g. Parr, 1931 and 1933; Fowler, 1956 ) have followed Normax (1929) in recognizing out of several available nominal genera only one genus, M/:lamphaes. The present study, however, reveals characters that seem to justify the division of the family into 5 well-defined genera, one of which is described as new. As here interpreted, therefore, the Melamphaida. comprise the genera Melamphaes Günther (=Plectromus Gill); Scopeloberyx Zugmayer; Scopelogadus. Vallant; Poromitra Goode and Bean (= Lophocephalus Osorio and Poromitrella Zegmayer), and Sin Moss. Although Regan (1911) included Anoplogaster (and its synonym Caulolepis) with the Melamphaidat, its peculiar scales, large fang-like teeth, deeply compressed body, and fin structure, among other differences. seem to preclude its placement in this family and to require the continued recognition of the monotypic family Anoplogastridae (Grey, 1955).

Because they ". . . differ from typical Berycomorphi [Beryciformes] in the toothless palate, the absence of a subocular shelf, and the triangular shape of the single supramaxillary," Regan (1911) erected the order Xenoberyces ( = Stephanoberyciformes of Berg) for the Melamphaidae (plus Anoplogaster) and the Stc. phanoberycidae. In this classification Jordan (1923) followed Regan. The toothless palate, the single tri angular supramaxillary, and the absence of a subocular shelf are characteristic of the order, although the species of Scopelogadus apparently lack a supramaxillary. In addition, the Stephanoberyciformes, in contras! with many other bathypelagic groups, usually lack luminescent organs, although small areas of undifferentiated luminous tissue may adorn some species. The applicability of the other characters is less certain. Regaxconclusion that in Stephanoberyx and Melamphaes the ". . . widely separated alisphenoids [are] not bridged by an orbitosphenoid. . ." was based solely on his making ". . . a temporary displacement of one eye in a spirit-specimen." Subsequent workers followed Regas in his conclusion. Actually in the Melamphaidar I find that the roof of the flattened, poorly ossified neurocranium approximates the parasphenoid bone, s. that the interorbital region is greatly reduced. It is impossible, therefore, to state with certainty whether any small area of bone in this region represents the orbitosphenoid or not, especially since sutures are very difficult to follow here. According to Regan the characters that the Stephanoberyciformes share with the Beryci-
formes are the spinous procurrent caudal rays, the 19 principal caudal rays ( 17 of which are branched), and the structure of the protractile mouth. In addition, the Melamphaidae, like the Beryciformes, have spines in both the median and pelvic fins; the Stephanoberycidae lack spines in the pelvics. Many berycoids have expanded frontals and cavernous superficial head bones, which are also characteristic of the Stephanoberyciformes.

Other families have since been added to the order. On the basis of "a great number" of osteological charaters, Parr (1929) followed by Berg (1947) and Matsubara (1955) allocated Rondeletia bicolor (Rondeleliidae), which with the Cetomimidae was placed in a suborder of iniomous fishes, Cetunculi, by Jordax (1923), to the Stephanoberyciformes. Furthermore, Rofes (personal communication) notes striking simibarities between this species and Gibberichtys pumilus, which he believes is a stephanoberyciform fish allied to the Melamphaidae. For the present, l concur with Rores and place the Melamphaidae, Stephanoberycidae, and Gibberichthyidae in the Stephanoberyciformes. Any statement as to the relationship of this group with the Cetunculi and the status and possible intermediacy of the Rondeletiidae should be deferred until those groups have been further investigated.

## Characters.

An examination of many species from all oceans has disclosed a considerable number of distinctive characters that previously had been overlooked or used sparingly without regard to their relative importance in distinguishing species, species groups, and genera. Among the characters mainly of generic importance are: the form and development of head ridges, the number and structure of the cheek scales, the shape of He stomach and the number of pyloric cacea, the presence and size of the supramaxillary bone, the condition and decoration of the head epidermis, the number of branchiostegal rays, and the development of the gas-bladder. Among characters important in separating species, species groups and genera are: the size at maturity; relative sizes of the head, eye, interorbital, mouth, and other body proportions (diagnostic proportions are usually those of body parts that exhibit allometric growth); the arrangement and size of ridges and spines on the head; the firmness and sculpturing of the head epidermis; the number, intactness, and structure of seales on the opercle and body; the form, development, and number of gill rakers; the number uf rows of teeth on the jaws; the number of rays in the dorsal, anal, pectoral, and pelvic fins; the relative mintion of the dorsal and anal fins and of the pectoral and pelvic fins; the size and proximity to each other if the pelvic fins; the number of vertebrae, both precaudal and caudal; the structure of the first caudal verkhra; the structure and shape of the gas-bladder and stomach; the shape of the larger postlarvae; and the distribution of pigment over the larger postlarvae. Intraspecific groups are distinguished mainly by counts and proportions.

## Diagnosis.

The stephanoberyciform family Melamphaidae comprise bathypelagic fishes with pelvic fins of one spine and $7-8$ soft rays; $3-5$ procurrent caudal rays; deciduous, usually large cycloid scales; well-developed nensory head canals, which underlie additional sensory structures in the form of epidermal embossed lines; wsentially no pored lateral lines; 5 - 8 pyloric caeca; and 10 patches of pharyngeal tecth, 5 on each side of the pharyngeal roof. The cavernous, relatively depressed neurocranium is composed of weakly ossified bones with thin, pliant ridges. The circumorbital bones are much expanded.

## Description.

Body and head form:-When viewed from the front the large thick head is generally squarish. From the side, the anterodorsal profile is abruptly angular or rounded. The body depth is nearly constant from the nape to the dorsal origin, from whence it evenly diminishes to a relatively slender caudal peduncle. Although senerally the rather streamlined body is blunted anteriorly by the head, a tapering profile and a subterete body render the contour of some species of Scopeloberyx and Poronitra almost fusiform.

Head ridges and sensory canals:-Cavernous superficial bones of the head and shoulders house the massive sensory-canal system. The canals, unlike those of typical percomorphs, are not covered by bone,
but only by head epidermis, which is stretched between paper-thin bony partitions. The system is super. ficially manifested by numerous ridges (the margins of the partitions), cavities, and pores. The two horizontal subparallel ridges (frontal ridges) on the top of the head above the eye, one on each of the paired frontals, partly enclose a cavity (frontal fossa) that extends from a vertical at or just before the anterior margin if the eve to a point just preceding the nape. A conspicuous medial protuberance of the frontals (frontal knol), bounds the frontal fossa anteriorly. Near the anterior, narrower end of the frontal fossa there is a translucent area, somewhat irregular in outline. Between the frontal ridges, this area subtends a hollow, which covers the epiphyseal region of the brain. Typically two pores lead from this sinus, which connects the paired supraorbital canals. Just behind the frontal fossa another sinus connects the peired supratemporal canals. The pores from this sensory canal also usually number 2 . The ridge that delineates the dorsal margin of the comcave snout extends obliquely on each side from the frontal knob, or from the internarial spine, if present, to the posterior nostril, where it meets the frontal ridge.

A cavity between the frontal ridge and the lateral margin of the frontal bone contains the supraorbit: branch of the sensory canal system. The posterior extremity of the frontal ridge ends opposite a dorsal ex tension of the variously armed cheek ridge, which follows the line of fusion of the hyomandibular with the preopercle, then extends ventrad to a point aligned with the angle of the preopercle, and after a perpendicular bend, continous to the maxillary. This ridge separates the ascending parts of the preopercular and infraorbital sensory canals. Prominent ridges form the orbital rim on three sides: the lateral extension of the frontal bone dorsally, and the upturned proximal margin of the circumorbital series posteroventrally. Although the fleshy orbit closely approximates the clear cornea, this bony orbital margin is irregular. It extends down the posterior edge of the eye in a series of 3 scallops, continues below the fleshy orbit, and slopes up with emarginations to the anteroventral margin of the eye. The resulting cavity between this margin and the check ridge contains the infraorbital canal. The decurved antorbital ridge, which extends to below and above the eye, is formed, more obviously in some species than in others, by the anterior of the frontal bone margin dorsally, by the prefrontal-lateral ethmoid bone anteriorly, and by the lachrymal ventrally. The check ridge on one side and the recurved margin of the preopercle on the other, form a through for the preoper cular canal. Dorsally this canal branches off the supratemporal canal and ventrally continues between ridges along the mandible as the mandibular canal. Other ridges above the preopercle bound the supratemporal canal, from which the infraorbital and preopercular branches originate.

Sensory canal pores:--Pores leading to the extorior from the sensory canals are scattered (in some species of Scopelogadus) or more, frequently, are regularly arranged, singly or in groups of 2 to 4 . Near the symphysis of the lower jaw a foramen connects a pore near the ventral tip of the dentary with another pore on the outer surface near the symphysis. This channel, which resembles the mental foramen of tetrapod, apparently houses the mandibular nerve and the anteriormost sensory placode of the mandibular canal. Just below the two nostrils another large slit-like pore leads into the infraorbital canal and, on the snout. into a large channel, which forms a median connection between the infraorbital canals on the two side . A vestigial lateral line is represented in all individuals by a few pores over the excavated posttemporal bone. and in some specimens, immediately posteriorly, by one or two pored scales. ${ }^{1}$

Epidermal embossed lines on head:-Narrow embossed dashes and lines, which resemble parallel folds, decorate most of the head epidermis. Since they are abundantly supplied with nerve endings of numer ous branches from the superficial nerves of the head (probably from branches of the seventh and, perhaps, secondarily, the tenth cranial nerves), it is assumed that their function is sensory. Near the front of each embossed line, a minute pore leads to the surface. The embossed lines are best developed over the sensor: canals between the frontal ridges, on the chcek, on the snout, and on the posterior half to three-fourths of the mandibles. On the snout they slant obliquely upward from a median line. Naked areas on the medial sides of the nostrils restrict these embossed lines to a well-defined triangular or trifureate area that ventrally covers the frenum. The embossed lines are minute and close-set in Melamphaes, but are sometimes more heavily pig mented, and generally more widely spaced in the other genera. They were first described by Bracer (1906).

[^7]Spines on head:--Just preceding the frontal knob, in Poromitra and less obviously in Scopeloberyx, all internarial spine projects from the fused nasals. In other genera this ipine is very weakly developed or is represented by a thin ridge. The opercular bones frequently have salient spines and radiating striae. On the opercle at about the level of the pupil a horizontal ridge ends in a weak spine that divides the posterior margin into an upper serrated part and a lower, more extensive smooth part. The individual serrations are exserted striae that radiate from a point on the opercle approximately opposite the pupil. From this same point another ridge extends obliquely ventrad. The subopercle is always smooth. The interopercle may bear a soft spine. The margin of the preopercle is smooth (Scopeloberyx, and most species of Melamphaes), very weakly serrate (Sio), weakly serrate (Scopelogadus), or strongly serrate and frequently with spines (Poromitra).

Mouth, teeth, and pharynx:- The cleft of the mouth is moderately wide and oblique. In adults minute prickles cover the lips and occasionally the front of the lower jaw. The minute conical teeth in the jaws are arranged uniserially or in cardiform bands. The palate is toothless, but small fleshy nodules are usually scattered on the lining of the buccal cavity, especially in larger specimens. Typically these are best developed over the vomer and palatines. Conical pharyngeal teeth form 5 patches on each side of the posterior gill arches. There are single patches on the second third, and fourth pharyngobranchials and on the third epibranchial and lower pharyngeal bone. The small, styliform first pharyngobranchial (suspensory pharyngeal) bears no teeth.

There are four complete gill arches; the fifth has no posterior slit and bears, in addition to the pharyngeal tecth, only a few rudimentary rakers. Small pseudobranchiae are present. The usually well-developed, compressed gill rakers number from 13 to 31 on the first arch and are usually closely set. On each arch, rakers from both inner and outer series have weak spines on their inner edges. The 7 or 8 branchiostegal rays are distributed along the hyoid in the following way: there are 4 or 5 on the ceratohyal, one between the ceratohyal and the epihyal, and 2 on the epihyal.

Two light-colored patches, possibly of luminous tissue, the lower of which is much the larger, are concealed under the operculum above the gill arches.

Scales:-Although the caducous, cycloid scales are usually moderate in size ( 20 to 40 in a longitudinal series), in Scopelogadus they are very large and somewhat irregularly arranged (12-15 in a longitudinal series). They appear to be frequently lost; many are replacement scales, with circuli only near the margins. The posterior margins are regular, but the covert anterior margins are either emarginate or scalloped. On each tale the circuli are either relatively widely spaced, so that the scales have a ridged, almost rugose appearance, m they are narrowly spaced and inconspicuous. Annuli are seldom, if ever differentiated and radii, though -uggested by emarginations in the circuli on the anterior field, are very poorly developed or absent. Besides hase on the body, modified scales shield the opercle and usually the cheeks.

Fins:-The single dorsal fin has 1 to 3 slender graduated spines and 9 to 18 soft rays. The anal fin originates tetween verticals from the middle of the dorsal hase to just behind the dorsal hase; the rays number I, $7-10$. The pectoral fins insert laterally on the body just under the posterior tip of the subopercle. The peetoral rays number 13-16. This count does not include an upper bony rudiment, which is probably a much reduced first pectoral ray. Typically it is a very short bony splint on a rounded base (Melamphaes, Poromitra, and owe species of Scopeloberyx), which in Scopelogadus is extend as a short filament. In Sio and some species of Scopelobery.x and Melamphaes the splint is greatly reduced or missing, leaving only the rounded base with an apical point. Situated just above the first actinost, the base of the splint articulates directly with the scapula. The thoracic or subabdominal pelvic has one spine and 7 or 8 soft ravs. The primeipal rays of the forked caudal number $10+9$; the $3-5$ dorsal and ventral procurrent rays are spinous.

Neurocranium and vertebral column:--The compressed neurocranium is notable for its broad, laterally extended and excavated frontals and for its greatly restricted interorbital space, which, in all species hut Poromitra megalops, is correlated with their having a relatively small eve. Because of this "flattening" of the neurocranium and the consequent proximity of the parasphenoid bone to the roof of the braincase, it was impossible to ascertain the presence or absence of an orbitosphemoid. Completely covering the cheek, the circumorbital ring is very wide and deeply channeled. The orbital margin is turned outward to partly
support the eye, the ring apparently has no "subocular shelf". The exoccipitals are broadly joined with thr basioccipital, which forms the main part of the occipital condyle. The structure of the condyle could not be related to either the percoid or berycoid type.

The vertebrae number $23-31$. The first caudal vertebra frequently has both a closed haemal arch and 2 spurs that extend ventrolaterally from the two elements of this arch (Sio, Scopeloberyx, some species of Melamphaes). There are 6 hypurals.

Digestive tract and gas-bladder:-The stomach consists of an anterior "esophagocardiac region" and a posterior "pyloric region". The duodenum projects ventrally from the anterior part of the pyloric region so that the posterior part extends caudad as a blind sac. Five to eight digitiform caeca surround the pylorus. The relatively simple intestine has but $2-4$ loops or bends. Behind the anus in both sexes a small anal papilla marks the exit of the urogenital tract. A functional gas-bladder is present in some species if Melamphaes, Poromitra, and Scopeloberyx.

Color:-Halfgrown and adults of most species are uniformly brown or black or somewhat mottled, depending on the amount of damage their epidermis sustained during capture and on the length of time they have been in preservative. Recently caught specimens are generally blackish or dark brown, whereas sperimens held long in preservative, particularly in the light, are lighter brown. The lining of the pharynx, gill arches, and buccal cavity is usually light or dark brown to blackish, occasionally with an iridescent bluish or grevish sheen. The disposition of larval pigment has proved important in the distinction of genera and of species groups within the genera.

## Analysis of Genera.

Because relatively few melamphaid specimens in genera other than Melamphaes have thus far been examined, the following key is tentative and may not include the best diagnostic characters. A definitive analysis must a wait further investigation of the family.

## Key to the Genera of the Melamphaidae.

1a. Scale rows fewer than 15 in longitudinal series (from nape to caudal base; scales always lost, leaving large, shaggy ill-defined scale pockets). Pyloric caeca 5 . Cheek scales absent (scale pockets never discerbible). Supramaxillary bone absent (Fig. 3A). Frontal ridges smooth (damage may secondarily cause ragged edges - Fig. 4C). Heamal arch of first caudal vertebra never with 2 downward-projecting spurs (Fig. 1A). Larger postlarvae robust ; body behind head to immediately preceding end of caudal peduncle evenly pigmented or mottled (Fig. 2A)

Scopelogadus Valllay.


Fig. 1. Series of 3 vertebrates. A, Scopelogadus bispinosus (standard length of specimen 71 mm .); B , Melamphaes laeviceps ( s . 1.125 mm . C, Melamphaes suborbitalis ( 5.1 .90 mm .). Left t 0 right, the first of each series is the last precaudal vertebra, the second is the first caudat vertebra, and the third is the second caudal vertebra. The arrow indicates the spurs at the front edge of the harmal arch and spine of the first caudal vertebra (I3, () or absence of these spurs (A).


Fig. 2. Postlarvae. A, Scopelogadus bispinosus (standard length of specimen 8.0 mm. ) ; B upper, Poromilra, sp. (s. l. 13.5 mm .); B lower, Poromilra megalops (s. 1.10 .0 mm .); C, Scopeloberyx, sp. (s. 1.6 .5 mm .); D upper, Melamphaes lugubris(?) (s. 1.8 .3 mm .); D lower, Melamphaes typhlops (s. 1. 9.4 mm .).


A


B

His. 3. Jaws. A, Scopelogadus beanii (standard length of specimen 98 mm .) ; B, Scopeloberyx, sp. (s. l. 69 mm .). The arrow indicates the supramaxillary bone (associated with the posterior expansion of the maxilla-B) or the absence of this bone (A). The hatched band marks the margin of the suborbital-bone series.

1b. Scale rows more than 20 in longitudinal series (scales usually mostly lost, but scale pockets well defined). Pyloric caeca usually $7-8$ ( 5 in some species of Poromitra). Cheek scales present, though usually lost (scale pockets frequently discernible). Supramaxillary bone present (Fig. 3B). Frontal ridges serrate and crestlike (Poro-mitra-Fig. 4A) or smooth (damage may cause secondarily jagged edges---Fig. $4 \mathrm{~B}-\mathrm{C}$ ). Haemal arch of first caudal vertebra with (Fig. 1 B-C) or without 2 downward-projecting spurs. Larger postlarvae slender or robust ; body not evenly pigmented or mottled, though in Melamphaes bands of pigment occur along either side of dorsal fin (Fig. 2B-D).

2 a. Frontal ridges crestlike with margins serrate (Fig. 4A). Conspicuous internarial spine at symphysis of paired nasals just before frontal knob (Fig. 4A). Ventral border, angle, and most of posterior border of preopercle serrate (Fig. $5 \mathrm{~A}-\mathrm{B}$ ). Total gill rakers on first arch $23--33$ (very rarely 22). Cheek scales $3-4$ (often lostFig. 7A-C). Larger postlarvae sparsely piginented or with narrow black dashes over most of body; margin of preopercle near angle with spines (Fig. 2B)

Poromitra Goode and Bean.
2b. Frontal ridges not crestlike, margins smooth (damage may cause edges to be secondarily ragged-Fig. 4B-C). Internarial spine absent or, if present, inconspicuous (Fig. $4 \mathrm{~B}-\mathrm{C}$ ). Border of preopercle smooth (Fig. 5D) weakly serrate Sio-Fig. 5E), or with a few relatively large, widely spaced spines around angle (M. spinifer-


A


B


C

Fig. 4. Head, mainly region in front of preopercle. A, Poromitra, sp. (standard length of specimen 121 mm .); B, Scopelogadus beanii (s. I. 87 mm .) ; C. Melamphaes laeviceps ( $\mathbf{s . 1 . 1 2 5 \mathrm { mm } \text { .). The arrows indicate the internarial spine or protuberance (IS) and frontal ridge (FR. } . ~ . ~}$


Fig. 5. Lower mid-lateral region of head behind eye, showing cheek and preopercle. A, Poromitra capito (standard length of specimen 99 mm ) ; B, Poromitra, sp. (s. 1.112 mm .) ; C, Melamphaes spinifer ( s .1 .72 mm .) ; D, Melamphaes acanthomus (s. 1.98 mm .) ; E, Sio nordenskjoldii (s. 1.76 mm .). Note the pattern of spines or the absence of spines around the preopercular angle.

Fig. 5C). Total gill rakers on first arch $13-30$. Cheek scales $2-3$ (often lost-Fig. 7D-E). Larger postlarvae sparsely pigmented or with pigment bands along case of dorsal fin, never with narrow black dashes over most of body; margin of preopercle near angle usually smooth (Fig. 2C-D)

3a. Elements of dorsal fin fewer than 13. Branchiostegal rays 7. Maxillary ends at a vertical from posterior border of pupil. Oral teeth uniserial. Diameter of eye in adults measures $0.72-1.0$ times distance from orbit to cheek ridges. Scales usually without circuli on posterior field (Fig. 6A)

3b. Elements of dorsal fin 13 or more. Branchiostegal rays 8. Maxillary extends to vertical from posterior edge of eye or beyond. Oral teeth in bands. Diameter of eye in adults measures $0.48-1.0$ times distance from orbit to cheek ridge. Scales with widely spaced and easily visible circuli (Fig. 6 B ), narrowly spaced and barely visible circuli, or without circuli on posterior field

1a. Elements of dorsal fin fewer than 16. Cheek scales usually more than 2 , the anteriormost not modified to form receptacle for end of maxillary (upper scales usually missing-Fig. 7D). Eye in adults usually more than 9 in head (rarely 7 or 8 ). Epidermis of head especially thin and fragile, usually damaged and missing, accentuating the head ridges (Fig. 8A). Larger postlarvae sparsely pigmented, never with pigment bands along base of dorsal fin; frequently a pigment spot near middle of caudal base, or one near end of anal base (Fig. 2C)

Scopeloberyx Zcgmayer.
4b. Elements of dorsal fin 17 or more. Cheek scales 2, the anteriormost modified to form receptacle for end of maxillary (Fig. 7E). Eye in adults usually less than 9 in head. Epidermis of head stronger so that it usually,

lig. 6. Scales from region under pectoral fin. A, Sio nordenskjoldii (standard length of specimen 76 mm .): B, Melamphaps leprus (s. I. 76 mm .). The anterior, scalloped field faces left. Magnification about $\times 7$.


Fig. 7. Cheek region with skin removed revealing cheek scales. A. Poromitra megalops (standard length of specimen 58 mm.): B. Poromitra. sp. (s. l. 138 mm .) ; C, Poromitra capito (s. 1.99 mm ); D, Scopeloberys, sp. (s. 1.69 mm ); E, Melamphaes laeviceps (s. 1.125 mm .).


Fig. 8. Heads. A, Scopeloberyx, sp. (standard length of specimen 110 mm .) ; B, Melamphaes laeviceps (s. 1.125 mm .). In "A" only a small patch of skin at the cheek angle remains. In " $B$ " all the head epidermis is intact.
but not always, remains mostly intact and the head is smooth (Fig. 8 B ). Larger postlarvae of all species except M. typhlops with pigment bands, which frequently continue into caudal peduncle, on either side of dorsal fin; a pigment spot always near middle of caudal base and usually also near end of anal base (Fig. 2D)

Melamphaes Günthf:.

## List of Nominal Species in each Genus.

The lists of species included under all genera except Melamphaes, which was extensively revised, are ntcessarily tentative and probably incomplete. Because not all the holotypes have been checked and not man! specimens of the consituent species examined, these lists mostly are of nominal species, the validity of whic! can be established only on the basis of further investigation. ${ }^{1}$

Although generic synonymies are given, the holotypes of the type species Scopelogadus cocles, Poromitrella nigriceps, and Scopeloberyx opercularis have not been directly examined or photographed. Examination of the holotypes of nigriceps and opercularis is especially important, because the original descriptions and illustrations are not diagnostic and it is difficult to ascertain even the generic affinities of these two species. Furthermore, it has been impossible to determine with certainty if any available specimens are conspecific with these species. Holotypes have been authenticated, however, for the type species of Poromitra ( $P$. capito), Lophocephalus (L. anthrax), Plectromus (P. suborbitalis), and Melamphaes (M. typhlops). Lophocephalus is an objective synonym of Poromitra. Evidence that Plectromus is a subjective synonym of Melamphaes is presented in the "Remarks" section that follows the description of the genus.

Decidedly not a melamphaid, the nominal species Melamphaes bericoides (Borodin, 1929) was referred by Parr (1937) to the genus Bathylagus (Bathylagidae).

## Scopelogadus Vaillant, 1888.

Scopelogadus mizolepis (Gënther, 1878) : new combination = Scopelus mizolepis Günther.
Scopelogadus beanii (GüNTHER, 1887) : new combination = Melamphaes beanii GüntıEn; probable synonym. Melamphaes eurylepis Holt and Byrne, 1906.
Scopelogadus cocles Vaillant, 1888: type species of Scopelogadus.
Scopelogadus bispinosus (Ghbert, 1890): new combination = Melamphaes bispinosus (inbert.
Poromitra Goode and Bean, 1883.
Synonym: Lophocephalus Osomo, 1906.
Probable synonym: Poromitrella Zcgmayer, 1911 a.

[^8]Poromitra megalops (Lütken, 1877): new combination = Melamphaes megalops Lë́tкел. Poromitra crassiceps (Güxther, 1878) : new combination = Scopelus crassiceps Güvther.
Poromitra capito Goode and Bran, 1883: type species of Poromitra; Probable synonyms, Lophocephalus anthrax Osonio, 1906 (haplotype of Lophocephalus) and Melamphaes triceratops Rocle and Angle, 1933. Promitra cristiceps (Gilbert, 1890): new combination $=$ Melamphaes cristiceps Gilmbrt. Poromitra frontosa (Garman, 1899): new combination $=$ Melamphaes frontosus Garman. Poromitra nigrofulva (Garman, 1899): new combination = Melamphaes nigrofulvus Garman. Poromitra macropthalma (Gilchrist, 1903): new combination = Plectromus macropthalmus Gilcheist. Poromitra unicornis (Ghbert, 1905): new combination = Melamphaes unicornis Gilbert. Poromitra nigriceps (Zugmayen, 1911a) : new combination = Poromitrella nigriceps Zegmayen (type species of Poromitrella).
Poromitra coronata (Gilchrist and von Bonde, 1924): new combination $=$ Plectromus coronatus Gilcintist and von Bonde.
Poromitra allantica (Norman, 1929): new combination $=$ Melamphaes atlanticus Nohman.
poromitra rugosa (Chapman, 1939) : new combination $=$ Melamphaes rugosus Chapman.

## Sio Moss.

Sio nordenskjoldii (Lönnberg, 1905): Melamphaes nordenskjoldii Lönnberg (type species).

## Scopeloberyx Zugmayen, 1911 a.

Sopeloberyx robustus (Günther, 1887): new combination = Melamphaes robustus Günther.
Scopeloberyx nigrescens (Braver, 1906): new combination = Melamphaes nigrescens Braver.
sopeloberyx maxillaris (Garman, 1899): new combination = Melamphaes maxillaris Garman.
Sopeloberyx opercularis Zlgmayer, 1911 a: type species of Scopeloberyx.
Sopeloberyx malayanus (Weber, 1913): new combination = Melamphaes malayamus Weber.
Sopeloberyx nycterinus (Gilbert, 1915): new combination = Melamphaes nycterinus Gilbert.
sopeloberyx opisthopterus (PARR, 1933): new combination = Melomphaes opisthopterus Parr.
Scopeloberyx microlepis (Norman, 1937): new combination = Melamphaes microlepis Norman.
Scopeloberyx rubriventer (Koefoed, 1953): new combination = Melamphaes rubriventer Koefoed.

Melamphaes Günther, 1864.
Synonymy: see under account of genus.
Melamphaes typhlops (Lowe, 1843) : type species of Melamphaes; synonym, Melamphaes crassicauda Koeford, 19 5̄3.
Melamphaes microps (Gënther, 1878).
Helamphaes suborbitalis (Gill, 1883).
Melamphaes lugubris Gilbert, 1890: synonym, Melamphaes cavernosas Chapman, 1939.
Melomphaes macrocephalus Panr, 1931.
.Melamphaes longivelis Parr, 1933.
Mclamphaes polylepis, new species.
Melamphaes acanthomus, new species.
Melamphaes cf. suborbitalis.
Helamphaes lepras, new species.
Melamphaes laeviceps, new species.
Velamphaes spinifer, new species.
Yelamphaes eulepis, new species.
Melamphaes parmus, new species.

Melamphaes janae, new species.
Melamphaes indicus, new species.
Melamphaes simus, new species.
Melamphaes hubbsi, new species.
Melamphaes danae, new species.
Melamphaes pumilus, new species.

## Melamphaes Günther.

Metopias Lowe, 1843 (not Metopias Gory, 1832) : 89-90 (type species, Metopias tivphlops Lowe, 1843 by monotypr: brief description).
Melamphaes Güntuer, 1864: 433 (type, Melopias lyphlops Lowe; substitute name for preoccupied Metopias; brief description).
Plectromus Gill, 1883: 257-268 (type species, Plectromus suborbitalis Gill, 1883 by monotypy; brief description).

## Distribution.

Melamphaes is distributed throughout all the major oceans except the Arctic, but does not occur in the Mediterrancan Sea. A majority of the species are tropical. The adults and halfgrown usually inhabit the bathypelagic region below $100-200$ meters; the larvae and young may occur at a lesser depth.

## Diagnosis.

Melamphaids with 17 or more dorsal rays (total), including 3 spines; 30 or more scale rows (from nape to caudal base 24 or more from end of posttemporal to caudal base); $7-8$ pyloric caeca; 2 cheek scales. the anteriomost of which is modified as a receptacle for the end of the maxillary; the oral teeth in bands; $x$ branchiostegal rays; a well-developed supramaxillary bone, no conspicuous internarial spine; a relatively smooth head (frontal ridges not serrate and the epidermis often intact); and relatively small head porcs. often in groups of 2,3 , or 4 . Antrorse spurs on the haemal arch of the first caudal vertebra are often present (Fig. 1).

## Description.

The following description includes, in addition to the diagnostic features, the characters that are common to all of the included species.

Body and head form:-Behind the dorsal origin the body contour slopes evenly to the caudal $\mathrm{p}^{\text {(- }}$ duncle. Anteriorly the contour of the dorsal profile is gently inclined from the dorsal origin to the frontal knob. Below this the concave snout abruptly drops so that the forehead appears angular. The slitlike posterior nostril is near the antorbital ridge, which ends in front of the eye over the mouth. The smaller, round anterior nostril is bordered by a slightly exserted rim. The diameter of the eye varies from slightly less to greater than the suborbital width.

Head spines and ridges:- The margins of the frontal ridges are smooth rather than serrate and crestlike as in Poromitra. Diverging downward and backward from the angle of the cheek ridge are two short. spinelike ridges, the lower of which is twice or more than twice the length of the upper. No obvious internarial spine projects from the nasal symphysis to support the prominent frontal knob. Pain (1931), however, mentioned the presence of a feeble "rostral spine" in Melamphaes macrocephalus. This spinelike strut, hom". logous with the well-developed intermarial spine in Poromitra, supports the thin epidermis at the front of th: frontal knob and is formed at the juncture of the paired nasals. When its epidermal cover is intact, the frontal knob is smooth and the strut is invisible. It is very weak and often lost, especially if the frontal knob has been damaged. Conversely, in Poromitra the spine is strong, sharp, and accentuated by the feeble developinent of the frontal knob. In the species descriptions, therefore, this structure is not described as a spine, although if the epidermis is damaged a ridge or strut is usually visible.

Except in Melamphaes spinifer, the preopercular margin is smooth and spineless. A characteristic ridgt. however, extends from the bend in the cheek ridge to the angle of the preopercle. Other weaker cross-ridges
may occur above this ridge. In both alcohol and formalin specimens the horizontal spine of the opercle and the denticulate border above it are weak and pliant. Though usually smooth, the dorsal margin of the posttemporal bone has an anteriorly directed "shoulder spine" on either side of the nape in M. acanthomus and 1. suborbitalis.

Head epidermis:-The relatively durable head epidermis is usually intact over most of the head ridges .ot that the head is usually smooth. The well-developed, but minute and narrowly spaced embossed epidermal lines cover most of the head, except for naked areas near the front of the head space, on either side of the frontal knob, on the medial side of the nostrils, at the anterior margin of the suborbitals, at the front of the mandibles, and behind the cheek ridge. On the snout they are restricted to a medial trifurcate area.

Sensory pores:-Pores from the infraorbital sensory canal comprise 3 groups of 2 pores each behind the eye, a variable group of $2-5$ pores in the space inside the angle of the cheek ridges, and 3 or 4 widely paced pores below the eye. Each group on the cheek and behind the eye is in a shallow recess that lies between two inconspicuous horizontal ridges. Above the eye along the supraorbital canal and proceeding posteriorly through the supratemporal canal the arrangement is $1-1+(1-2)+(3-4)+(2-3)$. The pores of the preopercular canal above the angle usually are arranged in 4 groups of $1-3$ pores each. Below the angle they number $2+1$. On the mandibular canal anteriorly to the symphysis, the pores are usually in 4 groups, the two end groups of which have single pores.

Jaws and teeth:-As seen from above there is a shallow groove at the maxillary symphysis. The jaws are subequal. Although the upper jaw is rounded, the lower jaw is bluntly pointed and bears a distinct symWhyseal knob. In side view the gape extends obliquely to near a vertical from the posterior border of the eye. The lips are narrow and the anterior part of the maxillary is hidden by the margins of the suborbitals and masals. On the distal, expanded part of the maxillary is a small, roughly triangular supramaxillary.

Minute, conical teeth form cardiform bands of $3-9$ rows on the jaws. In the upper jaw the band is widest just beyond the middle and narrows toward the ends, but is narrowest at the symphysis. In the lower jaw the band of teeth remains narrow ( $1-3$ rows) to near the middle, then widens. The width of the band remains :onstant forward and then abruptly broadens just behind the symphysis where the tecth are in about $3-5$ rows. Toward the symphysis of the upper jaw the teeth, in contrast, are almost uniserial. Whereas in the upper jaw the largest teeth occur in the outer rows, in the lower jaw they occur in the inner rows. The narrow patches of teeth on the second pharyngobranchial and third epibranchial are only $1-3$ teeth wide. The wider patches on the third and fourth pharyngobranchials, at their greatest breadth, are $5-7$ teeth wide. A long, narrow patch of teeth on the lower pharyngeal bone is hidden by the last gill arch.

Gill rakers and branchiostegal rays:-All species except M. typhlops and close relatives have long, well-developed gill rakers on the first arch. The longest, near the upper part of the lower limb or at the angle, equals or exceeds in length the diameter of the orbit. M. typhlops and siblings have narrow, poorly developed gill rakers which are only one-half to three-fourths the orbital diameter. The branchiostegal rays number 8.

Scales:-The medium sized body scales number $29-36$ in a longitudinal series. Over most of the body they are regularly arranged in horizontal rows, but the arrangement becomes irregular near the breast. In seneral, the scales are less easily lost than in the other genera, of which relatively few specimens are captured with even a part of the squamation intact.

Rows of rhomboid-ovate scales sheathe the bases of the median fins. A single file of $11-14$ scales extends along the dorsal base from just behind the first or second soft ray to the last ray. Along the anal base another raw of $6-7$ scales extends from between the first and second soft rays to the last ray. About 16 scales in two rows cover the base of the caudal fin. The sheathe seales extend only a short distance from the bases of the median fins outward on each interradial membrane. The bases of the pectoral and pelvic fins are also scaled. On the breast, in the wide space between the pelvic fins, a large triangular or clypeate scale is bordered on (ither side by smaller, slender scales; the breast in front of the pelvics is covered by enlarged scales.

Typically, 3-4 imbricate scales shield the opercle, subopercle, and interopercle. These consist of a relalively small scale adjacent to the upper border of the preopercle, a large median scale moulded to shape, and of one or two other smaller scales ventrally. Strikingly different, however, is M. lugubris, which has 8
subequal imbricate scales on this region. Only two imbedded scales are developed on the cheek. One is crowded into the angle of the cheek and the other is modified and sculptured for reception of the expanded end of the maxillary.

Fins:-The rays of the median fins are seldom intact. The longest dorsal ray is noticeably longer than the head space, while that of the anal is slightly longer than the distance from orbit to preopercle. A relatively high dorsal count is characteristic of the genus: the rays number III, $14-18$; only 5 specimens in almost 900 have 13 soft rays. The spines are weak and in a graded series, whose first member is about one-third the length of the last. The interspinous membrane is usually damaged, but appears deeply incised, nust deeply anteriorly. The anal fin originates under or just behind the last few rays of the dorsal fin. The rays typically number $I, 8-9$; a very few specimens have 7 or 10 soft rays. The weak anal spine is about a third to over a half the length of the first (umbranched) soft ray. The usually damaged interradial membranes appear incised, at least anteriorly.

The long alar pectoral fin, which obliquely reaches the last third to end of the dorsal base, is shallowly falcate. Although a few specimens have pectoral fins with 14 rays, the usual number is $\mathbf{1 5}-16$. The large pelvic fins, which originate near a vertical from the pectoral insertion, are set widely apart; they reach tis within $1-2$ scales of the vent. Both dorsal and ventral procurrent caudal rays typically number 4 ; the two longest ventral procurrents are fused basally.

Digestive tract and gas-bladder:-The slender pyloric caeca number 7-8. When fully extended, the longest is about as long as the stomach. The gas-bladder sits just above the stomach. It is either relatively thick-walled with a hypertrophied rete mirabile and gas gland, which together occupy a large part of the structure, or degenerate and partly or completely invested with fat.

Color:-In alcohol or formalin the unfaded specimens are generally dark brown to blackish, darkest on the operculum. Freshly caught specimens are blackish. On the distal parts of the fins the interradial membranes are usually light to hyaline, thought the rays are pigmented. This is partly the result of abrasion during capture because on a few specimens, especially of $M$. laeviceps, bits of pigment remain on these membranes. The gill arches are lighter than the lining of the pharynx. The branchiostegal membranes are dark brown to blackish.

Larvae and young:-Except in $M$. spinifer, the larvae and young have no spines on the preopercle. The body usually is slender, but in M. typhlops it is robust. The pigmentation of most larger postlarvae is distinctive. In all species but M. typhlops pigment bands occur along the dorsum on either side of the dorsal fin and usually extend onto the caudal peduncle. On the premetamorphic stage of some species these bands broaden laterally onto the posterior body and caudal peduncle. Larvac of M. typhlops characteristically have large dark pelvic fins. Areas of pigment characteristic of all species are: a punctate patch on the head above the eyes, a few scattered spots behind the eve and/or on the opercle, solid areas on the coclomic peritoneum, and a caudal spot or patch medially at the end of the hypural plate. In addition, spots or patches are usually developed just behind the anal base and bands or lines of pigment occasionally occur along the fin. After metamorphosis a general development of pigment over all the body rapidly obscures the larval pigmentation.

## Remarks.

From time to time the status of the nominal genus Plectromus has been questioned. Although, in his original diagnosis of Plectromus, Gill (1883) gave no characters that would separate this genus from Melamphaes as here interpreted, he did mention, in the description of the single included species $P$. suborbitalis, that the two forward-directed shoulder spines ". . . have gained for it the generic name Plectromus." He also gave the dorsal count III, 16 and the anal count I, 8. I have verified on the holotype the anal count and the presence of shoulder spines. Lnfortunately, however, some of the dorsal rays are missing. The dorsal count and shoulder spines taken together are, indeed, diagnostic of the species suborbitalis, but within the genus Melamphaes are useful for separating species only.

Goode and Bean (1895) quoted details of Plectromus furnished by Gill. Besides the characters mentioned above, important additions were that the preopercle is rounded, the operculum has large cycloid scales,
and the eye is about a quarter of the head length. Gill also included two characters from his original diagnosis "f the genus: namely that the small teeth are in more than one row and that the scales are moderate in size. All these characters, however, are found in most or all species of Melamphaes and, taken either together or singly, are certainly not diagnostic of a new genus. Other characters mentioned by Grle, e. g. toothless palate aind operculum with radiating ridges, characterize the family or order.

Güntimer (1864), in his redescription of M. typhlops (Lowe), confused the issue by incorrectly stating that this species has 6 spines in the dorsal and an anal count of II, 6. Goode and Bean (1895) used these characters and the posterior position of the anal fin to distinguish M. typhlops, the type species of Melamphaes, from species of Plectromus and, therefore, to retain that nominal genus. Braver (1906), however, in denying His separation, correctly showed that some species have both a posteriorly inserted anal and a dorsal with aly 3 spines. Gill was correct in his dorsal count of III, 16 and anal count of I, 8. Furthermore, all species of Melamphaes, including typhlops, have 3 dorsal spines and one anal spine; and the position of the anal in varies within the genus from the condition found in Melamphaes suborbitalis ( $=$ Plectromus suborbitalis) !n that in M. typhlops.

In summary, then, it is emphasized that Melamphaes as here interpreted is a natural unit. Furthermore, in describing Plectromus, Gill listed characters that either diagnose only species or distinguish Melamphaes w: higher categories as a whole and certainly do not justify the retention of the nominal genus Plectromus. Pinally, since Goode and Bean erred in separating Plectromus generically from M. Iyphlops, I conclude, in :arrement with Bracer, Normax (1929), and others, that Plectromus should be a synonym of Melamphaes.

Analysis of Species (based primarily on adults).
As here interpreted, the 19 or 20 species of Melamphaes can be divided into 6 species groups, of which the lugubris, suborbitalis, and typhlops groups are, perhaps, the more weakly constituted and the macroceHalus, spinifer, and simus groups are the more well-defined (Table 2).

Table 2. Comparison of the six species groups in Melamphaes.
Usual ranges of counts and proportions are given. Head length is in per cent, diameter of eye is in thousandths of standard length.


Table 2. - continued

|  | lugubris group | macrocephalus group | suborbitalis group | spinifer group | typhlops group | simus group |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Dev. gill rakers, th arch.... | well-formed stumpss | well-formed stunnps | well-formed stumps | low knobs | low knobs; spinous patches | well-formed stumps |
| Teeth: <br> rows in premaxillary | $1-7$ | $3-6$ | $5-8$ | $6-8$ | 5--9 | 2-7 |
| Origin of pelvic relative to pectoral. | behind | before | behind; under | behind | well-behind; under | well-behind |
| Origin of anal relative to dorsal | under last 2 dorsal rays | $\begin{aligned} & 3-1 \text { from } \\ & \text { last d. ray } \end{aligned}$ | $\begin{aligned} & 3-5 \text { from } \\ & \text { last d. ray } \end{aligned}$ | last 2 d. rays; under last | under last d.ray: well-behind | $\begin{aligned} & 2-4 \text { from } \\ & \text { last d. ray } \end{aligned}$ |
| Condition of epidermis . . . . | poor; very poor | very poor | poor | good | poor | poor; very poor |
| Ossitication of operculum.... | weak | weak | weak | strong | rather weak; weak | weak |
| Eye size | 42-56 | 41-50 | 42-55 | 52-62 | 42-54 | 40-52 |
| Head length | 35-. 38 | $40-41$ | 34-38 | 37-42 | 34-42 | 33-38 |
| No. of expansions in frontal fossa | 2-3 | 3 | 3 | 3 | $2-3$ | 2 |
| Size of individuals . . . . . . . . | "giant" | "giant" | "giant" | small; large | small; "giant" | "dwarf" |

The utilitarian separation of taxa is the primary function of a taxonomic key; only secondarily shoul: the key indicate relationships and preserve all natural groupings. The following key provides a compromis, between a natural and a convenient system. Only when the preservation of presumed natural grouping. interferes with the key's taxonomic operation are species groups broken. On the following outline the tw. poorly defined broken groups (lugubris, suborbitalis groups) are indicated by brackets.


## Key to the Species of the Genus Melamphaes:

1a. Total gill rakers on first arch 20 or more (rarely 19); width of largest rakers, near their midsections, subequal width of spaces on arch between them (Fig. 9A); length of longest raker at least 1.33 times eye diameter. Gill rakers on lower limb of fourth arch usually $10-13$ (range 9 14). Adults mature at $70-117 \mathrm{~mm}$. ...

1 b . Total gill rakers on first arch 19 or fewer (rarely 20); width of largest rakers, near their midsections, not more than three-fourths width of spaces on arch between them (e.g., Fig. 9 B ); length of longest raker usually less than 1.33 times eye diameter. Gill rakers on lower limb of fourth arch usually $7-9$ (range $6-11$ ). Adults mature at $18-134 \mathrm{~mm}$.

2a (1a). Pelvic rays I,8. Dorsal rays III,17-18 (rarely III,16). Body scales with width of widest grooves between circuli on posterior field only $3-5$ times width of narrowest grooves on anterior field. Vertebrae usually 29-30 (range 28-30). Posttemporal spines absent (cf. Fig. 10C). Melamphaes microps complex. Antitropical: North Atlantic, north of $32^{\circ} \mathrm{N}$, and Subantarctic Region.
23. Pelvic rays $\mathrm{I}, 7$. Dorsal rays $\mathrm{II}, 13 \cdots 16$. Body scales with width of widest grooves between circuli on posterior field 3-12 times narrowest grooves on anterior field or with smooth posterior fields without circuli. Vertebrac nsually 26-29 (range 26-30). Posttemporal spines present or absent (Fig. 10A-C).
$3 \mathrm{a}(2 \mathrm{~b})$. Scales in diagonal series $9-10$; scale rows $33-36$ (rarely 32 ); body scales without circuli on posterior field. Origin of anal fin under or behind penultimate dorsal ray. Spurs on first hacmal arch well-developed (Fig. 1C). Posttemporal spines absent (Fig. 10C)
33. Scales in diagonal series 8 ; scale rows $30-33$ (rarely 34 or 35 ); body scales with well-developed cireuli on posterior ficld. Origin of anal fin under third to fifth from last dorsal ray. Spurs on first haemal arch well developed or absent. Posttemporal spines present or absent (l $7 \mathrm{ig} .10 \mathrm{~B}-\mathrm{C}$ ).
4a (3a). Opercular scales 8 (usually missing) (Fig. 18). Pectoral ravs usually 16 (range 15-17). Head pores mostly single; on preopercle above angle they number 4-6, on mandible usually 4 (range 4-5) (Fig. 11 A). Precaudal vertebrae 12. Dorsal rays IH,15-16 (rarely III, 14). . Melamphaes lugubris. North Pacific Subarctic and Transitional Water masses.


A


B

His. 9. Sections, near the angle, of the first gill arch showing gill rakers. A. Melamphops lugubris (standard length of specimen 88 mm.); 1. Melamphaes typhlops (s. 1.68 mm .). The arrows span the width of the largest raker and the space between two adjacent rakers on the arch.


A

$B$


C

Fig. 11. Lpper mid-hatetal region of head behind eye, showing posttempotal bone, tpper cheek, and operculum. A. Melampheses acanthomus (standard length of specimen 98 mm .) ; 13, Mclamphaes suborbitalis ( s .1 .90 mm .) : C. Melamphaes lepras ( s . t . 76 mm .). The arrow indicates the spine at the anterodorsal margin of the posttemporal hone (A. B) or the absence of this spine (C).

4 b. Opercular scales 4 (usually missing). Pectoral rays 15 . Head pores mostly in groups; on preopercle above angle they number $10-11$, on mandible 5-7 (Fig. 11 B). Precaudal vertebrae 11. Dorsal rays usually III, 14 (range III,13-15) Western North and South Pacific Central Water masses, tropical Atlantic and Indo-Pacific.

5 a (3b). Body scales with width of widest grooves between circuli on posterior field $3-7$ times narrowest grooves on anterior field. Spurs on first haemal arch absent ; vertebrae 26-27 (rarely 28). Head length $40-44$ per cent of standard length. Pores on cheek inside angle 4-5 (rarely 3) (cf. Fig. 11). Insertion of pelvic fin directly under or slightly before that of pectoral ( $M$. macrocephalus group).


B


A

Fig. 11. Arrangement of pores in the cephalic sensory canal system. A, Melamphaes lugubris (standard length of specimen 88 mm.); l: Melamphaes polylepis ( s .1 .62 mm .). The arrows indicate taxonomically important groups of pores (enclosed by dashed rectangles): CH. cheek, inside angle (on infraorbital canal); MA, outer margin of mandible (atong mandibular canal); OR, under posteroventral angle ut orbit (on infraorbital canal); PR, preopercle, above angle (along preopercular canal); SL', supratemporal canal directly above preoperclt SY, pores at mandibular symphysis.

5b. Body scales with width of widest grooves between circuli on posterior field 10 or 11 times narrowest grooves on anterior field (less extreme in M. cf. suborbitalis) (Fig. 6 B ). Spurs on first haemal arch present and well developed or absent (Fig. 1); vertebrae 27-29. Head length $34-38$ per cent of standard length ( 40 per cent in M. cf. subarbitalis). Pores on cheek inside angle 3 (cf. Fig. 11). Insertion of pelvic fin slightly behind that of pectoral

6a (5a). Dorsal edge of posttemporal without antrorse spine. Total gill rakers on first arch 20-21 (rarely 19 or 22) Melamphaes macrocephalus. Eastern tropical Pacific.

6b. Dorsal edge of posttemporal with sharp, antrorse spine (Fig. 10A). Total gill rakers on first arch $22-24$ Eastern tropical Pacific.

Melamphaes acanthomus.
7 a (5b). Dorsal edge of posttemporal with sharp, antrorse spine (Fig. 10 B ). Vertebrae 28-29; spurs on first haemal arch well developed (Fig. 1 C ) (less extreme in $\boldsymbol{M}$. cf. suborbitalis). Dorsal rays III, 16 (rarely III,15). Atlantic specimens (at least) with well-developed gas-bladder twice length of stomach (Fig. 12A).

Melamphaes suborbitalis.
North Atlantic, Tasman Sea; M.cf. suborbitalis, central North Pacific.
7b. Dorsal edge of posttemporal without antrorse spine (Fig. 10 C ) (inconspicuous rudiment occasionally present). Vertebrae 27 ; spurs on first haemal arch absent. Dorsal rays III,14-15. Gas-bladder rudimentary (Fig. 12B) Eastern tropical Atlantic.

Melamphaes leprus.
8 a ( 1 b ). Adults mature at $34-106 \mathrm{~mm}$. (two sexually mature adults of the Indian Ocean population of $M$. janae are 28 and 29 mm .). Body scales with width of grooves between circuli on posterior field $2--10$ times narrowest grooves on anterior field or with posterior field without circuli; scales in diagonal series 8 . Pores on cheek inside angle usually 3-4 (range 2-5) (cf. Fig. 11). Diameter of eye equal to or noticeably greater than suborbital width.

ig. 12. Gas bladder and stomach. A, Atlantic specimen of Melamphaes suborbitalis (standard length of specimen 86 mm.); B, Melamphaes !!fis (s. :. 53 mm .). M, membranous sac (regressed in "B"); RG, rete mirabile and gas gland; S, stomach (note pigmentation). The hatched region marks the top of the coelom.

Sb. Adults ("dwarf species") mature at $18-27 \mathrm{~mm}$. (rarely $28-29 \mathrm{~mm}$.). Body scales with circuli equally spaced on all fields; scales in diagonal series 8-11. Pores on cheek inside angle 2 (rarely 3) (cf. Fig. 11). Diameter of eye noticeably less than suborbital width (M. simus group).
16.
!a (8a). Anal rays $I, 9$ (rarely $\mathrm{I}, 8$ or $\mathrm{I}, 10$ ); anal origin under fourth or fifth from last dorsal ray. Body scales with width of widest grooves between circuli on posterior field 9 or 10 times narrowest grooves on anterior field. Precaudal vertebrae 11. Adults mature at $112-134 \mathrm{~mm} . . . .$. . . . . . . . . . . . . . . . . . . . . Melamphaes laeviceps. Eastern tropical Pacific.

4b. Anal rays $I, 8$ (rarely $I, 7$ or I,9); anal origin under or behind last dorsal ray. Body scales with width of widest grooves between circuli on posterior field only 2-5 times narrowest grooves on anterior field or with posterior field without circuli. Precaudal vertebrae 11-12. Adults mature at $28-106 \mathrm{~mm}$.
10.
"a (9b). Either preopercle with well-developed spines, including large antrorse falciform spine at anterior border (M. spinifer) or head ridges expanded to reveal flanges of reticulate bone at their margins (M.eulepis) (Figs. 5C, 27). Body scales with width of widest grooves between posterior circuli 3-5 times narrowest grooves on anterior field. Squamation and head epidermis durable, usually mostly intact (M. spinifer group)

IIb. Preopercle without well-developed spines; head ridges thin, not expanded to reveal flanges of reticulate bone at their margins. Body scales with width of widest grooves on posterior field only $2-3$ times narrowest grooves on anterior field or with posterior field without circuli. Squamation caducous, rarely more than half intact ; head epidermis frequently damaged (M. typhops group).

1a (19a). Pores on cheek inside angle 4-5 (cf. Fig. 11). Scale rows usually 32 (range $31-33$ ). Teeth on third pharyngobranchial 25-40 (cf. Fig. 13). Vertebrae 26-28 (very rarely 29 ). Scales usually partly missing (see 10a for other characters)

Melamphaes spinifer. Eastern tropical Pacific.

1b. Pores on cheek inside angle 3 (cf. Fig. 11). Scale rows usually $34-35$ (range $33-36$ ). Teeth on third pharyngobranchial 45-55 (cf. Fig. 13). Vertebrae 29-30. Scales usually intact................... . Melamphaes eulepis. Tropical Atlantic, Indo-Pacific, and central equatorial Pacific.
$2 \mathrm{a}(10 \mathrm{~b})$. Anal origin directly under or slightly behind last dorsal ray (by considerably less than width of a scale pocket). Gill rakers on lower first arch, including raker at angle, $13-15$. Depth of caudal peduncle slightly more than twice in length.
13.

2b. Anal origin well behind last dorsal ray (usually by as much as width of one or one and a half scale pockets). Gill rakers on lower first arch, including raker at angle, 11-13. Depth of caudal peduncle twice or slightly less than twice in length
3a (12a). Adults mature at $76-106 \mathrm{~mm}$. Dorsal rays III,16-17 (rarely 1II,15 or III,18). Teeth on fourth pharyngobranchial $18-35$ (cf. lïg. 13). Vertebrae $28-30$; spurs on first haemal arch absent. Fin rays, base of pectoral fin, and head never punctulate. Scales with circuli on all fields. Predorsal length usually less than 42 per cent of standard length Melamphaes longivelis complex. Central North Atlantic to central North Pacific.
 ryngobranchial 7-18 (cf. Fig. 13). Vertebrae $25-29$; short spurs on first haemal arch usually present (cf. Fig. 1 I3). Fin rays, base of pectoral fin, and head (mainly in front of preopercle) in most young, halfgrown and smaller adults very finely punctulate. Scales with circuli on all fields or with posterior field without circuli. I'redorsal length usually more than 42 or 43 per cent of standard length.

14 a (13b). Scale rows $32--33$; body scales with circuli on all fields. Vertebrae 27-29. Head usually less than 40 per cent of standard length

Melamphaes parvus. Transitional Water of western North Pacific.


Fig. 13. Patches of pharyngeal teeth on the left side only of the roof of the pharynx of Melamphaes lugubris (standard length of specime 88 mm.$)$. Gill arches 2 and 3 are shown parted. The arrows indicate discrete patches of teeth: E3. patch of teeth on third epibranchial P2, on second pharyngobranchial; 『3. on thi'd pharyngob:anchial; P4, on fourth pharyngobranchial. A tifth patch of teeth on the upp. pharyngeal bone (ceratobranchial of fifth gill aich) is not visible in the view illustrated. The arrangenment of patches is similar in all mu lamphaids (see description of family).

14b. Scale rows $29-31$; body scales with posterior field without circuli. Vertebrae $25-27$. Head usually more than 40 per cent of standard length

Melamphaes janu Eastern tropical Pacific and tropical Indian Ocean.

15a (12b). Body scales with posterior field without circuli. Total gill rakers on first arch usually 16--17 (range 14-17); length of longest subequal eye diameter. Gill rakers on fourth arch distinct knobs or convexities with 7--9 spines (Fig. 14A) (rarely reduced to spinous patches of more than 8 spines each)... Melamphaes indicu: Tropical Indian and western Pacific oceans.

15h. Body scales with circuli on all ficlds. Total gill rakers on first arch $14-15$; length of longest less than eye diameter. Gill rakers on fourth arch reduced to low convexities or patches of 7 - 20 spines each (Fig. 14 B )... mainly North Atlantic Ocean.

Melamphaes typhlops.
16a(8b). Anal rays I,9. Dorsal rays III,16 (rarely III, 15 or III,17). Total length of gas-bladder twice that of rete and gas gland (Fig. 15A)

Melamphaes simus. Eastern North Atlantic, western central North and South Pacific, Indian Ocean, Indonesia.

16b. Anal rays I, 7 - 8 . Dorsal rays $111,14-15$ (rarely II 1,16 ). Total length of gas-bladder $3-5$ times that of rete and gas gland (Fig. 15 B)

17a (16b). Scale rows $35-36$; scales in diagonal series $10-11$. Head length 33 or 34 per cent of standard length. Vertebrae 28-29

Melamphaes hubbsi South Atlantic Ocean.
17). Scale rows $30-32$ (rarely 33 or 34 ); scales in diagonal series $8-11$. Head length $35-39$ per cent of standard length (rarely 33 or 34 ). Vertebrae 25-28
18 a (17b). Scales in diagonal series $10-11$ (rarely 9 ). Vertebrae $25-27$ (rarely 28 ); precaudal vertebrae usually 11; short spurs on first haemal arch present. Tooth formula 2-4 (rarely 5)/2-3...... Melamphaes danae. Tropical Indo-Pacific.


His. 14. Fourth gill arch, showing rudimentary gill rakers and patches of spines. A, Melamphaes indicus (standard length of specimen 48 mm .) ; 1, Melamphaes typhlops (s. 1.59 mm .). Gill filaments have not been completely sketched in.


Hig. 15. Gas bladder and stomach. A, Melamphaes simus (standard length of specimen 26 nmm.); 13, Melamphaes danae (s. 1. 21 mm.). II. membranous sac (partly invested by gelatinous or fatty tissue in "B"): RG, rete mirabile and gas gland; S, stomach (note pigmentation). The hatched region marks the top of the coelom.

19b. Scales in diagonal series 8. Vertebrae 27-28; precaudal vertebrae 12 ; spurs on first haemal arch absent.
Tooth formula 5-7/3-5
Melamphaes pumilus.
Western central North Atlantic.

## Relationships of Species.

Not all the species of Melamphaes are immediately separable into distinct natural groups. Morphological trends can be traced for several characters, but these trends are seldom correlated from group to group. Some of the more obvious of these character trends are the following. The number of check seales is 8 in M. lugubris, and 4 in all other species. The sculpturing of the scales differs between and within the species groups, but the more rugose type of scale is characteristic of the primitive suborbitalis group. There is a tenlency for a reduction in number and decrease in size of the gill rakers: whereas on the first arch several primitive species have numerous long rakers that are wide and closely packed, others, more specialized, have them relatively narrow and short; in $M$. typhlops they are almost rudimentary and the rakers on the fourth arch are replaced by spinous patches. The spurs on the first haemal arch are more often well developed in the primitive groups. Size of mature adults seems to be of utmost importance phylogenerically: whereas
some large adults of the more primitive microps, suborbitalis, and mucrocephalus groups attain lengths of 4 or $\overline{5}$ inches, the specialized simus group comprises only "dwarf species", the individuals of which seldom exceed and inch in standard length (Table 2).

Initially, the six species groups in Melamphaes were constituted primarily on the basis of these few characters of presumed phylogenetic importance. The lugubris group was considered the most primitive and the typhlopsis and simus the most specialized. Because it is based only on a few characters and "educated guesses", howewr, such an arrangement may be illusory. Each species, moreover, exhibits a combination of primitive and $\mathrm{s}_{\mathrm{p}} \mathrm{c}$. cialized characters in nearly equal numbers. Hubbs and Black (1947) aptly referred to a similar profusion of characters in the cyprinid genus Ceratichthys as "the jumbled association of archaic and modified features in each species." Does this arrangement, then, have any relation whatsoever to a phylogeny of the genus: To attain a logical hierarchy of specialization within Melamphaes an "index of primitiveness", adapted from Hebbs and Black, was calculated for each species. As here applied the weakness of this method lies in the quantification of 28 characters into 3 or 4 states of specialization, from the most primitive (1) to the most specialized (t); although a plausible order of states was generally assumed, they were often scored somewhat arbitrarily. A theoretical archetype of Melamphaes might exhibit characters in the following states: counts of dorsal rays, pelvic rays, scale rows, opercular scales, gill rakers, and vertebrae high; counts of tooth rows and sensory pores low; spines on posttemporal and spurs on first caudal vertebra well developed; scalss relatively rugose and durable, with raised, widely spaced circuli on the posterior field; epidermis intact: head bones well ossified and the opercular bones spiniferous; gill rakers long, wide, and densely packed. on the fourth arch forming definite stumps, rather than being reduced to spinous patches; pelvic insertion behind the pectoral, but the anal origin well in front of the end of the dorsal; gas-bladder pneumatic; stomach long, slender and evenly pigmented; eye relatively large, but the head not bulky; size of mature adults relatively large.

Difficulty besets the justification of erecting primitive and specialized states of characters. Any decision as to the state of specialization of any character is necessarily somewhat arbitrary, for some characters more so than for others. The decisions originate in highly subjective interpretations of character trends within the berycoid fishes and relatives or in probable assumptions as to the form and habit of a likely archetype. High vertebral $(30-50)$ and scale ( $30-50$ ) counts characterized primitive berycoid-like clupeiform fishes (e.… Ctenothrissa, Aulolepis, Pseudoberyx) from the Upper Cretaceous (Woodward, 1901). Throughout the Beryciformes and allies, in fact, there has been a general reduction in vertebrae, scales, and other meristic count, in the more specialized groups. For example, the more generalized extant species (Beryx, Holocentrus, Myripristis) usually retain longer series of fin rays, better developed gill rakers, and more scales than do the melamphaids. The relatively large number of unspecialized opercular scales in Melamphaes lugubris obviously represents a more primitive state than the sculptured 4 -piece opercular armor of M. spinifer and M. eulepis. Both the presence of well-developed spurs on the first haemal arch and of a spine on the posttemporal are primitive states; some species retain rudiments of spines, which indicates that these structures are being lost. Rough ctenoid scales and spiniferous opercular bones shield many primitive beryciform-like fishes; many specialized species have thinner, smoother body armor (the clupeiform-like ancestors of the Upper Cretaceous, however, may have had smooth heads and scales). In Melamphaes typhlops and close relatives a trend realized degeneration of the gill rakers. On the fourth arch the rakers are atypical spinous patches in $M$. typhlops. Because in succeeding stages of teleost evolution, the pelvic fins are inserted more anteriorly, it is assumed that within the genus Melamphaes, the more forward insertion is the more specialized state. Relative to the dorsal, the anal fin moves backward during ontogenesis in most species of Melamphaes. Because of this developmental positioning and of the fact that each of the more specialized species in the typhlops groul has a posteriorly inserted anal, the anterior position is assumed the more primitive.

Other characters (e.g., size of head and eye, development of gas-bladder, condition of epidermis) are modified along certain lines during adaptation to a deeper, more completely bathypelagic habitat. A form resembling the archetype would, perhaps, be a relatively shallow-dweller, feeding on smaller plankton. Later trends might include either adaptations for a deeper habitat and a carnivorous (e.g., degeneration of gill
rakers, optical sense, and gas-bladder; enlargement of the sensory canal system, therefore also of the head; deossification of the skeleton and decrease in density of the body tissues) or adaptations leading to a better exploitation of the mesopelagic realm (e.g., increase in numbers of teeth in the jaws and pharynx and formation of an effective pharyngeal filtering apparatus; decrease in adult size, which might cause the individuals tw be more effective plankton traps in the less productive areas; streamlining of the body and smoothing of siales).

For each species the index of primitiveness is the total score for the quantified states of the 28 characters; for the species group this index is the average among the constituent species (Fig. 16). The scores of the extreme


Fis. 16. Evaluation of specialization in each species and species group of Melamphaes. The index of primitiveness for each species is plotted, but for each group it is numerically listed as the average value for the constituent species. The method of calculating these indices is wplained in the text. Vertical lines separate species groups; horizontal lines, stages of specialization. Hatched boxes denote correspondence between subjectively determined species groups and stages of specialization.
tates of 3 characters, the number of opercular scales, the size of adults, and the condition of gill rakers, were weighted by 2 units because these characters are thought to be the most important phylogenetically.

In general, the results tend to substantiate the subjective arrangement of the species accounts (according w the order of species established in the key; however, the specialized macrocephalus group is placed immediatcly after the primitive lugubris group in the species accounts). The lugubris, suborbitalis, and typhlops groups have within them primitive or specialized species that transcend stages of specialization, i.e. are outside the hatched boxes in Fig. 1 (M. polylepis, suborbitalis, longivelis, parvus). Also, even though in the species accounts the most primitive species in the typhlops group (M. longivelis) has a lower index than any species in the "inus group, the listing of the "dwarf" simus group after the typhlops group may be erroneous.

As pointed out by Carl L. Hebbs, the indices of primitiveness are not necessarily indicative of morphol, ${ }^{\text {gical }}$ correlation between species, but are evaluations of differential specialization. For example, one species if a pair might be primitive with respect to the first half of a series of characters, but specialized with respect
to the second; the situation might be reversed in the second species. Therefore, although obviously not closely related, both species would have similar indices.

## Species Accounts.

To save space elements of the descriptions common to all species within a particular species group are presented only once, following the diagnosis of the species group. Head-pore counts are designated in Fig. 11, pharyngeal-tooth counts in Fig. 13.

## M. lugubris species group.

'The characters that unite the species referred to this group generally overlap those of other species groups. All three species have numerous, wide, close-set gill rakers on the first arch and well-formed stumps on the fourth. Usually numbering 28 or more, the vertebral counts, always with 12 precaudal, are also high. All three species reach a relatively large size. M. lugubris and M. polylepis definitely appear to constitute a natural unit: both have well-developed spurs on the haemal arch of the first caudal vertebra and scales with snomith posterior fields. M. microps is provisionally referred to the lugubris group because of common characters, but the placement is somewhat uncertain because the available specimens are few or in poor condition.

Although polylepis is almost circumtropical in the Atlantic, lndian Ocean, and western Pacific, lugubris and microps are subarctic or antitropical in distribution and do not occur in the mid-latitude.

The following descriptive excerpts pertain to all 3 species.
Head ridges:-The margins of the head ridges are not expanded. The frontal knob is smooth.
Spines, opereulum, and posttemporal:-Except on the opercle the head bears no obvious spiner. The angle of the thin, pliant preopercle is smooth, rounded, and only slightly emarginate. At the preopercular angle a small convexity marks the end of a weak ridge that originates near the cheek angle. No reticulate bone reinforces the opercular series. The smooth preopercle is practically unsculptured. The thin dorsal edge of the posttemporal is spineless.

Gill rakers:- On the first arch the rakers are long, widely compressed, and closely packed, with the spaces between them approximating the greatest width, near the middle, of the larger rakers. The rakers on the lower fourth arch usually number 9-12. Each of the larger rakers is a short, but well-formed stump, the length of which equals the adjacent width of the ceratobranchial; the inner edge bears $4-8$ spines.

## Melamphaes microps (Güvther) complex.

Fig. 17.
Heretofore, besides the large holotype dredged between Africa and Kerguelen Island, only a few small specimens from the North Atlantic could possibly have been correctly reported in the literature as M. microls. The holotype was not examined directly, but photographs, counts, and a body scale were obtained. The count-, proportions, and descriptions in the present account are partly based on these. Because of this lack of material and the fact that the number of available Subantarctic specimens has been supplemented here by only 2 postlarvac, it is impossible to tell if the few individuals from the North Atlantic north of $32^{\circ} \mathrm{N}$ should be identified with microps. For this reason, characters for these two groups will be separated throughout this account.
M. microps-references to Subantarctic specimens.

Scopelus microps.-Günther, 1878: 186 (original description; dredged in 1375 fathoms, between Cape of Good Hop: and Kerguelen Is.).

Melamphaes micrups.-GËnther, 1887: 26-27 (new combination; short description; measurements). Vaillant. 1888: 386 (close relationship with Scopelogadus cocles). Murray, 1895: 447 (in "Challenger" station-capture list). Gapman, $1899: 383$ (listed). Bfacter, 1906: 279, 280 (in key; distinguished from S. cocles). Norman, 1929: 155, 157-154 (in part [see also M. simus and M. suborbitalis]; description based in part on holotype; synonymy; notes and com parisons; in key; holotype examined). Parı, 1931: 39 (in part; in key); 1933: 14,15-16,17 (in part [see also $M$. lon
yivelis and M. pumilus]; erects subspecies; captures; in key). Fowler, 1936: 1264-1265 (synonomy; comparisons; in key). Chapman, 1939: 533,534,535 (in key; comparison with M. cavernosus).

Plectromus (?) microps.—Goode and Bean, 1895: 518 (doubtful new combination; type locality).
Melamphaes "microps"--references to North Atlantic specimens, including probable records (?).
Melamphaes microps.-(?) Roule and Angel, 1933: 68 (one young specimen in bad condition trawled in 4000 meters at $40^{\circ} 15^{\prime} \mathrm{N} 56^{\circ} 25^{\prime} \mathrm{W}$ ). Beebe, 1937: 206 (in part [see also M. pumilus, suborbitalis, typhlops]; tabular sumnary of (aptures). Koefoed, 1953: 16-17,19 (in part [see also M. suborbitalis]; description; table of measurements; synonymy ; (wimparisons). Albuquerque, 1954-56: 585 (comparison with M. tuphlops).

Melamphaes lugubris (misidentifications).-PARR, 1933: 17-18 ( $32^{\circ} 24^{\prime} \mathrm{N} 64^{\circ} 29^{\prime} \mathrm{W}$; tabular comparisons of morphometrics; discussion). (?) Fowler, 1944: 441 (in check list, probably after Parr).

## Distribution.

If, in fact, the microps complex is homogencous, it will be, with M. suborbitalis, one of the several known antitropical species of bathypelagic fishes. To my knowledge, only 3 Subantarctic specimens have been talen: one near the southwest tip of Africa, one off New Zealand, and the holotype of microps between the Cape of Good Hope and Kerguelen Island (Fig. 43). The two "Dana" specimens are postlarvae, one trawled in 300 meters, but the holotype is a large adult taken in 2520 meters.

Specimens of the North Atlantic form are all from $32^{\circ}$ N to $58^{\circ} \mathrm{N}$, between the Secondary Polar Front and the Arctic Convergence (Fig. 43). Both young and adults are from deep tows.

## Counts and measurements.

Counts:--For ease of comparison, the values for the holotype and the ranges for the other Subantarctic and North Atlantic specimens are presented in tabular form.

|  | Holotype <br> M. microps | 2 Subantarctic specimens | 8 North Atlantic specimens |
| :---: | :---: | :---: | :---: |
| Dursal | III, 18 | 1II, 17-18 | III, 16-17 |
| dial. | I, 8 | I, 7-8 | I, 8 |
| Caudal | $10+9$ | $4+10-9+4$ | $4+10-9+4$ |
| lsctoral | 15 | 15 | 14-15 |
| Pelvic. | I, 8 | I, 8 | I, 8 |
| Scale rows | 33 or 34 | 35 ? | 32-33 |
| rales in diagonal series | 8 ? | . | 8 |
| Vertebrae. | . | 30 | 28-30 |
| Gill rakers on first arch | $6+18$ | $6+17-18$ | $5-7+15-17$ |
| (iill rakers on lower fourth arch. | . | 10-11 | 10-12 |
| Jandibular pores | . | $\cdots$ | 4 |

Proportions:-The following are proportions for the holotype ( 99.1 mm .), taken from photographs and the original description, each followed, in parenthesis, by the range for the 4 largest North Atlantic specimens ( $34-48 \mathrm{~mm}$.) : body depth 277 (270-280); predorsal 429 ( $439-462$ ); postdorsal 605 ( $594-617$ ); head length 350 ( $378-398$ ); postorbital 211 (227-238); snout to preoperele ( $274-283$ ); orbit to cheek ridge 56 ( $64-70$ ); head depth 260 ( $257-280$ ); head width ( $203-208$ ); interorbital (117-135); length of frontal fossa ( $151-165$ ); width of frontal fossa ( $74-85$ ) ; prepectoral 340 ( $383-410$ ); prepelvic 385 ( $404-$ H13) ; isthmus to pelvie 341 ( $339-343$ ); pelvic to anal 321 ( $288-316$ ); pectoral 293 (304-328); pelvic (213-257) ; preanal $689(667-693)$; anal to caudal 333 (326-339) ; length of caudal peduncle 232 ( $244-$ 2.97 ); depth of caudal peduncle 107 ( $89-98$ ); upper jaw ( $178-195$ ); orbit to cheek angle 111 (111-130); shout length 101 ( $94-98$ ); suborbital 45 ( $45-55$ ); eye 51 ( $54-62$ ).


Fig. 17. Melamphaes microps (Günther). A, holotype, traced and modified from a photograph obtained through the courtesy of the I3ritish Museum (Natural History) (standard length 99.1 mm ) ; 13, postlarva, D 3979(2), taken off southwest tip of Africa (s. I. 21.8 mm ).

## Description.

For each section the holotype will be described first, usually followed by contrasting or supplementary notes on the North Atlantic specimens.

Body and head form:-The streamlined body narrows abruptly at the anus to a tapered caudal peduncle, which is noticcably more than twice as long as deep (Gëxther gave the least depth as "two fifths in its free portion"). The body contour along the dorsal fin is almost straight. The ventral contour remain straight from the pelvic symphysis to the anus. From the dorsal origin to the frontal knob the profile descendmost abruptly over the cheek, in a weakly convex curve. In contrast, the ventral contour of the head remain almost straight from the pelvic symphysis to the isthmus, where it abruptly bends up to the mandibulai symphysis. The diameter of the eye exceeds the suborbital width.

In the North Atlantic specimens, the body narrows gradually at the anus to a more slender caudal peduncle which is more than 2.5 times as long as deep. The diameter of the eye measures about 0.6 times the snout length. From the premaxillary symphysis to the anterior end of the frontal knob is slightly less than the distanct between the anterior nostrils.

Head ridges and epidermis:-Gëxther described the "internasal space (as) ... much narrower than in Melamphaes typhops." The fragile spinelike ridges at the cheek angle diverge symmetrically. The head epidermis is collapsed and partly missing, especially over the preopercle. The widely spaced embossed lines (referred to by Gësther as "a peculiar longitudinal striation") stand out as lighter streaks on a dark background.

About twice as long as wide, the frontal fossa, which resembles a pear in cross-section, expands twice (1) thrice before its constricted posterior end in the North Atlantic specimens; rather than being square as in most of the other species, the margins of the posterior expanded part are rounded as in M. lugubris. A sarecly perceivable angle in the frontal margin over the front of the pupil gradually narrows the interorbital space. Between these angles the interorbital only slightly exceeds the distance from the orbit to the preopercular Alge. Even though the head epidermis is mostly missing, the embossed lines appear widely spaced.

Sensory pores:-On the North Atlantic specimens pores are almost impossible to count. In one small yecimen, the pores inside the check angle number 2 or 3 ; those on the supratemporal canal above the prenpercle number 3. On the outer margin of the mandible, from just behind the angle to the symphysis the prises number $1+1+1+1$.

Operculum:-The posteroventral border of the interopercle is slightly produced, but bears no spines (r) ubvious ridges. The opercular bones of the North Atlantic specimens are very thin and pliant. The poster"wentral border of the last branchiostegal is weakly angular.

Jaws and teeth:-In his original description, Géstiner stated that ". . . the maxillary reaches to below the posterior margin of the eye." In the photograph, however, it appears to overreach the bony orbit. Güxther described the teeth as ". . . very small, rather irregularly placed, so as to appear at places to form a double and others a single series." Hubbs (personal communication), moreover, noted the following:

In the upper jaw, teeth are practically uniserial at the end but soon become definitely biserial and remain so to the front with considerable irregularity and occasional definite interpolations so that anterior teeth approach a triserial arangement. In the lower jaw the teeth remain uniserial from the rear end almost to the middle, then become irregularly Inserial. The band narrows forward, then abruptly broadens just behind the symphysis, where the teeth can be aligned intu about 5 rows. Toward the symphysis of the upper jaw, the teeth in contrast become almost uniserial.

The thoth formula is for the 2 postlarvae $1 / 1-2$.
In the North Atlantic specimens, the maxillary overreaches by the diameter of the lens a vertical from the perterior bony orbit. The tooth formula is $2-3 / 2-3$, for 5 specimens $24 \cdots 48 \mathrm{~mm}$. and $1-2 / 1-2$ for 3 specimens 18 - 22 mm . Thr expanded part of the prenaxillary tooth-band includes no noticcably oblique rows; all teeth, like those in the mandible, are scattered or aligned in 2-3 irregular rows. In the 3 largest specimens the pharyngeal teeth number $9-12$ on the second pharyngobranchial, $17-21$ on the third, $8-10$ on the fourth, and $10-14$ on the third epibranchial. All counts are from young and halfgrown and probably do not denote lige full complement of teeth characteristic of adults.

Gill rakers:-In the North Atlantic specimens the gill rakers usually number $5-6+16-17 ; 1$ of 16 counts including a small rudiment is $7+17,4$ are $5+15$. The longest raker, on the ceratobranchial near the argle slightly exceeds the distance from orbit to cheek ridge.

Scales:-Represented entirely by pockets, the scale rows number approximately 33 or 34 . On a typical liapezoidal or semicircular body scale from under the pectoral the narrow grooves between circuli increase in width gradually from the anterior to the posterior field, where the widest are $3-5$ times the width of the narrowest grooves on the anterior field. Inconspicuous or absent on the anterior field, numerous cross-striae breach the grooves on the posterior field. Ten or eleven seallops, between which end distinct "radii" (formed of sharp bends in the circuli), render the anterior margin of the scale irregular; the posterior margin is even. The focus is nearest the anterior margin of the scale. The opercular seales are missing.

In all but one of the North Atlantic specimens, the seales are missing. On this specimen, but one delicate wale remains on the interopercle and lower tip of the opercle. Pockets indicate there may have been at least \& scales on the operculum.

Fins:--The dorsal is relatively long; the counts of III, 18 are maximum for the family. Gixturn observed the first anal ray to be under the last dorsal ray. The pectoral fin reaches to within 3 or 4 scales of the end of the dorsal. Numbering l, 8 rays, each pelvic fin inserts well behind the pectoral insertion. In the two postlarvae the anal originates under the second or third from last dorsal ray ; the pelvic insertion is directly below the pectoral.

The dorsal rays of the North Atlantic specimens number III, 16-17. The anal rays number I, 8. In 7 of 8 counts the pectoral rays number 15 , the pelvic rays $I$, 8 ; the high pelvic count is diagnostic of the species complex. The pelvic inserts directly below or slightly before the pectoral.

Internal characters:- The vertebrae of the 2 postlarvae number $12+18$. In the North Atlantic specimens the vertebrae nsually number $12+17-18$; counts of 2 young are only 27 ! The haemal arch of the first caudal vertebra bears a rudimentary spur in some, but in others only angles at the base of the slender, retrorse spine.

Color:--Color notes for the holotype are unavailable; the North Atlantic specimens are badly faded. The pharynx is brownish, with a superficial bluish sheen. Light brownish pigment mottles the coelonic peritoneum. The Subantarctic postlarvae are lightly pigmented or punctulate on either side of the dorsal fin, on the dorsal half of the caudal peduncle, on the posterior third of the anal base, on the urosome, and on the base of the caudal fin.

## Size at maturity.

The large ( 99.1 mm .) holotype was not sexed. None of the North Atlantic specimens, the largest of which is 48 mm ., is sexually mature.

## Distinctions.

The high pelvic count of I, 8 distinguishes the microps complex from all other species in the genus. From contiguous and sympatric forms it generally differs by its high dorsal count (usually III, 17-18), high vertibral count ( $12-17-18$ ), and high gill raker count (usually $6+17-18$ ). Having wider grooves than do scales of the species in the typhlops group, the one available scale from the holotype differs in sculpturing from the scales of M. leprus, suborbitalis, laeviceps, and lugubris.

## Remarks.

Until now the nominal species microps has served as a catchall for various forms of Melamphaes. Although the holotype was not directly examined, excellent photographs and accurate notes were obtained. It is reasonably certain, therefore, that previously in the literature the name may have been correctly applied, besidis the holotype, to only a few North Atlantic specimens reported by Koefoen (1953) and, possibly, by Rocir and Angel (1933) and Brebe (1937). In the present account Koefoed's specimens are described anew.

Specimens examined- 11 from 10 collections.
Holotype: (not directly examined): BM(NH) 1887.12.7.5; 99.1 mm .; southern Indian Ocean, between Cape ,f Good Hope and Kerguelen Island, $46^{\circ} 46^{\prime} \mathrm{S} 45^{\circ} 31^{\prime} \mathrm{W}$; capture, in 1375 fathoms (bottom); dredge; 29 December 187it: H.M.S. "Challenger", station 146.

Additional material: Eastern South Atlantic, off southwest tip of Africa: D 3979(2), $27^{\circ} 10^{\prime} \mathrm{S} 8^{\circ} 59^{\prime} \mathrm{E}, 600 \mathrm{w} .(\mathrm{l}: 1$. $1 \mathrm{PL}(22)$.

Western South Pacific, off New Zealand: D $3640(8), 41^{\circ} 47^{\prime}$ S $176^{\circ} 55^{\prime}$ E, 2000 w .(d), 1 PL(21).
North Atlantic, between $32^{\circ} \mathrm{N}$ and $58^{\circ} \mathrm{N}$ (Melamphaes, sp.): BZM 4323 ("Michael Sars" sta. 101), $57^{\circ} 41^{\prime} \mathrm{N} 1!$ $48^{\prime}$ W, $2500 \mathrm{w} ., 2\left(34-48\right.$ ) ; BZM 4366 (MS sta. 43 ), $34^{\circ} 59^{\prime}$ N $33^{\circ} 01^{\prime} \mathrm{W}$, 1600 w ., 1(19); BZM 4382 (MS sta. 90 ), $46^{\circ} 58^{\prime}$ ㅅ $19^{\circ} 06^{\prime}$ W, 2006 w ., 1(34): BZM 4387 (MS sta. 81 ), $48^{\circ} 02^{\prime}$ N $39^{\circ} 55^{\prime} \mathrm{W}$, 2500 w ., 1 (40); BZM 4389 (MS sta. 92 ), $48^{\circ} 29^{\prime}$ ㅅ $13^{\circ} 55^{\prime} \mathrm{W}, 2000 \mathrm{w} ., 1(18)$; BOC 2832 , $32^{\circ} 24^{\prime} \mathrm{N} 64^{\circ} 29^{\prime} \mathrm{W}, 1(22)$; SU $42318,32^{\circ} 12^{\prime} \mathrm{N} 64^{\circ} 36^{\prime} \mathrm{W}$, $540-1800,1(24)$.

## Melamphaes lugubris Gilbert. <br> Fig. 18.

Melamphues lugubris.-Gilbert, 1890:50,59-60,61 (original description; trawled in 822 fathoms, off San Diegn. Calif.; comparisons) ; 1895a: 404 (range extension; Albatross Sta. 3327, N. of Cnalaska in 322 fathoms). Braven, 190 ; 280 (in key). Norman, 1929: 158 159 (in part; destription based in part on specimen of M. acanthomus, which ser: symonymy; in key; range). Parr, 1931: 31,41 (comparison with macrocephalus; in key); 1933: 14,18 (comparison if
M. crassicauda with photograph of lugubris). Rass, 1954: 1315,1319,1320 (tabular distribution, Bering Sea and coast of California); 1955: 337 (Bering Sea). Maruyama, 1957: 33 (North Pacific, not yet recorded from Japan; name misspelled luguburis). Whimovsky, 1958: 41 (in key, Bering Sea to California). Aron, 1959: 415,416 (captures in eastern subarctic North Pacific). Aron, 1960: 40, appendix (distribution in water masses, captures in northeastern North Pacific).

Plectrumus lugubris.-Goode and Bean, 1895 (new combination, comments). Jordan and Evermans, 1896a: 337 in check list); 1896b: 841,842 (description after Gllbert; comparisons; in key; holotype, south of Pt. Conception, California). Jordan and Gllbert, 1899: 445 (north of Lnalaska). Evermany and Goldsborolgh, 1907: 275 (listed frum "north of Cnalaska" after Gilbert). Hubbs, 1928: 12 (California and Alaska). Jordan, Evermans, and Clark, 1930: 233 (references, range). Barnhart, 1936: 32 (short description; range). Schultz, 1936: 159 (in key; range). surltz and Delacy, 1936: 69 (in catalog; range; references).

Melamphaes cavernosus.- Chapman, 1939: 533-535, fig. 68 (original description; Gulf of Alaska; comparisons; in: key; holotype USNM 108147, 3 paratypes); 1940: 1 (reference to original description; name misspelled cavernus). Glemens and Wilby, 1949: 142-143, fig. 82 (short description and records, after Chapman). Koefoed, 1953: 18 (comparison with M. crassicauda). Aron, 1958: 49 (some of trawl specimens probably lugubris; Gulf of Alaska and vicinity). Wilmovsky, 1958: 41 (in key, range).

Melamphaes sp.-Aron, 1958 : between p. 19 and 31 (captures from Gulf of Alaska and vicinity).

## Dislribution.

As far as known M. lugubris occurs only in the Subarctic North Pacific, mainly between $40^{\circ} \mathrm{N}$ and $56^{\circ} \mathrm{N}$, including the Bering Sea and Gulf of Alaska, and in the transitional region off California and northern Baja (:alifornia, Mexico (Fig. 43). Five collections, however, are from the central North Pacific between $30^{\circ} \mathrm{N}$ and $40^{\circ} \mathrm{N}$. Vertically, in the Subaretic region the upper limit of adults and halfgrown is about 200-250 meters; the young occur more shallowly, up to $50-75$ meters. In the southern part of the transitional region b, th stages apparently live deeper, the adults and halfgrown below $400-\mathbf{5 0 0}$ meters and the young below 200--300 meters.

## t.ounts and measurements.

Counts:-The following are usually based on samples of 100-120. For the characters (pectoral rays, vertebrae) analyzed by locality under "Variation", the means are not given. Dorsal III, 14-16 (15.12); inal I, $7-9(8.00)$; caudal $(n=70) 3-5+9-10-9+4-5(4.0+10.0-9.0+4.0)$; pectoral $15-17$; pelvic $(n=80)$ I, 7 ; scale rows $32-36(34.19)$; scales in diagonal series $(n=24) 9-10(9.3)$; vertebrae ( $n=90$ ) 28-31; gill rakers on first arch $5-6+15-18(5.42+16.39)$; gill rakers on lower limb of fourth arch $8-11$ (9.24): mandibular pores $(\mathrm{n}=79) 3-6$ (4.16).

Proportions:-Based on 23-25 specimens, mostly adults, the following are proportions for which the (hata suggest little or no allometric change or are insufficient to detect it: body depth $263-327$ ( 290 ); postifirsal 584-640 (612); postorbital 229-268 (242); head depth 251-304 (278); head width 187-239 (219); width of frontal fossa $77-92$ (85); prepectoral 344-383 (367); prepelvic 375-420 (397); isthmus to pelvic :310-359 (344); pectoral 301-329 (314); pelvic 200-248 (223); preanal 652-708 (677); anal to caudal :32-373 (349); depth of caudal peduncle $95-119$ (109); orbit to cheek angle 108-135 (120); snout length s.t-108 (96); suborbital 46-54 (49).

The following are proportions for which the data suggest allometric change. Head length and predorsal are further analyzed by locality under "Variation". If the values of the proportions of the halfgrown are imilar to those of the adults, the two categories are bracketed together. Proportions are based on 22-24 adults (Ad) $56-89 \mathrm{~mm}$., $20-25$ halfgrown ( Hg ) $35-55 \mathrm{~mm}$., and $30-40$ young ( Yg ) $19-34.9 \mathrm{~mm}$.

|  | Predorsal | Head length | Shout-preopercle | Interorbital |
| :---: | :---: | :---: | :---: | :---: |
| Ad |  |  | 235-255(243) | 121-133(126) |
| Hg | 409-458(431) | $\int^{351-398(369)}$ | 240-415(384) | 109-135(122) |
| Ig. | 419-467(450) | $360-415(384)$ | 243-283(264) | 99-128(116) |


|  | Length of frontal fossa | Pelvic to anal | Length of caudal ped. | Upper jaw |
| :---: | :---: | :---: | :---: | :---: |
| Ad | 129-149(140) |  | 243-270(258) | 155-179(165) |
| Hg | 133-153(144) | 26(299) | 258-302(273) | 162-182(169) |
| Yg. | 130-164(152) | 239-302(269) | 257-302(279) | 160-185(179) |


|  |  |
| :--- | :---: |
| Ad $\ldots \ldots \ldots \ldots \ldots$ | Eye |
| $\mathrm{Hg} \ldots \ldots \ldots \ldots \ldots \ldots$ | $\{47-57(52)$ |
| $\mathrm{Yg} \ldots \ldots \ldots \ldots \ldots$ | $50-78(64)$ |

## Description.

Body and head form:-The rather robust body narrows abruptly from the anus to a tapered caudal peduncle, which is $2.33-2.6$ times as long as deep. The body contour along the dorsal fin ascends in a weally convex are. The ventral contour remains weakly convex from the pelvic symphysis to the anus. Althoush behind the dorsal origin the dorsal contour is somewhat steeper than the ventral, the body frequently appears subsymmetrical in side view. The point of greatest body depth subtends or slightly succeeds the pelvic insertion. From the dorsal origin to the frontal knob the profile descends in a weakly convex curve. The ventral contour of the short head curves steeply outward from the pelvic symphysis to the isthmus, where it bends up to the mandibular symphysis. A somewhat rounded muzzle blunts the symmetrical anterior profile. The diameter of the eve slightly exceeds the suborbital width and measures about 0.6 times the snout length. From the premaxillary symphysis to the anterior end fo the frontal knob is about three-fourths the distance between the anterior nostrils.

Head ridges and epidermis:-About 1.67 times as long as wide, the frontal fossa, which resembles a pear in cross-section, expands thrice before its acutely constricted posterior end; rather than being square as in most of the other species, the margins of the posterior expanded part are rounded. Behind the frontal knob a semicircular area frequently is weakly pigmented. A moderately sharp angle in the frontal margia over the front of the eve abruptly narrows the interorbital space. Between these angles the interorbital exceeds by the diameter of the pupil the distance from the orbit to the preopercular edge. The fragile spinelike ridge at the cheek angle slightly diverge; but the upper ridge slants steeply downward, usually almost parallel with the lower. In most specimens the fragile head epidermis is collapsed and mostly missing, especially over thr preopercle, cheek, and frontal fossa. Frequently lighter on their midlines, the close-set embossed lines, though slightly darker than the backgrounds, blend in color with the epidermis. The spaces between the embossel lines are smooth and generally without prickles.

Sensory pores:-The unusually small groups generally contain fewer pores than in the other specicThe pores in the group inside the cheek angle number 2 or 3 . There is only one pore under the posteroventria angle of the orbit. In the group on the supratemporal canal directly above the preopercle the pores usually number 2 ; only 2 of 32 counts are 1 or 3 . The pores on the preopercle above the angle number $1+1+1-2$ in 6 counts out of 10 ; other counts are $1+1+1+1,1+2+1+1$, and $1+1+1+3$. On the outer margin of the mandible, from just behind the angle to the symphysis, the pores usually number $1+1+1+1$; occasionally one of the middle counts is 2 . The pore on the outer surface of the mandible near the symphysis is abot: half the size of its equivalent behind the symphysis

Operculum:--The posteroventral border of the interopercle and of the last branchiostegal may be slightly produced, but bear no spines or obvious ridges.

Jaws and teeth:--The maxillary barely reaches a vertical from the posterior edge of the eye. The tooth formula is for adults $4-6 / 2-4$, for halfgrown $3-5 / 2-3$, and for young $1-3 / 1-2$. The expanded part "f the premaxillary tooth-band includes no noticeably oblique inner rows; all teeth, like those in the mandible are scattered or aligned in irregular rows. Near the symphysis this band narrows to 1 or 2 rows. In the larger specimens the pharyngeal teeth number $12-27$ on the second pharyngobranchial, $37-52$ on the third, 10--2! on the fourth, and $17-41$ on the third epibranchial.


Fig. 18. Melamphaes lugubris Gllbert. A, adult specimen, CW 14553 No. 1, traced and modified from photograph (standard length $\rightarrow 7.5 \mathrm{~mm}$.) ; B, postlarva, UW 14544 No. 9 (s. 1. 16.2 mm .): C, postlaria, California Cooperative Oceanic Fisheries Investigations Cruise 5705, Sta. 103.45, $30^{\circ} 37^{\prime} \aleph^{\prime} 117^{\circ} 25^{\prime}$ W (s. 1.8 .3 mm ).

Gill rakers:- The gill rakers usually number $\bar{j}-6+16-17$. The longest raker, on the ceratobranchial near the angle, measures $1.33-1.5$ times the diameter of the eve.

Scales:-Represented mostly beckets, the scale rows usually number 34 or $35 ; 14$ of 96 counts are 33 or 36. A typical body scale from under the pectoral is squarish or nearly circular. No circuli or radii pattern the relatively small, triangular posterior field. However, microscopic striae, only about 0.1 the width of grooves between circuli on the anterior field, radiate from the focus to the posterior edge of the scale. At
their widest the grooves between circuli on the anterior and lateral fields measure about 0.1 mm . Numerous, coarse cross-striae breach these grooves. Four to seven scallops, between which end distinct "radii" (formed of sharp bends in the circuli), render the anterior margin of the scale irregular; the posterior margin is evem. The focus is usually about half as far from the posterior border as from the anterior. A single file of absut $13-15$ slender scales sheathes the base of the soft dorsal fin. On the flat or slightly curved breast the rather large, thin scales are usually missing. Resembling body scales in size, shape, and sculpturing, 8 especially pliant scales shield the subopercle, interopercle, and opercle. Few specimens retain their opercular scales.

Fins:-The modal dorsal count is III, 15 ; 34 of 121 counts are either III, 14, or, more commonly, III, 16 . The anal rays almost always number I, 8 ; only 4 of 120 counts are 1,7 or I, 9 . Although in adults and halfgrown the anal originates directly under or slightly behind the last dorsal ray, it is slightly farther forward in the young. Diagnostic of lugubris, the pectoral rays usually number $16 ; 26$ of 118 counts are 15,4 are 17 . The pectoral fin reaches to within 3 or 4 scales of the end of the dorsal. Though directly under the pectoral insertion in young, the pelvics insert well behind it in adults.

Internal characters:-The vertebrae usually number $12+17$ or $12+18$. Although only 2 of 70 precaudal counts are 11, the caudal counts range from 16 to 19 vertebrae. The haemal arch of the first caudal vertebrate bears well-developed spurs. Almost half the length of the arch, their shadow appears in radiographs as a single downward-projecting spine, which is situated anteriorly near the base of the slender, retrorse haemal spine. lnvested with fat, the small, degenerate gas-bladder is not pneumatic. The slender stomach is evenly and heavily pigmented and is almost 5 times as long as deep.

Color:-Although each scale pocket is lightest anteriorly, the integument is not generally mottled. The bases of the median fins usually are no darker than the rest of the body, which, with the head and fins, is never punctulate. The pharynx is dark brown to blackish, usually with a superficial metallic sheen. Lisht brownish pigment mottles the coelomic peritoneum. In color the young resemble the adults.

Sex ratio and size at maturity.
Among the 70 specimens sexed there are 4 males and 8 females. Mature or near mature adults range in standard length from 70 to 88 mm .

Geographical variation.
Samples of lugubris varied, usually significantly, in numbers of vertebrae and pectoral rays, and values of head length and predorsal length (Fig. 19). For the counts, samples were analyzed from four localitin: (A) Transitional Water off Baja California and the west coast of North America to $45^{\circ} \mathrm{N}$ at $140^{\circ} \mathrm{W}$; (B) the Gulf of Alaska and vicinity north of $45^{\circ} \mathrm{N}$ and west of $170^{\circ} \mathrm{W}$; (C) the zone of mixing between the Subareiiand Central waters west of $140^{\circ} \mathrm{W}$ and south of $45^{\circ} \mathrm{N}$; and (D) the Subarctic Water between the KurilsKamchatka area and $175^{\circ} \mathbb{W}$, north of $45^{\circ} \mathrm{N}$. For the proportions, C and D were combined. Since the pro. portions are allometric, they were analyzed by growth stages.

In the counts the specimens from area $C$ have significantly fewer pectoral rays than those from areas $A$ or D, with I intermediate. Furthermore the specimens from area A have significantly fewer vertebrae thin those from areas C and D, with B again intermediate. For the proportions, the specimens from area A again differ from those representing areas $C$ and 1 ) in head size, especially in the adults, with area B intermediate. Adult specimens from areas C and D appear to have a shorter predorsal than those from A and B.

These data suggest that in certain characters lugubris does vary geographically. There may be broad populations that exhibit a fair amount of genetic integrity, but generally, with the exception of the pectoral ray. the variation appears clinal from area $A$ through area $B$ to areas $C$ and $D$, with specimens from areas $A$ and C showing the greatest differences.

## Distinctions.

M. lugubris is distinguished from all other species in the genus by its large number (8) of opercular scale. Other trenchant differences separate lugubris from the closely related and contiguous M. polylepis and partly
smpatric M. acanthomus (sec distinctions under this species) and M. parvus. M. polylepis never has more than 15 pectoral rays, has only 11 precaudal rertebrae, usually only 14 soft rays in the dorsal, a smaller eye (less than suborbital width), and more sensory peres (more than 4 on mandible). $M$. proms has fewer gill rakers (usually $+13-14$ on first arch and 8 on lower hatlf of fourth arch), never more than 1.) pectoral rays, more sensory pores (always more than 5 on mandible), and fewer vertebrae (usually $12+16$ or fewer).

## Remarks.

The holotype of Iugubris is in very peor condition and difficult to handle. Among other things, the flesh is falling oll, the caudal peduncle is broken, and all fins except the pectorals are badly damaged or missing. There are, howwer, several good reasons for identifying the specimens used in this study with M. lugubris. The most important : that, although Gilbert in his original description counted only 14 pecthal ravs, I counted 16 on both sides. This high pectoral count is diagnostic , if the species and precludes confusion of the holotype with its only generic - mmpatrics, M. acanthomus or M. parwis. Furthermore, instead of approximately 14 gill rakers in the lower first arch as counted by Gillbirt, there are 1.5 plus 6 in the upper. This count is within the range for lugubris, but higher than in parous and lower than is usual for acanthomus. The holotype ( 78 mm .) is much larger than any adult of parpus. The premaxillary teeth are not, as stated by Ginmert, in a single series, but in a narrow band characteristic of lugubris. Finally, though accurate body proportions are impossible to determine in the holotype, Gilbert stated that the maxillary raches a vertical from the posterior edge of the eye, which is $6^{1} / 2$ in the head; the large eve and short maxillary are characteristic of the specimens here referred to lugubris. Though the holotype was trawled off San Diego, the type locality is still well within the range of the species.

The holotype and one of 3 paratypes of Melamphaes cavernosus, from the Gulf of Alaska, were examined and found to be virtually identical with specimens here presumed to be lugubris and one specimen (SE 3066) so identified by Gilbent. They agree well with the holotype of lugubris and with the more accurate parts of its original description, exeept that the paratype of conernosus has only 1.5 pectoral rays. This variation,
however, is not uncommon. In the original description of $M$. cavernosus, Chapman listed several ways in which it can be distinguished from lugubris:

This species is distinguished from M. luyubris by the greater number of scales in a longitudinal series ( 29 to 31 in M. cavernosus, 26 to 27 in M. lugubris); by the wider interorbital space ( 2.0 to 2.4 in head in M. cavernosus, 3.0 in $1 /$. lugubris); shorter maxillary (ending under middle of eye in M. cavernosus, ending below posterior border of eye in II. lugubris); wider peetoral fin ( 16 rays in M. cavernosus, 14? in M. lugubris); longer caudal peduncle ( 3.7 to 3.9 in length without caudal in M. cavernosus, 5.0 in M. lugubris); and in the position of the origin of the pelvics (behind the insertion of the pectorals in M. cavernosus, ahead in M. lugubris).

Chapmas stated in a footnote that the measurements are from Noman (1929). Here Norman said that his description is based on ". . . a single specimen, 90 mm . in total length" and listed it from "off coast of Cali. fornia ( $23^{\circ} \mathrm{N}$ ) 1180 m . "Albatross"." This specimen, reported as lugubris by Townsend and Nichols (192.) was examined and found actually to be M. acanthomus, which see. This means that Chapmax's distinction, with his data on lugubris after Norman, anent the interorbital (Gilbert gives $2^{3} / 5$ in head), caudal peduncle, and origin of the pelvics, all refer to $M$. acanthomus and may be immediately disregarded as differences hetween comernosus and lugubris. Furthermore, the statements that lugubris has 14 pectoral rays and that the maxillary ends under the middle of the eye in cavernosus (cheeked on holotype) are incorrect. This leavis only the difference in number of scales in a longitudinal series. Gilbert lists 26 in "Lat. 1.", Chapman lists 29-31 "in a lateral series", and I find 33-- 36 from the nape to the edge of the hypural in specimens from "fl California and vicinity (near the type locality of lugubris). Therefore, if we assume Gilbert's count to be from the opercle to the hypural edge and, further, that there are usually about 5 or 6 scales between the nape and opercle, then it falls within the range for the species. Moreover, Chapmax's counts for cavernosus probally are too low, since I counted $32-34$ in the holotype and paratype and the range for all specimens from the Gulf of Alaska is $32-35$. Inasmuch as all the supposed differences between cavernosus and lugubris are here shown to be unreal, it is concluded that the two species should be synonymized.

Specimens examined. -134 from 80 collections.
Holotype of M. lugubris: CSNM 44287; adult (ca. 78 mm .); off San Diego, California, $32^{\circ} 40^{\prime} 30^{\prime \prime} \mathrm{N} 117^{\circ} 31^{\prime} 30^{\prime \prime} \mathrm{W}$ trawled between surface and bottom, 822 fathoms; large beam trawl; 19 January 1889 ; R Y "Albatross" station 292.3.

Types of M. cavernosus: Holotype, LSNM 108147: (I.F.C. 147147) subadult ( 66.5 ); Gulf of Alaska, $56^{\circ} 06^{\prime}$ N $15 \geqslant$ $09^{\prime} \mathrm{W}$; capture $900-800-700$ meters of wire; 8 June 1932, International Fisheries Commission station 824 c . Paratype, l'SNM 108157, $55^{\circ} 25^{\prime} \mathrm{N} 141^{\circ} 12^{\prime} \mathrm{W}, 1200-1100-1000 \mathrm{w}$., $1(69)$.

Additional material: Transitional Water of Baja California, Mexico and the west coast of North America th 45 N Lat. at $140^{\circ} \mathrm{W}$ Long. (area A): SIO $50-265,32^{\circ} 28^{\prime} \mathrm{N}^{\prime} 117^{\circ} 23^{\prime} \mathrm{W}, 700(\mathrm{n}), 1(21)$; SIO $50-290,32^{\circ} 57^{\prime} \mathrm{N} 11^{1}$ $44^{\prime} \mathrm{W}$, $640(\mathrm{~d}), 1(25)$; SIO $51-148,32^{\circ} 41^{\prime} \mathrm{N} 117^{\circ} 36^{\prime} \mathrm{W}, 1010(\mathrm{~d}), 1(70)$; SIO $51-187,32^{\circ} 54^{\prime} \mathrm{N} 117^{\circ} 47^{\prime} \mathrm{W}, 275(\mathrm{n}), 1\left(39^{\prime}\right.$ SIO $51-188,33^{\circ} 07^{\prime}$ N $118^{\circ} 01^{\prime} \mathrm{W}, 366(\mathrm{~d}), 1(20)$; SIO $51-189,32^{\circ} 57^{\prime} \mathrm{N}^{\circ} 117^{\circ} 49^{\prime} \mathrm{W}$, $550(\mathrm{~d}), 1(21)$; SIO $51-278,3$ ? $31^{\prime}$ ㅅ $117^{\circ} 46^{\prime} \mathrm{W}, 320(11), 4(42-46)$; S 10 51-351, $40^{\circ} 31^{\prime}$ N $129^{\circ} 01^{\prime} \mathrm{W}, 860(\mathrm{dn}), 3(46-80)$; S $1051-352,40^{\circ} 27^{\prime} \times$ $131^{\circ} 06^{\prime} \mathrm{W}, 1100(\mathrm{dn}), 2(23-24)$; SIO $51-353,39^{\circ} 52^{\prime} \mathrm{N} 134^{\circ} 11^{\prime} \mathrm{W}$, $750(\mathrm{n}), 4(19-22)$; SIO $51-354,40^{\circ} 26^{\prime} \mathrm{N} 137^{\circ} 26^{\prime} \mathrm{W}$. $650(\mathrm{n}), 3(22-23)$; SIO $51--377,33^{\circ} 01^{\prime}$ N $127^{\circ} 30^{\prime} \mathrm{W}, 3920(\mathrm{nd}), 1(22)$; SIO $51-392,32^{\circ} 39^{\prime}$ N $117^{\circ} 37^{\prime} \mathrm{w}, 1100(\mathrm{~d}), 1(24)$ : SIO $51-397,32^{\circ} 43^{\prime}$ ㄷ $117^{\circ} 37^{\prime} \mathrm{W}, 1160(\mathrm{~d})$, $1(31)$; SIO $52-11,32^{\circ} 37^{\prime} \mathrm{N} 117^{\circ} 37^{\prime} \mathrm{W}, 366(\mathrm{n}), 1(32)$; SIO $52-40,33^{\circ} 48^{\prime}$ 人 $119^{\circ} 40^{\prime} \mathrm{W}, 1460(\mathrm{~d}), 2(54-58) ;$ SIO $56-76,28^{\circ} 51^{\prime} \mathrm{N} 118^{\circ} 11^{\prime} \mathrm{W}$, $1280(\mathrm{n}), 1(22)$; SLO $57-185,28^{\circ} 54^{\prime} \mathrm{N} 118^{\circ} 12^{\prime} \mathrm{W}$. $395(11), 1(25)$; SIO $57-207,29^{\circ} 09^{\prime}$ N $118^{\circ} 27^{\prime}$ W, 1010 (d), $1(28)$; LW $14520,38^{\circ} 46^{\prime}$ N $138^{\circ} 09^{\prime} \mathrm{W}$, $800 \mathrm{w} .(\mathrm{n}), 2(25)$; しW $14522,38^{\circ} 51^{\prime} \mathrm{N}^{\prime} 137^{\prime} 51^{\prime} \mathrm{W}$, 400 w .(n), $3\left(25-26\right.$ ); CW $14526,39^{\circ} 43^{\prime}$ N $135^{\circ} 04^{\prime} \mathrm{W}$, 400 w .(n), $1(22)$; UW $14527,40^{\circ} 02^{\prime}$.
 1(23); LW 14533, $33^{\circ} 42^{\prime}$ N' $126^{\circ} 23^{\prime} \mathrm{W}$, 800w.(n), 1(23); CW $14544,36^{\circ} 48^{\prime} \mathrm{N} 130^{\circ} 53^{\prime} \mathrm{W}$, 400 w (n), 4(20-30); UW $1454^{\circ}$. $39^{\circ} 41^{\prime}$ N $131^{\circ} 56^{\prime}$ W, $1400 \mathrm{w} .(\mathrm{n}), 1(55)$; LW $14549,41^{\circ} 13^{\prime}$ N $133^{\circ} 11^{\prime} \mathrm{W}$, $400 \mathrm{w} .(\mathrm{n}), 1(24)$; LW $14550,41^{\circ} 16^{\prime} \mathrm{N} 133^{\circ} 13^{\prime}$ W 1400 w .(n), $1(48)$; CW $14551,42^{\circ} 56^{\prime}$ N $135^{\circ} 33^{\prime} \mathrm{W}$, 400 w (n), 2(24-25); LW(BB 199, haul 173 ), $39^{\circ} 56^{\prime}$ N $130^{\circ} 23^{\prime}$ W. $160(\mathrm{n}), 3(22-23)$; [ ${ }^{W}(\mathrm{WB} 199$, haul 270$), 41^{\circ} 02^{\prime} \mathrm{N} 132^{\circ} 57^{\prime} \mathrm{W}, 225(\mathrm{n}), 1(20)$.

Gulf of Alaska and vicinity, north of $45^{\circ} \mathrm{N}$ and west of $170^{\circ} \mathrm{W}$ (area B): POFI 1807, $49^{\circ} 34^{\prime} \mathrm{N} 157^{\circ} 55^{\prime} \mathrm{W}, 200(\mathrm{n})$. $4\left(37\right.$ 48): POFI 1810, $48^{\circ} 07^{\prime}$ N $164^{\circ} 55^{\prime} \mathrm{W}, 200(\mathrm{n}), 1(44)$; SIO $51-361$, $51^{\circ} 35^{\prime} \mathrm{N} 150^{\circ} 00^{\prime} \mathrm{W}, 1600(\mathrm{dn}), 2(61-68)$ : SIO $51-366,5 f^{\circ} 15^{\prime} \mathrm{N} 144^{\prime} 50^{\prime} \mathrm{W}, 3020(\mathrm{dn}), 2(58-70)$; SU $3066,53^{\circ} 44^{\prime} \mathrm{N} 167^{\circ} 30^{\prime} \mathrm{W}$, 590 , $1(85)$; LW 14406, $51^{\circ} 59^{\prime}$ र $143^{\circ} 10^{\prime} \mathrm{W}, 225(\mathrm{n}), 1(62)$; ('W $14407,52^{\circ} 39^{\prime}$ N $152^{\circ} 29^{\prime} \mathrm{W}$, $225(\mathrm{n}), 1(52)$; CW $14408,52^{\circ} 30^{\prime}$ N $160^{\circ} 43^{\prime} \mathrm{W}, 225(\mathrm{n}), 1(661$ :
! W $14409,52^{\circ} 14^{\prime} \mathrm{N} 165^{\circ} 42^{\prime} \mathrm{W}, 225(\mathrm{n}), 1(52)$; UW $14413,50^{\circ} 37^{\prime} \mathrm{N} 147^{\circ} 44^{\prime} \mathrm{W}, 225(\mathrm{n}), 1(54) ;$ I'W 14511 , $48^{\circ} 39^{\prime} \mathrm{N}$
 $336-39$ ); UW $14552,45^{\circ} 39^{\prime} \mathrm{N} 139^{\circ} 29^{\prime} \mathrm{W}, 200 \mathrm{w}$ ( n ), $1(20)$; CW $14553,45^{\circ} 49^{\prime}$ N $139^{\circ} 41^{\prime} \mathrm{W}, 1400 \mathrm{w}$ (n), $4(24-88)$; । W $14554,49^{\circ} 54^{\prime}$ N $133^{\circ} 14^{\prime} \mathrm{W}, 800 \mathrm{w} .(\mathrm{n}), 1(53)$; LW $14555,49^{\circ} 52^{\prime}$ N $134^{\circ} 11^{\prime} \mathrm{W}, 1400 \mathrm{w} .(\mathrm{n})$, 1 ( 61 ); CW $14556,49^{\circ} 00^{\prime} \mathrm{N}$ $1+1^{\circ} 00^{\prime} \mathrm{W}, 1400 \mathrm{w} .(\mathrm{n}), 1(49)$; UW 14557, $48^{\circ} 00^{\prime} \mathrm{N} 138^{\circ} 03^{\prime} \mathrm{W}, 1400 \mathrm{w} .(\mathrm{n}), 1(49)$; LW (BB 199, haul 292), $47^{\circ} 30^{\prime} \mathrm{N}$ $1+1^{\circ} 50^{\prime} \mathrm{W}, 60(\mathrm{n}), 1(26)$.

North Pacific, zone of mixing between Subarctic and Central waters west of $140^{\circ} \mathrm{W}$ and south of $45^{\circ} \mathrm{N}$ (area C ): POFI $1574,39^{\circ} 31^{\prime} \mathrm{N}^{\prime} 79^{\circ} 54^{\prime} \mathrm{W}, 200(\mathrm{n}), 3(20-23)$; POFI 1612, $36^{\circ} 05^{\prime} \mathrm{N}^{\prime} 164^{\circ} 48^{\prime} \mathrm{W}, 200(\mathrm{n}), 1(25)$; POFI $1815,42^{\circ} 22^{\prime}$ N $164^{\circ} 55^{\prime} \mathrm{W}, 200(\mathrm{n}), 1(25)$; POFI 1819, $41^{\circ} 08^{\prime} \mathrm{N} 172^{\circ} 22^{\prime} \mathrm{W}, 200(\mathrm{n}), 1(27)$; SIO $51-357,40^{\circ} 37^{\prime} \mathrm{N} 143^{\circ} 25^{\prime} \mathrm{W}$, 4000(nd), $1!1)$; SIO $51-358,40^{\circ} 35^{\prime} \mathrm{N} 147^{\circ} 55^{\prime} \mathrm{W}, 600(\mathrm{nd}), 2(21-46)$; SIO $51-373,41^{\circ} 20^{\prime} \mathrm{N} 155^{\circ} 13^{\prime} \mathrm{W}, 2140(\mathrm{n}), 1(73)$; SIO ;3 - $307,39^{\circ} 34^{\prime}$ N $142^{\circ} 30^{\prime} \mathrm{W}, 4950(\mathrm{nd}), 2(23)$; SIO $53-372,36^{\circ} 58^{\prime} \mathrm{N} 164^{\circ} 30^{\prime} \mathrm{E}, 288(\mathrm{n}), 2(21-22)$; UW 14514 , $42^{\circ} 53^{\prime} \mathrm{N}$ $1.45^{\circ} 30^{\prime} \mathrm{W}, 800 \mathrm{w} .(\mathrm{n}), 1(23)$; UW $14515,42^{\circ} 36^{\prime} \mathrm{N} 145^{\mathrm{c}} 05^{\prime} \mathrm{W}, 800 \mathrm{w} .(\mathrm{n}), 3(21-23)$; しW $14516,41^{\circ} 22^{\prime} \mathrm{N} 143^{\circ} 45^{\prime} \mathrm{W}$,
 $1(20)$; UW $14529,41^{\circ} 31^{\prime}$ N $144^{\circ} 00^{\prime} \mathrm{W}, 800 \mathrm{w} .(\mathrm{n}), 2(24-25)$; UW $14547,39^{\circ} 41^{\prime}$ N $131^{\circ} 56^{\prime} W, 1400 \mathrm{w} .(\mathrm{n}), 1(55)$; UW 14550 ,


Western North Pacific, Subarctic Water between the Kurile-Kamchatka area and $175^{\circ} \mathrm{W}$ Long., north of $45^{\circ} \mathrm{N}$ Lat. (area D): POFI $1817,48^{\circ} 20^{\prime} \mathrm{N} 179^{\circ} 47^{\prime} \mathrm{W}, 200(n), 2(40-41)$; L'W 14410 , $50^{\circ} 31^{\prime} \mathrm{N}^{\prime} 176^{\circ} 54^{\prime} \mathrm{E}, 22 \overline{5}(\mathrm{n}), 2(63-64)$; しW $14411,52^{\circ} 40^{\prime}$ N $178^{\circ} 21^{\prime} \mathrm{E}, 225(\mathrm{n}), 2\left(63-67\right.$ ); UW 14412 , $51^{\circ} 26^{\prime}$ N $174^{\circ} 10^{\prime} \mathrm{W}, 225(\mathrm{n}), 1(54)$; V $3256(\mathrm{a}, \mathrm{b}), 49^{\circ} 00^{\prime} \mathrm{N}$ $157^{\circ} 00^{\prime} \mathrm{E}, 6750,2(75-79)$; V 3363, $48^{\circ} 00^{\prime} \mathrm{N} 169^{\circ} 50^{\prime} \mathrm{E}, 6250,1(89)$.

## Melamphaes polylepis, new species.

Fig. 20.
Melamphaes malayanus (in part).-Weber, 1913: 187-188 (original description; comparison; [one of 3 syntypes from Indonesia]). Weber and de Beaufort, 1929: 264,430 (description after Weber; taxonomic notes).

Histribution.
A widely distributed tropical species, M. polylepis has been taken in the North Atlantic between the equator and $20^{\circ} N$, in the Indian Ocean and Indonesia between $15^{\circ} N$ and $15^{\circ} \mathrm{S}$, in the North Pacific between $34^{\circ} N$ and $6^{\circ} \mathrm{N}$, and in the South Pacific at $30^{\circ} 56^{\prime} \mathrm{S} 109^{\circ} 17^{\prime} \mathrm{W}$ (Fig. 43). Inasmuch as, to my knowledge, there h:we been no captures from off South Africa, it is possible that the Atlantic and Indo-Pacific populations are scographically isolated. The only 2 adults were trawled in 2250 meters. Young and halfgrown probably ọur below 200-300 meters.

## Counts and measurements.

Counts:-The following counts are usually based on samples of 36-40: dorsal III, 13-15 (14.2); anal 1. $\overline{-}-8(8.0)$; caudal $4-\overline{3}+10-9+4-5(4.0+10.0-9.0+4.0)$; pectoral 15 ; pelvic $1, \overline{7}$; scale rows ( $n=27$ ), : $: 3-35(34.2)$; scales in diagonal series $(n=24) 8-10(9.0)$; vertebrac $28-30(28.8)$; gill rakers on first arch (excluding 4 postlarvae) $5-6+15-17(5.3+15.6)$; gill rakers on lower limb of fourth arch $9-13$ (10.3); mandibular pores ( $n=: 9$ ) $\overline{\mathbf{j}}--7$ ( $\overline{5} .4$ ).

Proportions:--Usually based on samples of $12-16$, the following are proportions for which the data vggest little or no allometric change: body depth 250-282 (267); predorsal 420-454 (438); end of dorsal t. caudal 331-..366 (350); postdorsal 581--628 (607); postorbital (Indo-Pacific specimens only) $219-260$ (241); orbit to cheek ridge ( $n=32$ ) $56-73$ ( 64 ); head depth $231-271$ (249); head width 162 210 (190); interorbital $109-127$ (117) ; width of frontal fossa $66-81$ ( 75 ) ; prepelvic $363-399$ (379); isthmus to pelvic :312-349 (329); pectoral 297--326 (308) ; pelvic ( $\mathrm{n}=9$ ) 208-232 (223); depth of caudal peduncle $98-119$ (109); upper jaw ( $n=32$ ) $163-180(172)$; orbit to cheek angle $96-117$ (108); snout length $8 \underline{2} 96$ ( 87 ); -uborbital $42-52$ (46).

Based mainly on Indo-Pacific specimens, the following are proportions for which the data suggest allometric change. Head length, snout to preopercle, and prepectoral are further analvzed by locality (Indol'acific ef. Atlantic) under "Variation". If the values of the proportions of the halfgrown are similar to those of the adults, the two categories are bracketed together. Proportions are based on 2 adults (Ad) 60-62 mm., $1-5$ halfgrown (Hg) 29—45 mm., and $18-26$ young (Yg) $12-56 \mathrm{~mm}$. (*, $\mathrm{n}=6-10$ ).

|  | Head length | Snoutpreopercle | Length of frontal fossa | Prepectoral |
| :---: | :---: | :---: | :---: | :---: |
|  | \} $350-382(365)$ | 245-249(247) | 130-144(138) | 354-373(361) |
| Yg. | 368-414(384) | 253-273(263) | 137-158(151) | 365-396(379) |
|  | Pelvic-anal | Preanal | Anal-caudal | Length of caudal ped. |
| Ad | 307-321(314) | 665-691(678) | 356-360(358) | 266-271(269) |
| Hg | 290-332(304) | 627-662(638) | 363--396(388) | 277-294(289) |
| Yg. | *264--320(291) | *599-644(626) | 373-413(396) | 275-307(291) |


|  | Eye |
| :---: | :---: |
| Ad $\ldots \ldots \ldots \ldots \ldots$ | $41-42(42)$ <br> $\mathrm{Hg} \ldots \ldots \ldots \ldots \ldots$ <br> $\mathrm{Yg} \ldots \ldots \ldots \ldots \ldots$ |
| $\mathbf{4 5 - 4 8 ( 4 7 )}$ |  |
| $54-69(61)$ |  |

## Description.

Body and head form:-The streamlined body narrows gradually from the anus to a tapered caudal peduncle, which is usually more than 2.5 times as long as deep. The body contour along the dorsal fin ascents almost straightly. The ventral contour remains straight and almost horizontal from the pelvic symphysis t the anus. The point of greatest body depth subtends or slightly succeeds the pelvic insertion. From the dorsal origin to the frontal knob the relatively steep profile descends straightly; this renders the silhouette of the head


Fig. 20. Melamphaes polylepis, n. sp. A. holotype, traced and modified from photograph (standard length 61.6 mm. ); B , postlarva, D 3915 (3) (s. I. 12.0 mm .).
and body obtusely angular, with the apex at the dorsal origin. The ventral contour of the head curves slightly ontward from the pelvie symphysis to the isthmus, where it abruptly bends up to the mandibular symphysis. The diameter of the eye equals the suborbital width and measures about half the snout length. From the premaxillary symphysis to the anterior end of the frontal knob is about $0.67 \ldots 0.75$ times the distance between the anterior nostrils.

Head ridges and epidermis:-About $1.67-175$ times as long as wide, the frontal fossa, which resembles a funnel in cross-section, expands twice before its acutely constricted posterior end. Behind the fromfal knob a semicircular area is almost unpigmented. A very obtuse angle in the frontal margin over the front of the eye gradually narrows the interorbital space. Between these angles the interorbital only slightly aseeds the distance from the orbit to the preopercular edge. The fragile spinelike ridges at the check angle diverge symmetrically. In most specimens the thin head epidernis is collapsed and partly missing, especially wer the preopercle. Although frequently lighter on their midlines, the delicate, widely spaced embossed lines and out as slightly darker streaks on a lighter background. The spaces between them are smooth and generally without prickles.

Sensory pores:- The pores in the group inside the cheek angle number approximately 3 . Those in the sroup under the posteroventral angle of the orbit number 2 in each of 6 counts. On one specimen the pores (in the preopercle above the angle number $1+3+3+3$. On the outer margin of the mandible, from just behind the angle to the symphysis, the pores usually number $1+2+1+1$; other counts are $1+3+2+1$ and $1+2+2 \div 1$. The pore on the outer surface of the mandible near the symphysis is about half the size of its equivalent bhind the symphysis.

Operculum:--The slightly produced posteroventral border of the interopercle bears no spines or obvious ritges; ventrally, the last branchiostegal is evenly rounded.

Jaws and teeth:-Occasionally by as much as the lens diameter, the maxillary overreaches a vertical from the posterior bony orbit. The tooth formula is for adults $6-7 / 3$, for halfgrown $3-6 / 2-3$, and for young $1-3,1-2$. Although in the expanded part of the premaxillary tooth-band the inner 3-4 rows of minute, closely packed teeth are usually oblique, the outer $2-3$ rows, like all rows in the mandible, align irregularly ir almost horizontally. Near the symphysis, this band becomes uniserial. In the 2 largest specimens the phayngeal teeth number $15-17$ on the second pharyngobranchial, 45-47 on the third, $14-17$ on the fourth, and $25-28$ on the third epibranchial.
(iill rakers:-The gill rakers usually number $5-6+15-16$. The longest raker, at the angle, measures $1.5-2.0$ times the diameter of the eye.

Scales:-Represented mostly by pockets, the scale rows usually number $34 ; 9$ of 27 counts are 33 or 35. 1 typical body scale from under the pectoral is subrectangular or semicircular. No circuli pattern the relatively 'arge posterior field. However, microscopic striae, only about $0.25-0.33$ times the width of grooves between :reuli on the anterior field, radiate from the focus to the posterior edge of the scale. In the 2 adults only, ; 12 distinct radii extend from the posterior margin part way to the focus. At their widest, the grooves between circuli on the anterior and lateral fields measure about $.02-.03 \mathrm{~mm}$. In contrast with many of the species, these grooves are smooth or are breached by indistinct cross-striae. Eight or nine scallops, between which end listinct "radii" (formed of sharp bends in the circuli), render the anterior margin of the seale irregular; the posterior margin is even. The focus is nearest the posterior margin. A single file of about 13-14 slender wales sheathes the base of the soft dorsal fin. On the flat or slightly curved breast the large, plate-like seales are usually missing; on one specimen, however, a large, diamond-shaped seale spans the pelvic bases. Moulded li) shape, 4 especiaily pliant, fine-ridged scales shield the subopercle, interopercle, and operele. Only one hecimen retains even part of its opercular squamation, but from an examination of the seale pockets the number and arrangement of the seales could be estimated.

Fins:- The modal dorsal count is III, $14 ; 8$ of 40 counts are III, 15, 1 is III, 13. The anal rays almost ways momber 1,8 ; only 1 of to counts is $\mathrm{I}, 7$. The anal originates under or slightly before the penultimate Horsal ray. The pectoral fin reaches to within 1 or 2 seales of the end of the dorsal. Though slightly before the pectoral insertion in young the pelvies insert slighty behind it in adults.

Internal characters:--The modal vertebral count is $11+18$; although only 1 of 36 precaudal counts is 12 , the caudal counts range from 17 to 19 vertebrae, with 17 more common than 19 . The haemal arch of the first caudal vertebra bears well-developed spurs. Almost half the length of the arch, their shadow appears in radiographs as a single downward-projecting spine, which is situated anteriorly near the base of the slender, retrorse haemal spine. The wide base of the haemal spine expands immediately behind the spur. In one immature specimen the rete and gas gland of the well-developed gas-bladder occupy only a sixth of the entire structure. The large membranous bladder is longer than the stomach, which, 4 times as long as deep, is evenly and heavily pigmented.

Colour:-Although due to abrasion some scale pockets may be lightest centrally, the integument is mot generally mottled. The bases of the median fins usually are no darker than the rest of the body, which, with the head and fins, is never punctulate. Under a thin covering of brown the pharynx appears pale iridescent bluish. Light brownish pigment mottles the coelomic peritoneum. In color, the young resemble the adults, except that a few fin rays may be punctulate.

## Sex ratio and size at maturity.

All specimens, including the largest examined ( 62 mm .), are immature.

## Geographical variation.

In shorter head, snout to preopercle, and prepectoral lengths, 8 young from the tropical North Atlantir differ significantly ( $\mathrm{P}<.05$ ) from 18 Indo-Pacific young, but no other characters substantiate these differenco.

## Distinctions.

M. polylepis is distinguished from contiguous M. lugubris of the North Pacific and possibly sympatic M. leprus of the Atlantic in their species accounts. Species in the typhlops group have fewer gill rakers (usually: $2-4+11-14$ ), the gill rakers of the fourth arch reduced to spiny convexities or nubbins, and fewer horizontal and oblique scale rows (usually $30-33$ and 8 respectively).

## Derivation of name.

Derived from the Greek, the species name polylepis ("many scales") refers to the relatively large number of horizontal and oblique scale rows.

Specimens examined.-40 from 30 collections.
Holotype: D $3909(1)$, specimen number $1 ; 61.6 \mathrm{~mm}$.; equatorial East Indian Ocean, off Ceylon, $5^{\circ} 21^{\prime} \mathrm{N} 80^{\circ} 38^{\prime}$ 1: capture, 4500 meters wire, bottom 4120 meters; 3-meter conical ring trawl; 22 November 1929; 1900 hours ; R/V "Dana".

Paratypes: Equatorial east Indian Ocean, off Ceylon: D 3909(1) specimen number 2, data as for holotype, $1(59 . \mathrm{z}$. Indonesia: D $3677(4), 5^{\circ} 28^{\prime}$ S $130^{\circ} 39^{\prime} \mathrm{E}$, 2000 w .(d), 1(37); D $3736(3), 9^{\circ} 17^{\prime} \mathrm{N} 123^{\circ} 58^{\prime} \mathrm{E}, 1500 \mathrm{w} .(\mathrm{dn})$, $1(30)$; D $3800(2)$. $7^{\circ} 53^{\prime} \mathrm{S} 116^{\prime} 18^{\prime} \mathrm{E}$, 600 w (n), $1(30)$.

Additional material: Tropical North Atlantic: D 1168(4), $9^{\circ} 30^{\prime} \mathrm{N} 42^{\circ} 41^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 1(19) ;$ D $1171(10), 8^{\circ} 19{ }^{\circ}$ $44^{\circ} 35^{\prime} \mathrm{W}, 400 \mathrm{w} .(\mathrm{d}), 1(23): \mathrm{D} 1174(2), 5^{\circ} 53^{\prime} \mathrm{N} 51^{\circ} 08^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 1(23) ;$ D $1215(2), 16^{\circ} 06^{\prime} \mathrm{N} 76^{\circ} 02^{\prime} \mathrm{W}, 1000 \mathrm{w} .(\mathrm{i}$, 1(17); D 1281(8), $17^{\circ} 43^{\prime}$ N $64^{\circ} 56^{\prime} \mathrm{W}, 700 \mathrm{w} .(\mathrm{n}), 1(16)$; D $1287(2), 16^{\circ} 04^{\prime} \mathrm{N} 61^{\circ} 52^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 1(18)$; D $4001(3), 3^{\circ} 56^{\prime}$ 人 $12^{\prime} 33^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 1(21) ; \mathrm{D} 4004(3), 10^{\prime} 21^{\prime} \mathrm{N} 17^{\circ} 59^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 1(26)$.

Equatorial Indian Ocean: D $3815(6), 3^{\circ} 36^{\prime}$ S $97^{\circ} 37^{\prime} \mathrm{E}, 300 \mathrm{w}$.(n), 1(12); D $3904(3), 5^{\circ} 18^{\prime} \mathrm{N} 90^{\circ} 55^{\prime} \mathrm{E}, 2500 \mathrm{w}$.(1). 1(18); D $3906(3), 4^{\circ} 27^{\prime}$ N $85^{\circ} 21^{\prime} \mathrm{E}, 400 \mathrm{w} .(\mathrm{n}), 1(19)$; D $3908(3), 4^{\circ} 28^{\prime}$ N $82^{\circ} 13^{\prime} \mathrm{E}, 400 \mathrm{w} .(\mathrm{n}), 1(17)$; D $3915(2) 3^{\circ} 14^{\prime}$ N $75^{\circ} 21^{\prime} \mathrm{E}, 600 \mathrm{w} .(\mathrm{n}), 1(22)$; D $3915(3), 3^{\circ} 14^{\prime}$ N $75^{\circ} 21^{\prime} \mathrm{E}, 300 \mathrm{w} .(\mathrm{n}), 5(12-22) ;$ D $3921(3), 3^{\circ} 36^{\prime}$ S $58^{\circ} 19^{\prime} \mathrm{E}, 400 \mathrm{w} .(\mathrm{n}), 1\left(1^{-1}\right.$ D) $3921(6), 7^{\prime \prime} 22^{\prime}$ N $121^{\circ} 16^{\prime}$ E, 3000 w .(d), $1(20)$.

Indonesia: AM 100442 (paratype of M. malayanus), $3^{\circ} 20^{\prime} S 127^{\circ} 23^{\prime} \mathrm{E}, 1536,1(17)$; D $3685(8), 7^{\circ} 22^{\prime} \mathrm{N} 121^{\circ} 1 \mathrm{G}^{\prime} 1$. 3000 w .(d), $1(20)$; I) $3686(3), 8^{\circ} 34^{\prime}$ N $119^{\circ} 55^{\prime} \mathrm{E}$, $300 \mathrm{w} .(\mathrm{n}), 5(14-19)$; D $3688(4), 6^{\circ} 55^{\prime} \mathrm{N} 114^{\circ} 02^{\prime} \mathrm{E}, 1000 \mathrm{w} .(\mathrm{d}), 1(16$ D $3739(9), 3^{\circ} 20^{\prime} \mathrm{N} 123^{\circ} 50^{\prime} \mathrm{E}, 2000 \mathrm{w} .(\mathrm{d}), 2(17-21) ; \mathrm{D} 3804(3), 9^{\circ} 09^{\prime} \mathrm{S} 114^{\circ} 47^{\prime} \mathrm{E}, 300 \mathrm{w} .(\mathrm{n}), 1(17)$.

North Pacific: POFI $1607,33^{\circ} 41^{\prime}$ N $180^{\circ} 00^{\prime} \mathrm{W}$, 200(n), 1(35): POFI $1821,6^{\circ} 25^{\prime} \times 153^{\circ} 24^{\prime} \mathrm{W}$, $382(\mathrm{n}), 1(44)$; V 3622, $26^{\circ} 06^{\prime}$ N $154^{\circ} 00^{\prime}$ E, 2700, 1(25).

South Pacific: Ob 428, $30^{\circ} 56^{\prime}$ S $109^{\prime} 17^{\prime} \mathrm{W}, 2000,1(30)$.

## M. macrocephalus species group.

Both M. macrocephalus and M. acanthomus reach a large size and inhabit, sympatrically in spots, the ravtern tropical Pacific. Differing appreciably from that of the other species groups, the sculpturing of the large body scales is practically identical in both species. Like the suborbitalis group, they have only 11 precaudal witebrae, have the long, widely compressed gill rakers on the first arch numerous and closely packed, and have the gill rakers on the fourth arch as well-developed stumps. Both, however, lack spurs on the first haemal arch, which is relatively narrow and smooth. The head epidermis is delicate and easily broken; the thin rmbossed lines are narrow, widely spaced, and not outstanding. Though the head is large, the eye is relatively mall.

Although M. acanthomus, like M. suborbitalis, has antrorse spines on the posttemporal and both it and mucrocephalus resemble species of the suborbitalis group in gill-raker characters, the two groups differ so 111 th in other ways that they are here considered separately.

The following descriptive excerpts pertain to both M. macrocephalus and M. acanthomus.
Head form:-The diameter of the eye slightly exceeds the suborbital width and measures $0.43-0.48$ times the snout length. From the premaxillary symphysis to the anterior end of the frontal knob is only about Hon-thirds the distance between the anterior nostrils.

Head ridges and epidermis:-The margins of the head ridges are not expanded. The frontal fossa, which resembles a goblet in cross-section, expands thrice before its barely constricted posterior end. A very , huse angle in the frontal margin over the front of the eye gradually narrows the interorbital space. The fragile spinelike ridges at the cheek angle diverge symmetrically. The spaces between the epidermal embossed lines of the head are smooth and generally without priekles.

Sensory pores:--Because the delicate head epidermis is usually collapsed, the pores are difficult to c, Tunt. Those in the group under the posteroventral angle of the orbit usually number 2 . In the group on the supratemporal canal directly above the preopercle the pores usually number $3 ; 2$ of 32 counts are 4 . The pre on the outer surface of the mandible near the symphysis equals or is slightly smaller than its equivalent l..hind the symphysis.

Spines and operculum:- Except on the opercle, the head bears no obvious spines. The angle of the thin, pliant proopercle is smooth, rounded and only slightly emarginate. At the angle of the preopercle a mall convexity marks the end of a weak ridge that originates near the cheek angle. No reticulate bone reinforces the opercular series. A ridge ending in a small point at the margin traverses the posteroventral part of the interopercle.

Gill rakers:- On the lower fourth arch each of the larger gill rakers is a short, but well-formed stump, baring 6-9 spines on its inner edge.

Scales:-Represented almost entirely by pockets, the scale rows usually number 31; about 1 specimen in 3 or 4 has 30 or 32 . A typical body scale from under the pectoral is almost cireular. The grooves between rinculi increase in width gradually from the anterior to the postrior field. Numerous, indistinct cross-striae theach these grooves. The focus is near the center of the scale. A single file of $12-14$ slender seales sheathes the base of the soft dorsal fin. On the flat or slightly curved breast the very large seales are thin, fragile, and usually missing. Moulded to shape, 4 thin, delicates shield the suboperele, interopercle, and opercle. Although why 1 specimen of macrocephahs and 2 of acanthomus retain even part of their opereular squamation, the fimmber and arrangement of seales was easily inferred.

Fins:- The anal usually originates under the third or fourth from last dorsal ray. The long pectoral fin waches to within 1 or 2 scales of, or to the end of, the dorsal. Though well iv front of the pectoral insertion in young, the pelvies insert directly under or only slightly before it in adults.

Internal eharacters.--The slender haemal arch of the first caudal vertebra bears no spurs, but smoothly curves into the retrorse spine.

Color:-Although some scale pockets are lightest centrally, the integument is not generally mottled. The
bases of the median fins usually are no darker than the rest of the body. The pharynx is brownish to dark blue-grey, frequently with a superficial metallic sheen. The coelomic peritoneum is uniformly dark brown to blackish.

## Melamphaes macrocephalus Park.

Fig. 21.
Melamphaes macrocephalus.-Parr, 1931: 39,40,41-43, Fig. 16 (original description: trawled with 625 fathoms wire out off Acapulco, Mexico; holotype, BOC 2697; [paratype series includes M. spinifer]); 1933: 14 (in key). Ch.s. man, 1939: 535,537 (in key, comparisons). Fowler, 1944: 495 (eastern Pacific). Kinwisher and Ebeling, 1957: 213 (gas composition of swimbladder). Morrow, 1957:59 (range extension at $4^{\circ} 35^{\prime} \mathrm{S} 82^{\circ} 52^{\prime} \mathrm{W}, 183 \mathrm{fms}$.; compared with type).

## Distribution.

M. macrocephalus is restricted to the eastern tropical Pacific, including areas off Baja California to 26 $27^{\circ} \mathrm{N}$ and off Peru to about $14--15^{\circ} \mathrm{S}$. At its westward limit, about $120^{\circ}$ or $130^{\circ} \mathrm{W}$, it occurs in the Equatorial Water between $18-20^{\circ} \mathrm{N}$ and $8-10^{\circ} \mathrm{S}$ (Fig. 55). Vertically, the upper limit of adults and halfgrown is about $400-500$ meters; the young occur more shallowly.

## Counts and measurements.

Counts:--The following counts are usually based on samples of $28-30$ : dorsal III, $13-16$ (14.6); anal I, $8-9(8.0)$; caudal $(n=18)+10-9+4-5(4.0+10.0+9.0+4.0)$; pectoral $14-15(14.9)$; pelvic 1,7 ; scale rows $(\mathrm{n}=18) 30 \ldots 33$ (31.1); scales in diagonal series $(\mathrm{n}=13) 8$; vertebrae $26 \quad 28$ (26.9); gill rakers on fint arch $5-7 \div 14-16(5.7 \div 14.7)$; gill rakers on lower limb of fourth arch $9-11$ (10.2); mandibular pores ( $\mathrm{n}=11$ ) $4-6$ ( 5.1 ).

Proportions:-Csually based on samples of $14-16$, the following are proportions for which the data suggest little or $n$ o allometric change. Body depth $266-318$ (294); orbit to cheek ridge ( $\mathrm{n}=28$ ) $66-90$ ( 81 ); head depth $254-302$ (282); head width $194-227$ (212); prepelvic $388-458$ ( 418 ); isthmus to pelvic 334 380 (356); pelvic to anal ( $\mathrm{n}=30$ ) 251--337 (280); pectoral 312-3.7 (330); pelvic 190-240 (211); preand $661-716$ (688); anal to caudal $291-355$ (336); Jength of caudal peduncle ( $\mathrm{n}=30$ ) 205--263 (229); depth of caudal peduncle $92-120$ (106); orbit to cheek angle $131-152$ (139); snout length $90-115$ (102).

The following are proportions for which the data suggest allometric change. If the values of the proportions of the halfgrown are similar to those of the adults, the two categories are bracketed together. Proportions att based on 5 adults ( Ad ) $96-117 \mathrm{~mm}$., 4 halfgrown ( Hg ) $57-82 \mathrm{~mm}$., and $20-21$ young ( Yg ) $24-54 \mathrm{~mm}$. (, based on only 6-7).

|  | Predorsal |
| :---: | :---: |
| Ad | 442-466(454) |
| Hg | +42--466(454) |
| Yg. | 461-497(480) |

Postdorsal
578-600(591)
578-580(579)
*544-584(568)
Snout-
preopercle

| Ad | 268-278(273) |
| :---: | :---: |
| Hg | 277-292(284) |
| Yg. | 272-310(288) |


|  | Prepectoral |
| :---: | :---: |
| Ad | 392-413(399) |
| Hg | 396-433(418) |
| Yg. | *422-464(434) |

Interorbital

120-129(125)
125-145(137)
$134-164(146)$

## Head length

396-423(408)
$424-429(427)$
411-470(441)

> Length of frontal fossa

145-154(149)
155-171(165)
148--185(168)

## Postorbital

261-285(276)
288-297(293)
*276-315(300)

Width of frontal fossa

72-79(74)
77-87(83)
*82-87(85)

| Upper jaw | Suborbital | Eye |
| :---: | :---: | :---: |
| $173-186(183)$ | $44-47(46)$ | $40-47(44)$ |
| $188-200(194)$ | $45-53(50)$ | 40 |
| $186-211(197)$ | $51-57(54)$ | $43-59(49)$ |



Fig. 21. Melamphaes macrocephalus Parr. A, adult specimen, SIO $31 \cdots$. 9 . traced and moditied from photograph (standard length 107.0 mm .); 13. young. BOC: 3746 (s. 1.26 .0 mm .): (.. young. BOC: uncataloged (s. 1.16 .9 mm .).

## Jescription.

Body and head form:--The rather robust body narrows gradually from the anus to a subrectangular atudal peduncle, which is barely twice as long as deep. The body contour along the dorsal fin ascends in : weakly convex arc. The ventral contour remains straight or weakly convex from the pelvic symphysis to the anus. Although behind the dorsal origin the dorsal contour is somewhat steeper than the ventral, the body frequeatly appears subsymmetrical in side view. The point of greatest body depth subtends or slightly succeeds the pelvic insertion. From the dorsal origin to the frontal knol the profile deseends in a weakly convex curve.

The ventral contour of the large head curves slighty outward from the pelvic symphysis to the isthmus, where it abruptly bends up to the mandibular symphysis.

Head ridges and cpidermis:-The frontal fossa is usually twice as long as wide. Between the angles in the frontal margin over the eye, the adult interorbital is less by the lens diameter than the distance from the orbit to the preopercular edge; in smaller halfgrown the interorbital equals this distance. In most speeimems the fragile head epidermis is collapsed and partly missing, expecially over the preopercle. Thin and widd spaced, the embossed lines stand out as light streaks on a slightly darker background.

Sensory pores:- The pores in the group inside the cheek angle usually nomber 3 or $4 ; 2$ of 12 coumb are 2 . The pores on the preoperele above the angle number $2+3+3+2$ (the 2 middle groups are triangulat, in 1 of 2 counts and $2+2+2+2$ in the other. On the outer margin of the mandible, from just behind the angle to the symphysis, the pores number $1+2-2+1$ in 3 counts out of 11 ; other counts are $1+2+1-1,1+1+2$. 1 . and $1-1-1-1$.

Spines, operculum, and posttemporal:-Better defined than in most species, smooth ridges distinctly sculpture the preopercle: several parallel horizontal ridges below the angle merge, above the angle. into weaker vertical ones that follow the marginal contour. The posteroventral margin of the last branchiosteqal is evenly rounded. The thin dorsal edge of the posttemporal is spineless.

Jaws and teeth:--The maxillary overreaches by the lens diameter a vertical from the posterior edge of the bony orbit. The tooth formula is for adults $4-7 / 2-4$, for halfgrowns $4-5 / 2-3$, and for young 2 1-2. Although in the expanded part of the premaxillary tooth-band of larger specimens the inner 2 roms are oblique, the outer rows, like the 2 or 3 rows in the mandible, align irregularly or almost horizontally in many of the smaller specimens, however, the premaxillary supports no oblique tooth-rows. Near the symphysis, this band narrows to '2 or 3 rows. In the larger specimens the pharyngeal teeth number $12-24$ on the second pharyngobranchial, $27-37$ on the third, $13-27$ on the fourth, and $22-36$ on the third epibranchial.

Gill rakers:- The gill rakers usually number $5-6+14-15$. On the first areh they are long, widely compressed and somewhat closely packed, with the spaces between them equal to or slightly longer than the greatest width, near the middle, of the larger rakers. The longest raker, at the angle, measures $1.5-1.7$ times the diameter of the eve. The gill rakers on the lower fourth arch usually number 10 or 11 . The longest is sub). equal to or slightly shorter than the adjacent width of the ceratobranchial.

Seales:- On a typical body scale the widest grooves on the posterior field are 3 - $\overline{3}$ times the width of the narrowest grooves on the anterior field. Three or four poorly developed scallops, between which are weat bends in the circuli, render the anterior margin of the scale relatively even. Though eroded, the posterion margin is even.

Fins:- The dorsal rays usually number III, $14-15 ; 2$ of 30 counts are III, 13 or 1II, 16 . The anal rav almost always number 1,8 . The pectoral rays almost always number 15 ; only 1 of 30 counts is 14 .

Internal characters:- The modal vertebral count is $11-16$; although the precaudal count is constan. 5 of 27 counts include 15 caudal vertebrae, 1 includes 17 . Anteriorly, the rete and gas gland of the gas-bladder orcupy more than half of the entire structure. The delicate membranous bladder is semitransparent. Tin" and a half times as long as deep, the thick stomach is evenly and heavily pigmented.

Color:-Although on 3 sperimens very fine punctulations decorate the cheek epidermis, there are usually no punctulations on the head, fins, or body. In color the young resemble the adults.

Sex ratio and size at maturity.
Among the 28 specimens sexed there are 14 males and 7 females. Mature adults range in standard lengiti from 102 lo 117 mm .

## Distinctions.

In its species account sympatric M. laeviceps is distinguished from macrocephalus. Closely related and sympatric M. acanthomus has shoulder spines, more gill rakers (usually $6-7+16-17$ ), and more gill raker on the lower limb of the fourth arch (usually 12 -13).

Specimens examined.--31 from 15 collections.
Holotype: BOC 2697; 54.0 mm .; eastern tropical Pacifie, off Acapulco, Mexico, $16^{\circ} 14^{\prime} \mathrm{N} 99^{\circ} 36^{\prime} 30^{\prime \prime} \mathrm{W}$ : eapture (2.) fathoms cable out, bottom 1800 fms.; 12 -foot conical ring trawl; 31 May 1926; approx, 1830 - 2130 hours; R.V "lawnee", L. L. Mowbray.

Paratypes: (From original type series, not designated). Eastern tropical l'acific, off Mexico: BOC 2698, data as for holotype, $13\left(24-49,4\right.$ other specimens in this series, M. spinifer); BOC $2699,14^{\circ} 31^{\prime} \mathrm{N}^{\prime} 96^{\circ} 14^{\prime} \mathrm{W}, 1125 \mathrm{w}$.(n), 3 $1: 35$ - 46, 2 other specimens in this series M. spinifer); USNM 92125, data as for holotype, 1(48).

Additional material: Mexico, off Baja California: Slo $51-91,25^{\circ} 52^{\prime} \mathrm{N}^{\prime} 114^{\circ} 49^{\prime} \mathrm{W}, 2200(d), 1(107)$.
Gulf of Panama and vicinity: D 1208(13), $6^{\circ} 48^{\prime} \mathrm{N} 80^{\circ} 33^{\prime} \mathrm{W}, 3600 \mathrm{w}$ (d), 1(57); 1) $3549(4), 7^{\circ} 16^{\prime} \times 78^{\circ} 30^{\prime} \mathrm{W}, 4000 \mathrm{w}$. (1f). $1(71)$; S1O $52-363,6^{\circ} 58^{\prime} \mathrm{N} 88^{\circ} 35^{\prime} \mathrm{W}, 1460(\mathrm{~d}), 1(117)$; S $1055-232,10^{\circ} 52^{\prime} \mathrm{N} 88^{\circ} 02^{\prime} \mathrm{W}, 450(\mathrm{n}), 1(40)$. SL 57051 ,


Eastern tropical Pacific, west of $100^{\circ} \mathrm{W}$ : SIO $52-419,8^{\circ} 58^{\prime} \mathrm{N} 104^{\circ} 32^{\prime} \mathrm{W}, 1900(\mathrm{dn}), 3(34-82)$; SIO $55-221,7^{\circ} 50^{\prime} \mathrm{N}$ $1_{210} 13^{\prime} \mathrm{W}, 2660(\mathrm{n}), 1(102)$; SIO $55-229,8^{\circ} 31^{\prime} \mathrm{N} 110^{\prime} 1^{\prime} \mathrm{W}, 1610(\mathrm{n}), 1(96)$.

Off Peru: SIO 52-372, $14^{\circ} 01^{\prime} \mathrm{S} 81^{\circ} 48^{\prime} \mathrm{W}, 1135(\mathrm{~d}), 1(108)$; BOC 3746 , $4^{\circ} 35^{\prime}$ S $82^{\circ} 52^{\prime} \mathrm{W}, 335(\mathrm{n}), 1(26)$.

Melamphaes acanthomas, new species.
lig. 22.
Plectromus lugubris (misidentification). Townsex́d and Nichols, 1925: 13,19 (2 sperimens from $22^{\circ} 46^{\prime} 45^{\prime \prime} \mathrm{N}$ $1190^{\prime} 50^{\prime} 15^{\prime \prime} \mathbf{W}$ ).

Melamphaes lugubris (in part)--Norman, 1929: 158-159 (description based in part on one of Townsend and Xichols' specimens; in key; notes; synonymy).

## mistribution.

A near-coastal species not taken more than 130 miles from land, M. aconthomus ranges from southern California to the Gulf of l'anamia and inhabits the middle and lower (iulf of California (Fig. 55). Whereas He large adults inhabit the deep water ( $700-3500$ meters) from l'anama to San Diego, the young occur more hallowly (ea. 250-500 meters) only in the warmer, more saline water of the Gulf of Panama and vicinity.

## (intints and measurements.

Counts:- The following counts are usually based on samples of $47-\overline{5}+$ : dorsal III, $14 \cdots 16$ (14.7); anal I. $79(8.0)$; caudal $3 \cdots+10(9-10)+4(4.0+10.0-9.0+4.0)$; pectoral $14-16(15.0)$; pelvic I , 7 ; scale mws ( $n=33$ ) 30-32 (31.2) ; scales in diagonal series $(n=21) 8$; vertebrac $26-28$ (26.9); gill rakers on first arth 6-7-15-17 (6.8+16.3); gill rakers on lower limb of fourth arch $10-14$ (12.0); mandibular pores (11 22) $6-7$ ( 6.5 ).

Proportions:- Lsually based on samples of 17 , the following are proportions for which the data suggest litlle or no allometric change: body depth $297-336$ ( 317 ); orbit to cheek ridge ( $n=52$ ) $60-87$ ( 70 ) : head depth $277-342$ (306); head width $203-247$ (233); prepelvic $394-435$ ( 414 ) ; isthmus to pelvic $335-368$ (3.51); pelvic to anal $(\mathrm{n}-47$ ) 258-331 (294); pectoral 315-375 (339) ; pelvic ( $n=7$ ) 189-244 (224); depth if caudal peduncle 105 - 126 (118); snout length $9+-117$ (102).

The following are proportions for which the data suggest allometric change. If the values of the proportions if the halfgrown are similar to those of the adults, the two categories are bracketed together. Proportions are haved on $21-23$ adults (Ad) $80-110 \mathrm{~mm}$. , 6-9 halfgrown (Hg) $47-79 \mathrm{~mm}$., and $14-22$ young ( Pg ) $19-43$ mm .

|  | Predorsal | Head Iength | Snoutpreopercle | Interorbital |
| :---: | :---: | :---: | :---: | :---: |
| Md | $417-464(440)$ | 394-44(422) | 239-271(261) | 128-151(140) |
| Hg | 452-486(462) | 390-471(433) | 267-290(278) | 140-162(150) |
| Yis. | 435-192(471) | 404-476(455) | 266-305(287) | 132-171(146) |


|  | Length of frontal fossa | Length of caudal ped. | Ipper jaw | Bye |
| :---: | :---: | :---: | :---: | :---: |
| Ad | 130-156(144) | $20.566(243)$ | 173--209(190) |  |
| Hg | 148-166(158) | $214-248(230)$ | 181-206(199) |  |
| Yg. | 159-186(173) | 209--250(232) | 175-226(216) | $53-65(58)$ |

These proportions are based on $12-13$ adults, 2 halfgrown, and 2 young.

|  | Postdorsal | Postorbital | Width of frontal fussa | I'ropectoral |
| :---: | :---: | :---: | :---: | :---: |
| Ad | 588-630(617) | 270--306(285) | 79.-.91(85) | 375-412(397) |
| Hg | .777-600(589) | $301-326(314)$ | $88-98(93)$ | $443-449(446)$ |
| İ. | 548-577(563) | 298-318(308) | $92.98(95)$ | 442 55) 449$)$ |
|  | Preanal | Anal-caudal | Orbit-cheek angle | Suborbital |
| Ad |  | $338-377(359)$ | 121--141(134) |  |
| Hg | 600-700(687) | $319-320$ (320) | 145-146(146) | ) |
| Yg. | 717-726(722) | $331-333(332)$ | 159-162(157) | $64-74(69)$ |



Fig. 22 A-B. Melamphaes acanthomus, n. sp. A, holotype (standard length 97.8 mm ); B, young, D 1208 (2) No. 1 (s. I. 32.0 mm. ).



## Jexcription.

Body and head form:-The robust body narrows gradually from the antus to a subrectangular caudal peduncle, which is slightly less than twice as long as deep. The body contour along the dorsal fin ascends in a weakly convex arc. In contrast with the dorsal the ventral contour remains straight or even weakly concave from the pelvic symphysis to the anus. The point of greatest depth of the relatively deep body subtends the pelvic insertion. From the dorsal origin to the frontal knob the profile descends in a relatively steep convex :arve. Almost symmetrically with the dorsal, the ventral contour of the large head curves outwardly from the pelvic symphysis to the isthmus, where it bends up to the mandibular symphysis.

Head ridges and epidermis:-The margins of the head ridges are especially thin and delicate. The wide frontal fossa is about 1.67 times as long as wide. Between the angles in the frontal margin over the eve, the wide interorbital exceeds by the diameter of the pupil the distance from the orbit to the preopercular edge. In most specimens the especially fragile head epidermis is collapsed and mostly missing, especially over the propercle, eheek, and frontal fossa. Thin, rather poorly developed, and widely spaced, the embossed lines , Aand out as light streaks on a darker background.

Sensory pores: The pores in the group inside the cheek angle usually number 4 . $\boldsymbol{T}$. The pores on the meopercle above the angle number $2-3+3+2-3$. On the outer margin of the mandible, from just behind the angle to the symphysis, the pores usually number $1+3+2+1$; other commts are $1+2+2+1$ and $1+3+1 \cdots 1$.

Spines, operculum, and posttemporal:-Compared with that of M. macrocephalus, the preoperrular sculpturing is poorly developed. On the posteroventral part of the last branchiostegal one or two very
weak ridges end in minute projections at the margin. Characteristic of M. acanthomus, a sharp, antronse spine springs from the dorsal edge of each posttemporal. This long, slender spine is quite outstanding, even on halfgrown and young.

Jaws and teeth:-In adults the maxillary slightly overreaches a vertical from the posterior edge of the bony orbit; in young and halfgrown it overreaches by the lens diameter this vertical. The tooth formula is for adults $3-5,2-4$, for halfgrown $3-5,1-3$, and for voung $1-3 / 1-3$. The expanded part of the premaxillary toothband includes no noticeably oblique inner rows; all teeth, like those in the mandible, are seattered or aligned in irregular rows. Near the symphysis the teeth are uniseriai. In the larger specimens the pharyngeal teeth number 11-19 on the second pharygobranchial, $27-40$ on the third, $10-25$ on the fourth and $14-29$ on the third epibranchial.

Gill rakers:- The gill rakers usually number $6-7+16-17$. On the first arch they are long, widely compressed, and closely packed, with the spaces between them equal to or slightly shorter than the greatst width, near the middle, of the larger rakers. The longest raker, at the angle, measures about 1.67 times the diameter of the eve. The gill rakers on the lower fourth arch usually number 12. The Iongest is slightly lonzer than the adjacent width of the ceratobranchial.

Seales:--On a typical body scale the widest grooves on the posterior field are $5--8$ times the width of the narrowest grooves on the anterior field. Four to seven poorly developed scallops, between which are weak bends in the circuli, render the anterior margin of the scale relatively even; though eroded, the posterin margin is even. On one opercular seale, but not on the others, the posterior circuli are not continous, but extend in broken lines horizontally to the posterior eroded border.

Fins:- The dorsal rays usually number HI, $14-15$; only 2 of 54 counts are HI, 16. The modal anal count is 1,$8 ; 5$ of 44 counts are 1.7 or 1,9 . The pectoral rays almost always number 15 ; only 1 of 52 count is 16 .

Internal characters: The modal vertebral count is 11.16 ; although the precaudal count is constani. 3 of 48 counts include 15 caudal vertebrae. Appearing degenerate, the small gas-bladder is doubtfully phe. matic. An anterior opaque area, presumably a rete and gas gland, precedes a thin diaphanous membrane of indeterminable shape. About 3 times as long as deep, the thick stomach is dark anteriorly and dorsalis. but lightens toward the end of the blind sac.

Color:--Oceasionally fine punctulations decorate the head epidermis, especially over the cheek. Athoush the young (in formalin) are faded, punctulations on head and body are relatively conspicuous; the lighlly spotted or mottled venter contrasted with the solidy pigmented dorsum countershades the young, ewn thomb the dark branchiostegal membrane and coelomic peritoneum are easily visible.

Sex ratio and size at maturity.
Among the 40 specimens sexed there are 15 males and 11 females. Mature adults range in standard length from 97 to 110 mm .

## Distinctions.

The antrorse shoulder spines distinguish M. acunthomus from all species in the genus except $M$. suborbitulis of the North Atlantic. M. actonthomus is distinguished from M. suborbitalis and closely related, sympatric M. macrocephalus in their species accounts. Sympatric M. lugubris lacks shoulder spines, has more pectoril rays (usually 16), has fewer mandibular pores ( $1+1+1+1$ ), has more opercular scales (usually 8 ), and has a well-developed spur on the first haemal arch.

## Derivation of name.

Derived from the Greek, the species name aconthomus ("shoulder spine") refers to the (antrorse) posttemporal spines.
specimens examined. - 55 from 30 collections.
Holotype: SIO $54-86$ specimen number 1 ; immature male ( 97.8 mm .); California, off san Diego, $322^{\circ} 46^{\prime} \mathrm{N}^{\prime} 117^{\circ}$ :3..) W: capture 0-840 meters, bottom 1040 meters; 10-foot Isaacs-Kidd midwater trawl; 24-25 February 1954; 295 0310 hours; R/V "Paolina T", R. L. Wisner and party.
'Paratypes: California, off San Diego and vicinity: SIO $50-269,3251^{\prime} N 11728^{\prime} \mathrm{W}$, $750(\mathrm{~d})$, 1 ( 99 ); SIO 50 286,
 H10(d), 1(106); SIO 52-39, $33^{\circ} 10^{\prime}$ N $118^{\circ} 32^{\prime} \mathrm{W}, 850(\mathrm{n}), 1(99) ;$ SIO $54 \cdots 83,3221^{\prime}$ N $11733^{\prime} \mathrm{W}$, 780(d), $1(103)$; SIO

 : 2 ' W, $1280(\mathrm{~d}), 2(80-91)$.

Mexico, off Baja California: SIO 51—-74, $28^{c} 58^{\prime} \mathrm{N} 118^{\prime \prime} 12^{\prime} \mathrm{W}, 915(\mathrm{~d}), 1(97) ;$ SIO $51-80,28^{\circ} 04^{\prime} \mathrm{N} 117^{\circ} 31^{\prime} \mathrm{W}, 460(\mathrm{n})$, (!!1): SIO 51-92, $26^{\circ} 02^{\prime} \mathrm{N} 114^{\circ} 22^{\prime} \mathrm{W}, 460(\mathrm{n}), 1(81)$.

Mexico, lower Gulf of California: SIO $59-200,26^{\circ} 15^{\prime} \mathrm{N} 109^{\circ} 51^{\prime} \mathrm{W}, 2300(\mathrm{dn}), 2\left(76^{\circ} \ldots 82\right): S 1059-202,26^{\circ} 54^{\prime} \mathrm{N}$ ! $10^{\circ} 01^{\prime} \mathrm{W}, 730(\mathrm{n}), 3(68-87) ;$ SIO $59-203,27^{c} 26^{\prime}$ N $111^{\prime} 27^{\prime} \mathrm{W}, 1460(\mathrm{n}), 1(79)$.


Mexico and Central America, off Cape San Lucas, Baja California to Nicaragua: AMNF 12821, $22^{2} 4 \mathbf{A}^{\prime}$ N 109
 ( $10-22$ ); S IO $58-422,12^{2} 11^{\prime}$ N $91^{\circ} 49^{\prime} \mathrm{W}, 3650(11), 1(89)$.

Gulf of Panama vicinity: D 1203(1), $7^{\circ} 30^{\prime}$ N $79^{\prime} 19^{\prime} \mathrm{W}, 1000 \mathrm{w}$ (n), $2(38-43)$; D $1205(2), 6^{\circ} 49^{\prime}$ N $80^{\circ} 25^{\prime} \mathrm{W}, 1000 \mathrm{w}$. 1!1). $3(20-41)$; D 1205(3), do., $9(19-42)$; D $1208(1), 6^{\circ} 48^{\prime}$ N $80^{\circ} 33^{\prime} \mathrm{W}, 1000 \mathrm{w} .(\mathrm{n}), 1(40) ; \mathrm{D} 1208(2)$, do., $600 \mathrm{w} .(\mathrm{n})$, - $1: 1-32$ ).

## M. suborbitalis species group.

With M. suborbitalis apparently the most generalized of the triad, the M. suborbitalis species group also rontains M. leprus and laeviceps. All three species reach a relatively large size; individuals of M. laeviceps, fir cxample, sometimes exced 130 mm . in standard length. Outstanding, widely spaced circuli pattern the posterior field of the relatively coarse-ridged body scales. The gill rakers are well-developed and usually widely compressed; short, but well-formed stumps stud the fourth arch. The precaudal vertebrac of all 3 pecies normally number 11 . The anal fin originates well in front of the end of the dorsal. Although subwhitalis has a well-developed spur on the haemal arch of the first caudal vertebrae, it is less well-developed in laeviceps and apparently absent in leprus.

Occurring only in the North Atlantic Ocean and the Subantarctic boundary region, suborbitalis is antitropical , a closely related form occurs in the North Pacific). M. leprus in the Atlantic and laeviceps in the Pacifie, on the other hand, are both restricted to the eastern tropies.

The following descriptive excerpts pertain to all 3 species.
Head ridges:--The margins of the head ridges are not expanded. The frontal knob is smooth.
${ }^{0}$ perculum:-The angle of the thin, pliant preopercle is smooth, rounded, and only slightly emarginate. It the preopercular angle a small convexity marks the end of a very weak ridge that originates near the cheek angle. No reticulate bone reinforees the opercular series. The posteroventral border of the interopercle and of the last branchiostegal are slightly produced, but bear no spines or obvious ridges.

Teeth:-Near the premaxillary symphesis the teeth are uniserial or biserial. In the mandible behind the expanded tooth-band near the symphysis, the 2 tooth-rows align irregulary or nearly horizontally.

Gill rakers:--On the first arch the longest gill raker, on the ceratobranchial near the angle, measures atout 1.33 times the diameter of the eve. The rakers on the lower fourth areh usually number 10 or 11 . Each of the larger rakers is a short but well-formed stump, the length of which equals the adjacent width of the "ratobranchial; its inner edge hears 4-8 spines.

Scales:-Represented mostly by pockets, the scale rows number about, 32 or 33 . A typical body seale from under the pectoral has a wedge-shaped posterior field of widely spaced circuli, which delimit grooves $9-12$ times the width of the narrowest grooves on the anterior field. Numerous fine cross-striae breach the ${ }_{n}$ rooves on the posterior field. Moulded to shape, 4 well-ossified, coarse-ridged scales shield the subopercle, interopercle, and opercle. Although the opercular scales on some specintens of $I /$. Iacuiceps are infact, only
$\overline{5}$ specimens of suborbitalis and leprus retain even part of their opercular squamation; the number of opercular scales on these 2 species was inferred from the arrangement of the pockets.

Color:--There are no punctulations on the head, fins, or body. Under a thin superficial covering of brown the pharens is pate iridescent bluish. The coclomic peritoneum is uniformly brownish or lightly mottert.

## Melamphats suborbitalis (Gin.L).

Fig. 23.
 shoulder spines; holotype, LiSNM 33271). Bean, 1885: 73 (systematic position). Jondan, 1885: 862 (listed). Ghbent, 1890: 60 (comparison with M. lugubris). Goode and Bean, 1895: 178-179 (in part ; description ; captures, "Albatros"" Station 2190, $39^{\circ} 40^{\prime} \mathrm{N} 70^{\circ} 20^{\prime} \mathrm{W}$; notes by Gill). Jordan and Evermann, 1896a: 841 - 8.12 (in part; description mainh after Goode and Bean: available material listed; in key); 1896b: 337 (Gulf Stream). Norman, 1929: 157-158 (2 sperimens examined, synonymized without eomment with M. microps). Jordan, Evermans, and Clark, 1930: 233 (in part; available material listed). Koefoed, 1953: 16, 18 (in part, in synonymy of M. microps after Nobman; $29^{\circ} 07^{\prime}$ $2.532^{\prime}$ W).

Melamphaes suborbilalis.-G"̈ntuer, 1887:30 (new combination; counts; type locality). Gammax, 1899: 383 (listen). Bracer, 1906: 280, 284-285, pl. 13, Fig. 5 (in part?; description, shoulder spines not always found; eastern tropical Atlantic and Indian Ocean; references; in key): 1908: 171, 222, pl. 33, Fig. 10 (structure of eves, histological section if retina). Rocle, 1919: 44 (identification). Beebe, 1929: 18 ( $39^{\circ} 15^{\prime}$ N $72^{\circ} \mathrm{W}$, 1000 fathoms). Rocle and Angel, 19:3; 68 (captures, eastern and central North Atlantic). Nobre, 1935: 4 (listed). Fowler, 1936b: 1265 (in part; listed in symonymy of M. microps after Normax). Norman, 1929: 157-158 (in part [see also M. microps]).

Melamphaes microps (misidentifications).-Koefoed, 1953: 16-17 (in part [see also M. microps]). Pirh, 1933: 17 (in part ; possible subspecies). BeEbe, 1937: 206 (in part ; $32^{\circ} 12^{\prime}$ N $64^{\circ} 36^{\prime}$ W).

## Distribution.

Though apparently never taken in the South Atlantic, M. suborbitalis oceurs in the North Atlantic on bohl sides between $10^{\circ}$ and $50^{\circ} \times$ Lat. (Fig. 53). Surprisingly enough, one large specimens was trawled in the Tasman Sea between New Zealand and Australia in about 2000 meters. Morphologically different from typical cxamples of suborbitalis, 3 specimens from approximately $26^{\circ}$ N $127^{\circ} \mathrm{W}^{\prime}$ may represent another species and are noted following the deseriptions of suborbitalis proper. Vertically the upper limit of adults and halfgrown is about 500 meters; the young occur more shallowly to about 150--200 meters.

Counls and measurements.
Counts:-The following counts are usually based on samples of 17-19: dorsal 111, 15-16 (15.9); antal I, $7-8$ ( 8.0 ) ; caudal $4-10-9+4$; pectoral $15-16(15.1)$; pelvic $\mathrm{I}, 7$; scales rows $32-35$ ( 32.7 ); scales in diagonal series $(\mathrm{n}=14) 8$; vertebrae $28-29$ (28.8); gill rakers on first areh $5-7+15-17$ ( $5.6+15.6$ ); gill rakers on lower limb of fourth areh 10--13 (10.6); mandibular pores ( $\mathrm{n}=8$ ) $4-\mathrm{-}$ (6.1).

Proportions:-- Csually based on samples of $14-16$, the following are proportions for which the data suggest little or no allometric change: lody depth 2.59 -295 (273); predorsal 404-436 (422) ; postdoral $597-638$ (620); postorbital $217-237$ (228); head depth $246-279$ (262) ; head width $175-203$ (189); inter orbital 106-129 (120); width of frontal fossa 63-76 (72); prepelvic 334-398 (375); isthmus to pedin $(\mathrm{n}=12) 286-329$ (318); pectoral 302-322 (311); pervic ( $n=9$ ) 206235 (226); depth of caudal pedunet 109-124 (116); upper jaw 1.57-169 (16.5); orbit to check angle 99-121 (111); snout length ( $\mathrm{n}=12$ ) 80-94 (87); suborbital 41-48 (45).

The following are proportions for which the data suggest allometric change. Here, for convenience, the data are grouped for only two stages. Proportions are based on $8-9$ halfgrown and adults (AH) $42-97 \mathrm{~mm}$. and $7-9$ young (Yg) $15-33 \mathrm{~mm}$.

## Head length

## AH

Yg. 340-354(347)
354-378(368)

## Orbitchcek ridge

237-245(242)
245-265(255)

$$
61-73(67)
$$

$$
57--65(61)
$$

## L.ength of frontal fossa

|  | Prepectoral | Pelvic-anal | Ireanal | Anal-caudal |
| :---: | :---: | :---: | :---: | :---: |
| . 11. | $336-363(350)$ | 295-338(315) | 635-675(653) | 355-399(376) |
| $1 \%$ | 358-401(371) | 280 286(283) | 613-643(626) | 37.5--397(388) |

## Length ol caudal ped.

Ev

| AH | 264-299(281) | 48-56(52) |
| :---: | :---: | :---: |
| Yg | $269-309(288)$ | 54-64(59) |



Tig. 23. Melamphaes suborbitalis (Gib.). A, adult specimen, D $4158(12)$, traced and modified from photograph (standard length 89.8 mm.); B, young, BOC 2836 (s. l. 28. 2 mm .) : C, postlaria, D 1353 ( 7 ) (s. $1.14 . \overline{\mathrm{mm}}$.).

## Description.

Body and head form:-The streamlined body narrows gradually from the anus to a tapered caudal peduncle, which is 2.33-2.5 times as long as deep. The body contour along the dorsal fin ascends in a weakly convex are. The ventral contour remains straight or weakly convex from the pelvic symphysis to the anus. Although behind the dorsal origin the dorsal contour is somewhat steeper than the ventral, the body frequently appears subsymmetrical in side view. The point of greatest body depth subtends or slightly succeeds the pelvic insertion. From the dorsal urigin to the frontal knob the profile deseend: in a weakly convex curve. Almost symmetrically with the dorsal, the ventral contour of the head curves outwardly from the pelvic symphysis to the isthmus, where it abruptly bends up to the mandibular symphysis. The diameter of the cye slightly exceeds the suborbital width and measures about 0.6 times the snout length. From the premaxillary symphyis to the anterior end of the frontal knob is about three-fourths the distance between the anterins nostrils.

Head ridges and epidermis:--Slightly less than wice as long as wide, the frontal fossa, which re sembles a goblet in cross-section, expands thrice before its noticeably constricted posterior end. A very oblus angle in the frontal margin over the front of the pupil gradually narrows the interorbital space. Between ther angles the interorbital exceeds by the width of the mandible the distance from the orbit to the preopercular edge. The fragile spinelike ridges at the cheek angle diverge symmetrically. In most specimens the thin heard epidermis is collapsed and partly missing, especially over the preopercle. The embossed lines stand out an dark streaks on a lighter background. On the second largest adult ( 90 mm .) minute prickles, cither seatterint or in rows, roughen the spaces between these lines. The prickles are strongest on the top third of the heat behind the gape, and on the mandibles. Strangely, the prickles are inconspicuous on the largest adult ( 97 mm . and on other smaller specimens.

Sensory pores: The pores in the group inside the cheek angle usually number 3; 1 of 9 connts is ". Those in the group under the posteroventral angle of the orbit usually number 1 or 2 . In the group on the supratemporal canal directly above the preopercle the pores number 3 . In 4 counts the pores on the propercle above the angle number $2-3 \div 3 \div 2,2+2+2+2$, or $2 \div 3 \div 3$. On the outer margin of the mandib! from just behind the angle to the symphysis, the pores usually number $1+2+2+1$ or $1+3+2+1$. The port on the outer surface of the mandible near the symphysis is about half the size of its equivalent behind the symphysis.

Posttemporal:-Characteristic of M. suborbitalis, a sharp, antrorse spine springs from the dorsal edp. of each posttemporal. Although short and occasionally broken, this spine is usually distinct, even on halfgrown and young.

Jaws and tecth:- The maxillary reaches or slightly overreaches a vertical from the posterior edge ef the bony orbit. The tooth formula is for adults ( 4 specimens longer than 54 mm .) $5-8 / 3-5$, for halfgro:n ( 3 specimens $33-43 \mathrm{~mm}$.) $2-32-3$, and for young (specimens shorter than 30 mm .) $1-2 / 1-2$. The w panded part of the premaxillary tooth-hand ineludes no noticeably oblique inner rows; all teeth are seatter. or aligned in irregular or nearly horizontal rows. In larger specimens the pharyngeal teeth number $10-22$ on the second pharyngobranchial, 25-48 on the third, 11-21 on the fourth, and 14-37 on the third ept branchial.

Gill rakers:-The gill rakers usually number $5-6+16$. On the first arch they are long, widely com pressed, and closely packed, with the spaces between them subequal to the greatest width, near the middle. of the larger rakers.

Scales:--Four to six scallops, between which end distinct "radii" (formed of sharp bends in the circuli) render the anterior margin of a typical body scale irregular; the posterior margin is frequently eroded. The focus is near the center of the scale. $A$ single file of 14 or 15 slender scales sheathes the base of the soft dorsal fin. On the flat or slightly curved breast the large scales are missing, but are assumed to be very thin ant caducous.

Fine:-The modal dorsal eount is III, 16; 2 of 18 counts are III, 15. The anal rays almost always number

8 ; only one of 18 counts is I, 7. The anal usually originates under the third or fourth from last dorsal ray. lhe pectoral fin reaches to within 1 to 2 scales of the end of the dorsal. Though directly under the pectoral nestion in young, the pelvics insert slightly behind it in adults.

Internal characters:-The modal vertebral count is $11+18$. Although the precaudal count is constant, in of 17 counts include 17 caudal vertebrae. The haemal arch of the first vertebra bears especially well-devel"ped spurs. Subequal the length of the arch, their shadow appears in radiographs as a single sharp, downward projecting spine which is situated anteriorly near the base of the slender, retrorse haemal spine. In pucimens from the North Atlantic the rete and gas gland of the well-developed gas-bladder occupy only about a sixth or seventh of the entire structure. The large, white bladder appears almost parchment-like and measures twice the length of the stomach (such a bladder was not found in the large adult from the Tasman sa, which, however, was not well preserved internally). Four or five times as long as deep, the slender stomach is evenly and heavily pigmented.

Color:-Noticeably lighter than the edges, the centers of the scale pockets, when integrated longitudinally, form a series of about 6 narrow, indistinct bands along the side of the body. In young, faded, or badly dam:aged specimens these bands are usually unrecognizable. The bases of the median fins and pectorals usually lark blackish arcas.

Sice ratio and size at maturity.
Among the 16 specimens sexed there are 3 males and 2 females. The mature or nearly mature adults are 90 and 97 mm . long.

## Gieographical variation.

In the few specimens available there are no obvious differences between those from different areas, except that 3 specimens in the Atlantic from south of $26^{\circ} \mathrm{N}$ have one fewer caudal vertebrae and the large Tasman Sea specimen has more scale rows (35), more gill rakers on the fourth arch (13), and more pharyngeal tecth $(2)-48+21+37)$ than usual. Three specimens, however, from the current boundary area off Baja California, Mexico are strikingly different and will be noted later.

## bistinctions.

The antrorse shoulder spines distinguish M. suborbitalis from all species in the genus except M. acanthomus (f the eastern tropical Pacific. M. acanthomus, however, differs in many other characters including proportions, gill rakers (usually $6-7+16-17$ ), tooth rows (3-5/1-4 in adults), the complete lack of spurs on the haemal arth of the first caudal vertebra, and the lack of a distinct posterior field of widely spaced circuli on the scales. Chosely related M. leprus has no shoulder spines, has fewer dorsal soft rays ( $14-15$ ), has fewer vertebrae 127) and lacks well-developed spurs on the haemal arches of the first caudal vertebra.

## Remarks.

The holotype is in very poor condition. The flesh is falling off, the fin rays are mostly gone, the upper jaw is broken, and parts of the operculum are missing. Along with the type locality in the North Atlantic, however, the presence of well-developed shoulder spines and a total gill raker count of at least 20 identifies it with suborbitatis as here described. Nonmax (1929), in synomymizing M. suborbitalis with M. microps, was olviously maware of the importance of the shoulder spines, spacing of circuli on the scales, and gill-raker counts, which separate the two species. Placed in a different species group, microps is actually quite distinct from vaborbitalis.

Specimens examined.--24 from 22 collections.
Holotype: USNM 33271; adult ( 89.0 mm .); western North Atlantic, $38^{\circ} 52^{\prime} 40^{\prime \prime}$ N $69^{\circ} 24^{\prime} 40^{\prime \prime} \mathrm{W}$; trawled between "urface and bottom, 1735 fms.; beam trawl; 18 July 1883; R/V "Albatross" Station 2036.

Additional material: Western North Allantic: BOC 2836, $32^{\wedge} 19^{\prime} \mathrm{N}^{\prime} 64^{\circ} 33^{\prime} \mathrm{W}, 2440 \mathrm{w} ., 1(28)$; SU 42316, $32^{\circ} 12^{\prime} \mathrm{X}$ $64^{\circ} 36^{\prime} W, 914(\mathrm{~d}), 1(23)$; SU 42810, do., 1646(d), 1(19); SL’42824, do., 914(d), 1(20); SU 42319, do., 1097(d), 1(18): USNM $35451,39^{\circ} 40^{\prime} \mathrm{N} 70^{\circ} 20^{\prime} \mathrm{W}, 2160$, $1(68)$; USNM $39253,39^{\circ} 27^{\prime} \mathrm{N} 71^{\circ} 15^{\prime} \mathrm{W}, 2330,1(65)$; WHOI (RHB 475), $39^{\circ} 44^{\prime}$. X $70^{\circ} 08^{\prime}$ W, 146(n), 1(24).

 (ii), $1(42)$; D $4007(6), 18^{\circ} 22^{\prime} \mathrm{N} 18^{\circ} 14^{\prime} \mathrm{W}, 4000 \mathrm{w} .(\mathrm{d}), 1(75) ; \mathrm{D} 4008(1), 21^{\circ} 40^{\prime} \mathrm{N} 18^{\circ} 00^{\prime} \mathrm{W}, 1000 \mathrm{w} .(\mathrm{n}), 1(54) ; \mathrm{D} 40(\mathrm{ss}(3)$,
 $4158(12), 46^{\circ} 28^{\prime} \mathrm{N}^{\circ} 01^{\prime} \mathrm{W}, 5000 \mathrm{w} .(\mathrm{d}), 1(90)$; FM 10705, Madeira, 1(89); FM 13873, Madeira, 1(86).

Tasman Sea, between Australia and New Zealand: Ob $348,42^{\circ} 34^{\prime} \mathrm{S} 159^{\circ} 00^{\prime} \mathrm{E}, 4000 \mathrm{w} ., 1(97)$.

## Melamphaes cf. suborbitalis.

Three specimens allied with suborbitalis, but differing strikingly by several characters, were collected. all at about the stome locality (Fig. 53 ), in the California Current boundary area off Baja California, Mexion
 $57-206,28^{c} 35^{\prime} \times 126^{\circ} 52^{\prime} W, 1235(n), 1(77)$ ) Lnfortunately no hydrographic casts were taken at the locadities of capture so that it is impossible to tell if they are from Transitional, deep Equatorial, Intermediate, or Central Water.

Besides the short shoukler spines, they resemble suborbitalis in the number of rows of teeth in the expandid band of the upper jaw ( $5-6$ ), gill rakers on the upper first arch (5), the posteriorly inserted pelvies, and especially the high vertebral number $(11+18)$. The dorsal count of $I 11,15$, however, is low. Because all 3 sperimens are twisted and otherwise damaged, it is difficult to evaluate the proportional differences. Some of the proportions are intermediate between suborbitalis and $M$. aconthomus of the eastern tropieal Pacific or are characteristic of suborbitalis. The long head length is characteristic of aconthomus.

The few remaining scales are atypical. The circuli are narrowly spaced on the anterior field and widrn only slightly to the broad lateral fields. The posterior field is smooth except for a few ill-defined ridges. Resembling that of suborbitalis, the haemal arch on the first caudal vertebra, although it has no developed spus. is thick and has a sharp bend between the arch and the retrorse spine. This sharp bend and expansion m:t. represent the spur. Nogas-bladder such as that described for suborbitalis was found. The coclomic peritoneum is dark and resembles that of aconthomus.

Inasmuch as suborbitalis is a species morphologically quite distinct from acanthomus, it is doubtful the troublesome specimens are intergrades. That they represent a new species confined to the Central Water ur are peripheral variants of suborbitclis is more likely. The answer, of course, must await the procurement of more and better specimens, which will likely be obtained when more intensive sampling of the North PacifuCentral Water mass is undertaken.

Melamphaes leprus, new species.
Fig. 24.

## Mis/ribution.

The $S$ records of $M$. leprus are all from the tropical Atlantic off Africa, from $11^{\circ} \mathrm{N}$ to $4^{\circ} \mathrm{S}$ (Fig. 53). Vertically at night, the upper limit of young and halfgrown is 150 - 300 meters; adults probably occur much deeper.

## Counts and measurements.

Counts:- The following counts are usually hased on samples of $9-10$ : dorsal III, 14-15 (14.7); anal I, 8 ; cautal $4-10-4+4$; pectoral 15 ; pelvic $I, 7$; scale rows $31-33(31.9)$; scales in diagonal series 8 ; vertebrae 27 ; gill rakers on first areh $5-6+15-16(5.1+15.6)$; gill rakers on lower limb of fourth arch $10-1$ ? (10.3) mandibukar pores $(n=5) 7$.

Proportions:-Based on samples of 5 - 6 , the following are proportions for which the data suggest little or no allometric change: body depth $269-286$ (275); postdorsal $587-613$ ( 604 ) postorbital $231-256$
241); head depth 245-259 (252); head widu 191--201 (197); interorbital 128 - 135 (132); length of frontal fowa 145-163 (153); width of frontal fossa 71-78 (75); prepectoral 366-385 (374); prepelvic 368-397 382 ) ; isthmus to pelvic 322-341 (331); pelvic to anal 286-324 (298); pectoral 324 340 (329); pelvic 2166256 (236); anal to caudal 359-374 (366); length of caudal peduncle 246-264 (254); depth of caudal eduncle 103-121 (113); upper jaw 172-186 (178) ; orbit to cheek angle 105-117 (111); snout length i. -98 (94); suborbital 42-50 (45).

The following are proportions for which the data suggest allometric change. Here, for convenience, the lata are grouped for only two stages. Proportions are based on 3 adults (Ad) $53-76 \mathrm{~mm}$. and 3 young and halfgrown (YH) $23-43 \mathrm{~mm}$.

|  |  | Predorsal | Heal length |  | Snoutpreopercle |  | Orbitcheek ridge |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| dri |  | 417. $439(127)$ | 36.5 | 381(371) | 24.5 | 2.99(0.54) |  | (i8( 6.5 ) |
| 111. |  | $435-49(442)$ | 379 | 393:3(387) | 2.5 | $\underline{270(263)}$ |  | 663( 62 ) |
|  |  |  | Preanal |  | beve |  |  |  |
|  | Ad |  | 6.54 | 671(663) |  | 50(49) |  |  |
|  | YH |  | 637 | 660(645) |  | ${ }^{60}(59)$ |  |  |

## Mescription.

Body and head form:-The streamlined body narrows gradually from the anus to a tapered caudal peduncle, which is slightly more than twice as long as deep. The body contour along the dorsal fin asecnds in a weakly convex are. In contrast, the ventral contour remains straight or weakly concave from the pelvic symphysis to the anus. The point of greatest body depth subtends the pelvic insertion. From the dorsal origin 1" the frontal knob the profile descends straightly. The ventral contour of the head curves slightly outward from the pelvic symphysis to the isthmus, where it abruptly bends up to the mandibular symphysis. The diameter of the eye slightly exceeds the suborbital width and measures about half the snout length. From the momaxillary symphysis to the anterior end of the frontal knob is about three-fourths the distance between the anterior nostrils.

Head ridges and epidermis:-Lsually twice as long as wide, the frontal fossa, which resembles a goblet in cross-section, expands thrice before its barely constricted posterior end. A very obtuse angle in the frontal margin over the front of the eye gradually narrows the interorbital space. Between these angles the interorbital exceeds by the width of the mandible the distance from the orbit to the preopercular edge. The very fragile, considerably reduced spine-like ridges at the cheek angle diverge symmetrically. In most


Fig. 24. Melamphaes leprus, n. sp. Holotype, traced and modiffed fion photograph (standard lengtil 75.9 mm .).
specimens the thin head epidermis is collapsed and partly missing, especially over the preopercle. Although frequently lighter on their midlines, the embossed lines stand out as slightly darker streaks on a lighter back. ground. The spaces between the embossed lines are smooth and generally without prickless, although a few very small ones are concentrated on ridges or are seattered on the mandible and snout.

Sensory pores:--The pores in the group inside the check angle number 3 in all 10 counts. Those in the group under the posteroventral angle of the orbit usually number 2 . In the group on the supratemporal canal directly above the opercle the pores number 3 . The pores on the preopercle above the angle usually number $\underline{2}-3+3+2 ; 1$ of 5 counts is $2+2+3+2$. On the outer margin of the mandible, from just behind the angle 16 the symphysis, the pores number $1+3+2+1$. The pore on the outer surface of the mandible near the symphysis is equal to or is slightly smaller than its equivalent behind the symphysis.

Posttemporal:-Even though the anterior edge is thickened with a bony rudiment, the posttemporal bears no distinct antrorse spine.

Jaws and teeth:-The maxillary slighly overreaches a vertical from the posterior edge of the bons orbil. The tooth formula is $4-5 / 3-4$ for specimens $37-76 \mathrm{~mm}$. and $1 \cdots 2 / 1$ for speeimens $17-24 \mathrm{~mm}$. Al though in the expanded part of the premaxillary tooth-band the inner $2-3$ rows are oblique, the outer rown align irregularly or nearly horizontally. In larger specimens the pharyngeal teeth number 7-10 on the second pharyngobranchial, $17-26$ on the third, $10-13$ on the fourth, and $12-15$ on the third epibranchial.

Gill rakers:-The gill rakers usually number $\overline{5}+15-16$. On the first arch they are long, widely compressell and closely packed, with the space between them equal to the greatest width, near the middle, of the larger rakers.

Scales:-Four to six poorly developed scallops, between which are weak bends in the circuli, render the anterior margin of a typical body scale relatively even; the posterior margin is frequently eroded. The focus is near the center of the scale. A single file of about 13 slender scales sheathes the base of the soft dorsal fin. On the flat or slightly curved breast the scales are missing, but are assumed to be very thin and caducous.

Fins:- The modal dorsal count is III, $15 ; 3$ of 9 counts are III, 14 . The anal rays always number $I, B$. The anal usually originates under the third or fourth from last dorsal ray. The pectoral fin reaches to within 1 or 2 seales of the end of the dorsal. Though almost directly under or slightly before the pectoral insertion in young, the pelvies insert slightly behind it in adults.

Internal characters:-The vertebrae number $11+16$. In sharp contrast with $M$. suborbitalis the haemal arch of the first caudal vertebra bears no spurs, but thickens and angles at the base of the curved, retrorse haemal spine. The gas-bladder appears degenerate. Four to tive times as long as deep, the slender stomach is evenly and heavily pigmented.

Color:--Noticeably lighter than the edges, the centers of the scale pockets, when integrated longitudinally. frequently form a series of indistinct horizontal bands, less obvious than in M. suborbitalis. In the smaller specimens the lateral bands are unrecognizable; the integument may appear somewhat mottled. The base of the median fins and pectorals usually lack blackish areas.

Sex ratio and size at maturity.
Among the 9 specimens sexed there are 2 males and 2 females. Even the largest specimen, a 76 num. male, has immature gonads.

## Distinctions.

In ils species account closely related M. suborbitalis is distinguished from M. leprus. Possibly sympatric M. polylepis has more vertebrac (usually $11+18$ ), the scales without a posterior field of widely spaced circuli. and more scale rows (usually 33-35).

## Derivation of name.

Derived from the Greek, the species name leprus ("rough") refers to the relatively coarse-ridged scales.

Specimens examined.- 10 from 9 collections.
Holotype: D 3999(1); maturing male ( 75.9 mm .); equatorial South Atlantic, north of Ascension Is., $3^{\circ} 45^{\prime} \mathrm{S} 10^{\circ} 00^{\prime} \mathrm{W}$; (apture, 1000 meters wire, bottom 3719 m .; 3-meter conical ring trawl; 2 March 1930; 1910 hours; R/V "Dana".

Paratypes: Eastern tropical Atlantic: D 3999(2), $3^{\circ} 45^{\prime} \mathrm{S} 10^{\circ} 00^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 1(59) ; \mathrm{D} 4001(2), 3^{\circ} 56^{\prime} \mathrm{N} 12^{\circ} 33^{\prime} \mathrm{W}$, (:) ${ }^{\prime}$ w.(n), 1(43); D $4004(2), 10^{\circ} 21^{\prime} \mathrm{N} 17^{\circ} 59^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 1(53)$; D 4004(3), do., 300w.(n), 1(37).

Additional material: Eastern tropical Atlantic: D 4000(3), $0^{\circ} 31^{\prime} \mathrm{S} 11^{\circ} 02^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 2(17-18)$; D 4003(5), $\left.\therefore 26^{\prime} \mathrm{N} 15^{\circ} 11^{\prime} \mathrm{W}, 200 \mathrm{w} .(\mathrm{d}), 1 \mathrm{PL}(22.5) ; 1\right) 4003(8), 8^{\circ} 26^{\prime} \mathrm{N} 15^{\circ} 11^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 1(23) ; \mathrm{D} 4003(9)$, do., $300 \mathrm{w} .(\mathrm{n}), 1(18)$.

## Melamphaes laeviceps, new speries.

Fig. 25.
Melamphaes lugubris (misidentification).—Garman, 1899: 63--64, 412, 583, (in part [see also M. spinifer]; description; (amparisons; distribution; $10^{\circ} 14^{\prime} \mathrm{N} 96^{\circ} 28^{\prime} \mathrm{W}$ ). (?) Fowler, 1938: 252 (Galápagos Ids.); 1944: 495 (in part, off Panama bay; after Gabman).

## Mislribution.

M. laeviceps is restricted to the eastern tropical Pacific. At its westward limit, about $150-160^{\circ} \mathrm{W}$, it occurs in Equatorial Water between $18-20^{\circ} \mathrm{N}$ and $8-10^{\circ} \mathrm{S}$ (Fig. 53). To my knowledge, no specimens have been laken as far north as Baja California or as far south as Peru. Vertically, the upper limit of adults and larger latfgrown is probably below 400-500 meters; the young occur more shallowly.

## Comnts and measurements.

Counts:--The following counts are usually based on samples of 16 : dorsal III, 16-18 (16.6); anal I, s-10 (8.9); caudal $4+10-9+4$; pectoral $15-16$ (15.1); pelvic I, 7; scale rows $31-33$ (32.1); scales in diagonal series ( $\mathrm{n}=10$ ) 8; vertebrae $27-28$ (27.8); gill rakers on first arch $4-5+13-15$ ( $4.5+13.8$ ); gill rakers on lower limb of fourth arch 9-11 (9.1); mandibular pores ( $\mathrm{n}=12$ ) $5-7$ (6.7).

Proportions:-Usually based on samples of $14-16$, the following are proportions for which the data uggest little or no allometric change: body depth 257-291 (280); predorsal 393-452 (428); postdorsal . 945 - 634 (614); postorbital 232-282 (255); head depth 245--286 (265); head width 179-208 (197); width uf frontal Cossa $70-80(74)$; prepectoral $357-402$ (378); prepelvic $375-405$ (391); isthmus to pelvic 304: 沙 (332) ; pelvic to anal $271-338$ (293); pectoral $294-339$ (312); pelvic ( $\mathrm{n}=9$ ) 187-232 (214); preanal ti47-695 (666); anal to caudal 346-393 (364); length of caudal peduncle 221-263 (242); depth of caudal peduncle 104-121 (112); snout length $90-100$ ( 95 ); suborbital 40-48 (43).

The following are proportions for which the data suggest allometric change. If the values of the proportions uf the halfgrown are similar to those of the adults, the two categories are bracketed together. Proportions are based on 7 adults (Ad) $110-134 \mathrm{~mm}$., 5 halfgrown ( Hg ) $56-83 \mathrm{~mm}$., and $3-4$ young ( Yg ) $26-37 \mathrm{~mm}$.

|  | Itead length | Snoutpreopercle | Interorbital | Length of frontal fossa |
| :---: | :---: | :---: | :---: | :---: |
| Ad | 348-389(377) | 234-260(250) | 112-121(117) | 136-143(140) |
| Hg | 380-411(392) | 256-271(263) | 121-130(125) | 144-156(148) |
| 广g | 380-431(404) | 262--294(275) | 120-134(129) | 149-177(162) |
|  | Orbitcheek ridge | Upper jaw | Orbitcheek angle | Eye |
| \|l| |  | 172-181(177) | 125-134(128) | 41-48(45) |
| Hg | 68--83(77) | 173-194(183) | 117-126(122) | 45-53(49) |
| lig. | 59-114(77) | 179-198(189) | 99-111(107) | $54-66(59)$ |



Fig. 25. Melamphues daeviceps, n. sp. Holotype (standard length 12.4 .6 mm .).

## Description.

Body and head form:--The streamlined body narrows gradually from the anus to a tapered caudal peduncle, which is 2.1-2.33 times as long as deep. The body contour along the dorsal fin ascends almost straightly: The ventral contour remains straight or weakly convex from the pelvic symphysis to the anus. Although behind the dorsal origin the dorsal contour is somewhat steeper than the ventral, the body frequently appears subsymmetrical in side view. The point of greatest body depth subtends or slightly succeeds the pelvic insertion. From the dorsal origin to the frontal knol the profile descends almost straightly. Almost symmetrically with the dorsal, the ventral contour of the head curves slightly outward from the pelvic symphysis $t$. the isthmus, where it abruptly angles up to the mandibular symphysis. The diameter of the eye equals the suborbital width and measures about half the snout length. From the premaxillary symphysis to the anterior end of the frontal knob is about two-thirds the distance between the anterior nostrils.

Head ridges and epidermis:-Slightly less than twice as long as wide, the head space, which resemble a goblet in cross-section, expands thrice before its barcly constricted posterior end. More acute than in . 1 suborbitalis and lacuiceps, but more obtuse than in M. spinifer, a noticeable angle in the frontal margin over the front of the pupil distinctly narrows the interorbital space. Between these angles the interorbital equat the distance from the orbit to the preopercular edge. The spinelike ridges at the angle of the cheek diver, almost symmetrically. In most specimens the epidermis of the smooth head is intact. The embossed lines at only slightly darker than the background. The spaces between the embossed lines are smooth and generally without prickles, although a few very small ones are concentrated on ridges or are scattered on the mandible and snout.

Sensory pores:- The pores in the group inside the cheek angle usually number 3 ; only 1 of 21 couri, is 2 . Those in the group under the posteroventral angle of the orbit usually number 2 . In the group on the supratemporal canal directly above the preoperele the pores usually number $3 ; 3$ of 23 counts are 4 . The pores on the preopercle above the angle usually number $2+3+3+2$, but occasionally one of the groups h:4 1 pore more or 1 pore fewer. On the outer margin of the mandible, from just behind the angle to the syn:physis, the pores usually number $1+3+2+1$; other counts are $1+3+3+1,1+2+2+1$, and $1+2+1+1$. The pore on the outer surface of the mandible near the symphysis is about half the size of its equivalent behind the symphysis.

Spines, operculum, and posttemporal:- Except on the opercle, the head bears no obvious spinc: the smooth dorsal edge of the posttemporal is spineless.

Jaws and teeth:- The maxillary overreaches by the lens diameter a vertical from the posterior bons orbit. The tooth formula is $5-7 / 3-5$ for halfgrown and adults, and $3-4 / 1-2$ for young. The expanded patt of the premaxillary tooth-band includes no inner oblique rows; all teeth are seattered or aligned in irregulat
"i nearly horizontal rows. In adults and halfgrowns the pharyngeal teeth number 11 - 18 on the second pharyngobranchial, $22-30$ on the third, $10-29$ on the fourth, and $15-31$ on the third epibranchial.

Gill rakers:- The gill rakers usually number $4-5+14$. On the first arch they are rather wide, but moderately spaced, with the spaces between them $1.3-1.5$ times the greatest width, near the middle, of the larger rakers.
scales: Five to seven seallops, between which end distinct "radii" (formed of sharp bends in the cirruli), render the anterior margin of a typical leody seale irregular; the posterior margin is frequently eroded. The focus is nearest the posterior margin of the scale. A single file of 13 or 14 slender seales sheathes the base of the dorsal tin. On the flat breast the seales are very large and thin, but distinctly seuptured and subvantial.

Fins:-The dorsal rays usually number 11I, $16-17 ; 1$ of 16 counts is 111,18 . The anal rays usually number $1,9: 1$ of 16 counts is 1,10 . The anal originates under the fourth or fifth from last dorsal ray. The pectoral rays usually number $15 ; 1$ of 16 counts is 16 . The pectoral fin reaches to within 3 or 4 seales of the end of the dirsal. Though slightly before the pectoral insertion in young, the pelvies insert directly under it in adults.

Internal characters:-The modal vertebral count is $11-17$. Atthough the precaudal count is constant, iof 16 counts inchude 16 caudal vertebrae. The haemal areh of the first eaudal vertebra bears well-developed purs in some specimens, weakly developed spurs in others. Only $0.2 .5-0.33$ times the length of the areh, their shadow appears in radiographs as a single short, downward-projecting knob or spine, which is situated anteriorly near the base of the slender, retrorse haemal spine. Anteriorly, the rete and gas gland of the small, porly developed gas-bladder occupy more than half the entire strueture. The deficate membranous bladder is shapeless and semitransparent. About 3 times as long as deep, the thick stomach is evenly and heavily pigmented.

Color:- Although each seale pocket is lightest anteriorly, the integument is not generally monlled or banded. Un larger specimens that are not badly faded, blackish areas surround the bases of the median fins and petnrals. Although they may merely represent pigmentation unabrased during capture, these areas are asually less pronounced in most of the other species. The young and halfgrown are generally lighter than the adults; the blackish areas about the fins are faint or absent.

Sex ratio and size at maturity.
Among the 13 specimens sexed there are 4 males and is females. Mature adults range in standard length from 112 to 134 mm .

## mistinctions.

M. Laeviceps is distinguished from M. spinifer in its species account. Superficially, laeviceps resembles Ympatric M. macrocephalus, which differs however in scale sculpturing (posterior field not so distinctly conlested from anterior ficld), in its larger head (usually $40-42$ per cent of standard length), in its anal count (1. 8 ), in its dorsal count (usually III, 14 15), and in lacking a spur on the first hatmal arch. Closely related, hul allopatric M. suborbitalis and M. leprus have fewer anal rays (I, 8), fewer dorsal rays (I, 1+-16), more will rakers on first arch ( $5-7+1517$ ), and smaller heads (about $34-36$ per cent of standard length). In addition, suborbitalis bears shoulder spines and leprus apparently lacks a spur on the first haemal arch.

## Herivation of name.

Derived from the Greek, the species name laeviceps ("smooth head") refers to the trim contours of the moothly sculptured head.

Sipecimens exdmined. 16 from 14 collections.
Holotype: SIO 52 - 409 specimen number 1 : adult male ( 124.6 mm ) : castern equatorial Pacific, nortlo of the (ialapagos Ids., $1^{\circ} 01.5^{\prime} \mathrm{N} 91^{\circ} 45.7^{\prime} \mathrm{W}$; capture $939-1109$ meters, bottom $2288 \mathrm{~m} . ; 10$-foot Isaacs-Kidd midwater trawl; 11-12 August 1952; 1816-0017 hours: R/N "Horizon", R. I. Wisner and party.

Paratypes: Gulf of Panama and vicinity: D $1203(10), 7^{\circ} 30^{\prime} \mathrm{N} 79^{\circ} 19^{\prime}$ W, $3500 \mathrm{w} .(\mathrm{d}), 1(122)$; D $3549(4), 7^{\circ} 16^{\prime}$ ल $78^{\circ} 30^{\prime} \mathrm{W}, 4000 \mathrm{w} .(\mathrm{d}), 1(12 \overline{7})$; POFI 1816 , $7^{\circ} 06^{\prime} \mathrm{N} 108^{\circ} 36^{\prime} \mathrm{W}, 322(\mathrm{n}), 1(66)$; SIO $52-363,6^{\circ} 58^{\prime} \mathrm{N} 88^{\circ} 35^{\prime} \mathrm{W}, 1464(\mathrm{~d})$, 1(110).

Eastern equatorial Pacific, Galápagos Is. and west: D $3558(1)$, $0^{\circ} 18^{\prime}$ S $99^{\circ} 07^{\prime}$ W, $4000 w .(d), 1(125)$; D $3558(2)$, $0^{\circ} 18^{\prime}$ S $99^{\circ} 07^{\prime} \mathrm{W}, 3000 \mathrm{w}$ (d), $1(82)$; SIO $52-338$, $0^{\circ} 18^{\prime}$ N $110^{\circ} 26^{\prime} \mathrm{W}$, 1280 (d), 2(77); SIO $52-409$ specimen number 2, $1^{\circ} 02^{\prime} \times 91^{\circ} 46^{\prime} \mathrm{W}, 1100(1), 1(112)$; SL $46355,11^{\circ} 42^{\prime}$ N $91^{\circ} 47^{\prime} \mathrm{W}$, $1(134)$.

Additional material: Gulf of Panama: MCZ 28754, $7^{\circ} 06^{\prime} \mathrm{N}^{\circ} 79^{\circ} 48^{\prime} \mathrm{W}, 1(34)$.
Eastern equatorial Pacific, near Galápagus Ids.: SIO $55-258,2^{\circ} 00^{\prime} \mathrm{S} 90^{\circ} 33^{\prime} \mathrm{W}, 1690(\mathrm{n}), 1(53)$.
Central equatorial Pacific, west of $150^{\circ} \mathrm{W}$ : POF1 1806, $7^{\circ} 15^{\prime} \mathrm{N} 155^{\circ} 04^{\prime} \mathrm{W}$, $1(56)$; POFI $1809,8^{\circ} 39^{\prime} \mathrm{N} 154^{\circ} 57^{\prime} \mathrm{W}$, $1(37)$; POFI $1820,10^{\circ} 50^{\prime} \times 156^{\circ} 07^{\prime} \mathrm{W}, 200(\mathrm{n}), 1(26)$.

## M. spinifer species group.

In general, specimens of M. spinifer and M. eulepis have most of their squamation and all of their heat epidermis intact; eulepis, especially, has permanent, well-fixed scales. Even though the grooves on the posterior field are narrower, the body scales resemble those of the suborbitalis-group species. As in M. laeviceps, furthermore, the first haemal arch usually bears small spurs; the precaudal vertebrae, however, number 12. Both species also resemble members of the typhlops group in having broad bands of teeth in the jaws, acutely narrowed or pinched interorbital spaces, and the gill rakers on the fourth arch reduced to nubbins. Whereas adults of spinifer reach a relatively large size, those of eulepis are small, rarely exceeding 45 mm . in standard length. Both species are tropical and primarily equatorial: eulepis in the South Atlantic, Indo-Pacific, and central Pacifie; spinifer in the eastern Pacific.

The following descriptive excerpts pertain to both M. eulepis and M. spinifer.
Body form:-The body contour along the dorsal fin ascends in a weakly convex arc. The ventral contour remains straight or weakly convex from the pelvic symphysis to the anus. The point of greatest body depth subtends or slightly precedes the pelvie insertion.

Head ridges and epidermis:- On the frontal fossa behind the frontal knob a small semicircular area remains pigmentless. A sharp angle in the frontal margin over the middle of the pupil abruptly narrows the interorbital space. In most specimens the head epidermis is intact and not collapsed. The spaces between the embossed lines are smooth and generally without prickles.

Sensory pores: The pores in the group under the posteroventral angle of the orbit number 2. The pores on the preopercle above the angle usually number $2+3+3+2$; frequently these groups vary by one pore. On the outer margin of the mandible, from just behind the angle to the symphysis the pores usually number $1-3-2-1$; other counts are $1+2-2+1,1+3+1+1$, and $1+2+1+1$.
posttemporal:-The dorsal edge of the posttemporal is spineless.
Teeth:-Although in the expanded part of the broad premaxillary tooth-band the inner 2-3 rows ar oblique, the outer rows, like those in the mandible, align irregularly or nearly horizontally. Near the symphysis this band narrows to about 3 rows.

Gill rakers:-On the first arch the gill rakers are slender and relatively widely spaced, with the spare between them usually twice the greatest width, near the middle, of the larger rakers. The longest raker, on the ceratobranchial near the angle, equals the diameter of the eye. The gill rakers on the lower fourth ard usually number 8 or 9 .

Scales:-On the flat breast the large seales are relatively thick and plate-like. Moulded to shape, 4 well. ossified, coarse-ridged scales shield the subopercle, interopercle, and opercle.

Fins:--The pectoral fin reaches to within 3 scales of the end of the dorsal. Though slightly before or directly under the pectoral insertion in young, the pelvics insert slightly behind it in adults.

Internal characters: The haemal arch of the first caudal vertebra bears poorly developed spurs. In radiographs their shadow appears as a single, sharp knob, which is situated anteriorly near the base of the slender, retrorse haemal spine.

Color:--Each seale pocket is lightest anteriorly. The pharynx is dark brown to blackish, usually with a superficial metallic sheen.

Melamphacs spinifer, new species.
Fig. 26.
Melamphaes lugubris (misidentifications).-- Garman, 1899: 63-64, 412, 415, 583 (in part [sec also M. laeviceps]; descriptions; comparisons; distribution; $10^{\circ} 14^{\prime} \mathrm{N} 96^{\circ} 28^{\prime}$ W). Fowler, 1938 : 252 (Galápagos Ids.); 1944: 495 (in part |see also M. laeviceps]; refers to Garman's specimens, off Panama Bay).

Melamphaes macrocephalus (in part).—Parr, 1931: 41-43 (original description, [6 specimens from paratype series are M. spinifer]).

## Distribution.

M. spinifer is restricted to the eastern tropical Pacific, including areas ofl Baja California to $27^{\circ} \mathrm{N}$ and aif Peru to $15^{\circ} \mathrm{S}$. At its westward limit, about $130^{\circ} \mathrm{W}$, it occurs between $20^{\circ} \mathrm{N}$ and $10^{\circ} \mathrm{S}$ (Fig. 54). Vertically, the upper limit of adults and halfgrown is about $400-500$ meters; the young occur more shallowly, to about 100.200 meters.

## Counts and measurcments.

Counts:-The following counts are usually based on samples of 46-50: dorsal III, 14-16 (15.2); anal $1.7-9(8.0)$; caudal $4+10-9+3-5(4.0+10.0-9.0+4.0)$; pectoral $14-15(15.0)$; pelvic $\mathrm{I}, 7$; scale rows (1n-22) $31-33$ (32.0); scales in diagonal series 8; vertebrae $26-29$ (27.1); gill rakers on first arch $3--5+$ $13-14(4.0+13.6)$; gill rakers on lower limb of fourth arch $8-10$ (8.8); mandibular pores ( $\mathrm{n}=25$ ) 6--7 (6.9).

Proportions:- C'sually based on samples of 22-26, the following are proportions for which the data -uggest little or no allometric change: body depth 268-328 (299); postdorsal $566-619$ (586); head depth 276313 (294); head width 196-231 (214); prepelvic 389-44 (413); pelvic to anal ( $\mathrm{n}=48$ ) 290-367 (336); pectoral 313-365 (336); depth of caudal peduncle 93-116 (104); orbit to cheek angle 118-139 (131); snout length 90--113 (99).

The following are proportions for which the data suggest allometric change. If the values of the proportions of the halfgrown are similar to those of the adults, the two categories are bracketed together. Proportions are based on 12 adults (Ad) $52-72 \mathrm{~mm}$., $16-17$ halfgrown ( Hg ) $36-48 \mathrm{~mm}$., and $18-21$ young ( Yg ) $23-35 \mathrm{~mm}$.

|  | Iredorsal | Head length | Snoutpreopercle | Interorbital |
| :---: | :---: | :---: | :---: | :---: |
| Id |  | 374-420(398) | 267-284(274) | 119-131(127) |
| Hg | 435-473(456) | 396-426(412) | 270-..292(283) | 125-144(133) |
| ig. | 4.3--500(476) | 410-464(438) | 281-320(298) | 136-161(147) |
|  | Length of frontal fossa | Length of caudal ped. | l pper jaw | Eye |
| Ad | 155-169(163) |  |  | 54-633(38) |
| Hg | 163-177(170) | 22.0(207) | 181-206(194) | $53-67(61)$ |
| Ig. | 168-192(180) | 200-236(213) | 190-290(204) | 57-77(67) |

Proportions based on 8-12 adults, 4-6 halfgrown, and 5-8 young.

|  | Postorbital | Width of <br> frontal fossa | Irepectoral |
| :---: | :---: | :---: | :---: |


|  | Pelvie | Preanal | Anal-caudal | Suborbital |
| :---: | :---: | :---: | :---: | :---: |
| Ad |  | $70.4-766(735)$ |  | 37--43(40) |
| Hg | 234-275(251) | 697 741(722) | 272-306(290) | $43 \cdots 47(45)$ |
| Ig. | 246 294(270) | 692-741(714) | 283 328(309) | 49.61 (54) |

## Description.

Body and head form: The robust body narrows abruptly from the anus to a pedieclar caudal peduncle, which is barely twice as long as deep. From the dorsal origin to the frontal knob the profile descend almost straightly. Similarly, the ventral contour of the head ascends almost straightly from the pelvie symphysito the isthmus, where it abruptly bends up to the mandibular symphysis. The diameter of the eye measurn about $1.4-1.5$ times the suborbital width and about 0.6 times the snout length. From the premaxillary symphysis to the anterior end of the frontal knob equals the distance between the anterior nostrils.

Head ridges and epidermis:-The margins of the head ridges are not expanded as in M. eulepis. but as in all other species are narrow and sharp-edged. Twice as long as wide, the frontal fossa, which re sembles a goblet in cross-section, expands thrice before its barely constricted posterior end. The smooth frontal knob lacks the series of ridges characteristic of $M$. eulepis. Between the angles in the frontal margin the inter. orbital width equals the distance from the orbit to the preopercular edge. The strong spinelike ridges at the check angle diverge symmetrically. Frequently outlined with a thin, dark line, the epidermal embossed linco of the head stand out as light streaks on a dark background.

Sensory pores:-The pores in the group inside the cheek angle usually number 4 or $\overline{5}$; ouly 1 of 21 counts is 3 . In the group on the supratemporal canal directly above the preopercle the pores usually number $3 ; 5$ of 90 counts are 4 . The pore on the outer surface of the mandible near the symphysis is about half the size of its equivalent behind the symphysis.

Spines and operculum:-Vnlike the other species, the angle of the thick, well-ossified preoperclbears well-developed spines and ridges: prominent among these are a large falciform spine that projects forward from the anteroventral border; a sharp retrorse spine, which arises from a strong, keeled ridge, at the angle; and between them a smaller spine and ridge. Reticulate bone reinforces the spaces between the ridges, which are weaker below the angle. The presence of spines on the preoperele distinguishes young, halfgrown. and adults of spinifer from all others in the genus. The upper part of the interoperele supports raised arean of reticulate bone. A ridge ending in a weak spine at the margin traverses the posteroventral part of the interopercle; one or two similar ridges ending in spines sculpture the last branchiostegal.

Jaws and teeth:-The maxillary slightly owerreaches a vertical from the posterior edge of the bony orbit


Fig. 26. Melamphaes spinifer, n. sp. Holotype (standard length $\mathbf{7 1 . 5} \mathbf{m m}$.).

The tooth formula is for adults $6-8 / 4-\overline{5}$, for halfgrown $5-7 / 2-4$, and for young $3-5 / 2-3$. In larger speimens the pharyngeal teeth number $10-15$ on the second pharyngobranchial, $25-40$ on the third, $12-20$ nin the fourth, and $14-22$ on the third epibranchial.

Gill rakers:-The gill rakers usually number $4+13-14$. About half the adjacent width of the ceratobranchial, each of the larger rakers on the lower fourth arch is a short nubbin, which is capped by $2-4$ - pines.

Scales:-Mostly intact, the scale rows usually number 32. A typical body scale from under the pectoral has a wedge-shaped posterior field of widely spaced circuli, which delimil grooves 4 or 5 times the width of the narrowest grooves on the anterior field. Numerous, coarse cross-striae breach the grooves on the posterior Lield: these striae render this area considerably rougher than the anterior field. Four to six scallops, between which end indistinct "radii" (formed of sharp bends in the circuli), render the anterior margin of the seale irregular; the posterior margin frequently is eroded. The focus is slightly nearest the anterior margin of the rate. A single file of $14-15$ slender scales sheathes the base of the soft dorsal fin.

Fins:-The modal dorsal count is III, 15; 10 of 49 counts are III, 16, 3 are III, 14. The anal rays usually number I, $8: 4$ of 49 counts are 1,7 or I, 9 . Although in adults the anal originates directly under or slightly behind the last dorsal ray, it is farther forward in the young. Though anterior to the pectoral insertion in roung, the pelvics insert slightly behind it in adults.

Internal characters:-The modal vertebral count is $12+15$. Although only 1 of 46 precaudal counts i, 11 , the caudal counts range from 14 to 17 vertebrae. Anteriorly, the rete and gas gland of the well-developed gas-bladder occupy more than a third of the entire structure. Adipose tissuc caps the posterior tip of the surdy membranous bladder, which frequently appears parchment-like and silvery. Four or five times as long a dep, the slender stomach is dark in front, but lightens toward the end of the blind sac.

Color:--Microscopic punctulations and blotches mottle the epidermal covering of the scales, especially wh the venters of most young and halfgrown. The fin rays and interradial membranes are finely, but more inkensely punctulate. The coclomic peritoneum is uniformly dark brown to blackish. On well-preserved young and halfgrown punctulations on head, fins, and body are relatively conspicuous; the punctulated venter conrasted with the solidly pigmented dorsum countershades the young, although the black coelomic peritoneum is visible through the body wall.

Sex ratio and size al malurity.
Among the to specimens sexed there are 16 females and 15 males. Mature adutts range in standard length form 53 to $7 \underline{2} \mathrm{~mm}$.
tiengraphical variation.
In the characters examined the species over most of its range is not differentiated. Each of 5 young to halfgrown specimens from off the coast of Peru, however, have one or two more caudal vertebrae (16-17), , he more dorsal soft ray (16), and one more scale row (33) than usual.

## Histinctions.

M. spinifer is easily distinguished from all other species in the genus by its preopercular spines. Besides ining geographically well separated from spinifer, closely related M. eulepis has more scale rows (usually is -35) and its head ridges expanded with reticulate bone. Sympatric M. laeviceps attains much larger size at maturity ( $110-134 \mathrm{~mm}$.) ; it has a more forwardly inserted anal (under the third to fifth from last dorsal ray), a Ionger dorsal (usually $19-20$ elements), longer anal (usually 10 elements), and fewer precaudal iettebrae (11).

## Herivation of name.

The species name spinifer is the Latin word meaning spine or thorn bearer, in reference to the enlarged pines on the preopercle.

Specimens examined.- 58 from 30 collections.
Holotype: SIO $52-409$; adult male ( 71.5 mm .); castern equatorial Pacific, north of the Galápagos Ids., $1^{\circ} 01.5^{\prime} \mathrm{N}$ $91^{\circ} 45.7^{\prime} \mathfrak{W}$; capture $939-1109 \mathrm{~m}$., bottom 2288 m .: 10-foot Isaacs-Kidd midwater trawl; 11-12 August 1952; 1816 0017 hrs.; R Y"Horizon", R. L. Wisner and party.

Paratypes: Mexico, of southern Mexico and vicinity of Revillagigedo Ids.: BOC 2698, $16^{\circ} 14^{\prime}$ N $99^{\circ} 37^{\prime} \mathrm{W}, 144 \mathrm{w}$ f(38-42): BOC 2699, $14^{\circ} 31^{\prime} \mathrm{N} 96^{\circ} 14^{\prime} \mathrm{W}$, 1144 w ., $2\left(41-43\right.$ ); SIO $54-89,19^{\circ} 09^{\prime} \mathrm{N} 110^{\circ} 59^{\prime} \mathrm{W}, 1510(\mathrm{~d}), 1(46)$.

Gulf of Panama and vicinity: G $716,9^{\circ} 23^{\prime}$ N $89^{\circ} 32^{\circ} \mathrm{W}$, $3680(\mathrm{~d}), 5(5.5-63)$ : D $1206(1), 6^{\circ} 40^{\prime} \mathrm{N} 80^{\circ} 47^{\prime} \mathrm{W}, 4500 \mathrm{w} .(\mathrm{n}$, $3(42-62) ; 1) 1208(4), 6^{\circ} 48^{\prime}$ N $80^{\circ} 33^{\prime} \mathrm{W}, 3500 \mathrm{w}$ (d), $6(30-69)$; D $1208(13), 6^{\circ} 48^{\prime}$ ल $80^{\circ} 33^{\prime} \mathrm{W}, 3600 \mathrm{w} .(\mathrm{n}), 3(33-42) ;$
 $38^{\prime} \mathrm{W}$, 1000w.(11), $1(48)$; S $1055-244,4^{\circ} 04^{\prime} \times 78^{\circ} 43^{\prime} \mathrm{W}, 1336(11), 1(65)$.

Eastern tropical Pacific, west of $100^{\circ} \mathrm{W}$ : SIO $52-419,8^{\circ} 58^{\prime} \wedge 104^{\circ} 32^{\prime} \mathrm{W}$, $1916(\mathrm{dn}), 1(48)$; SIO $55-221,7^{\circ} 50^{\prime}$ 人 $1200^{\prime} 13^{\prime} \mathrm{W}, 2600(11), 1(61)$.

Additional material: Mexico, off Baja California and vicinity of Revillagigedo Ids.: S10 51-92, 26 $6^{\circ} 02^{\prime} \times$ $117^{\circ} 22^{\prime} \mathrm{W}, 458(\mathrm{n}), 1(54) ;$ SIO $54-88,20^{\circ} 16^{\prime} \mathrm{N} 111^{\circ} 32^{\prime} \mathrm{W}, 137(\mathrm{n}), 1(30)$; SIO $54-92,19^{\circ} 52^{\prime} \mathrm{N} 113^{\circ} 33^{\prime} \mathrm{W}, 183(11)$. $2(23-26)$; S $1059-248,20^{\circ} 04^{\prime}$ N $110^{\circ} 39^{\prime} \mathrm{W}$, $307(11), 1(27)$.

Gulf of Panama and vicinily: D $1205(2), 6^{\circ} 49^{\prime} \times 80^{\circ} 25^{\prime} \mathrm{W}, 1000 \mathrm{w}$ (a), $1(28)$; D $1208(5), 6^{\circ} 48^{\prime} \mathrm{N} 80^{\circ} 33^{\prime} \mathrm{W}, 3000 \mathrm{w}$.(d). 1(31): D $1208(6), 6^{\circ} 48^{\prime}$ N $80^{\circ} 33^{\prime} \mathrm{W}, 2500 \mathrm{w}$ (d), $1(30)$; D $3549(5), 7^{\circ} 16^{\prime} \mathrm{N} 78^{\circ} 30^{\prime} \mathrm{W}, 3000 \mathrm{w}$.(d), $1(23)$; SIO $52-3311$.

 LSNM 2875.5, $10^{\circ} 14^{\prime} \mathrm{N} 96^{\circ} 28^{\prime} \mathrm{W}, 2232(\mathrm{~d}), 1(36)$.

Off Perı and west: SIO $52-328$, $6^{\circ} 40^{\prime} \mathrm{S} 115^{\circ} 03^{\prime} \mathrm{W}, 1629(1)$, $1(27)$; S $1052 \cdots 372,14^{\circ} 01^{\prime} \mathrm{S} 81^{\circ} 48^{\prime} \mathrm{W}, 1135(\mathrm{~d})$, (30--52).

Melamphaes eulepis, new species. Fig. 27.

## Distribulion.

The 10 a vailable records indicate M. culepis to be widely distributed in the Atlantic south of $13^{\circ} \mathrm{N}$, around Africa, in the Indian Ocean, throughout Indonesia, and in the central equatorial Pacific (Fig. 54). Vertically: at night, off the west coast of Africa, the upper limit of adults and halfgrown is about $150-200$ meters.

## Counts and measurements.

Counts:-The following counts are based on samples of 13 : dorsal 1II, 14-16 (15.0); anal I, 8; caudal $4+10-9+3-4(4.0+10.0-9.0+3.8)$; pectoral $14-15(14.9)$; pelvic I, $7-8(7.1)$; scale rows $33-36(34 . i)$; scales in diagonal series 8; vertebrae $29-30$ ( 29.2 ) ; gill rakers on first arch $4+14-15$ ( $4+14.2$ ) ; gill rakers on the lower limb of fourth arch 8-9 (8.8); mandibular pores $4-7$ ( 6.4 ).

Proportions:-Based on samples of $12-13$, the following are roportions for which the data sugg. little or no allometric change: body depth $274-305$ (292) ; postdorsal $578-624$ (603); postorbital 240-26 (253); head depth $274-298$ (286); head width $204-224$ ( 212 ); interorbital $127-140$ (134); prepectoral $373-413$ (389) ; isthmus to pelvic $307-346$ (330); pelvic to anal 287-343 (313); pectoral 308-334 (317): pelvic 240-261 (252); preanal 655-702 (676); depth of caudal peduncle 103--112 (108); orbit to check angle $122-137$ (129); snout length $94-105$ (99).

The following are proportions for which the data suggest allometric change. If the values of the proportio: of the halfgrown are similar to the values of the adults, the two categories are bracketed together. Proportions are based on 9 adults (Ad) $36-46 \mathrm{~mm}$., 1 halfgrown ( Hg ) 31 mm ., and 3 young ( Yg ) $19-22 \mathrm{~mm}$.

|  | Predorsal | Head length | Snoutpreopercle | Length of frontal fossa |
| :---: | :---: | :---: | :---: | :---: |
|  | 422-448(438) | 370-397(380) | 258-271(264) | 152-168(162) |
| Yg | 453-457(456) | 387-417(401) | 266-282(275) | 164-175(171) |


|  | Width of frontal fossa | Prepectoral | Anal-caudal | Length of caudal ped. |
| :---: | :---: | :---: | :---: | :---: |
| Ad | 89-96(93) | 364-387(378) | 329-368(337) | 234--264(245) |
| Hg | 99 | 383 | 348 | 265 |
| ls. | 95-101(99) | 387-399(394) | 341-370(357) | 247-282(263) |


|  | Upper jaw | Suborbital | Eye |
| :---: | :---: | :---: | :---: |
| Ad |  |  | 50-56(53) |
| Hg | 174--187(182) | ${ }^{44-51(48)}$ | 55 |
| Yg. | 187-193(139) | 48-55(52) | 59-69(64) |

## Mescription.

Body and head form:-The robust body narrows abruptly from the anus to a tapered caudal peduncle, which is noticeably more than twice as long as deep. From the dorsal origin to the frontal knob the profile deseends almost straightly or in a weakly convex curve. The ventral contour of the head curves slightly outward from the pelvic symphysis to the isthmus, where it abruptly angles up to the mandibular symphysis. The diameter of the eye measures $0.83-1.0$ times the suborbital width and $0.53-0.56$ times the snout length. From the premaxillary symphysis to the anterior end of the frontal knob is about $0.75-0.80$ times the distance between the anterior nostrils.

Head ridges and epidermis:--The head ridges expand to reveal reticulate bone, at their wide, blunt margins. Their reduction or complete lack of epidermal cover exposes these reticulated margins, which are bes developed on the cheek, preopercle, circumorbital, posttemporal, parietal, and frontal bones. About f.if. 1.67 times as long as wide, the frontal fossa, which resembles a goblet in eross-section, expands thrice before its acutely constricted posterior end. Under the head epidermis, $4-6$ ridges extend on cither side of the irmal knob normal to the midline. Between the angles in the frontal margin the interorbital slightly exceeds the distanee from the orbit to the preopercular edge. The 2 ridges at the cheek angle are not spinclike, but enstitute a furcula of reticulate bone. The embossed lines sland out as dark streaks on a lighter background; moasionally a few extend past the cheek ridge into the preopercle.

Sonsory pores:--The pores in the group inside the cheek angle usually number 3 ; only 1 of 18 counts is 4 . In the group on the supratemporal canal directly above the preopercle the pores usually number 4 ;


Fig. 27. Melamphaes eutepis, n. sp. Holotype, traced and modified from photograph (standard length 46.3 mm.).

4 of 18 counts are 3. The pore on the outer surface of the mandible near the symphysis is equal to or slightly larger than its equivalent behind the symphysis.

Spines and operculum:-Except on the opercle, the head bears no obvious spines. The angle of the well-ossified preopercle is smooth, rounded, and only slightly emarginate. Nevertheless, a well-developed ridge at the angle extends by the margin as a slight protuberance. Areas of reticulate bone reinforce this ridge and the preopercular margin. The posteroventral borders of the interopercle and last branchiostegal are slighty produced, but bear no spines; a weak ridge traverses the angle of the interopercle only. Lacking raised areas of reticulate bone, the surfaces of both bones are smooth.

Jaws and tecth:-The maxillary overreaches by half the width of the pupil a vertical from the posterion edge of the bony orbit. The tooth formula is for adults $6-8 / 4-6$, for the halfgrown $5-6 / 4$, and for young 2-4/2-3. In larger specimens the pharyngeal teeth number $12-18$ on the second pharyngobranchial, 45-i.) on the third, $14-20$ on the fourth, and $25-35$ on the third epibranchial.

Gill rakers:--The gill rakers usually number $4+14$. About two-thirds the adjacent width of the cerat,branchial, each of the larger rakers on the lower fourth arch is a short nubbin, which is capped by $4-9$ spincs.

Scales:-Amost always intact, the scale rows usually number 34 or 35 . On a typical body scale from under the pectoral the circuli on the wedge-shaped posterior field, in contrast with M. spinifer, are usually worn down or eroded, so that the surface appears smooth; these inconspicuous circuli delimit grooves 3-4 timis the width of the narrowest grooves on the anterior field. Poorly developed, indistinct scallops, between which end weak bends in the circuli, render the anterior margin of the scale relatively even; though slightly eroded, the posterior margin is even. The focus is near the center of the scale. A single file of about 13 slender scales sheathes the base of the dorsal fin.

Fins:-The modal dorsal count is III, 15 ; 2 of 13 counts are III, 14 or III, 16. The anal originates under the last two dorsal rays.

Internal eharacters:- The modal vertebral count is $12+17$. Although the precaudal count is constant. 2 of 13 counts include 18 caudal vertebrac. The small gas-bladder is rudimentary. The stomach is eventy pigmented.

Color:-The integument is not generally mottled. The bases of the median and pectoral fins may la darker than the rest of the body, which, with the head and fins, is never puctulate. The coelomic peritonemm is mottled or uniformly light brown. Though faded, the young resemble the adults.

## Sex ratio and size at maturity.

Among the 13 specimens sexed there are 5 females and 4 males. Mature adults range in standard length from 38 to 46 mm .

## Distinctions.

The peculiar bony expansions of the head ridges and the intact squanation distinguish M. culepis from all other species in the genus. M. eulepis is distinguished from M. spinifer in its speefes account. SympatriiII. leprus has more gill rakers (5-6-15-16), fewer scale rows (usually 32) and fewer vertebrae (27).

## Derivation of name.

Derived from the Greek, the species name eulepis refers to the intact squamation and to the plate-lik: sculptured opercular scales.

Specimens examined.-13 specimens from 9 collections.
Holotype: D $4000(2)$ specimen number 1; adult female ( 46.3 mm .); equatorial South Atlantic, off Ghana, $0^{\circ} 31^{\prime}$ s $11^{\circ} 02^{\prime} \mathrm{W}$; capture, 600 meters wire, bottom $3760 \mathrm{~m} . ; 2$-meter conical stramin net ; 4 March $1930 ; 0230 \mathrm{hrs}$.; R/V "Dana".

Paratypes: Eastern tropical Atlantic: D $1180(1), 12^{\circ} 11^{\prime} \mathrm{N} 57^{\circ} 12^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 1(36)$; D $4000(2)$ spec. $2-3,0^{\circ} 31^{\prime}$ s $11^{\circ} 02^{\prime}$ W, $600 \mathrm{w} .(\mathrm{n}), 2(43-44)$; D $4001(2), 3^{\circ} 56^{\prime}$ N $12^{\circ} 33^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 1(46)$; D $4001(3), 3^{\circ} 56^{\prime}$ N $12^{\circ} 33^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{in})$. 1(41); D $4003(8), 8^{\circ} 26^{\circ} \mathrm{N}^{\circ} 15^{\circ} 11^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 3(22-38)$.

Western Indian Ocean: D 3922(1), $3^{\circ} 45^{\prime}$ S $56^{\circ} 33^{\prime}$ E., 1000 w .(11), 1(37); D 3966(1), $29^{\circ} 25^{\prime}$ S $32^{\circ} 00^{\prime}$ E, $300 \mathrm{w} .(\mathrm{n}), 1(19)$; (; $263,4^{\circ} 14^{\prime} \mathrm{S} 44^{\circ} 52^{\prime} \mathrm{E}, 4770(\mathrm{~d}), 1(41)$.

Indonesia: D $3678(7), 4^{\circ} 05^{\prime}$ S $128^{\circ} 16^{\prime} \mathrm{E}, 600 \mathrm{w} .(\mathrm{n}), 1(31)$.
Central equatorial Pacific: SIO 60-239, $4^{\circ} 5 \overline{3}^{\prime} \times 142^{\circ} 55^{\prime} \mathrm{W}$, $2500(\mathrm{nd})$, 1 (47).

## M. typhiops species group.

The large typhlops group, which contains M. Iongivelis, parvus, janae, indicus and typhlops, is loosely-knit, but because there are no good intragroup separations the group is retained as a unit.

Within this group a trend realizes the reduction of the gill rakers on the first areh to widely spaced splints and of the rakers on the fourth arch to spinose patches; M. typholps exhibits this extrene condition. The rakers in the other species are more typical of the genus but are relatively short and widely spaced. All species except parmus and janne, the adults of which are relatively small, lack spurs on the first haemal arch. In general, all have smooth or delicately sculptured scales, wide bands of teeth, except janac, 12 precaudal vertebrae, and, except parmus, acutely narrowed or pinched interorbitals. The frontal fossa usually resembles a funnel in cross-section. On the young of most species a broad pigment band connects the posterior base of the dorsal fin with the base of the anal. The pelvic fins of the larvac typically are decply pigmented.

Having restricted ranges, M. parmus inhabits the North Pacific Transitional Water off America, M. indicus the Indo-Pacific, and M. typhlops the North Atlantic. The M. longivelis complex, on the other hand, is widely distributed in tropical and subtropical waters from the North Atlantic to the Western Pacific. The peculiar disjunct distribution of M. janae--eastern tropical Pacific and Indian Ocean is unique for the genus.

The following deseriptive excerpts pertain to all $\overline{5}$ species.
Body and head form:- The ventral body contour remains straight or weakly convex from the pelvic ymphysis to the anus. From the dorsal origin to the frontal knob the profile deseends almost straightly.

Head ridges:-The margins of the head ridges are not expanded. The frontal knob is smooth.
Sensory pores:- The pore on the outer surfaces of the mandible near the symphysis is about half the vize of its equivalent behind the symphysis.

Spines, opereulum, and posttemporal:-- Execpt on the opercle, the head bears no obvious spines. The smooth preopercle is practically unsculptured. The thin dorsal edge of the posttemporal is spineless.

Teeth:-Although in the expanded part of the broad premaxillary tooth-band the inner 2 or 3 rows are usually oblique, the outer rows, like the 2 or 3 rows in the mandible, align irregularly or almost horizontally. Near the symphysis this band narrows to 2 or 3 rows.

Scales:- A typical body scale from under the pectoral is almost semicircular or trapezoidal. Moulded (1) shape, 4 especially pliant, fine-ridged scales shield the subopercle, interopercle, and opercle. Although the "percular seales on 2 specimens of M. typhlops are intact, only 7 other specimens in the species group retain ceen part of their opercular squamation; the number of opercular scales usually was inferred from the arrangement of the pockets.

Fins:--The pectoral fin reaches to within $1-3$ scales of the end of the dorsal.
Color:-The pharynx is dark brown to blackish, frequently with a superficial metallic sheen.

Melamphaes longivelis Parn complex.
Fig. 28.
This complex includes a small number of specimens belonging to the typhlops group, the counts of which (dorsal, gill rakers, vertebrae) average slightly higher than in M. typhlops. Widely distributed from the North Atlantic to the Pacific Ocean, longivelis exhibits considerable variability. Because the lack of material precludes analysis of this variability, it was impossible to decide whether or not this complex comprises more than one species or subspecies.

Melamphaes microps longivelis．－PARR，1933：16，17，Fig． 6 （original description as short diagnosis；trawled with 10,000 feet of wire out at $22^{\circ} 31^{\prime} \times 74^{\circ} 26^{\prime} \mathrm{W}$ ；tabular comparisons；holotype BOC 2833，one paratype）．Chapman，1939： 534（compared with M．cabcrnosus）．Fowlen，1944： 441 （Bahama Ids．）．

Melamphacs microps（in part）．－Norman，1930：345（［see also M．simus］；one specimen from equatorial east Atlantic）．

## Distribution．

Melamphaes longibelis occurs in both the North and South Atlantic，throughout Indonesia，and in the western Equatorial，North Central，and South Central waters of the Pacific（Fig．44）．The adults probably live below 500 meters；young have been taken in hauls up to 150 meters．

## Counts and measurements．

Because the longitelis complex may represent more than one species or subspecies，averages for the counts and proportions might be misleading；therefore，only the ranges are given．

Counts：－The following counts are usually based on samples of 18 － 20 ：dorsal III， $15-18$ ；anal I，8－9： caudal 4－10 $9-4$ ；pectoral 15 ；pelvic 1,7 ；scale rows（ $n=12$ ） 31 or $32-34$ or 35 ；scales in diagonal series （ $n=10$ ） 8 ：vertebrae $28-30$ ；gill rakers on first arch $4-5 \div 13-15$ ；gill rakers on lower limb or fourth arch 8 － 10 ；mandibular pores（ $n=10$ ） $4-8$ ．

Proportions：－Based on samples of $12-13$ ，the following are proportions for which the data suggest little or no allometric change：hody depth $254-280$ ；postdorsal $604-642$ ；postorbital $223-260$ ；head depth ソ 41 －ソプ；head width $177-218$ ；interorbital $106-126$ ；width of frontal fossa $68-83$ ；prepelvic $362-39!$ isthmus to pelvic $312-340$ ；pelvic to anal $298-354$ ；pectoral $304-347$ ；pelvic（ $n=7$ ）223－261；preanal $662-725$ ；anal to caudal $297-355$ ；length of caudal peduncle $199-267$ ；depth of caudal peduncle $97-113$ ； wrbit to cheek angle $10 \overline{-}-125$ ；snout length $84-102$ ；suborbital $36-49$ ．

The following are proportions for which the data suggest allometric change．Here，for convenience，the data are grouped for only two stages．Proportions are based on $7-8$ halfgrown and adults（AH） $42-106 \mathrm{~mm}$ ． and 5 young（lg）20－－2．5 mm．

|  | Predorsal | Head length | Snoul－ preopercle | Orbit－ cheek ridge |
| :---: | :---: | :---: | :---: | :---: |
| AH | $390-435$ | 349－392 | 234－264 | 63－76 |
| Yg． | 433－457 | 371－400 | 263－286 | 60－72 |
|  | Length of frontal fossa | Prepectoral | Upper jaw | Eye |
| AH | 141－154 | 357－－382 | 16－180 | 49－54 |
| Vg． | 156－168 | 362－－392 | 179－194 | 60－64 |

## Description．

Body and head form：－The streamlined body narrows abruptly from the anus to a tapered eaudal peduncle，which is $2.0-2.5$ times as long as deep．The body contour along the dorsal fin ascends straightly or in a weakly convex are．The point of greatest body depth subtends the pelvic insertion．The ventral contour of the head curves slightly outward from the pelvie symphysis to the isthmus，where it abruptly bends up to the mandibular symphysis．The diameter of the eve measures $1.1-1.4$ times the suborbital width and 0.47 0.62 times the smout length．From the premaxillary symphysis to the anterior end of the frontal knob equal or is slightly less than the distance between the anterior nostrils．

Head ridges and epidermis：－About twice as long as wide，the frontal fossa，which resembles a goblet in cross－section，expands thrice before its barely constricted posterior end．A sharp angle in the frontal margin over the iniddle of the pupil abruptly narrows the interorbital space；in halfgrown，including the holotype，and young，however，this angle is much more obtuse．Between these angles，the interorbital slightly
exceeds the distance from the orbit to the preopercular edge. The fragile spinelike ridges at the cheek angle dither diverge almost symmetrically or project obliquely downward. In most specimens the thin epidermis of the head is intact, except over the preopercle. Although frequently lighter along their midlines, the embossed lines blend with the background. Best-developed on the mandible and between the preoperele and frontal fossia, very minute priekles, either seattered or in rows, roughen spaces between embossed lines on the largest adult ( 106 mm .) ; smaller adults, halfgrown, and young generally lack these prickles.

Sensory pores:-The pores in the group inside the cheek angle number 3 or 4 . Those in the group under the posteroventral angle of the orbit number 2 . In the group on the supratemporal canal directly above the


1:ig. 28. Melamphaes longivelis Park. Adult specimen, D $4003(7)$ No. 1, traced and moditied from photograph (standard length 75.3 mm .).
preopercle, the pores usually number $4 ; 2$ of 18 counts are 3 . The pores on the preopercle above the angle usually number $2+3+3+2$; either of the middle groups may occasionally comprise only $\mathbf{2}$ pores, but the wuter groups may have 3 or even 4 . On the outer margin of the mandible, from just behind the angle to the smphysis, the pores usually number $1-3-2+1$, other counts are $1-1+1-1,1+2+1+1,1-2+2+1$, and $1-3-3+1$.

Spines, operculum, and posttemporal:-The angle of the thin, pliant preopercle is smooth, rounded, and only slightly emarginate. At the preopercular angle a slight eonvexity marks the end of a weak ridge that originates near the cheek angle. No reticulate bone reinforces the opercular series. A weak ridge conding in a small point at the margin traverses the posteroventral part of the interoperele and last branchiostegal.

Jaws and teeth.-The maxillary reaches or slightly overreaches a vertical from the posterior bony whit. Both orat and pharyngeal teeth are unusually numerous: the tooth formula is for halfgrown and adults $6-9 / 4-6$ (the larger adults have $9 / 5-6$ ) and for young $3-+2-3$. In the largest specimen ( 106 mm .) the inner oblique rows are irregular and poorly differentiated. In adults and larger halfgrown ( $56--106 \mathrm{~mm}$.) the pharyngeal teeth number $11-23$ on the second pharyngobranchial, $43-94$ on the third, $18-35$ on the fourth, and $17-29$ on the third epibranchial.

Gill rakers:-The gill rakers usually number $4-14-15 ; 6$ of 20 counts are $3-14$ or $\overline{5}-15$. On the first areh they are rather short, slender, and relatively widely spaced, with the spaces between them twice or more the greatest width, near the middle, of the larger rakers. The longest raker, on the ceratobranchial near the angle, measures $0.67-0.9$ times the diameter of the eye. The gill rakers on the lower fourth areh usually number 9 or 10 . Measuring half the adjacent width of the ceratobranchial, each of the larger is reduced to a low knob beset with 6-12 spines.

Scales:-Represented mostly by pockets, the seale rows usually number 32-34. The relatively narrow grooves between circuli increase in width gradually or somewhat abruptly from the anterior to the posterior field, where the widest are about thrice the width of the narrowest grooves on the anterior field. Inconspicuous
or absent on the anterior field, numerous poorly developed cross-striac breach the grooves on the posterior field. Six to eight seallops, between which end distinct "radii" (formed of sharp bends in the circuti), render the anterior margin of the scale irregular; though eroded, the posterior margin is even. The focus is near the center of the scale. A single file of about 14 slender scales sheathes the base of the soft dorsal fin. On the that breast the large scales are missing, but assumed to be very thin and caducous.

Fins:- The dorsal rats usually number 111, 16-18; 5 of 20 counts are 111, 15. The anal rays usually number 1, 8; only the holotype has I, 9. The anal originates slightly behind or directly under the last dorsal ray. Though slightly before the pectoral insertion in young, the pelvies insert direetly under or slightly behind it in adults.

Internal eharacters:- The vertebrae usually number $12+17$ or $12+16 ; 1$ of 18 counts is $12+18$. The precaudal count is musually variable: 2 of 18 counts are 11,3 are 13 , which is the highest count in all thr species. The haemal arch of the first caudal vertebra bears no spurs, but thickens at the base of the slender, retrorse haemal spine. The small gas-bladder appears degenerate.

Color:- Although due to abrasion some seale pockets may be lightest centrally, the integument is nol generally mottled. Protected from abrasion, the bases of the median and pectoral fins may be darker than the rest of the body, which, with the head and fins, is never punctulate. Brownish or blackish pigment lighty mottles the coelomic peritoneum.

Sex ratio and size al malurity.
Among the 11 specimens sexed, there are 2 males and 3 females. Mature adults range in standard length from 75 to 106 mm .

## Geographical variation.

The longivelis complex is quite variable in several characters, important among which is the dorsal ray count. Whereas the dorsal rays of the North Atlantic specimens usually number 111, 17-18, those of the IndoPacific and Pacific specimens usually number III, 16; only two of the latter specimens have III, 18 or III, 15 . The pores in the group inside the cheek angle usually number 4 in the Atlantic specimens, but only 3 in the Pacific specimens. Other characters vary considerably though less systematically. The number of precaudai vertebrac number from 11 to 13 . The North Atlantic specimens apparently average more gill rakers than do those from the South Atlantic and Pacific. Several proportions, among which are head length, preanal length. length of caudal peduncle, and suborbital width, exhibit unusual variation.

One specimen (D $3979(2)$ ) from the South Atlantic off South Africa was especially peculiar in that, while it has the vertebral count, gill raker count, spurless first haemal arch, and positioning of the anal fin typical of the longivelis complex, the scales, like those of janae and indicus, and gill rakers closely resemble those of M. polylepis. Furthermore, it superficially resembles M. parvus of the North Pacific. However, this specimen is provisionally identified with M. longivelis.

## Distinctions.

M. longivelis is distinguished from M. parous in its species account; distinctions from M. microps are listed under "Remarks". Closely related and sympatric M. typhlops has fewer gill rakers ( $2-3+11-12$ ), the gill rakers on the fourth arch reduced to low convexities or patches studded with numerous spines, fewer vertebrar $(12+14$ or 15$)$, fewer dorsal rays (usually 111,15 ), and a smaller eye (usually less than 5 per cent of standari length). M. indicus, which is also closely related to and sympatric with longivelis, hats fewer vertebrae (usually 12--14 or 15 ), usually fewer gill rakers ( $2-4-12-13$ ), fewer scale rows ( $29-31$ ), and scales with smooth posterior fields without circuli. M. janae from the tropical Pacific and Indian oceans is smaller (maximum size about 42 mm .), has only 11 precaudal vertebrae, has a spur on the first haemal areh, has a larger head (usually longer than 40 per cent of standard length), has a snaller eye (less than 4.6 per cent of standard length), and has a longer predorsal (more than 45 per cent).

Remarks.
Pann (1931: 16) briefly diagnosed M. microps longivelis and tabulated its counts and proportions. He noted ". . . the specimens designated as subsp. longivelis as showing a rather distinctly shorter vadal peduncle $[19-20$ per cent of standard length, and also a tendeney to somewhat larger heads and eyes and a sighty higher dorsal fin count." He further observed that "the first of these characters seems particularly valuable and does not show any signs of intergradations..." lnasmuch ats Pank had only ex specinnens of this from from the North Athantic and only a few more since have beeome available, it is dif ficult to evaluate these characters listed as diagnostic by Panis. The length of the caudal peduncle, especially, is highly variahle and values of $19-26$ per cent of the standard length are recorded for North Atlantic specimens. Conversely, the eaudal pedumele length (22 per cent of standard length) of 3 specinens from the l'adifie are in aceord with those of the holotype and paratype ( 20 per cent). That this character might be an index of subspecific ur wen specific diflerentiation is a possibility that for confirmation awail further variational study. The head longths and eve diameters do average higher than in other members of the typhtops or microps groups, but the ranges generally overlap. Finally, the high dorsal count also exhibits eonsiderable variation and does not diagnose longivelis.

There is no justification for considering $M$. longivelis a subspecies in the microps eomplex as here delineated. With the ranges for the counts generally not overlapping, the number of gill rakers ( $5-7 \div 15-18$ ), pelvic mass ( 1,8 ), and the shape and size of the gill rakers on both the first and fourth arches in microps distinctly separate the microps from the longivelis complex.

Specimens examined.-22 from 19 collections (some specimens are provisionally determined and not included in the counts and measurements).
Holotype: BOC 2833; 41.6 mm : North Atlantic, Bahama Islands, $22^{\circ} 31^{\prime} \times \boldsymbol{N}^{2} 2 \mathrm{i}^{\prime} \mathrm{W}$ : capture, 10000 feet wire: i2-foot diameter conical ring net; 30 March 1927: R ${ }^{\prime}$ "Pawnee". Station 41.

Paratype: North Atlantic, Bahama Islands. BOC 2834, $24^{\circ} 11^{\prime}$ N $75^{\circ} 37^{\prime}$ W, 2440w., 1 (211).
Idditional material: North Atlantic and equatorial South Atlantic: BM (NH) 1930.1. 12.981, $2^{\circ} 50^{\prime} \mathrm{S}!26^{\prime} \mathrm{W}$, ㄴ. 4, 1(23); D $1160(4), 15^{\circ} 50^{\prime} \times 26^{\circ} 32^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 1(22) ; \mathrm{D} 1256(3), 17^{\circ} 43^{\prime} \mathrm{N} 64^{\circ} 56^{\prime} \mathrm{W}, 600 \mathrm{w} .(11), 1 \mathrm{PL}$ (15); D $1280(2)$, $\left.1743^{\prime} \mathrm{N} 64^{\circ} 56^{\prime} \mathrm{W}, 800 \mathrm{w} .(\mathrm{n}), 2 \mathrm{PL}(12) ; \mathrm{D}\right) 1320(3), 23^{\circ} 18^{\prime} \mathrm{N} 56^{\circ} 58^{\prime} \mathrm{W}, 600 \mathrm{w}(1), 1 \mathrm{PL}(11) ; \mathrm{D} 4003(7), 8^{\circ} 26^{\prime} \mathrm{N} 15^{\prime} 11^{\prime} \mathrm{W}$,


Indonesia: D $3677(1), 5^{c} 28^{\prime} \mathrm{S} 130^{\circ} 39^{\prime} \mathrm{E}, 5000 \mathrm{w} .(\mathrm{d}), 1(76)$.
Tropical North Pacifie: POFI 1808, $9^{\circ} \mathrm{N} 140^{\circ} \mathrm{W}, 1(56) ; 51057-88,28^{\circ} 46^{\prime} \mathrm{N} 1266^{\circ} 33^{\prime} \mathrm{W}, 637(11 d)$, 1683$)$.
Eastern South Pacific: Ob 436, $30^{\circ} 06^{\prime} \mathrm{S} 90^{\circ} 10^{\prime} \mathrm{W}, 2000,1(106)$.
 $313^{\prime} \times 14^{\circ} 12^{\prime} \mathrm{W}, 1000 \mathrm{w}$ (dn), $2(20-23)$.
 jonlow.(u), 1 PL (18); D 3979(2), $27^{\circ} 10^{\prime} \mathrm{S} 8^{\circ} 59^{\prime} \mathrm{E}, 600 \mathrm{w}$.(1), 1(42).

Indonesia: D $3689(8), 7^{\circ} 14^{\prime}$ N $111^{\circ} 49^{\prime} \mathrm{E}, 300 \mathrm{w}$.(n), 1 PL (15).

## Melamphaes parvus, new species.

Fig. 29.

## Distribution.

A transitional species, M. parmus is restricted mainly to the California Current ofl Cahifornia and Baja California, Mexico and to the boundary area between $35^{\circ} \mathrm{N}$ and $42^{\circ} \mathrm{N}$, where it ranges westward to about $145^{\circ} \mathrm{W}$; off Baja California it is limited by the westward boundary of the California Current all about $130^{\circ}$ W (Fig. 44). One doubtful record, possibly of an intergrade, is from $17^{\circ} 48^{\prime} \mathrm{N} 124^{\circ} 07^{\prime} \mathrm{W}$. Adults mostly oceur helow 200 meters.

## Counts and measurements.

Counts:-The following counts are usually based on samples of 36-39: dorsal 1[1, 13-15 (14.3); anal $1.7-9(8.0)$; caudal $4-5+10-9+4(4.0+10.0-9.0+4.0)$; pectoral $14-15(15.0)$; pelvie 1 , 7 ; scale rows

32-33 (32.5); scales in diagonal scries $(\mathrm{n}=13$ ) 8 ; vertebrac $27-29$ (28.0); gill rakers on first arch 4-5. $13-15(4.3+14.0)$, gill rakers on lower limb of fourth arch $7-9$ (8.1); mandibular pores ( $\mathrm{n}=30$ ) 5-9 (6.9).

Proportions:--Based on $15-16$ specimens, mostly adults, the following are proportions for which the data suggest litte or no allometric change or are insufficient to detect it: body depth ( $\mathrm{n}=33$ ) $250-276$ (262); predorsal 424-461 (44); postdorsal 571-608 (589); postorbital $223-255$ (239); snout to preopercle 238-257 (248); orbit to cheek ridge ( $n=31$ ) $53-68(63)$; head depth $242-26.5(255)$; length of frontal fossa $(n=30)$ 133-153 (144); width of frontal fossa $69-81$ (76); prepectoral $363-387$ (37.); prepelvic $376-417$ (398); pelvic to anal $264-330$ (300); pectoral 295-322 (311); pelvic 192--230 (215); preanal 650-721 (683); depth of caudal peduncle $90-109(100)$; upper jaw ( $n=31$ ) 161--182 (172) ; orbit to cheek angle ( $\mathrm{n}=30$ ) 101--114 (108); snout length 83-104 (93); suborbital 38-44 (42).

The following are proportions for which the data suggest allometric elange. If the values of the proportion of the halfgrown are similar to those of the adults, the two categories are bracketed together. Proportion are based on 21-23 adults (Ad) $40-48 \mathrm{~mm}$., $7-8$ halfgrown ( Hg ) $32-39.6 \mathrm{~mm}$., and 4 young (Yg) 18 24 mm .

|  | Head length | Length of caudal ped. | Eye |
| :---: | :---: | :---: | :---: |
| Ad |  | 227-272(249) | 49--54(51) |
| Hg | 348-386(366) | 246-265(257) | 51-55(52) |
| Yg. | 370-385)(378) | 270-302(280) | 55-58(57) |

Proportions based on 14 adults and halfgrown ( AH ) and 2 young.

|  | Head width | Interorbital | Isthmus to <br> pelvic | Anal to <br> caudal |
| :---: | :---: | :---: | :---: | :---: |
| $\mathrm{AH} \ldots \ldots \ldots \ldots \ldots \ldots$ | $181-209(191)$ | $108-124(117)$ | $343-362(351)$ | $297-352(322)$ |
| $\mathrm{Ig} \ldots \ldots \ldots \ldots \ldots \ldots$ | $173-174(174)$ | $99-101(100)$ | $329-339(334)$ | $356-365(361)$ |

## Description.

Body and head form:- The streamlined borly narrows gradually from the anus to a tapered caudal peduncle, which is about 2.5 times as long as deep. The body contour along the dorsal fin ascends almost straightly. The point of greatest body depth subtends or slightly succeeds the pelvic insertion. The ventral contour of the head curves slightly outward from the pelvic symphysis to the isthmus, where it bends up t" the mandibular symphysis. The diameter of the eye slightly exceeds the suborbital width and measures 0.5 ..


Fig. 29. Melamphaes parvus, n. sp. Holotype (standard length 45.6 mm .).
11.6 times the snout length. From the premaxillary symphysis to the anterior end of the frontal knob is less than the distance between the anterior nostrils by the width of a nostril.

Head ridges and epidermis:-About 1.75 times as long as wide, the frontal fossa, which resembles a funnel in cross-section, expands twice before its acutely constricted posterior end. Behind the frontal knob, a relatively large diamond-shaped area, extending from the back of the frontal knob almost to the angle of the expanded part of the frontal fossa, is almost unpigmented. A very obtuse angle in the frontal margin over the front of the pupil gradually narrows the interorbital space. Between these angles the interorlital slightly weceds the distance from the orbit to the preopercular edge. The fragile spinelike ridges at the cheek angle diverge symmetrically. In most specimens the fragile head epidermis is collapsed and partly missing, especially wer the preopercle. The embossed lines stand out as light streaks on a dark background. Although slightly wrinkled, the spaces between them are generally smooth and without prickles.

Sensory pores:-The pores in the group inside the cheek angle usually number 3 or $4 ; 7$ of 17 counts ar.' 4 . Those in the group under the posteroventral angle of the orbit usually number $2 ; 2$ of 25 counts are 1 . In the group on the supratemporal canal directly above the preopercle, the pores usually number $4 ; 5$ of 23 counts are 3,5 , or 6 . The pores on the preopercle above the angle usually number $2-3+3+3+2-3$; occasionally there are only 1 or 2 pores in either of the 2 middle groups. On the outer margin of the mandible, from just behind the angle to the symphysis, the pores usually number $1+3-2+1 ; 8$ of 30 counts are $1+2+2+1$, 1 is $2+3+3+1$.

Spines, operculum, and posttemporal:-The angle of the thin, pliant preopercle is smooth, rounded, and only slightly emarginate. At this angle a slight projection marks the end of a weak ridge that originates near the cheek angle. No reticulatc bone reinforces the opercular series. A very weak ridge ending in a small point at the margin traverses the posteroventral part of the intcropercle; the posteroventral margin "f the last branchiostegal, however, is evenly rounded or, more rarely, slightly produced.

Jaws and tecth:-The maxillary reaches or slightly overreaches a vertical from the posterior edge of the bony orbit. The tooth formula is for adults $4-7 / 3-5$, for halfgrown $4-6 / 3-4$, and for young $1-3 / 1-2$. In adults the pharyngeal teeth number $11-23$ on the second pharyngobranchial, $28-51$ on the third, $7-14$ (1n the fourth, and 17-29 on the third epibranchial.

Gill rakers:--The modal gill-raker count is $4+14 ; 4+15$, however, is common. On the first arch they are moderately long and slender, with the spaces between them about 1.5 times the greatest width, near the middle, of the larger rakers. The longest raker, at the angle, measures about 1.2 times the diameter of the eye. The rakers on the lower fourth arch usually number 8 or 9 . Each of the larger is a short, but well-formed tump, the length of which equals the adjacent width of the ceratobranchial; the inner edge bears $5-8$ spines.
scales:-Represented almost entirely by pockets, the scale rows number 32 or 33 . On a typical body scale the narrow grooves between circuli increase in width gradually from the anterior to the posterior field, where the widest are about twice the width of the narrowest grooves on the anterior field. Inconspicuous or absent (1) the anterior field, numerous cross-striae breach the grooves on the posterior field. Four to six scallops, hetween which end distinct "radii" (formed of sharp bends in the circuli), render the anterior margin of the scale irregular; the posterior margin is frequently eroded. The focus is nearest the posterior margin. I single file of about $14-15$ slender seales sheathes the base of the soft dorsal fin. On the flat, relatively narrow breast the seales are missing, but assumed to be very thin and caducous.

Fins:-The dorsal rays usually number III, $14-15 ; 3$ of 39 counts are III, 13. The anal rays usually number $\mathrm{I}, 8$; 2 of 39 counts are $\mathrm{I}, 7$ or 1,9 . The anal originates slightly behind or directly under the last dorsal ray. The pectoral rays almost always number 15 ; only 1 of 38 counts is 14 . Though directly under the pectoral insertion in young, the pelvics lnsert well behind it in adults.

Internal characters: The modal vertebral count is $12+16$. The precaudal count is unusually variable: 12 of 38 counts are $11+16$ or $11+17$. The haemal arch of the first caudal vertebra bears well-developed, albeit short, spurs in most specimens, rudiments or no spurs in others. Only about 0.33 times the length of the arch, their shadow appears in radiographs as a single short, downward-projecting knob or spine, which is situated anteriorly near the base of the slender, retrorse haemal spine. The small gas-bladder appears
degencrate: the anterior rete and gas gland precede a very small membranous sac, which is completely in vested with fat. About 3 times as long as deep, the thick stomach is dark in front, but lightens toward the end of the blind sac.

Color:- The fin rays of most, but not all, young, halfgrown, and smaller adults are punctulate uniserially, some more strongly than others; in a few of the better-preserved specimens the interradial membranes are also finely punctulate. The head (mainly in front of the preoperele) and area around the base of the pectoral tin are usually punctulate or motlled. In the larger adults ( $45-48 \mathrm{~mm}$.), including the holotype, the punctul. ations on the head, lins, and body disappear. Brownish black pigment lighty mottles the coelomic peritoneum.

Sex ratio and size at maturily.
Among the 39 sperimens sexed there are 17 males and 17 females. Mature adults range in standard length from 40 to 47 mm . Oddly, very few young were taken.

## Geographical variation.

In the characters examined, M. pervens is little differentiated over most of its range, although the specimens from off Baja California may have a few more teeth in the jaws and their haemal spurs better developed. One specimen, however, taken at $17^{\circ}+8^{\prime} \times 124^{\circ} 07^{\prime} \mathrm{W}$, beyond the normal range of the species, was strikingly different ant would have been identified with the tropical species $M$. janae were it not for its high coments if $12 \div 16$ rettebrae and 33 scale rows.

## Distinctions.

M. parbus is distinguished from sympatric M. Lugubris in its species account. The tropical species M. janar, which at the northeastern part of its range is almost contiguous with parvus, has fewer vertebrae $(11+14-15)$. fewer seale rows (usually 30 or 31 ), fewer gill rakers (usually $4+12-13$ ), a larger head (usually more than 40 per cent of standard length), and more dorsal rays (almost always 15 ). Some of the specimens in the M. longivelis complex from the South Atlantic closely resemble parvus. They attain, however, a greater size than parvus and lack the spur on the first haemal arch. Furthermore, their predorsal length is shorter (usualls less than 42 per cent of standard length) and the rakers on the fourth gill arch are not well-formed stumps as in perrens, but are low knohs studded with spines. They usually hase more dorsal rays (III, 16-19).

## Derivation of name.

Derived from the Latin, the species name parvos ("small") refers to the relatively small size of adults an compared with those of its sympatries.

Specimens examined.--40 from 27 collections.
Holutype: SIO 57-216; ripe female (45.6mm.) ; Mexico, southeast of Guadalupe Is., $28^{\circ} 37^{\prime}$ N $118^{\circ} 13^{\prime}$ W; capture 0 - 860 meters, bottom more than 1830 meters: 6-foot Isaacs-Kidd midwater trawi; 17 December 1957; 0005-05.t1 hours; K V "'Stranger", Cinhl L. HebBs and party.



Transitional water off California and westward to $140^{\circ} \mathrm{W}$ at $41^{\circ} \mathrm{N}$ : SIO $51-354,40^{\circ} 26^{\prime} \mathrm{N} 137^{\circ} 26^{\prime} \mathrm{W}, 650(111$. $2(38-41)$ : SIO $51-377,33^{\circ} 01^{\prime}$ N $127^{\circ} 30^{\prime} \mathrm{W}, 3920(\mathrm{~d}), 1(40)$; SIO $53-305,37^{\circ} 03^{\prime} \mathrm{N} 140^{\circ} 04^{\prime} \mathrm{W}, 1720(\mathrm{~d})$, $1(47)$; ('W $14 \overline{5} 19,38^{4} 46^{\prime}$ N $138^{\circ} 09^{\prime} \mathrm{W}, 225(n), 1(44)$; [W $14521,38^{\circ} 51^{\prime}$ N $137^{\circ} 51^{\prime} \mathrm{W}, 120(\mathrm{n}), 1(42)$; しW $14523,38^{\circ} 53^{\prime} \times 137^{\circ} 45^{\prime}$ W. $200(\mathrm{n})$. $1(43)$; LW $14524,38^{\circ} 56^{\prime}$ N $137^{\circ} 37^{\prime} \mathrm{W}, 225(\mathrm{n}), 2(41)$; UW $14525,39^{\circ} 36^{\prime}$ N $135^{\circ} 29^{\prime} \mathrm{W}, 225(\mathrm{n})$, 1 (45); UW 14532.
 $225(\mathrm{n}), 3(37-41)$ : VW $14537,33^{\circ} 27^{\prime}$ N $126^{\circ} 41^{\prime}$ W, $400(11), 2(42-45)$; UW $14538,32^{\circ} 15^{\prime} \times 128^{\circ} 33^{\prime}$ W, 225(n), $1(441$; [W $14541,36^{\circ} 27^{\prime} N 130^{\circ} 45^{\prime} W$, $400(\mathrm{n}), 3(40-45)$; UW $14543,36^{\circ} 44^{\prime}$ N $130^{\circ} 51^{\prime} \mathrm{W}, 225(\mathrm{n}), 1(44)$; CW $14545,36^{\circ} 48^{\prime}$ 人
 fol(11), 1(43).

Additional material: Mexico, of Guadalupe Island and vicinity: SIO 51-84, $25^{c} 28^{\prime} N 115^{\circ} 29^{\prime} \mathrm{W}, 915(3$. 1(23): SIO $5\left(6-76,28^{\circ} 51^{\prime} \mathrm{N} 118^{\circ} 11^{\prime} \mathrm{W}, 1280(\mathrm{n}), 1(20)\right.$; SIO $56-83,28^{\circ} 47^{\prime} \mathrm{N}^{\prime} 118^{\circ} 11^{\prime} \mathrm{W}, 1150(\mathrm{n}), 1(41)$.

Transitional water off California: SIO $50-269,32^{\circ} 51^{\prime} \mathrm{N} 117^{\circ} 28^{\prime} \mathrm{W}, 750(\mathrm{~d}), 1(23)$; UW $14530,33^{\circ} 46^{\prime} \mathrm{N} 125^{\circ} 12^{\prime} \mathrm{W}$, $200(\mathrm{n}), 1(33)$.

Doubtful identification: Mexico, southwest of Revillagigedo Islands: SIO $52-309,17^{\circ} 48^{\prime} \mathrm{N} 124^{\circ} 07^{\prime} \mathrm{W}, 1180(\mathrm{~d})$, 1(38).

## Melamphaes janae, new species.

Fig. 30.
Melamphaes typhlops (misidentification).-Morrow, 1957: 59 (trawled off Peru in 136 fathoms; notes).

## 1)isisibution.

M. janae has a curious disjunct distribution: it inhabits the eastern and central equatorial Pacific and the Indian Ocean but apparently is excluded from intervening Indonesia and the western Pacific (Fig. 47). Specimens were taken in the eastern Pacific between latitudes $15^{\circ} \mathrm{N}$ and $15^{\circ} \mathrm{S}$, in the central equatorial Indian Ocean between $10^{\circ} \mathrm{N}$ and $10^{\circ} \mathrm{S}$. Whereas the adults probably occur below $300-400$ meters, the young have been taken in 150 meters.

## Counts and measurements.

Counts:-The following counts are usually based on samples of 55-66. For the character "gill rakers on the first arch," which is analyzed by locality under "Variation", the mean is not given. Dorsal III, 14-16 (14.9); anal I, $7-8$ (8.0); caudal $4-5+10-9+4-5$ ( $4.0+10.0-9.0+4.0$ ); pectoral $14-16$ ( 15.0 ); pelvic ( $1=45$ ) $1,7-8(7.0)$; scale rows $29-31$ (30.5); scales in diagonal series ( $n=26$ ) 8; vertebrae 25-27 (25.9); sill rakers on first arch $4-5+13-15$; gill rakers on lower limb of fourth arch $7-10$ (8.1); mandibular pores ( $\mathrm{n}=25$ ) $5--7$ (6.2).

Proportions:--Usually based on samples of $25-30$, the following are proportions for which the data suggest little or no allometric change. The proportions of specimens from the Indian Ocean are grouped with those of specimens from the eastern Pacific. Body depth ( $\mathrm{n}=46$ ) 267-302 (282); postdorsal 571-608 (.587); orbit to cheek ridge 72-81 (76); head depth 253-293 (273); head width 190-217 (203); prepectoral $3 ; 1-420$ (400); prepelvic 387-420 (407); isthmus to pelvic 333-374 (349); pelvic to anal 310-378 (334); pectoral 306-332 (321); pelvic ( $n=10$ ) 220-252 (237); preanal 668-735 (697); depth of caudal peduncle 196-116 (105); orbit to cheek angle ( $\mathrm{n}=49$ ) 108-137 (124); snout length 88-109 (96).

The following are proportions for which the data suggest allometric change. If the values of the proportions of the halfgrown are similar to those of the adults, the two categories are bracketed together. Proportions are based on 10 adults (Ad) $36-42 \mathrm{~mm}$., $16-22$ halfgrown ( Hg ) $16-22 \mathrm{~mm}$. ( ${ }^{*}, \mathrm{n}=6$ ), and $15-24$ young (Yg) $13-26 \mathrm{~mm}$. (*) $^{*} \mathrm{n}=10-11$ ).

|  | Predorsal |
| :---: | :---: |
| Ad |  |
| Hg | *443-470(454) |
| Ig. | 455-495(472) |


|  | Interorbital |
| :---: | :---: |
| Ad |  |
| $\mathrm{Hg}_{\mathrm{g}}$ | *112-129(121) |
| I's. | *119-136(128) |

Length of caudal ped.
Length of
caudal ped.

| $\mathrm{Ad} \ldots \ldots \ldots \ldots$ | $\ldots \ldots$ | $210--238(225)$ |
| :--- | :--- | :--- |
| $\mathrm{Hg} \ldots \ldots \ldots$ | $213-242(232)$ |  |
| $\mathrm{Yg} \ldots \ldots \ldots \ldots$ |  |  |

Yg.
233-270(245)

Head length
386-419(400)
*250-284(270)
246-299(271)

> Width of frontal fossa

77-86(81)
*83-88(85)
*80--97(89)

Snout to preopercle
*257-269(262)
270-303(285)
Anal to caudal

287-326(310)
*309-325(318)
*318--355(334)


Fig. 30. Melamphaes janae, n. sp. Holotype, traced and modified from photograph (standard length 40.6 mm .).

## Description.

Body and head form:-The almost fusiform body narrows abruptly from the anus to a rectangular caudal peduncle, which is $2.1-2.33$ times as long as deep. The steep body contour along the dorsal fin ascends in a weakly convex are. Although behind the dorsal origin the dorsal contour is somewhat steeper than the ventral, the body frequently appears subsymmetrical in side view. The point of greatest body depth subtends or slightly succeeds the pelvic insertion. The relatively steep dorsal profile renders the silhouette of the head and body obtusely angular, with the apex at the dorsal origin. The ventral contour of the head angles slighty (with the apex below the preopercle) from the pelvic symphysis to the isthmus, where it abruptly angles up to the mandibular symphysis. The diameter of the small eye is noticeably less than the suborbital width and measures slightly more than half the snout length. From the premaxillary symphysis to the anterior end uf the frontal knob is less than the distance between the anterior nostrils by the width of a nostril.

Head ridges and epidermis:-About 1.75 times as long as wide, the frontal fossa, which resembles a funnel in cross-section, expands only twice before its wide, barely constricted posterior end. The pigmentless area behind the frontal knob is smaller than in M. parvus and extends only part way to the angle of the expanded part of the frontal fossa. A moderately sharp angle in the frontal margin over the front of the lens abruptly narrows the interorbital space. Between these angles, the interorbital is equal to or slightly leas than the distance from the orbit to the preopercular edge. The delicate spinelike ridges at the cheek angle are considerably reduced; in better-preserved specimens, however, they slightly diverge, but the upper ridge slants steeply downward, almost parallel with the lower. In most specimens the fragile head epidermis is collapsed and partly missing, especially over the preopercle and cheek. The indistinct embossed lines are poorly developed. Because these lines blend with the color and texture of the epidermis, they can be seen best when the head is tilted and light is reflected off their raised surfaces. The embossed lines are easily located by following the parallel white subcutaneous nerves that subtend them. The spaces between the lines are smooth and generally without prickles.

Sensory pores:-Because the delicate head epidermis is usually damaged and collapsed, the pores are difficult to count. The pores in the group inside the cheek angle usually number $3 ; 4$ of 15 counts are 2 . Those in the group under the posteroventral angle of the orbit number 2 . In the group on the supratemporal canal directly above the preopercle the pores usually number 4 ; only 1 of 13 counts is 3 . In 2 incomplete counts the pores on the preopercle above the angle number $2 ?+2+2+?$. On the outer margin of the mandible, from just behind the angle to the symphysis, the pores usually number $1+2+2+1$ or $1+3+2+1$.

Operculum:-The angle of the very thin, especially pliant preopercle is smooth, rounded, and only slightly emarginate. At the preopercular angle a small projection marks the end of a weak ridge that originates near the cheek angle. No reticulate bone reinforces the opercular series. A very weak ridge ending in a small
projection at the margin traverses the posteroventral part of the interopercle; the last branchiostegal, however, is evenly rounded or, more rarely, very slightly produced.

Jaws and teeth:--The maxillary overreaches by the lens diameter a vertical from the posterior edge of the bony orbit. The tooth formula is for adults $6-7 / 4-5$, for halfgrown $4-6 / 3-4$, and for young $1-4 / 1-3$; two mature females, $28-29 \mathrm{~mm}$., from the Indian Ocean have $6-7 / 4-5$. In adults and larger halfgrown, the pharyngeal teeth number 13-22 on the second pharyngobranchial, 45-67 on the third, 8-18 on the fourth, and $20-40$ on the third epibranchial.

Gill rakers:--The gill rakers usually number $4+13$ or $4+14 ; 5$ of 67 counts are $4+12$, only 1 is $5+14$. On the first arch the rakers are rather short, slender, and relatively widely spaced, with the spaces between them 2.0-2.2 times the greatest width, near the middle, of the larger rakers. The longest raker, on the ceratobranchial near the angle is slightly longer than the suborbital width. The rakers on the lower fourth arch usually number 7-9. Measuring half the adjacent width of the ceratobranchial, each of the larger is reduced to a low knob beset with $5-9$ spines.

Scales:-Represented entirely by pockets, the scale rows number 30 or 31. On a typical body scale from under the pectoral no circuli or radii pattern the relatively large posterior field. However, microscopic striae, $0.20-0.25$ times the width of grooves between circuli on the anterior field, radiate from the focus to the posterior edge of the scale. At their widest the narrow grooves between circuli on the anterior and lateral fields measure about $.02-.03 \mathrm{~mm}$. Inconspicuous at the scalloped margin, numerous, well-developed crossstriae breach these grooves. Eight or nine scallops, between which end distinct "radii" (formed of sharp bends in the circuli), render the anterior margin of the scale irregular; the posterior margin is even. The focus is near the center of the scale. A single file of 12 or 13 slender scales sheathes the base of the soft dorsal fin. On the flat breast the large scales are missing, but assumed to be thin and caducous.

Fins:--The modal dorsal count is III, 15 ; 5 of 66 counts are III, 14,3 are III, 16. The anal rays almost always number I, 8 ; only 2 of 65 counts are I, 7 . The anal originates directly under or slightly behind the last dorsal ray. The pectoral rays almost always number 15 ; only 2 of $6 \pm$ counts are 14 or 16 . Though slightly before the pectoral insertion in young, the pelvics insert directly under or slightly behind it in adults.

Internal characters:-The modal vertebral count is $11+15 ; 6$ of 50 counts are $11+14 ; 2$ specimens from the Indian Occan have 12 precaudal vertebrac. The haemal arch of the first caudal vertebra bears short but well-developed spurs in some specimens, weakly developed or no spurs in others. Only about a third the length of the arch, their shadow appears in radiographs as a single short, downward-projecting knoh or spur which is situated anteriorly near the base of the slender, retrorse haemal spine. Anteriorly, the rete and gas gland of the well-developed gasbladder occupy about a third the entire structure. Adipose tissue caps the posterior tip of the membranous bladder, which is silvery near the vascular tissue, but further on becomes translucent white. About 3 times as long as deep, the thick stomach is dark in front, but lighter toward the end of the blind sac.

Color:-Mlicroscopic punctulations, appearing as though introduced by a fine air brush, cover the venters of most, but not all, young, halfgrown, and smaller adults; these punctulations are especially strong around the bases and adjoining areas of the pectoral, pelvic, and anal fins. As in M. parous, the fin rays are frequently punctulate uniserially, some more strongly than others. Usually, minute, black melanophores dot the head, including the operculum, and the area about the base of the pectoral fin. They are most widely spaced on the cheek, and supraorbital regions. In the larger adults ( $40-42 \mathrm{~mm}$.), including the holotype, the punculations on the head, fins, and body disappear. Some of the young, halfgrown, and smaller adults, moreover, exhibit more intense punctulation than others; the solid color of the dorsum countershades the punctulate venter. Although badly faded, a few of the specimens from the lndian Ocean are punctulate, at least on the fin rays and head. In color, the young, when in fairly good condition, resemble the adults, though they may be more intensely punctulate and countershaded.

## Sex ratio and size at maturity.

Among the 58 specimens sexed there are 17 males and 22 females. Whereas adults from the eastern tropical Pacific range in standard length from 34 to 42 mm ., two mature females from the Indian Ocean measure only 28 and 29 mm .

## Geographical variation.

The most striking difference between the Indian Ocean and the eastern Pacific populations of janae concerns, in the females at least, their size at onset of sexual maturity. Whether this difference is real or merely apparent due to the lack of material from the Indian Ocean and western Pacific is of course conjectural, but no eastern Pacific specimen shorter than 34 nm . is mature.

The specimens from the Indian Ocean, including one from the central equatorial Pacific, have significant! more gill rakers on the lower arch (Fig. 31). For the young the proportions of head length, length of head space, and width of frontal fossa differ slightly between the two populations, but in such a way as to suggest that this might merely be concomitant to the earlier onset of sexual maturity in individuals of the Indian Ocean population.


Fig. 31. Geographical variation in selected counts and proportions of Melamphaes janae between 2 areas, tropical Indian Ocean and the eastern tropical Pacific Ocean. For further information see Fig. 19.

## Distinctions.

M. janae is distinguished from M. longivelis and contiguous M. parvus in their species accounts. Closely related M. indicus has more precaudal vertebrae (12), usually has fewer gill rakers on the lower first arch (11 or 12 in over half the specimens), lacks spurs on the haemal arch of the first caudal vertebra, and, among other proportional differences, has a shorter head (35-38 per cent of standard length) and predorsal (41-44 per cent).

## Derivation of name.

M. janae is named in honor of my wife, Jan, who sorted the first specimens of this new species from collections made during the Scripps Institution of Oceanography Eastropic Expedition.

Specimens examined.--88 from 35 collections.
Holotype: SIO $55-244$; ripe female ( 40.6 mm .); Eastern tropical Pacific, off Colombia, $4^{\circ} 04^{\prime} \mathrm{N} 78^{\circ} 43^{\prime} \mathrm{W}$; capture 1335 meters, bottom 3810 meters; 10-foot Isaacs-Kidd midwater trawl; 14 November 1955; 0000-0526 hours; R/V "Horizon" (Scripps Institution of Oceanography Eastropic Expedition); Alfred W. Ebeling and party.

Paratypes: Eastern tropical Pacific, between $10^{\circ} \mathrm{N}$ and $10^{\circ} \mathrm{S}$ and east of $125^{\circ} \mathrm{W}$ : BOC $3745,4^{\circ} 35^{\prime} \mathrm{S} 82^{\circ} 52^{\prime} \mathrm{W}$, $250(\mathrm{n}), 1(33)$; D $1206(1), 6^{\circ} 40^{\prime} \mathrm{N} 80^{\circ} 47^{\prime} \mathrm{W}, 4500 \mathrm{w}$.(dn), 1(36); D $1206(9), 6^{\circ} 40^{\prime} \mathrm{N} 80^{\circ} 47^{\prime} \mathrm{W}, 500 \mathrm{w} .(\mathrm{n}), 1(26)$; D $3548(1)$, $7^{\circ} 06^{\prime} \mathrm{N} 79^{\circ} 55^{\prime} \mathrm{W}, 4000 \mathrm{w} .(\mathrm{d}), 3(26-41)$; D $3556(1), 2^{\circ} 52^{\prime} \mathrm{N} 87^{\circ} 38^{\prime} \mathrm{W}, 2500 \mathrm{w}$.(d), $1(29)$; D $3556(2) 2^{\circ} 52^{\prime} \mathrm{N} 87^{\circ} 38^{\prime} \mathrm{W}$, 2000 w .(d), $3\left(13-37\right.$ ); SIO $52-355,4^{\circ} 06^{\prime} \mathrm{N} 97^{\circ} 10^{\prime} \mathrm{W}, 1395(\mathrm{n}), 1(35)$; S $1055-221,7^{\circ} 50^{\prime} \mathrm{N} 120^{\circ} 13^{\prime} \mathrm{W}, 2630(\mathrm{n}), 1(40)$ : SIO $55-244$, data as for holotype, 21(16-41); SIO $55-246,5^{\circ} 00^{\prime} \mathrm{N} 78^{\circ} 09^{\prime} \mathrm{W}, 1435(\mathrm{n}), 1(31)$; SIO $55-249,4^{\circ} 03^{\prime}$ ㅅ $81^{\circ} 40^{\prime} \mathrm{W}, 390(\mathrm{~d}), 4(34-37)$.

Additional material: Eastern tropical Pacific, between $10^{\circ} \mathrm{N}$ and $10^{\circ} \mathrm{S}$ and east of $125^{\circ} \mathrm{W}$ : D 1205(3), $6^{\circ} 49^{\prime} \mathrm{N}^{\prime}$ $80^{\circ} 25^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 1 \mathrm{PL}(9)$; D $1206(5), 6^{\circ} 40^{\prime} \mathrm{N} 80^{\circ} 47^{\prime} \mathrm{W}, 2500 \mathrm{w} .(\mathrm{n}), 1 \mathrm{PL}(13)$; D $3548(3), 7^{\circ} 06^{\prime} \mathrm{N} 79^{\circ} 55^{\prime} \mathrm{W}, 2000 \mathrm{w} .(\mathrm{d})$, 1(13); D $3548(6), 7^{\circ} 06^{\prime}$ N $79^{\circ} 55^{\prime}$ W, $300 \mathrm{w} .(\mathrm{n}), 1(20)$; D $3549(4), 7^{\circ} 16^{\prime} \mathrm{N} 78^{\circ} 30^{\prime} \mathrm{W}, 4000 \mathrm{w} .(\mathrm{d}), 1(28) ;$ D $3549(6), 7^{\circ} 16^{\prime}$ ㅅ $78^{\circ} 30^{\prime} \mathrm{W}, 2000 \mathrm{w} .(\mathrm{d}), 1(15)$; D $3556(4), 2^{\circ} 52^{\prime} \mathrm{N} 87^{\circ} 38^{\prime} \mathrm{W}, 1000 \mathrm{w} .(\mathrm{n}), 6 \mathrm{PL}(6-11)$; D $3561(7), 4^{\circ} 20^{\prime} \mathrm{S} 116^{\circ} 46^{\prime} \mathrm{W}, 600 \mathrm{w} .(1)$ ), $1(21)$; POFI 1816, $7^{\circ} 06^{\prime} \mathrm{N} 108^{\circ} 36^{\prime} \mathrm{W}$, $322(\mathrm{n}), 3(19-29)$; SIO $52-391,8^{\circ} 16^{\prime} \mathrm{N} 84^{\circ} 58^{\prime} \mathrm{W}, 450(\mathrm{n}), 1(19)$.

Equatorial central Pacific: POFI 1806, $7^{\circ} 15^{\prime} \mathrm{N} 155^{\circ} 04^{\prime} \mathrm{W}, 1(25)$.
Indian Ocean (small form): G $314,15^{\circ} 54^{\prime} \mathrm{N} 90^{\circ} 17^{\prime} \mathrm{E}, 2580(\mathrm{n}), 1(29)$; D $3824(6), 0^{\circ} 08^{\prime} \mathrm{S} 97^{\circ} 15^{\prime} \mathrm{E}, 300 \mathrm{w}$ (n), $2(20-22)$ :

D $3906(3), 4^{\circ} 27^{\prime} \mathrm{N} 85^{\circ} 21^{\prime} \mathrm{E}, 400 \mathrm{w} .(\mathrm{n})$, $3(13-14)$; D 3907(1), $3^{\circ} 59^{\prime} \mathrm{N} 82^{\circ} 57^{\prime} \mathrm{E}, 1000 \mathrm{w} .(\mathrm{n}), 1(28) ; \mathrm{D} 3908(3), 4^{\circ} 28^{\prime} \mathrm{N}$
 D $3915(2), 3^{\circ} 14^{\prime} \mathrm{N} 75^{\circ} 21^{\prime} \mathrm{E}, 600 \mathrm{w} .(\mathrm{n}), 2(19-22)$; D $3915(3), 3^{\circ} 14^{\prime} \mathrm{N} 75^{\circ} 21^{\prime} \mathrm{E}, 300 \mathrm{w} .(\mathrm{n}), 7(6-15) ;$ D $3917(8), 1^{\circ} 45^{\prime} \mathrm{N}$ $71^{\circ} 05^{\prime} \mathrm{E}, 300 \mathrm{w} .(\mathrm{n}), 1 \mathrm{PL}(10)$; D $3920(7), 1^{\circ} 12^{\prime} \mathrm{S} 62^{\circ} 19^{\prime} \mathrm{E}, 600 \mathrm{w} .(\mathrm{n}), 1(22) ;$ D $3925(2), 7^{\circ} 13^{\prime} \mathrm{S} 52^{\circ} 22^{\prime} \mathrm{E}, 600 \mathrm{w} .(\mathrm{n}), 1(15)$; 1) $3947(1), 4^{\circ} 21^{\prime} \mathrm{S} 42^{\circ} 56^{\prime} \mathrm{E}, 400 \mathrm{w} .(\mathrm{n}), 7 \mathrm{PL}(6-9)$.

## Melamphaes indicus, new species.

Fig. 32.

## Distribution.

An Indo-Pacific species, M. indicus occurs in the tropical Indian Ocean, Indonesia northward to the Philippines, and the western North and South Pacific (Fig. 47). Whereas the adults probably occupy depths well below 500 meters, the young have been taken up to 200 meters.

## Counts and measurements.

Counts:-The following counts are usually based on samples of 14-15: dorsal III, 14-15 (14.9); anal I, 8; caudal $4+10-9+4$; pectoral 15 ; pelvic $\mathrm{I}, 7$; scale rows $29-31$ (30.5); scales in diagonal series ( $\mathrm{n}=12$ ) 8; vertebrae $26-27$ (26.5); gill rakers on first arch $3-4+11-13(3.7+12.3)$; gill rakers on lower limb of fourth arch 7-9 (7.9); mandibular pores ( $n=8$ ) 6-7 (6.5).

Proportions:-Based on samples of 6-7, the following are proportions for which the data suggest little or no allometric change or are insufficient to detect it: body depth 259--284 (272); postorbital ( $\mathrm{n}=14$ ) 220$266(240)$; orbit to cheek ridge $60-80(71)$; head depth $249-280$ (265); head width $190-217$ (199); prepelvic $381-402$ (392); isthmus to pelvic 324-347 (335); pelvic to anal 329-371 (348); pectoral 308-342 (324); pelvic 204-257 (238); preanal 701-751 (717); anal to caudal 296-325 (312); length of caudal peduncle $(\mathrm{n}=14) 216-238$ (230); depth of caudal peduncle 101-117 (111); snout length 88--99 (93).

The following are proportions for which the data suggest allometric change. If the values of the proportions of the halfgrown are similar to those of the adults, the two categories are bracketed together. Proportions are based on 2 adults (Ad) $48-62 \mathrm{~mm} ., 4$ halfgrown (Hg) $29-39 \mathrm{~mm}$., and 8 young (Yg) $16-21 \mathrm{~mm}$. (*, based on only 1 young).

|  | Predorsal | Postdorsal | Head length | Snout to preopercle |
| :---: | :---: | :---: | :---: | :---: |
|  |  | 607-616(612) | 353--383(368) | 240--257(249) |
| Hg | 413-449(430) | 591-620(606) | 368-384(375) | 249-262(256) |
| Yg. | 443--500(463) | *599 | 379-431(403) | 262-294(274) |
|  | Interorbital | Length of frontal fossa | Width of frontal fossa | Prepectoral |
|  | 117-128(120) | 136-155(148) | $77--79(78)$ | 361-385(374) |
| Yg. | *127 | *157 |  | 377-419(397) |
|  | Upper jaw | Orbit to cheek angle | Suborbital | Eye |
|  |  | 122-128(125) |  | 42-49(46) |
|  | 175-180(177) | 105-117(114) | 44-52(48) | 48-49(49) |
| Yg. | *188 | 101-116(111) | 44-59(53) | 48-69(59) |

## Description.

Body and head form:-The streamlined body narrows abruptly from the anus to a tapered caudal peduncle, which is barely twice as long as deep. The body contour along the dorsal fin ascends almost straightly. On the squarish torso the point of greatest body depth subtends the pelvic insertion. The ventral contour of

 (s. 1. 8.7 mm .).
the liead angles slightly outward (with the apex under the preopercle) from the pelvic symphysis to the isthmus. where it abruptly angles up to the mandibular symphysis. The diameter of the eye equals the suborbital width and measures about half the snout length. From the premaxillary symphysis to the anterior end of the frontal knob is about three-fourths the distance between the anterior nostrils.

Head ridges and epidermis:-About twice as long as wide, the frontal fossa, which resembles a goblet in cross-section, expands thrice before its wide, slightly constricted posterior end. A sharp angle in the frontal margin over the front of the pupil abruptly narrows the interorbital space; in halfgrown and young this angle is more obtuse. Between these angles, the interorbital measures slightly less than the distance from the orbit to the preopercular edge. The fragile spinelike ridges at the cheek angle diverge symmetrically: In most specimens the thin head epidermis is collapsed and partly missing, especially over the preopercle. Although frequently lighter on their midlines, the embossed lines stand out as dark streaks on a lighter back. ground. The spaces between them are smooth and generally without prickles.

Sensory pores:-The pores in the group inside the cheek angle usually number 3;1 of 6 counts is 2 . Those in the group under the posteroventral angle of the orbit number 2. In the group on the supratemporal canal directly above the preopercle, the pores number 3 or 4 . In 3 counts the pores on the preopercle abow the angle number $2+3+3+3$ or $2+3+2+3$. On the outer margin of the mandible, from just behind the angh to the symphyseal knob, the pores usually number $1+2+2+1$ or $1+3+2+1 ; 1$ count is $1+2+3+1$.

Spines, operculum, and posttemporal:-The angle of the thin, pliant preopercle is smooth, rounded. and only slightly emarginate. At the preopercular angle a small convexity or projection marks the end of a weak ridge that originates near the cheek angle. Except for slight developments along the cheek ridge and at
the base of the opercle, no reticulate bone reinforces the opercular series. Relatively strong in some specimens, a ridge ending in an acute point at the margin traverse the posteroventral part of the interopercle; the posteroventral margin of the last branchiostegal, however, is evenly rounded or strongly convex and bears no obvious ridge.

Jaws and teeth:- The maxillary overreaches by the lens diameter a vertical from the posterior bony urbit. The tooth formula is for adults $6-8 / 4-5$, for halfgrown $5-7 / 3-4$, and for young $2-4 / 1-3$. For the pharyngeal teeth, ranges for the 1 adult and 1 subadult (holotype) will be given, followed, in parentheses, by ranges for 2 halfgrown and 1 young; they number $14-17(11-16)$ on the second pharyngobranchial, $35-64(25-37)$ on the third; $10-13(8-12)$ on the fourth, and $20-22(14-22)$ on the third epibranchial.

Gill rakers:--The gill rakers usually number $4+12-13 ; 4$ of 15 counts are $3+11-12$. On the first arch they are short, slender, and relatively widely spaced, with the spaces between them $2-3$ times the greatest width, near the middle, of the larger rakers. The longest raker, at the angle, measures $0.67-0.9$ times the diameter of the eye. The rakers on the lower fourth arch number 7-9. In the halfgrown and subadult each of the larger, measuring about half the adjacent width of the ceratobranchial, is reduced to a low knob beset with $6-7$ spines; in the largest specimen ( 62 mm .), however, they are reduced to low convexities studded with $7-9$ spines.

Scales:-Represented almost entirely by pockets, the scale rows usually number about 30 or 31 . On a typical body scale from under the pectoral (as in M. janae) no circuli or radii pattern the relatively large posterior field. However, microscopic striae, $0.25-0.33$ times the width of grooves between circuli on the anterior field, radiate from the focus to the posterior edge of the scale. At their widest the narrow grooves between circuli on the anterior and lateral fields measure about $.02 \cdots .03 \mathrm{~mm}$. The cross-striae breaching these grooves are poorly developed and inconspicuous. Seven to nine scallops, between which end distinct "radii" (formed of sharp bends in the circuli), render the anterior margin of the scale irregular; the posterior margin is even. The focus is near the center of the scale. A single file of about 13 or 14 slender scales sheathes the base of the soft dorsal fin. On the flat breast the large scales are missing, but assumed to be thin and cadicous.

Fins:-The modal dorsal count is III, 15 ; 2 of 15 counts are III, 14 . Usually by as much as the width of a scale pocket, the anal originates well behind the last dorsal ray. Though slightly before or directly under the pectoral insertion in young, the pelvics insert slightly behind it in adults.

Internal characters:-The vertebrae usually number $12+14-15$; the holotype has $13+13$. The haemal arch of the first caudal vertebra bears no spurs, but thickens at the base of the slender, retrorse haemal spine. The rete and gas gland of the well-developed gas-bladder occupy a large part of the entire structure. The membranous bladder is translucent white.

Color:--Unfortunately, fading of specimens precludes an accurate color description. One of the halfgrown is finely punctulate on the bases of the dorsal and anal fins, on the rays of all the fins, and very lightly on the snout, but no parts of the holotype are punctulate. In the young a distinctive dark band, $2-3$ scale rows wide, descends from immediately behind the dorsal fin to the crotch at the end of the anal; the fins are finely punctulate.

## Sex ratio and size at maturity.

Among the 10 specimens sexed there are 2 males and 2 females. The only mature or almost mature adults, both females, measure 48 and 62 mm . in standard length.

## Distinctions.

M. indicus is distinguished from closely related M. janae and sympatric M. longivelis in their species accounts. Closely related M. typhlops of the North Atlantic has body scales with circuli on all fields (no "smooth" posterior field); usually fewer gill rakers (almost always $2-3+11-12$ ), and the gill rakers on the fourth arch always reduced to low convexities or patches studded with numerous spines.

## Derivation of name.

The species name indicus signifies the fact that this species is limited in distribution mainly to the IndoPacific.

Specimens examined.--15 from 14 collections. The largest specimen ( 62 mm .) is teratologically misshapen.
Holotype: D $3682(1)$; near ripe female ( 48.3 mm .) ; Indonesia, Celebes Sea, $1^{\circ} 42^{\prime} \mathrm{N} 124^{\circ} 29^{\prime} \mathrm{E}$; capture 1000 meters wire, bottom 3660 meters; 3 -meter conical ring trawl; 29 March 1929; 2120 hours; R/V "Dana".

Paratypes: Indonesia and vicinity: D 3683(3), $4^{\circ} 03^{\prime} \mathrm{N} 123^{\circ} 26^{\prime} \mathrm{E}$, 3000 w .(d), 1 (34); D $3751(8), 3^{\circ} 41^{\prime} \mathrm{N} 137^{\circ} 53^{\prime} \mathrm{E}$, 2500w.(d), 1(39); D $3847(1), 12^{\circ} 02^{\prime}$ S $96^{\circ} 43^{\prime}$ E, 3500w.(n), 1(35).

Additional material: Indonesia and vicinity: D $3678(6), 4^{\circ} 05^{\prime} \mathrm{S} 128^{\circ} 16^{\prime} \mathrm{E}, 1000 \mathrm{w} .(\mathrm{n}), 1(21) ; \mathrm{D} 3751(7), 3^{\circ} 41^{\prime} \mathrm{N}$ $137^{\circ} 53^{\prime} \mathrm{E}, 3000 \mathrm{w}$.(d), $2(29-62)$; D $3814(1), 4^{\circ} 38^{\prime} \mathrm{S} 99^{\circ} 24^{\prime} \mathrm{E}, 600 \mathrm{w} .(\mathrm{n}), 1(18)$; D $3815(6), 3^{\circ} 36^{\prime} \mathrm{S} 97^{\circ} 37^{\prime} \mathrm{E}, 300 \mathrm{w} .(\mathrm{n})$, $1 \mathrm{PL}(9)$; 1) $3817(2), 2^{\circ} 15^{\prime} \mathrm{S} 98^{\circ} 56^{\prime} \mathrm{E}$, 600 w .(n), $1(16)$; V $3663,6^{\circ} 15^{\prime} \mathrm{S} 153^{\circ} 44^{\prime} \mathrm{E}, 3500,1(19)$.

Western and central Indian Ocean: D $3906(3), 4^{\circ} 27^{\prime} \mathrm{N} 85^{\circ} 21^{\prime} \mathrm{E}, 400 \mathrm{w} .(\mathrm{n}), 1(16)$; D $3933(2), 11^{\circ} 18^{\prime} \mathrm{S} 50^{\circ} 03^{\prime} \mathrm{E}$, 3500w.(d), 1(16).

Central North Pacific, south of Midway Island: V $3823,23^{\circ} 17^{\prime} \mathrm{N} 175^{\circ} 13^{\prime} \mathrm{W}, 4700,1(19)$.
Central South Pacific, southeast of Tonga Islands: D $3603(2), 22^{\circ} 00^{\prime} \mathrm{S} 170^{\circ} 26^{\prime} \mathrm{E}, 600 \mathrm{w} .(\mathrm{n}), 1(16)$.

## Melamphaes typhlops (Lowe). <br> Fig. 33.

Metopias typhlops.-Lowe, 1843: 89-90 (original description; captured while swimming at the surface off Madeira: notes) ; 1850: 251-252 (capture of larger topotype [to be designated neotype]; holotype destroyed).

Melamphaes typhlops.-GÜnther, 1864: (new combination, Metopias preoccupied; redescription of topotype; related to Berycidae). Lëtken, 1877: 177, 179 (comparison with M. megalops). Güther, 1887: 27, pl. 5, Fig. A (brief description, figure of topotype). Gilbert, 1890: 60 (comparison with M. lugubris). Goode and Bean, 1895: 177-178, atlas-pl. 53, Fig. 198 (description after Günther; synonymy). Jordan and Evermann, 1896 a: 842 (comparison with M. lugubris). Garman, 1899: 64, 383 (comparison with M. lugubris; listed). Brauer, 1906: 279 (in key). Zugmayer, 1911b: 98 (young specimen from $36^{\circ} 46^{\prime}$ N $26^{\circ} 41^{\prime} \mathrm{W}$, in $0-3250$ meters; description; synonymy). Rovle, 1919: 43-44, pl. 2, Fig. 5 (dead at surface, $36^{\circ} 08^{\prime} \mathrm{N} 8^{\circ} 02^{\prime} 45^{\prime \prime} \mathrm{W}$; description; measurements). Norman, 1929: 155, 156-157 (in part [see also M. simus]; description; synonymy; Lowe's topotype examined; eastern North Atlantic). Parr, 1931: 39 (in key): 1933: 13 (in key); De Buen, 1935: 87 (listed). Fowler, 1936a: 534 (brief description after Gënther; in key); 1936b: 1063, 1264 (listed with references; in key). Beebe, 1937: 206 (in tabular summary of captures off Bermuda). Madı.. 1949: 148 (ofl Madeira). Lozano y Rey, 1952: 38-40, pl. 2, Fig. 2 (description; in key). Albuquerque, 1954-56: 584 - 585 (short description after Fowler and Norman; references; in key; comparison with M. microps).

Melamphaes microps (in part). -Beebe, 1937: 206 ([see also M. pumilus, suborbilalis, microps]; in tabular summary of captures off Bermuda). Nybelin, 1948: 72-73 (captures from eastern North Atlantic; notes; see also M. simus). Grey, 1955 b : 296 ([see also M. pumilus]; captures off Bermuda).

Melamphaes crassicauda. -Koefoed, 1953:17-19, pl. 4, Fig. A (original description; neither of 2 syntypes designated holotype, but 18 mm . specimen figured; trawled with 2600 meters wire out, $35^{\circ} 36^{\prime} \mathrm{N} 8^{\circ} 25^{\prime} \mathrm{W}$; tabular morphometrics; comparisons). Dollfus, 1955: 134 (listed).

## Distribution.

M. typhlops mainly inhabits the North Atlantic between latitude $10^{\circ} \mathrm{N}$ and $45^{\circ} \mathrm{N}$; only 2 records (one dubious) are from further south in the equatorial east Atlantic (Fig. 47). Vertically at night, the upper limit of adults and halfgrown probably is between 1000 and 500 meters; the young occur more shallowly, to about 150 meters, but postlarvae have been taken up to 50 meters.

## Counts and measurements.

Counts:- The following counts are usually based on samples of $27-36$ : dorsal III, $14-15$ (14.9), anal I, 8 ; caudal $4-5+10-9+4(4+10-9+4)$; pectoral $14-16$ ( 15.0 ); pelvic I, 7 ; scale rows $29-32$ (30.7); scales in diagonal series $(\mathrm{n}=19) 8$; vertebrae $25-27(26.1)$; gill rakers on first arch $3-4+11-12(3.1+11.3)$; gill rakers on lower limb of fourth arch $6-8$ (7.3); mandibular pores $4-7$ (5.3).

Proportions:- -Csually based on samples of $10-12$, the following are proportions for which the data suggest little or no allometric change : orbit to cheek ridge 69-82 (74); prepelvic $369-418$ (392); isthmus to
pelvic 314-363 (337); pelvic to anal 327-366 (344); pectoral ( $\mathrm{n}=8$ ) 308-330 (317); pelvic ( $\mathrm{n}=5$ ) 241-281 (261); preanal 683-747 (707); anal to caudal 278-336 (319); length of caudal peduncle ( $\mathrm{n}=25$ ) 208-253 (229); depth of caudal peduncle 103-120 (113); orbit to cheek angle ( $\mathrm{n}=25$ ) 108-130 (117).

The following are proportions for which the data suggest allometric change. If the values of the proportions of the halfgrown are similar to those of the adults, the two categories are bracketed together. Proportions are based on 4 or 5 adults (Ad) $46-78 \mathrm{~mm}$., 3 halfgrown ( Hg ) $25-30 \mathrm{~mm}$., $17-18$ young ( Yg ) $13-20 \mathrm{~mm}$. ( ${ }^{*}, \mathrm{n}=4$ ), and, for body depth and eye, 8 postlarvae ( PL ) $6.7-12.7 \mathrm{~mm}$.

|  | Body depth | Eye | Predorsal | Postdorsal |
| :---: | :---: | :---: | :---: | :---: |
| Ad |  | 45--52(49) | 397-410(406) | 616-636(626) |
| Hg | 251-285(268) | 48--54(51) | 436-443(440) | 607-621(613) |
| Yg. | *299-332(316) | 58-67(63) | 446-476(461) | *567-608(584) |
| PL | 319--381(356) | 75-103(90) |  |  |
|  | Head length | Postorbital | Snoutpreopercle | Head depth |
| Ad | 328-359(345) | 219-243(231) | 222-241(231) | 248-265(253) |
| Hg | 373-379(376) | 248-254(251) | 254-267(259) | 262-279(269) |
| Yg. | 388-421(405) | 225-259(244) | 269-296(284) | *294-329(308) |
|  | Head width | Interorbital | Length of frontal fossa | Width of frontal fossa |
| Ad | 175-198(191) | 109-124(115) | 137-143(141) | 73-85(78) |
| Hg | 198-223(213) | 118-130(124) | 151-158(154) | 77--87(83) |
| ソg. | *226-230(228) | *132-138(135) | *165-175(170) | *86-98(92) |
|  | Prepectoral | Upper jaw | Snout length | Suborbital |
| Ad | 350-361(356) | 160-172(165) | 78-84(82) | 37-44(41) |
| Hg | 373-388(382) | 183-195(187) | 90-91(91) | 43-49(46) |
| Yg. | 372-419(398) | *198-217(205) | *98-113(105) | 47-58(52) |

## Description.

Body and head form:-The streamlined body narrows abruptly from the anus to a subrectangular caudal peduncle, which is about twice as long as deep. The body contour along the dorsal fin ascends almost straightly. The point of greatest body depth subtends or slightly succeeds the pelvic insertion. The ventral contour of the head angles slightly (with the apex under the cheek ridge) from the pelvic symphysis to the isthmus, where it abruptly angles up to the mandibular symphysis. The diameter of the eve slightly exceeds the suborbital width and measures $0.55-0.6$ times the snout length. From the premaxillary symphysis to the anterior end of the frontal knob is about three-fourths the distance between the anterior nostrils.

Head ridges and epidermis:-About 1.8 times as long as wide, the frontal fossa, which reseinbles a funnel in cross-section, expands only twice before its noticeably constricted posterior end. Behind the frontal knob a small, crescent-shaped area remains pigmentless. More extreme than in M. indicus, a sharp angle in the frontal margin over the front of the pupil abruptly narrows the interorbital space. Between thesc angles the interorbital equals or is slightly less than the distance from the orbit to the preopercular edge. The fragile spinclike ridges at the cheek angle diverge symmetrically. In most specimens the thin head epidermis is collapsed and partly missing, especially over the preopercle. Although frequently lighter on their midlines, the close-set embossed lines stand out as dark streaks on a lighter background. The spaces between them are smooth and generally without prickles.

Sensory pores:-The pores in the group inside the cheek angle usually number 3; $\mathbf{2}$ of 9 counts are 2. Those in the group under the posteroventral angle of the orbit usually number 1 ; only 1 of 10 counts is 2 . In the group on the supratemporal canal directly above the preopercle the pores number 3 or 4 . $\ln 6$ counts


Fig. 33. Melumphues typhlops (lowz). $\lambda$, specimen to be designated neotype, traced and modified from a photograph obtained through the courtesy of the British Museum (Natural History) (standard length 75 mm .); B, young, D 1328(9) (s. 1. 13.0 mm.); C, postlarva, I) $1332(15)$ s. 1.10 .9 mm ): D, postlarva, D $1332(15)$ (s. 1.6 .2 mm.$)$.
the pores on the preopercle above the angle number from $1+1+1+2$ to $2+3+3+3$. On the outer margin of the mandible, from just behind the angle to the symphysis, the pores number $1+1+1+1$ to $1+3+2+1$, with the lower counts predominating.

Operculum:-The angle of the thin but sturdy preopercle, although rounded. bears weak serrations, which mark the ends of 3 or 4 weak ridges that radiate from the cheek angle. Except for small patches along the cheek ridge in some specimens, no reticulate bone reinforces the opercular series. At least one weak ridge, unding in a small projecting at the margin, traverses the posteroventral part of the interopercle and last branchiostegal.

Jaws and teeth:-'The maxillary overreaches by the lens diameter a vertical from the posterior edge of the bony orbit. Both oral and pharyngeal teeth are numerous: the tooth formula is for adults 6-7/4-7, for halfgrown $4-5 / 3-4$, for young $3-5 / 2-4$, and for postlarvae $0-1 / 0-1$. In adults the pharyngeal teeth number 7-23 on the second pharyngobranchial, 61-75 on the third, $9-20$ on the fourth, and $23-37$ on the third epibranchial.

Gill rakers:--The modal gill-raker count, $3+11$, is lowest in the genus; 9 of 37 counts are $3+12,2$ are $t-11-12$. On the first arch the rakers are very short, slender, widely spaced, and frequently degenerate. The spaces between them are thrice or more the greatest width, near the middle, of the larger rakers. The longest raker, on the ceratobranchial near the angle, measures only $0.67-0.75$ times the diameter of the eye. The rakers on the lower fourth arch usually number 7 or 8 . Usually diagnostic of the species, they form low convexities or, simply, patches studded with $7-20$ small spines.

Sc ales:-Represented mostly by pockets, the scale rows usually number 30 or 31 . On a typical body scale the narrow grooves between circuli increase in width gradually or somewhat abruptly from the anterior to the posterior field, where the widest are about 2-3 times the width of the narrowest grooves on the anterior field. The narrowly spaced circuli on the anterior and lateral fields lie only $.02-.03 \mathrm{~mm}$. apart. Inconspicuous or absent on the anterior field, numerous cross-striae breach the grooves on the posterior field. Six to nine scallops, between which end distinct "radii" (formed of sharp bends in the circuli), render the anterior margin of the scale irregular; the posterior margin frequently is eroded. The focus is near the center of the vale. A single file of 12 or 13 slender scales sheathes the base of the soft dorsal fin. On the flat breast the large scales are thin but substantial; a clypeate scale between the pelvics has 2 posterior scallops.

Fins:- The modal dorsal count is III, 15; 2 of 36 counts are III, 14. Csually by as much as the width of whe or one and a half scale pockets, the anal originates well behind the last dorsal ray. Though slightly before or directly under the pectoral insertion in young, the pelvics insert well behind it in adults.

Internal eharacters:- The modal vertebral count is $12+14$; although the precaudal count is constant, 5 of 27 counts include 15 caudal vertebrae, 1 includes 13 . The haemal arch of the first caudal vertebra bears no spurs, but thickens at the base of the slender, retrorse haemal spine; in radiographs the bend of the haemal arch appears either angular or smooth. Anteriorly, the rete and gas gland of the well-developed gas-bladder wcupy almost a third of the entire structure. Adipose tissue caps the posterior tip of the sturdy membranous bladder. Four or five times as long as deep, the slender stomach is dark in front, but lightens toward the end of the blind sac.

Color:-Although due to abrasion some scale pockets may be lightest centrally, the integument is not generally mottled. The bases of the median fins usually are no darker than the rest of the body, which, with the head and fins, is never punctulate. Blackish or brownish pigment lightly mottles the coelomic peritoneum. In the young a distinctive dark band, the width of $2-3$ scale rows, descends obliquely backward from immediately behind the dorsal fin to the crotch at the cnd of the anal; it is well differentiated in some specimens, but faded in others. In the laterally compressed postlarvae this dark dorsal-anal band disrupts the pale white of the body. The pelvic fins are dark brown or blackish. Melanophores fleck the gill arches.

Sex ratio and size at maturity.
Among the 15 specimens sexed, there are 3 males and 2 females. Three mature adults ( 2 males, 1 female) range in standard length from 68 to 78 mm .

## Distinctions.

M. typhlops is distinguished from sympatric M. longivelis and closely related M. indicus in their species accounts. M. janae from the eastern tropical Pacific and Indian Ocean, among other differences, is smaller (mature adults $34-42 \mathrm{~mm}$.), has more gill rakers ( $4+13-15$ ), usually has fewer precaudal vertebrae (11), has the gill rakers on the fourth arch not reduced to patches, and has scales without circuli on the posterior field.

## Remarks.

In the original description of M. typhlops, Lowe stated of the single specimen, "Although full-grown or adult, being in roe, it was only an inch and a half long. . ." He described the teeth in the jaws as "minuti uniseriati". Unfortunately, due to wastage of alcohol, this holotype was lost so that the above statements, which are inconsistent with the description of typhlops as recognized in the present study, cannot be checked. Further, the original description is confusing because in one way or another it eliminates the other species of Melamphaes as well.

Later, in 1850, Lowe described as typhlops a second, larger specimen (BM(NH) 64.11.8.1): "It is of much larger size, measuring three inches and a half in length. I find nothing whatever to correct in the account above referred to, except that the maxillary teeth, instead of being "uniseriate", are in a scobinate or brushlike band in both jaws; narrow in the upper, broader in the lower jaw." Further on he verified the loss of the holotype. Although I did not directly examine this specimen, I received accurate counts from Carl L. Hebrs and excellent photographs from the British Museum. From these, there is no doubt that this specimen is M. typhlops as here interpreted. Norman (1929) based his description of M. typhlops on this specimen. The gill-raker count in this description, however, is too low and should have been $3+11$.

Inasmuch as the holotype is lost and the original description is confusing, it will be in the best interests of zoological nomenclature to designate Lowe's second specimen (BM(NH) 64.11.8.1) as the neotype of M. typhlops. Besides preserving a time-honored name, this action will stabilize the type species of the genus Melamphaes.

A syntype of M. crassicauda Koefoed, 1953 (BZM 4345, $34^{\circ} 59^{\prime} \mathrm{N} 33^{\circ} 01^{\prime} \mathrm{W}$ ), was examined and found to agree in every way with typhlops as here described. Measuring only 14.3 mm ., this specimen has a very faint dorsal-anal band. Also characteristic of typhlops are the low gill-raker count ( $3+12$ ), the low vertebral count (26), the development of the gill rakers on the fourth arch, the relatively high (for young) tooth formula (3/2), and the posterior position of the anal origin relative to the end of the dorsal. The proportions of both syntypes (measurements of the second specimen are from Koefoed, 1953) are within the range of typhlops.

In the original deseription of M. crassicauda, however, one incongruity tends to associate this species with M. suborbitalis. Koefoed stated (p. 19) that there is a pair of ". . . nuchal spines . . . on either side above the upper end of the shoulder girdle.' On the second of the syntypes (BZM 4345), I could find no such spines. Inasmuch as the depression of surrounding tissue renders the dorsal edges of the posttemporals outstanding, these edges possibly could be mistaken for spines. Furthermore, in Koefoed's figure of crassicauda (Pl. 4, Fig. A) bona fide spines are either very indistinct or omitted. Also in this figure, the origin of the anal fin appears to be under the last ray of the dorsal; in suborbitalis the origin is under the third or fourth from last. These facts, together with the agreement of counts and proportions of crassicauda with those of typhlops but not with those of suborbitalis, suggest the synonymy of crassicauda with typhlops.

Specimens examined.-128 from 68 collections.
Specimen to be designated neotype: (not directly examined): BM(NH) 64.11.8.1; 75 mm .; eastern North Atlantic, off Magdalena, Madeira; May, 1849; brought to Rev. R. T. Lowe.

Syntype of M. crassicauda: BZM 4345, $34^{\circ} 59^{\prime} \mathrm{N} 33^{\circ} 01^{\prime} \mathrm{W}, 300 \mathrm{w} ., 1(14)$.
Additional material: Western North Atlantic, between $10^{\circ} \mathrm{N}$ and $40^{\circ} \mathrm{N}$ and west of $40^{\circ} \mathrm{W}$; CNHM 49652. $32^{\circ} 16^{\prime} \mathrm{N} 64^{\circ} 35^{\prime} \mathrm{W}, 1100(\mathrm{~d}), 1(13)$; CNHM $49656,32^{\circ} 13^{\prime} \mathrm{N} 64^{\circ} 36^{\prime} \mathrm{W}, 550(\mathrm{n}), 1 \mathrm{PL}(12)$; CNHM $49680,32^{\circ} 13^{\prime} \mathrm{N} 64^{\circ} 35^{\prime} \mathrm{W}$, $1100(\mathrm{n}), 1(13)$; CNHM $49726,32^{\circ} 07^{\prime} \mathrm{N} 64^{\circ} 37^{\prime} \mathrm{W}, 275(\mathrm{n}), 1(13)$; CNHM $49727,32^{\circ} 11^{\prime} \mathrm{N} 64^{\circ} 33^{\prime} \mathrm{W}, 820(\mathrm{n}), 1(25)$; D 839(1),
$24^{\circ} 31^{\prime} \mathrm{N} 46^{\circ} 46^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 3 \mathrm{PL}(5-9) ; \mathrm{D} 858(1), 29^{\circ} 31^{\prime} \mathrm{N} 64^{\circ} 00^{\prime} \mathrm{W}, 200 \mathrm{w} .(\mathrm{n}), 1 \mathrm{PL}(10)$; D 858(2), do., $150 \mathrm{w} .(\mathrm{n})$, 13 PL(4-9); D 858(3), do., 100w.(n), 3 PL(5士); D 1314(4), $17^{\circ} 43^{\prime} \mathrm{N} 64^{\circ} 56^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 1 \mathrm{PL}(5)$; D 1321(1), $24^{\circ} 13^{\prime} \mathrm{N}$ $54^{\circ} 36^{\prime} \mathrm{W}, 500 \mathrm{w} .(\mathrm{n}), 4 \mathrm{PL}(4-6) ; \mathrm{D} 1322(4), 27^{\circ} 02^{\prime} \mathrm{N} 53^{\circ} 39^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 3 \mathrm{PL}(6-8)$; D $1322(27), 27^{\circ} 02^{\prime} \mathrm{N} 53^{\circ} 39^{\prime} \mathrm{W}$, $400 \mathrm{w} .(\mathrm{n}), 1(13)$; D 1323(7), $27^{\circ} 17^{\prime} \mathrm{N} 54^{\circ} 35^{\prime} \mathrm{W}, 700 \mathrm{w} .(\mathrm{n}), 1 \mathrm{PL}(7) ; \mathrm{D} 1323(10), 27^{\circ} 17^{\prime} \mathrm{N} 54^{\circ} 35^{\prime} \mathrm{W}, 100 \mathrm{w} .(\mathrm{n}), 1 \mathrm{PL}(8)$; D $1326(3), 27^{\circ} 14^{\prime} \mathrm{N} 51^{\circ} 25^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 8 \mathrm{PL}(4-7) ; \mathrm{D} 1327(4), 27^{\circ} 34^{\prime} \mathrm{N} 51^{\circ} 47^{\prime} \mathrm{W}, 200 \mathrm{w} .(\mathrm{n}), 1 \mathrm{PL}(6)$; D 1327(5), $27^{-} 34^{\prime} \mathrm{N} 51^{\circ} 47^{\prime} \mathrm{W}, 100 \mathrm{~W} .(\mathrm{n}), 1 \mathrm{PL}(8) ; \mathrm{D} 1328(9), 27^{\circ} 05^{\prime} \mathrm{N} 52^{\circ} 11^{\prime} \mathrm{W}, 800 \mathrm{w} .(\mathrm{n}), 1(13) ; \mathrm{D} 1332(16), 26^{\circ} 58^{\prime} \mathrm{N} 56^{\circ} 58^{\prime} \mathrm{W}$, 200 w .(n), $5 \mathrm{PL}(6-9)$; D 1336(3), $28^{\circ} 15^{\prime} \mathrm{N} 63^{\circ} 40^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 1 \mathrm{PL}(8) ; \mathrm{D} 1336(6), 28^{\circ} 15^{\prime} \mathrm{N} 63^{\circ} 40^{\prime} \mathrm{W}, 100 \mathrm{w} .(\mathrm{n}), 2 \mathrm{PL}(8)$; D $1337(8), 29^{\circ} 36^{\prime} \mathrm{N} 64^{\circ} 01^{\prime} \mathrm{W}, 200 \mathrm{w} .(\mathrm{n}), 3 \mathrm{PL}(5-8) ; \mathrm{D} 1341(4), 33^{\circ} 15^{\prime} \mathrm{N} 68^{\circ} 20^{\prime} \mathrm{W}, 200 \mathrm{w} .(\mathrm{n})$, $1 \mathrm{PL}(6)$; D 1356(4), $2956^{\prime}$ N $59^{\circ} 33^{\prime} \mathrm{W}, 200 \mathrm{w} .(\mathrm{n}), 6 \mathrm{PL}(7-8)$; D $1358(6), 28^{\circ} 15^{\prime} \mathrm{N} 56^{\circ} 00^{\prime} \mathrm{W}, 2000 \mathrm{w}$.(d), $1(15)$; D $1358(10), 28^{\circ} 15^{\prime} \mathrm{N} 56^{\circ} 00^{\prime} \mathrm{W}$, $300 \mathrm{w} .(\mathrm{n}), 2 \mathrm{PL}(7-9)$; D $1358(11), 28^{\circ} 15^{\prime} \mathrm{N} 56^{\circ} 00^{\prime} \mathrm{W}, 200 \mathrm{w} .(\mathrm{n}), 2 \mathrm{PL}(7-8) ; \mathrm{D} 1358(12), 28^{\circ} 15^{\prime} \mathrm{N} 56^{\circ} 00^{\prime} \mathrm{W}$, $150 \mathrm{w} .(\mathrm{n})$, $1 \mathrm{PL}(6)$; D $1360(3), 26^{\circ} 56^{\prime} \mathrm{N} 53^{\circ} 09^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 1 \mathrm{PL}(6)$; D $1362(3), 28^{\circ} 57^{\prime} \mathrm{N}^{\prime} 47^{\circ} 24^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 2 \mathrm{PL}(7-8)$; D 1362 (4), $28^{\circ} 57^{\prime} \mathrm{N} 47^{\circ} 24^{\prime} \mathrm{W}, 200 \mathrm{w}$.(n), $3 \mathrm{PL}(6-7)$; D $1363(4), 30^{\circ} 25^{\prime} \mathrm{N} 44^{\circ} 46^{\prime} \mathrm{W}, 100 \mathrm{w} .(\mathrm{n}), 2 \mathrm{PL}(6-9)$; D $1365(2), 31^{\circ} 47^{\prime} \mathrm{N}$
 $1 \times 30,1(27)$; SU 42315, do., 1280 (d), 1(46); SU 42320, do., 914(d), 1(11); [SU 42809], do., 1280(G), 1(17); SU 42933, do., 1463(d), 1(17); SU 43057, do., 914(d), 1(15); SU 43060, do., 1097(d), 1(19).

Eastern North Atlantic, between $10^{\circ} \mathrm{N}$ and $40^{\circ} \mathrm{N}$ and east of $40^{\circ} \mathrm{W}$ : D 830, $24^{\circ} 44^{\prime} \mathrm{N} 22^{\circ} 32^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 1(16)$; 1) $1107(1), 36^{\circ} 28^{\prime} \mathrm{N} 8^{c} 38^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 1(16)$; D $1157(12), 21^{\circ} 57^{\prime} \mathrm{N} 22^{\circ} 58^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 2 \mathrm{PL}(13-14)$; D $1157(13)$, d. $, 500 \mathrm{w} .(\mathrm{n}), 1(16)$; D $1160(4), 15^{\circ} 50^{\prime} \mathrm{N} 26^{\circ} 32^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 1 \mathrm{PL}(12)$; D $1162(3), 13^{\circ} 35^{\prime} \mathrm{N} 30^{\circ} 11^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 1 \mathrm{PL}(10)$; D $1163(4), 12^{\circ} 59^{\prime} \mathrm{N} 32^{\circ} 49^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 8 \mathrm{PL}( \pm 13)$; D $1165(7), 12^{\circ} 11^{\prime} \mathrm{N} 35^{\circ} 49^{\prime} \mathrm{W}, 4000 \mathrm{w} .(\mathrm{d}), 4 \mathrm{PL}(8-12)$; D 1367(6), $33^{\circ} 42^{\prime} \mathrm{N} 36^{\circ} 16^{\prime} \mathrm{W}, 100 \mathrm{w} .(\mathrm{n}), 1 \mathrm{PL}(8) ; \mathrm{D} 1369(1), 35^{\circ} 44^{\prime} \mathrm{N} 29^{\circ} 33^{\prime} \mathrm{W}, 1000 \mathrm{w} .(\mathrm{n}), 1(20) ; \mathrm{D} 4005(1), 13^{\circ} 31^{\prime} \mathrm{N} 18^{\circ} 03^{\prime} \mathrm{W}$,
 (4), $28^{\circ} 09^{\prime} \mathrm{N} 15^{\circ} 19^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 1(15) ; \mathrm{D} 4019(2), 33^{\circ} 08^{\prime} \mathrm{N} 10^{\circ} 22^{\prime} \mathrm{W}, 3500 \mathrm{w} .(\mathrm{d}), 1(18) ; \mathrm{D} 4023(6), 35^{\circ} 06^{\prime} \mathrm{N} 7^{\circ} 00^{\prime} \mathrm{W}$, 400w.(1), 1 PL(8); D 4023(15), $35^{\circ} 17^{\prime} \mathrm{N} 6^{\circ} 56^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 1 \mathrm{PL}(11) ;$ D 4195(2), $41^{\circ} 55^{\prime} \mathrm{N} 32^{\circ} 22^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n})$, 1(15); F 14967, off Madeira, 1(59); F 15261 A, do., 1(71); F 15339, do., 1(68).

Equatorial eastern Atlantic: D $3999(1), 3^{\circ} 45^{\prime} \mathrm{S} 10^{\circ} 00^{\prime} \mathrm{W}, 1000 \mathrm{w} .(\mathrm{n}), 1(30)$.
Doubtful identification: Equatorial eastern Atlantic: D 4001(4), $3^{\circ} 56^{\prime} \mathrm{N} 12^{\circ} 33^{\prime} \mathrm{W}, 100 \mathrm{w} .(\mathrm{n})$, $3 \mathrm{PL}(6-10)$.

## M. simus species group.

This "dwarf" species group comprises 4 species: M. simus, M. hubbsi, M. danae, and M. pumilus. Whereas the adults in all other species groups are moderate in size to large (usually $40-130 \mathrm{~mm}$.), the dwarf individuals in the simus group are less than 25 to 28 mm . in standard length. The group is tightly knit. Besides the astonishingly small size of its adults, each of the 4 species is characterized by a salient antorbital ridge, body scales with equally spaced circuli on all fields, slender, but well-developed gill rakers, a funnel-shaped frontal fossa, and an anal fin originating well in front of the end of the dorsal.

The four species inhabit mainly the Central Water masses of the oceans. Both with restricted distributions, M. pumilus occurs only in the Sargasso Sea area of the North Atlantic, M. hubbsi only in the South Atlantic. On the other hand, M. simus ranges from the eastern North Atlantic to the central water masses of the Pacific and M. danae occurs throughout the Indo-Pacific and Pacific Central water.

The following descriptive excerpts pertain to all 4 species.
Body form:-.-The body contour along the dorsal fin ascends in a weakly convex arc. The ventral contour remains straight or weakly convex from the pelvic symphysis to the anus. Although behind the dorsal origin the dorsal contour is somewhat steeper than the ventral, the body frequently appears subsymmetrical in side view. The point of greatest body depth subtends or slightly precedes the pelvic insertion.

Head ridges and epidermis:-The margins of the head ridges are not expanded. About 1.67 times as long as wide, the frontal fossa, which resembles a funnel in cross-section, expands only twice before its acutely constricted posterior end. The frontal knob is smooth. The fragile spinelike ridges at the cheek angle diverge symmetrically, but are frequently missing. In most specimens the thin head epidernis is collapsed and partly missing, especially over the preopercle. The embossed lines stand out as slightly darker streaks on a lighter background; because these lines are often abrased over the subtending nerves, their midlines frequently are lighter. The spaces between the ambossed lines are generally without prickles.

Spines, operculum and posttemporal:-Except on the opercle, the head bears no obvious spines.

The angle of the thin, pliant preopercle is smooth, rounded, and only slightly emarginate. No reticulate bone reinforces the opercular series. The smooth preopercle is practically unsculptured. The thin dorsal edge of the posttemporal is spineless.

Gill rakers:- Each of the larger gill rakers on the lower fourth arch is a short, but well-formed stump, the length of which equals the adjacent width of the ceratobranchial; its inner edge bears $4-7$ spines.

Scales: A typical body scale from under the pectoral is especially thin and almost semicircular or ovoid. The width of the grooves between the relatively few circuli (fewer than 45) averages about the same on the anterior, lateral, and posterior fields. Inconspicuous or absent on the outer anterior field, numerous crossstriae breach the grooves on the posterior field and on the anterior field near the focus. A single file of 13 or 14 slender seales sheathes the base of the soft dorsal fin. On the flat, relatively narrow breast the large scales are missing, but assumed to be very thin and caducous. Moulded to shape, 4 especially pliant, delicate scales shield the subopercle, interopercle, and opercle. Although the opercular scales on 5 specimens of M. pumilus are intact, only a few other specimens in the species group retain even part of their opercular squamation; the number of opercular scales on the 3 remaining species usually was inferred from the arrangement of the pockets relative to a few remaining scales.

Fins:-The pectoral fin reaches to within 2-4 scales of the end of the dorsal fin. Though directly under or slightly before the pectoral insertion in young, the pelvics insert well behind it in adults.

## Melamphaes simus, new species.

Fig. 34.
Melamphaes microps (in part).-Norman, 1929: 157-158 ([see also M. microps and M. suborbitalis]; description): 1930; 345 ([see also M. longivelis]; captures from equatorial east Atlantic and eastern South Atlantic). Nybelin, 1948: 72 - 73 ([see also $M$. typhlops]; captures from eastern North Atlantic; notes).

Melamphaes typhlops (misidentifications).-Norman, 1929: 156 (in part [see also M. typhlops]; description, etc.): 1930: $344\left(6^{\circ} 55^{\prime} \mathrm{N} 15^{\circ} 54^{\prime} \mathrm{W}\right.$; in list).

## Distribution.

A widely distributed central-tropical species, M. simus has been taken in the North and South Atlantic, the Indo-Pacific, and the central North Pacific (Figs. 61, 48). It exhibits, however, significant geographic variation between these four areas. Whereas the adults occur mainly below $150-200$ meters, the young and postlarvae have been captured at night up to 35 or 40 meters.

## Counts and measurements.

Counts:-The following counts are usually based on samples of $90-107$. For the characters (dorsal rays, scale rows, vertebrae, gill rakers on lower first and fourth arches) analyzed by locality under "Variation" the means are not given. Dorsal 111, $15-17$; anal 1, $8-10$ (8.99); caudal $3-5+9-10-8-9+4-5$ ( 4.06 $10.0-9.0+4.03$ ); pectoral $14-16(15.00)$; pelvic 1 , 7 ; scale rows $32-36$; scales in diagonal series ( $n=60$ ) $10-11$; vertebrae $28-30$; gill rakers on first arch $3-4+12-15$ (3.89); gill rakers on lower limb of fourth arch 7-9; mandibular pores ( $\mathrm{n}=67$ ) 4-7 (5.46).

Proportions:- Csually based on 26--29 adults ( $21-29 \mathrm{~mm}$.) from over the entire geographical range of the species, the following proportions may or may not be allometric: body depth $250-285$ (266); postdorsal $579-642(604)$; end of dorsal to caudal ( $\mathrm{n}=19$ ) $292-342(313)$; postorbital $223-263(243)$; snout to preopercle 236-260 (247); orbit to cheek ridge 69-82 (76); head depth 240-272 (255); head width 185-200 (192); width of frontal fossa $74-84$ (78); prepectoral $347-389$ (367); prepelvic $368-423$ (390); isthmus to pelvic-$324-365$ (346) ; pelvic to anal 275-354 (303); pectoral 257-307 (290); pelvic ( $\mathrm{n}=13$ ) 202-240 (218); preanal $623-690$ ( 662 ); anal to caudal $320-371$ (353); length of caudal peduncle $230-255$ (242); snout length 87--101 (93).

The following are proportions, based on samples of $99--101$, for which the data suggest little or no allometric change: predorsal 411-451 (427); upper jaw 151-178 (165).

Next are proportions for which the data suggest allometric change. Head length, interorbital, depth of caudal peduncle, and suborbital are further analyzed under "Variation". If the values of the proportions of the halfgrown are similar to those of the adults, the two categories are bracketed together. Proportions are based on 58 adults (Ad) $20-29 \mathrm{~mm}$., 24 halfgrown ( Hg ) $16-19.7 \mathrm{~mm}$., and $15-19$ young ( Yg ) 9-15.8 mm.

|  | Head length | Interorbital |  | Length of frontal fossa | Depth of caudal ped. |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Ad | 343-398(369) | $102-129(117)$ |  | 134-153(143) | 89-118(101) |
|  |  |  |  | 99-118(107) |
| Yg | 332-394(357) | 101-141(122) |  |  | 134-164(149) | 98-114(106) |
|  |  |  | Subo |  |  |
| Ad | 94 | 112) | 49- | 8) 38- |  |
| Hg | 94 | 104) | 49-6 | 4) 46- |  |
| Yg. | 80 | 92) | 38- | 2) 52- |  |

## Jescription.

Body and head form:-The streamlined body narrows gradually from the anus to a tapered caudal peduncle, which is about 2.5 times as long as deep. From the dorsal origin to the frontal knob the profile descends in a weakly convex curve and is rounded behind the nape. Symmetrically with the dorsal, the ventral contour of the head curves outwardly from the pelvic symphysis to the isthmus, where it abruptly bends up to the mandibular symphysis. The diameter of the small eye measures only $0.67-0.75$ times the suborbital width and about $0.43-0.46$ times the snout length. From the premaxillary symphysis to the anterior end of the frontal knob is about $0.75-0.80$ times the distance between the anterior nostrils.

Head ridges:-Rounding and stubbing the side of the snout, the antorbital ridge, in front of and extending hack to below and above the eye, is especially well developed and outstanding. A very obtuse angle in the frontal margin over the front of the eye gradually narrows the interorbital space. Between these angles the interorbital width equals the distance from the orbit to the preopercular edge.

Sensory pores:-The pores in the group inside the cheek angle usually number 2 ; only 1 of 18 counts is 1. Those in the group under the posteroventral angle of the orbit also number $2 ; 1$ of 22 counts is 1 . In the group on the supratemporal canal directly above the preopercle the pores usually number $4 ; 1$ of 16 counts is 3 . In 4 counts the pores on the preopercle above the angle number $2+2-3+2-3+3-4$. On the "uter margin of the mandible, from just behind the angle to the symphysis, the pores usually number $1+1+2+1$ (1) $1+2+2+1 ; 7$ of 67 counts are $1+1+1+1,5$ counts (especially of North Pacific specimens) are $1+1+2+2+1$. The pore on the outer surface of the mandible near the symphysis is $0.33-1.0$ times the size of its equivalent hehind the symphysis.

Operculum:-At the preopercular angle a feeble projection marks the end of a weak ridge that originates near the cheek angle. A very weak ridge ending in a small projection at the margin traverses the posterorentral part of the interopercle; the last branchiostegal, however, is evenly rounded.

Jaws and tecth:-The maxillary reaches or slightly overreaches a vertical from the posterior cdge of the bony orbit. The tooth formula is for adults $4-7 / 3-5$, for halfgrown $2+2$, and for young $1-2 / 1-2$. Although in the expanded part of the premaxillary tooth-band the inner 2 or 3 rows are usually oblique, the outer rows, like the 2 or 3 rows in the mandible, align irregularly or nearly horizontally. Near the symphysis this band narrows to 1 or 2 rows. In adults the pharyngeal teeth number $8-17$ on the second pharyngobranchial, $21-48$ on the third, $7-14$ on the fourth, and $11-24$ on the third epibranchial.

Gill rakers:- The gill rakers usually number $4+13-14$. On the first arch they are moderately long and slender, with the spaces between them about $1.5-1.75$ times the greatest width, near the middle, of the larger rakers. The longest raker, on the ceratobranchial near the angle, measures $1.33-1.5$ times the diameter of the eye. The rakers on the lower fourth arch usually number 8 , less frequently, 7 or 9 .


Fig. 34. Melamphaes simus, n. sp. A, holotype, traced and modified from photograph (standard length 27.5 mm .) ; B, postlarva, D 1108 (1 (s. l. 11.0 mm .) ; C, postlarva, D 3535 (2) (s. 1.5 .0 mm .).

Scales:-Usually represented entirely by pockets, the scale rows generally number 33 or 34 . Six to ten scallops, between which end distinct "radii" (formed of sharp bends in the circuli), render the anterior margin of a typical scale irregular; the posterior margin frequently is croded. The focus is usually about half as far from the anterior border of the scale as from the posterior.

Fins:-The modal dorsal count is III, 16; 30 of 107 counts are III, 15 or III, 17. The anal rays almost always number I, 9 ; only 7 of 107 counts are I, 8 or I, 10 . Although in young the anal originates under the fifth or sixth from last dorsal ray, it is under the second to fourth from last in adults. The pectoral rays almost always number 15 ; only 4 of 100 counts are 14 or 16 .

Internal characters:-The modal vertebral count is $12+17$. Although only 6 of 88 precaudal counts are 11 or 13,23 caudal counts are 16 or 18 vertebrae. The rather slender haemal arch of the first caudal vertebra bears no spurs, but smoothly curves into the slender, retrorse haemal spine. Anteriorly, the rete and gas gland of the well-developed gas-bladder occupy slightly less than half the entire structure. Adipose tissue invests areas of the membranous bladder. About 2.5-3.0 times as long as deep, the thick stomach is dark in front, but lightens toward the end of the blind sac.

Color:--Although due to abrasion some scale pockets are lightest centrally, the integument is not generally mottled. The bases of the median fins usually are no darker than the rest of the body, which, with the head and fins, is never punctulate. The pharynx is dark brown to blackish, frequently with a superficial metallic sheen. The coelomic peritoneum is also dark brown to blackish.

In color no distinguishing characters mark the young. The slender postlarvae, however, are somewhat listinctive. Whereas most of the body is colorless, distinct narrow bands of pigment or rows of melanophores in front of and on either side of the dorsal extend to the caudal fin. Similar bands or rows along the posterior anal fin extend via the ventral half of the caudal peduncle to the caudal. A broad band of pigment, darkest at the mid-lateral line, connects the top and bottom of the caudal peduncle just before the caudal fin, which has a spot of pigment at the fork in larger postlarvae. Finally, melanophores and spots of pigment dot the head region: above the pectoral fin, over the brain, and above the eyes. Melanophores do not fleck the gill arches.

Sex ratio and size at maturity.
Among the 90 specimens sexed there are 32 males and 34 females. Mature adults range in standard length from 22 to 29 mm .

## freographical variation.

Samples of $M$. simus vary significantly in numbers of dorsal soft rays, scale rows, vertebrae, and gill rakers , in the lower first and fourth arches; and values of head length, interorbital, depth of caudal peduncle, and suborbital (Fig. 35). Samples were analyzed from four localities: A) North Atlantic between $5^{\circ} \mathrm{N}$ and $40^{\circ} \mathrm{N}$ (most specimens are from the eastern North Atlantic); B) South Atlantic between $4^{\circ} \mathrm{N}$ and $35^{\circ} \mathrm{S} ; \mathrm{C}$ ) tropical Indo-Pacific from off Madagascar, across the Indian Ocean, through Indonesia, northeast to the western North Pacific Central Water Mass, and southeast to off New Zealand; and D) the North Pacific Central Water Yass from $180^{\circ}$ to $120^{\circ} \mathrm{W}$.

Some of the characters vary clinally from areas A or B to D. The best example is depth of caudal peduncle, which has relatively high values in specimens from area $A$ and low values in specimens from $D$; areas $B$ and C are stepwisely intermediate. Again with specimens from area D exhibiting the lowest values, values of interorbital and suborbital diminish clinally from B to $D$, but with values from area $A$ equal to those from intermediate C. The variation in counts is less distinctly clinal. Of the counts, scale rows exhibit the most distinct clinal variation, with counts from area D much the highest. Gill-raker counts on the first and fourth arches, which are apparently correlated, are also higher in specimens from the Pacific and Indian Ocean than in specimens from the Atlantic.

Other characters show no such systematic variation. Coincidentally, the dorsal soft rays and head length exhibit similar variations; in specimens from area B both these characters are significantly greatest. The IndoPacific specimens have significantly fewer vertebrae than the others.

## Distinctions.

lts high anal count of $I, 9$ distinguishes $M$. simus from the other 3 "dwarf" species, all of which have 1,8 . In addition, sympatric $M$. hubbsi has fewer gill rakers (usually $3-4+12$ ), usually has more scale rows (35--36),


Fig. 35. Geographical vaitiation of Melamphaes simus in selected counts and proportions between 4 areas. Area $A$, North Atlantic between $5^{\circ} \mathrm{N}$ and $40^{\circ} \mathrm{N}$ (most specimens are from the eastern North Atlantic); area B, South Atlantic between $4^{\circ} \mathrm{N}$ and $35^{\circ} \mathrm{S}$, mainly off the west coast of Africa; area C. thopical Indo-Pacific from off Madagascar, across the Indian Ocean, through Indonesia, northeast to the western North Pacific Central Water Mass, and southeast to of New Zealand; and area D, the North Pacific Central Water Mass from $180^{\circ}$ to $120^{\circ} \mathrm{W}$. For further explanation see Fig. 19.
has a shorter head ( $33-34$ per cent of standard length), and apparently lacks a functional gas-bladder with developed rete. M. danae is smaller (maximum size only 21-22 mm.), has fewer vertebrae (usually $11+15-16$ ), usually. has a spur on the first precaudal vertebra, has fewer scale rows (usually about 32), has a larger eye (usually 5 per cent of standard length), and has an elongate gas-bladder, whose membranous bladder is about 3 times as long as the rete plus gas gland and is partly invested with fat. Contiguous M. pumilus has only 8 scales in a diagonal series. fewer scale rows (usually about 32 ). fewer vertebrae (usually $12+16$ ), and an elongate gas-bladder, whose membranouse bladder is about 4-5 times as long as the rete plus gas gland and is partly invested with fat.

## Derivation of name.

Derived from the Latin, the species name simus ("pug-nosed") refers to the fancied flat or pug-nosed appearance rendered by the raised antorbital ridge.

Specimens examined.-400 from 104 collections.

Holotype: D 4010(1); 27.5 mm ; eastern North Atlantic, south of Canary Islands, $27^{\circ} 19^{\prime} \mathrm{N} 16^{\circ} 41^{\prime} \mathrm{W}$; capture, 1000 meters wire, bottom 3460 meters; 3meter conical ring trawl; 19 March 1930: 1945 hours; R/V "Dana".

Paratypes: Western North Atlantic. off New York: RBH (Woods Hole) 482, $39^{\circ} 47^{\prime}$ N $70^{\circ} 36^{\prime} \mathrm{W}, 290(\mathrm{n}), 1(25)$.

Eastern North Atlantic, between $5^{\circ} \mathrm{N}$ and $40^{\circ} \mathrm{N}$ and west of $35^{\circ} \mathrm{W}: \mathrm{BM}(\mathrm{NH})$ 1930.1.12.977, $6^{\circ} 55^{\prime} \mathrm{N} 15^{\circ} 54^{\prime} \mathrm{W}$, 800 , 1(23); D $829(1), 25^{\circ} 07^{\prime}$ N $19^{\circ} 20^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 5(15-22)$; D $1157(3), 21^{\circ} 57^{\prime} \mathrm{N} 22^{\circ} 58^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 2(16-21)$; D $1157(5), 21^{\circ} 57^{\prime}$ N $22^{\circ} 58^{\prime}$ W, 5000 w (d), $1(18)$; D $1380(1), 39^{\circ} 26^{\prime}$ N $21^{\circ} 51^{\prime} \mathrm{W}, 1000 \mathrm{w}$ (n), $1(28)$; D $4003(1), 8^{\circ} 26^{\prime}$ ․ $15^{\circ} 11^{\prime} \mathrm{W}, 6000 \mathrm{w} .(\mathrm{d}), 1(22)$; D $4003(9), 8^{\circ} 26^{\prime} \mathrm{N} 15^{\circ} 11^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 6(16-22)$; D $4004(2), 10^{\circ} 21^{\prime} \mathrm{N} 17^{\circ} 59^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n})$, $1(23)$; D $4004(3), 10^{\circ} 21^{\prime}$ N $17^{\circ} 59^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 2(14-19)$; D $4010(3), 27^{\circ} 19^{\prime}$ N $16^{\circ} 41^{\prime} \mathrm{W}$, $300 \mathrm{w} .(\mathrm{n}), 5(13-22)$; D $4017(1)$, $29^{\circ} 11^{\prime} \mathrm{N} 14^{\circ} 14^{\prime} \mathrm{W}, 5000 \mathrm{w} .(\mathrm{d}), 1(28) ; \mathrm{D} 4017(7), 29^{\circ} 13^{\prime} \mathrm{N} 14^{\circ} 12^{\prime} \mathrm{W}, 1000 \mathrm{w} .(\mathrm{n}), 1(26) ; \mathrm{D} 4019(3), 33^{\circ} 08^{\prime} \mathrm{N} 10^{\circ} 22^{\prime} \mathrm{W}$, 3000 w .(d), $1(28)$; D $4192(6), 39^{\circ} 57^{\prime} \mathrm{N} 24^{\circ} 59^{\prime} \mathrm{W}, 500 \mathrm{w} .(\mathrm{n}), 4(15-19)$; GNM $1431,36^{\circ} 40^{\prime} \mathrm{N} 13^{\circ} 05^{\prime} \mathrm{W}, 400 \mathrm{w} .(\mathrm{n}), 1(22)$.

Equatorial North Atlantic and South Atlantic, between $4^{\circ} \mathrm{N}$ and $35^{\circ} \mathrm{S}: \mathrm{BM}(\mathrm{NH})$ 1930.1.12.978, $32^{\circ} 45^{\prime} \mathrm{S} 8^{\circ} 47^{\prime} \mathrm{W}$, $650,1(27) ; \mathrm{BM}(\mathrm{NH})$ 1930.1.12.979-980, $2^{\circ} 44^{\prime} \mathrm{S}^{\circ}{ }^{\circ} 57^{\prime} \mathrm{W}, 175,2(22)$; CZM (Java-South Africa Expedition), $15^{\circ} 52^{\prime} \mathrm{S}$ $6^{\circ} 02^{\prime}$ W, $3(23-27)$; D $3964(1), 25^{\circ} 19^{\prime}$ S $36^{\circ} 13^{\prime}$ E, 1000w.(n), 1(24); D $3980(1), 23^{\circ} 26^{\prime}$ S $3^{\circ} 56^{\prime}$ E, $1000 \mathrm{w} .(\mathrm{n}), 1(25) ;$ D
 $12^{\circ} 33^{\prime}$ W, $300 \mathrm{w} .(\mathrm{n}), 4(19-24)$.

Additional material: Eastern Gulf of Mexico, Straits of Florida: D $1225(2), 23^{\circ} 58^{\prime} \mathrm{N} 83^{\circ} 22^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 5(14-19)$.
Eastern North Atlantic, bet ween $5^{\circ} \mathrm{N}$ and $40^{\circ} \mathrm{N}$ and west of $35^{\circ} \mathrm{W}: \mathrm{D} 830(1), 24^{\circ} 44^{\prime} \mathrm{N} 22^{\circ} 32^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 2(14-20)$; D $830(2), 24^{\circ} 44^{\prime} \mathrm{N} 22^{\circ} 32^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 3(14)$; D $1107(1), 36^{\circ} 28^{\prime} \mathrm{N} 8^{\circ} 38^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 12 \mathrm{PL}-\mathrm{Hg}(10-15)$; D $1107(2)$, $36^{\circ} 28^{\prime} \mathrm{N} 8^{\circ} 38^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 200 \mathrm{w} .(\mathrm{n}), 10 \mathrm{PL}-\mathrm{Hg}(9-17)$; D $1107(10), 36^{\circ} 28^{\prime} \mathrm{N} 8^{\circ} 38^{\prime} \mathrm{W}, 75 \mathrm{w} .(\mathrm{n}), 3 \mathrm{PL}-\mathrm{Hg}(8-17)$; D $1108(1), 35^{\circ} 11^{\prime} \mathrm{N} 8^{\circ} 28^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 34 \mathrm{PL}-\mathrm{Hg}(14-16)$; D $1110(1), 34^{\circ} 18^{\prime} \mathrm{N} 8^{\circ} 10^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 2 \mathrm{PL}-\mathrm{Hg}(11-16)$; D $1116(2), 35^{\circ} 18^{\prime} \mathrm{N} 6^{\circ} 51^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 8 \mathrm{PL}-\mathrm{Yg}(9-15)$; D $1139(1), 35^{\circ} 37^{\prime} \mathrm{N} 7^{\circ} 24^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 6(14-18) ;$ D $1139(2)$, $35^{\circ} 37^{\prime} \mathrm{N} 7^{\circ} 24^{\prime} \mathrm{W}, 200 \mathrm{w} .(\mathrm{n}), 1(18) ; \mathrm{D} 1141(11), 34^{\circ} 15^{\prime} \mathrm{N} 16^{\circ} 53^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 1(17) ; \mathrm{D} 114(16), 34^{\circ} 15^{\prime} \mathrm{N} 16^{\circ} 53^{\prime} \mathrm{W}$, $500 \mathrm{w} .(\mathrm{n}), 3(14-16)$; D $1142(10), 33^{\circ} 26^{\prime} \mathrm{N} 16^{\circ} 59^{\prime} \mathrm{W}, 1000 \mathrm{w} .(\mathrm{n}), 8(14-15)$; D $1145(1), 32^{\circ} 07^{\prime} \mathrm{N} 16^{\circ} 50^{\prime} \mathrm{W}, 500 \mathrm{w} .(\mathrm{n}), 1(16)$; D $1146(2), 32^{\circ} 00^{\prime} \mathrm{N} 19^{\circ} 11^{\prime} \mathrm{W}, 400 \mathrm{w} .(\mathrm{n}), 4 \mathrm{PL}-\mathrm{Hg}(+-16)$; D $1148(1), 32^{\circ} 55^{\prime} \mathrm{N} 21^{\circ} 51^{\prime} \mathrm{W}, 500 \mathrm{w} .(\mathrm{n}), 13 \mathrm{PL}-\mathrm{Hg}(9-19)$; D $1148(2), 32^{\circ} 55^{\prime} \mathrm{N} 21^{\circ} 51^{\prime} \mathrm{W}, 400 \mathrm{w} .(\mathrm{n}), 21 \mathrm{PL}-\mathrm{Hg}(8-16)$; D $1152(5), 30^{\circ} 17^{\prime} \mathrm{N} 20^{\circ} 44^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 1(18) ; \mathrm{D} 1153(5)$, $28^{\circ} 48^{\prime} \mathrm{N} 20^{\circ} 45^{\prime} \mathrm{W}, 500 \mathrm{w} .(\mathrm{n}), 2(15-16)$; D $1153(6), 28^{\circ} 48^{\prime} \mathrm{N} 20^{\circ} 45^{\prime} \mathrm{W}, 400 \mathrm{w} .(\mathrm{n}), 4 \mathrm{PL}-\mathrm{Hg}(8-18) ; \mathrm{D} 1157(2), 21^{\circ} 57^{\prime} \mathrm{N}$ $22^{\circ} 58^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 3(14-15)$; D 1159(7), $17^{\circ} 55^{\prime} \mathrm{N} 24^{\circ} 35^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 1(19)$; D $1160(4), 15^{\circ} 50^{\prime} \mathrm{N} 26^{\circ} 32^{\prime} \mathrm{w}, 300 \mathrm{w} .(\mathrm{n})$, 1(16); D $1162(3), 13^{\circ} 35^{\prime} \mathrm{N} 30^{\circ} 11^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 1(14)$; D $1379(5), 38^{\circ} 02^{\prime} \mathrm{N} 25^{\circ} 52^{\prime} \mathrm{W}, 200 \mathrm{w} .(\mathrm{n}), 1(14)$; D $3534(1), 35^{\circ} 12^{\prime} \mathrm{N}$ $9^{\circ} 45^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 10 \mathrm{PL}(9-12)$; D $3535(2), 34^{\circ} 21^{\prime} \mathrm{N} 12^{\circ} 19^{\prime} \mathrm{W}, 200 \mathrm{w} .(\mathrm{n}), 33 \mathrm{PL}(5-8)$; D $3536(1), 34^{\circ} 08^{\prime} \mathrm{N} 13^{\circ} 05^{\prime} \mathrm{W}$, $300 \mathrm{w} .(\mathrm{n}), 57 \mathrm{PL}(5-12)$; D $3538(1), 32^{\circ} 25^{\prime} \mathrm{N} 18^{\circ} 32^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 11 \mathrm{PL}(6-8)$; D $4003(5), 8^{\circ} 26^{\prime} \mathrm{N} 15^{\circ} 11^{\prime} \mathrm{W}, 2000 \mathrm{w} .(\mathrm{d})$, $1(15)$; D $4006(2), 15^{\circ} 31^{\prime} \mathrm{N} 18^{\circ} 05^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 1(16)$; D $4009(2), 24^{\circ} 37^{\prime} \mathrm{N} 17^{\circ} 27^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 1(21) ;$ D $4009(9), 24^{\circ} 37^{\prime} \mathrm{N}$ $17^{\circ} 27^{\prime} \mathrm{W}, 2500 \mathrm{w}$.(d), $3(14)$; D $4010(2), 27^{\circ} 19^{\prime} \mathrm{N} 16^{\circ} 41^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 2(14) ;$ D 4014(2), $28^{\circ} 09^{\prime} \mathrm{N} 15^{\circ} 19^{\prime} \mathrm{W}, 1200 \mathrm{w} .(\mathrm{n})$, 1(14); D 4014(4), $28^{\circ} 09^{\prime} \mathrm{N} 15^{\circ} 19^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 2(14)$; D 4192(7), $39^{\circ} 57^{\prime} \mathrm{N} 24^{\circ} 59^{\prime} \mathrm{W}, 400 \mathrm{w} .(\mathrm{n}), 2(16)$.

Equatorial North Atlantic and South Atlantic, between $4^{\circ} \mathrm{N}$ and $35^{\circ} \mathrm{S}$ : D $3980(2), 23^{\circ} 26^{\prime} \mathrm{S} 3^{\circ} 56^{\prime}$ E, $600 \mathrm{w} .(\mathrm{n}), 1(15)$; D) $3980(3), 23^{\circ} 26^{\prime}$ S $3^{\circ} 56^{\prime}$ E, $300 \mathrm{w} .(\mathrm{n}), 1(13)$; D $3996(2), 15^{\circ} 41^{\prime}$ S $5^{\circ} 50^{\prime} \mathrm{W}, 3000 \mathrm{w} .(\mathrm{nd}), 1(21) ;$ D $3996(8), 15^{\circ} 41^{\prime} \mathrm{S} 5^{\circ} 50^{\prime} \mathrm{W}$, $300 \mathrm{w} .(\mathrm{n}), 1(18) ; \mathrm{D} 4001(3 \mathrm{~b}), 3^{\circ} 56^{\prime} \mathrm{N} 12^{\circ} 33^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 3(14--15)$; D $4001(4), 3^{\circ} 56^{\prime} \mathrm{N} 12^{\circ} 33^{\prime} \mathrm{W}, 100 \mathrm{w} .(\mathrm{n}), 18 \mathrm{PL}(5-12)$.

Tropical Indo-Pacific, from near Madagascar, across Indian Ocean, through Indonesia, northeast to western central North Pacific: D 3678(5), $4^{\circ} 05^{\prime}$ S $128^{\circ} 16^{\prime}$ E, 1000 w (dn), $1(18)$; D $3678(6), 4^{\circ} 05^{\prime}$ S $128^{\circ} 16^{\prime}$ E, $1000 \mathrm{w} .(\mathrm{n}), 1(29)$; D $3689(5)$, $7^{\circ} 14^{\prime}$ ㄱ $111^{\circ} 49^{\prime}$ E, $1000 \mathrm{w} .(\mathrm{n}), 1(13)$; D $3689(7), 7^{\circ} 14^{\prime} \mathrm{N} 111^{\circ} 49^{\prime} \mathrm{E}, 600 \mathrm{w} .(\mathrm{n}), 1(26) ;$ D $3689(8), 7^{\circ} 14^{\prime} \mathrm{N} 111^{\circ} 49^{\prime} \mathrm{E}, 300 \mathrm{w} .(\mathrm{n})$, 2(13); D $3712(1), 12^{\circ} 44^{\prime} \mathrm{N} 110^{\circ} 45^{\prime} \mathrm{E}, 1000 \mathrm{w}$ (n), $1(26)$; D $3712(3), 12^{\circ} 44^{\prime} \mathrm{N} 110^{\circ} 45^{\prime} \mathrm{E}, 300 \mathrm{w} .(\mathrm{n}), 1(14)$; D $3714(4), 15^{\circ} 22^{\prime} \mathrm{N}$ $115^{\circ} 20^{\prime}$ E, $100 \mathrm{w} .(\mathrm{n}), 2(13-16)$; D 3815(4), $3^{\circ} 36^{\prime}$ S $97^{\circ} 37^{\prime}$ E, 1000 w.(n), $1(27)$; D $3850(1), 6^{\circ} 01^{\prime}$ S $93^{\circ} 12^{\prime}$ E, $600 \mathrm{w} .(\mathrm{n})$, 1(25); D $3915(3), 3^{\circ} 14^{\prime} \mathrm{N} 75^{\circ} 21^{\prime} \mathrm{E}, 300 \mathrm{w} .(\mathrm{n}), 2(13-16)$; D $3917(8), 1^{\circ} 45^{\prime} \mathrm{N} 71^{\circ} 05^{\prime} \mathrm{E}, 300 \mathrm{w} .(\mathrm{n}), 2 \mathrm{PL}(10-13)$; D $3919(2)$, (f07' S $63^{\circ} 56^{\prime}$ E, $600 \mathrm{w} .(\mathrm{n}), 2(17-25)$; D $3920(8), 1^{\circ} 12^{\prime}$ S $62^{\circ} 19^{\prime} \mathrm{E}, 300 \mathrm{w} .(\mathrm{n}), 2(13)$; D $3922(2), 3^{\circ} 45^{\prime} \mathrm{S} 56^{\circ} 33^{\prime} \mathrm{E}, 600 \mathrm{w} .(\mathrm{n})$, $1(25)$; V $3625,29^{\circ} 06^{\prime}$ N $154^{\circ} 00^{\prime}$ E, 2700, $1(20)$.

Western tropical Pacific, north of and off New Zealand: D 3620(3), 2447' S $170^{\circ} 19^{\prime}$ E, 300w.(n), 4(19-23); D 3621(3), $27^{\circ} 47^{\prime}$ S $172^{\circ} 24^{\prime}$ E, 3000 w .(d), $1(18)$; D $3623(3), 27^{\circ} 21^{\prime}$ S $175^{\circ} 11^{\prime} \mathrm{E}, 600 \mathrm{w} .(\mathrm{n}), 2(13-14)$; D $3623(4), 7^{\circ} 21^{\prime} \mathrm{S} 175^{\circ} 11^{\prime} \mathrm{E}$, $300 \mathrm{w} .(\mathrm{n}), 1(16)$; D $3624(8), 28^{\circ} 20^{\prime}$ S $176^{\circ} 56^{\prime}$ E, 300w.(n), 1(25); D $3626(2), 27^{\circ} 00^{\prime}$ S $177^{\circ} 41^{\prime}$ W, $600 \mathrm{w} .(\mathrm{n}), 1(21)$; D $3627(1)$, $30^{\circ} 08^{\prime}$ S $176^{\circ} 50^{\prime}$ W, 5000 w .(d), $1(28)$; D $3639(1), 39^{\circ} 19^{\prime}$ S $179^{\circ} 18^{\prime}$ E, 300 w .(n), 1(24).

North Pacific Central Water Mass, from $180^{\circ} \mathrm{W}$ to $120^{\circ} \mathrm{W}$ : D $4774,31^{\circ} 10^{\prime} \mathrm{N} 171^{\circ} 35^{\prime} \mathrm{W}, 220 \mathrm{w} .(\mathrm{n}), 2 \mathrm{PL}(9-10)$; POFI $1804,30^{\circ} 08^{\prime} \mathrm{N} 171^{\circ} 48^{\prime} \mathrm{W}$, $200(\mathrm{n}), 2(25-27)$; POFI $1805,26^{\circ} 11^{\prime} \mathrm{N} 167^{\circ} 17^{\prime} \mathrm{W}, 200(\mathrm{n}), 1(22)$; POFI $1811,29^{\circ} 54^{\prime} \mathrm{N}$ $168^{\circ} 32^{\prime}$ W. 1(27); POFI 1812, $27^{\circ} 37^{\prime} \mathrm{N} 177^{\circ} 58^{\prime} \mathrm{W}$, $200(\mathrm{n})$, $1(23)$; POFI $1814,27^{\circ} 11^{\prime} \mathrm{N} 170^{\circ} 54^{\prime} \mathrm{W}, 200(\mathrm{n}), 1(22)$; POFI $1818,25^{\circ} 37^{\prime} \mathrm{N} 157^{\circ} 30^{\prime} \mathrm{W}, 200(\mathrm{n}), 1 \mathrm{PL}(13)$; SIO $51-375,31^{\circ} 54^{\prime} \mathrm{N} 152^{\circ} 22^{\prime} \mathrm{W}, 3280,1(25)$; SIO $54-96,24^{\circ} 36^{\prime} \mathrm{N}$ $1210^{\circ} 07^{\prime} \mathrm{W}, 189(\mathrm{n}), 1(26) ; \mathrm{V} 3783,22^{\circ} 12^{\prime} \mathrm{N} 174^{\circ} 31^{\prime} \mathrm{W}, 1000$, $1(26)$; V $3825,25^{\circ} 39^{\prime} \mathrm{N} 176^{\circ} 25^{\prime} \mathrm{W}, 4000,1(13)$.

## Melamphaes hubbsi, new species.

Fig. 36.

## Distribution.

The 3 captures (Fig. 48) of M. hubbsi are from the central tropical South Atlantic, northwest and southeast of St. Helena Island ( $11^{\circ} \mathrm{S}-19^{\circ} \mathrm{S}$ ). Vertically, halfgrown and adults were taken in trawls as shallow as 150 meters.

## Counts and measurements.

Counts:-Because of the small size (6) of the samples, ranges will be given, followed in parentheses by the mode rather than the average : dorsal III, 14-16 (15) ; anal I, 8; caudal $4+10-9+4$; pectoral 15 ; pelvic I, 7; scale rows $35-36$ (35); scales in diagonal series 10 or 11 (10); vertebrae 28-29 (28); gill rakers on first arch $3-4+11 \cdots 12(3+12)$; gill rakers on lower limb of fourth arch $7-8(7)$; mandibular pores $5-6$ (5).

Proportions:- Usually based on samples of 6 halfgrown and adults ( ${ }^{*}, 3$ adults), the following are proportions for which the data suggest little or no allometric change or are insufficient to detect it. Because of the small size of the samples, only the ranges are given. Predorsal $396-413$; end of dorsal to caudal 325--351;
postdorsal *615-629; postorbital *211-220; orbit to cheek ridge 62-69; head width $165-183$; interorbital $94-107$; length of frontal fossa $122-133$; width of frontal fossa $71-75$; prepectoral *333-346; prepelvic *357-378; isthmus to pelvic *310-333; pelvic to anal *280-296; pectoral *300-305; pelvic *198-211; preanal $621-635$; anal to caudal * $369-398$; length of caudal peduncle $260-289$; depth of caudal peduncle ${ }^{*} 99$ -104 ; upper jaw $146-156$; orbit to cheek angle 89-108; snout length * $82-87$; suborbital $48-55$; diameter of pupil 23-26.

Based on 3 "adults" ( $21-25 \mathrm{~mm}$.) and 3 halfgrown ( $16-18 \mathrm{~mm}$.), the following are proportions for which the data suggest allometric change.

|  | Body depth | Head length | Snoutpreopercle | Head depth |
| :---: | :---: | :---: | :---: | :---: |
| Ad | 252-254 | 329-338 | 223-226 | 230-236 |
| Hg | 263-270 | 335-345 | 228-244 | 242-253 |
| Eye |  |  |  |  |
|  | Ad | 44-46 |  |  |
|  | Hg | 46-51 |  |  |

## Description.

Body and head form:-The streamlined body narrows gradually at the anus to a tapered caudal peduncle, which is $2.5-2.6$ times as long as deep. From the dorsal origin to the frontal knob the profile. in contrast with M. simus, descends straightly or angles over the preopercle. The ventral contour of the head curves slightly outward from the pelvic to the isthmus, where it abruptly bends up to the mandibular symphysis. The diameter of the eye is subequal to or slightly less than the suborbital width and measures 0.50 0.55 times the snout length. From the premaxillary symphysis to the anterior end of the frontal knob is about $0.9-1.0$ times the distance between the anterior nostrils.

Head ridges:-The antorbital ridge is well developed, raised, and outstanding; but because the snout is slightly more protrusive than in M. simus, its side appears less stubbed. A very obtuse angle in the frontal margin over the front of the pupil gradually narrows the interorbital space. Between these angles, the interorbital width equals or slightly exceeds the distance from the orbit to the preopercular edge.

Sensory pores:-The pores in the group inside the cheek angle usually number $2 ; 1$ of 8 counts is 3 . Those in the group under the posteroventral angle of the orbit number 2 . In the group on the supratemporal canal directly above the preopercle, the pores number 4 . None of the preopercular pores remains. On the outer margin of the mandible, from just behind the angle to the symphysis, the pores usually number $1+1+2+1$; 1 of 5 counts is $1+2+2+1$. The pore on the outer surface of the mandible near the symphysis is about two thirds the size of its equivalent behind the symphysis.


Fig. 38. Melamphaes hubbsi, n. sp. Holotype, traced and modiffed from photograph (standard length $\mathbf{2 5 . 2} \mathbf{~ m m}$.)

Operculum:-At the preopercular angle a feeble projection marks the end of a weak ridge that originates near the cheek angle. A very weak ridge ending in a small projection may traverse the posteroventral part of the interopercle; the last branchiostegal, however, is evenly rounded.

Jaws and teeth:-The maxillary overreaches by half the lens diameter a vertical from the posterior edge of the bony orbit. The tooth formula is for the 3 "adults" $4-5 / 3$ and for the 3 halfgrown $2-3 / 2$. Although in the expanded part of the premaxillary tooth-band the inner 3-4 rows of teeth are either horizontal or oblique, the outer rows, like the 2 or 3 rows in the mandible, align more irregularly. Near the symphysis this band is uniserial. For the pharyngeal teeth, ranges for the 3 "adults" are followed in parentheses by ranges for 2 halfgrown: they number $9-17(8-10)$ on the second pharyngobranchial, 22-34 (15-20) on the third, $8-15(7-8)$ on the fourth, and $10-15(7-11)$ on the third epibranchial.

Gill rakers:-The gill rakers usually number $3-4+12 ; 1$ of 6 counts is $3+11$. On the first arch they are moderately long and somewhat widely compressed, with the spaces between them about $1.33-1.5$ times the greatest width, near the middle, of the larger rakers. The longest raker, at the angle, measures about 1.2-1.33 times the diameter of the eye. The rakers on the lower fourth arch number 7 or 8 .

Seales:-Represented almost entirely by pockets, the scale rows usually number 35 or 36 . Five to seven scallops, between which end distinct "radii" (formed of sharp bends in the circuli), render the anterior margin of a typical body scale irregular; the posterior margin is usually eroded. The focus is usually about half as far from the anterior border of the scale as from the posterior.

Fins:-The modal dorsal count is III, 15; 2 of 6 counts are III, 14 or III, 16. The anal originates under the third or fourth from last dorsal ray.

Internal characters:-The vertebrae usually number $12+16 ; 1$ of 6 counts is $12+17$. The haemal arch of the first caudal vertebra bears no spurs, but thickens at the base of the slender, retrorse haemal spine. Anteriorly, the rete and gas gland of the elongate gas-bladder measure only about a fifth or sixth the length uf the entire, fat-invested structure. Only about 2.5 times as long as deep, the thick stomach is dark in front, but lightens toward the end of the blind sac. Near the top of the blind sac the pigmentation assumes a pattern of irregular longitudinal bands.

Color:-On 2 "adults" the proximal parts of the pectoral rays are punctulate uniserially and the head epidermis is finely punctulate, especially on the cheek and about the eyes. The pharynx has faded to light brown. On the halfgrown deeper pigmentation marks the area along the dorsal fin, but no punctulations dot the head, fins, or body.

## Sex ratio and size at maturity.

Among the 6 specimens sexed, there are 2 males and 1 female. Only one specimen, a 25 mm . male, has near-ripe gonads.

## Distinctions.

In its species account $M$. simus is distinguished from M. hubbsi. The Indo-Pacific species M. danae has fewer scale rows (usually about 32 ), fewer vertebrae (usually $11+15$ or 16 ), a well-developed spur on the haemal arch of the first caudal vertebra, and a shorter length from end of dorsal to caudal (about 30-32 per cent of standard length). M. pumilus from the North Atlantic has fewer scales in a diagonal series (8), fewer scale rows (usually about 32), possibly more teeth in the jaws (tooth formula usually $6 / 4-5$ in adults), and a larger head (about 36-38 per cent of the standard length).

## Derivation of name.

M. hubbsi is named in honor of Dr. Carl L. Hubbs, in recognition of his broad interests in oceanography and the systematics of pelagic fishes.

Specimens examined.-6 from 3 collections.
Holotype: D 3981(3), specimen number 1, half-ripe male ( 25.2 mm .), central tropical South Atlantic, southeast of St. Helena Island, $19^{\circ} 16^{\prime} \mathrm{S} 1^{\circ} 48^{\prime} \mathrm{W}$, capture 300 metres wire, bottom 5070 meters; 2-meter conical stramin net: 19 February 1930, 2000 hours; R/V "Dana".

Paratypes: Central tropical South Atlantic, northwest and southeast of St. Helena Island ( $11^{\circ} \mathrm{S}-19^{\circ} \mathrm{S}$ ): D $3981(3)$ specimen number 2, data as for holotype, 1(21); D 3997(1), $11^{\circ} 00^{\prime}$ S $7^{\circ} 36^{\prime} \mathrm{W}, 1000 \mathrm{w} .(\mathrm{n}), 1(25)$; D $3997(3), 11^{\circ} 00^{\prime}$ S $7^{\circ} 36^{\prime}$ W, 300 w .(n), 3(16-17).

## Melamphaes danae, new species.

Fig. 37.

## Distribution.

A widely distributed Indo-Pacific species M. danae has been taken in the western tropical Indian Ocean off Madagascar, throughout Indonesia and northward to $25^{\circ} \mathrm{N}$, in the South Pacific southeastward to $110^{\circ} \mathrm{W}$, and in the equatorial North Pacific southwest of Hawaii (Fig. 61). In contrast with M. simus, M. danae exihibits little geographic variation. It is a relatively shallow-dweller; young, halfgrown, and adults were taken regularly. in net hauls to only $125-150$ meters.

## Counts and measurements.

Counts:-The following counts are usually based on samples of $75--82$. Vertebrae and total gill rakers on the first arch are further analyzed by locality under "Variation". Dorsal III, 14-16 (15.01); anal I, 8-9 (8.02); caudal $4-5+10-9+4-5(4.0-10.0-9.0+4.0)$; pectoral $14-16$ (14.99); pelvic 1 , 7 ; scale rows ( $\mathrm{n}=67$ ) $31-34(32.04)$; scales in diagonal series $(\mathrm{n}=64) 9-11$ (10.00); vertebrae $25-28$ (26.81); gill rakers on first arch $3-1+11-13(3.24+12.35)$; gill rakers on lower limb of fourth arch $6-8$ (7.19); mandibular pores ( $\mathrm{n}=63$ ) $4-5$ (4.84).

Proportions:--Based on 12 adults ( $19-21 \mathrm{~mm}$.) from over the entire geographical range of the species, the following proportions may or may not be allometric: end of dorsal to caudal 304-321 (313); postdorsal $589-615$ (605); postorbital $214-247$ (229); orbit to cheek ridge 61-71 (65); head depth 248-264 (254): head width $179-199$ (189); interorbital $107-118$ (113); length of frontal fossa 126-142 (137); width of frontal fossa $7 \pi-91$ (83); prepectoral 315-365 (343); prepelvic $350-396$ (375); isthmus to pelvic $308-358$ (328); pelvic to anal 288-348 (312); pectoral 276-326 (301); pelvic 208-245 (219); preanal 641-681 (656); anal to caudal 348-380 (360); length of caudal peduncle 232-260 (246); depth of caudal pedunch $95-107$ (101); snout length 83-94 (88).

The following are proportions, based on samples of $80-81$, for which the data suggest little or no allometric change: body depth $245-291$ (266); head length $332-383$ (355); suborbital $52-63$ ( 57 ).

Next are proportions for which the data suggest allometric change. Head length and predorsal are further analyzed by locality under "Variation". If the values of the proportions of the halfgrown are similar to those of the adults, the two categories are bracketed together. Proportions are based on 46 adults (Ad) $17-21 \mathrm{~mm}$., 16 halfgrown ( Hg ) $14-17 \mathrm{~mm}$., and 19 young (Yg) $10-13 \mathrm{~mm}$.

|  | Predorsal | Snoutpreopercle | Upper jaw | Orbitcheek angle |
| :---: | :---: | :---: | :---: | :---: |
| Ad |  |  | 144-162(153) | 92-109(100) |
|  | 404-447(427) | 212-257(239) | 151-169(158) | 88--105(97) |
| Yg. | 418-468(445) | 233-261(247) | 157-176(165) | 83-100(93) |

## Eye

| Ad | 46-52(47) |
| :---: | :---: |
| Hg | 46-53(51) |
| Yg. | 54-64(58) |



Fig. 37. Melamphaes danae, n. sp. A, holotype, traced and modified from photograph (standard length 21.2 mm ); B, postlarva, D 3683 (2) (s. 1.10 .7 mm .).

Description.
Body and head form:-The streamlined body narrows gradually from the anus to a tapered caudal peduncle, which is about 2.5 times as long as deep. From the dorsal origin to the frontal knob the profile descends in a weakly convex curve. Symmetrically with the dorsal, the ventral contour of the head curves slightly outward from the pelvic symphysis to the isthmus, where it abruptly bends up to the mandibular symphysis. The diameter of the eye measures $0.80-0.86$ times the suborbital width and about $0.52-0.56$ times the snout length. From the premaxillary symphysis to the anterior end of the frontal knob is $0.85-0.90$ times the distance between the anterior nostrils.

Head ridges:-The antorbital ridge is well developed and raised, but because the snout is more protrusive than in M. simus, its side appears less stubbed. A curve or very obtuse angle in the frontal margin over the front of the pupil gradually narrows the interorbital space. Between these angles, the interorbital width exceeds, sometimes by as much as the lens diameter, the distance from the orbit to the preopercular edge.

Sensory pores:--The pores in the group inside the cheek angle number 2. Those in the group under the posteroventral angle of the orbit number 1 or 2 . In the group on the supratemporal canal directly above the preopercle, the pores usually number $4 ; 4$ of 21 counts are 3 . None of the specimens has a full complement of pores on the preopercle, but there appear to be 2 or 3 pores in the first and fourth groups. On the outer margin of the mandible, from just behind the angle to the symphysis, the pores usually number $1+1+2+1$; 10 of 63 counts are $1+1+1+1$ or $1+2 \cdots$. The pore on the outer surface of the mandible near the symphysis is $0.67-1.0$ times the size of its equivalent behind the symphysis.
${ }^{( }$perculum:--At the preopercular angle a feeble projection marks the end of a weak ridge that originates
near the cheek angle (in a few specimens another weak ridge may run above this). A very weak ridge ending in a small projection at the margin may traverse the posteroventral part of the interopercle; the posteroventral margin of the last branchiostegal is very slightly produced or is evenly rounded.

Jaws and teeth:- The relatively short maxillary barely reaches a vertical from the posterior margin of the eve. The tooth formula is for adults $2-5 / 2-3$, for halfgrown $2-3 / 1-2$, and for young $1-2 / 1 \cdots 2$ The expanded part of the premaxillary tooth-band usually includes no noticeably oblique inner rows; all teeth, like those in the mandible are scattered or aligned in nearly horizontal rows. Near the symphysis this band is uniserial. In the mandible the teeth behind the wider band at the symphysis are usually uniserial. In adults the pharyngeal teeth number 8-13 on the second pharyngobranchial, 19-35 on the third, 6-11 on the fourth, and $11-21$ on the third epibranchial.

Gill rakers:- The gill rakers usually number $3-4+12-13 ; 4$ of 82 counts are $3+11$. On the first arch they are moderately long, but somewhat compressed, with the spaces between them about $1.5-1.75$ times the greatest width, near the middle, of the larger rakers. The longest raker, on the ceratobranchial near the angle, measures about $1.1-1.2$ times the diameter of the eye. The rakers on the lower fourth arch usually number $7 ; 18$ of 81 counts are 8,5 counts are 6 .

Scales:--l'sually represented entirely by pockets, the scale rows modally number 32. Five to seren scallops, between which end well developed "radii" (formed of sharp bends in the circuli), render the anterior margin of a typical body scale irregular; though slightly eroded, the posterior margin is even. The focus is nearest the anterior margin of the scale.

Fins:-The modal dorsal count is III, 15; 28 of 82 counts are III, 14 or III, 16. The anal rays almont always number I, 8 ; only 2 of 82 counts are I, 9 . Although in young the anal originates under the fourth or fifth from last dorsal ray, it is under the second to fourth from last in adults. The pectoral rays almost always number 15; only 7 of 78 counts are 14 or 16 .

Internal characters:-The modal vertebral count is $11+16$. Although only 8 of 75 precaudal count are 12, 21 caudal counts are 15 or, more rarely, 14 vertebrae. The haemal arch of the first caudal vertebra bears well-developed spurs. Almost half the length of the arch, they project downward from near the anteri,n end of the base of the slender, retrorse haemal spine. Basally, the haemal spine is relatively wide; it expand immediately below the spurs. Anteriorly, the rete and gas gland of the well-developed gas-bladder occup: about a fifth or sixth of the entire structure. In the long, slender membranous bladder pockets of gas are interspersed between the relatively few areas of adipose tissue. About $2.0-2.5$ times as long as deep, the thich stomach is dark in front, but lightens toward the end of the blind sac; although the posterior dorsal surface is mottled, the ventral surface of the blind sac is almost unpigmented.

Color:-Although due to abrasion most scale pockets are lightest centrally, the integument is not generally mottled. The bases of the median fins usually are no darker than the rest of the body, which, with the heal and fins, is never punctulate. In unfaded specimens the pharynx is dark brown to blackish, frequently with a superficial bluish sheen. Light brown pigment mottles the coelomic peritoneum.

In color no distinguishing characters mark the young. The slender postlarvae, however, are somewhat distinctive. Whereas most of the body is colorless, distinct narrow bands of pigment or rows of melanophore in front of and on either side of the dorsal, extend, usually interrupted over the middle of the caudal peduncle, to the caudal fin. A few isolated melanophores accentuate the urosome and the anal base. A characteristic saddle-shaped pigmentation just behind the anal fin precedes a short band on the caudal peduncle. juvt before the caudal base. On the side of the caudal peduncle a pigment spot marks the region of the urostyle: behind this a pigmented area, darkest at the caudal fork, originates immediately behind the hypural fan Finally, melanophores and pigment spots dot the head region: above the pectoral fin, over the brain, and above the eyes. Melanophores do not fleck the gill arches, except in the near-metamorphosing stages.

Sex ratio and size at maturity.
Among the 70 specimens sexed there are 33 females, but only 19 males. With mature adults ranging in size from 18 to 21 mm . in standard length, $M$. danae contains the smallest individuals of any melamphaid.

Geographical variation.
There is no significant morphological variation between samples of danae. Only numbers of vertebrae and total gill rakers on the first arch, and values of predorsal and head length (Fig. 38) exhibit possible differences, though of no significance. Samples were analyzed from three localities: A) western tropical Indian Ocean, ,fll Madagascar; B) Indonesia, northward to $24^{\circ} \mathrm{N}$ and eastward to $145^{\circ} \mathrm{E}$; and C) equatorial Pacific and central south Pacific, north of $30^{\circ} \mathrm{S}$, east of $150^{\circ} \mathrm{E}$, and west of $110^{\circ} \mathrm{W}$ (most spe(imens are from the western South Pacific).

Considcring its wide geographic range, M. danae shows relatively little spacial variation. Although the 4 characters analyzed exhibit similar variational patterns, the differences are not significant. With lowest values in specimens from area $A$ and highest values in specimens from area $C$, all these characters may vary clinically from east to west; values of specimens from area B are almost exactly intermediate. This clinal variation and the similarity between the 3 groups indicates broad genetic interchange beiween populations.

## Distinctions.

The spurs on the first haemal arch distinguish M. danae from the other 3 "dwarf" species. M. danae is further distinguished from partly sympatric II. simus and allopatric M. hubbsi in lineir species accounts. M. pumilus from the North Atlantic has fewer seales in a diagonal series (8), more vertebrae (usually $12+16$ ), on the average more


PREDORSAL

head length


Fig. 38. Geographical variation of Melamphaes danae in selected counts and proportions between 3 areas. Area A, western tropical Indian Ocean. off Madagascar: area $B$, Indonesia, northward to $24^{\circ} \mathrm{N}$ and eastward to $145^{\circ} \mathrm{E}$ : and area C . equatorial Pacific and central South Pacific, north of $30^{\circ} \mathrm{S}$, east of $150^{\circ} \mathrm{E}$, and west of $110^{\circ} \mathrm{W}$ (most specimens are from the western South Pacific). For further explanation see Fig. 19. gill rakers (usually $4+13$, but as many as $4+14$ on the first arch; usually 8 , but as many as 9 on the lower fourth arch), more teeth (tooth formula, $6 / 4-5$ in adults), and a greater proportion, orbit to cheek ridge (about 12 per cent of standard length).

## Derivation of name.

M. danae is named after the $\mathrm{R} / \mathrm{V}$ "Dana", in honor of her scientific party and crew, who, by compiling and interpreting vast quantities of facts concerning the biology, physics, and chenistry of the oceans, have contributed much more than their share to the establishment of the science of biological oceanography.

## Specimens examined.-131 from 49 collections.

Holotype: D $3683(1)$; mature male ( 21.2 mm .) ; Indonesia, Celebes Sea, $4^{\circ} 03^{\prime} \mathrm{N} 123^{\circ} 26^{\prime}$ E; capture 5000 meters wire, botton 4940 meters; 3-meter conical ring trawl; 2 April 1929; 1320 hours; R/V "Dana".

Paratypes: Western tropical Indian Ocean, off Madagascar (area A): D 3929(2a), $12^{\circ} 11^{\prime} \mathrm{S} 50^{\circ} 18^{\prime} \mathrm{E}, 500 \mathrm{w} .(\mathrm{n})$, 2(14-21); D 3934(4, 9, 14 and 19), $11^{\circ} 24^{\prime} \mathrm{S} 50^{\circ} 05^{\prime} \mathrm{E}, 300 \mathrm{w} .(\mathrm{n}), 2(19)$; D $3935(1), 10^{\circ} 50^{\prime} \mathrm{S} 48^{\circ} 30^{\prime} \mathrm{E}, 500 \mathrm{w} .(\mathrm{n}), 1(19)$; D $3952(1), 15^{\circ} 05^{\prime} \mathrm{S} 41^{\circ} 53^{\prime} \mathrm{E}, 500 \mathrm{w} .(\mathrm{n}), 10(12-21)$; D $3952(2), 15^{\circ} 05^{\prime} \mathrm{S} 41^{\circ} 53^{\prime} \mathrm{E}, 400 \mathrm{w} .(\mathrm{n})$, $5(12-20)$; D $3954(2), 16^{\circ} 53^{\prime} \mathrm{S}$ $42^{\circ} 12^{\prime} \mathrm{E}, 300 \mathrm{w}$.(n), 1(17).

Throughout Indonesia and eastward to $145^{\circ} \mathrm{E}$ : D $3682(3), 1^{\circ} 42^{\prime} \mathrm{N} 124^{\circ} 29^{\prime} \mathrm{E}, 300 \mathrm{w} .(\mathrm{n}), 4(11-20)$; D $3683(2)$, $4^{\circ} 03^{\prime} \wedge 123^{\circ} 26^{\prime} \mathrm{W}, 4000 \mathrm{w} .(\mathrm{d}), 5(11-21)$; D $3683(6), 4^{\circ} 08^{\prime} \mathrm{N} 123^{\circ} 00^{\prime} \mathrm{E}, 1000 \mathrm{w} .(\mathrm{n}), 1(20)$; D $3746(2), 3^{\circ} 50^{\prime} \mathrm{N} 131^{\circ} 42^{\prime} \mathrm{E}$, $600 \mathrm{w} .(\mathrm{n}), 17(11-20)$; D $3766(18), 1^{\circ} 13^{\prime} \mathrm{S} 138^{\circ} 42^{\prime} \mathrm{E}, 2900 \mathrm{w} .(\mathrm{d}), 1(19) ;$ D $3768(6), 1^{\circ} 20^{\prime} \mathrm{S} 138^{\circ} 42^{\prime} \mathrm{E}, 700 \mathrm{w} .(\mathrm{n}), 2(18-19)$; D 3768(9), $1^{\circ} 20^{\prime}$ S $138^{\circ} 42^{\prime}$ E, 400w.(n), 3(11-19).

Western North Pacific, south of Japan and north of the Philippines, north of $20^{\circ} \mathrm{N}$ and west of $145^{\circ} \mathrm{E}$ : V 3502 , $24^{\circ} 00^{\prime} \mathrm{N} 144^{\circ} 00^{\prime} \mathrm{E}, 7300,1(20)$; V $3750,20^{\circ} 04^{\prime} \mathrm{N} 126^{\circ} 58^{\prime} \mathrm{E}, 1000$, $1(21)$.

Central and equatorial South Pacific, north of $39^{\circ} \mathrm{S}$, east of $150^{\circ} \mathrm{E}$, and west of $110^{\circ} \mathrm{W}: \mathrm{D} 3570(4), 14^{\circ} 01^{\prime} \mathrm{S} 147^{\circ} 52^{\prime} \mathrm{W}$, 1000w.(n), 2(11-19); D 3586(4), $9^{\circ} 33^{\prime}$ S $170^{\circ} 40^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 1(19)$; D $3591(3), 5^{\circ} 03^{\prime} \mathrm{S} 175^{\circ} 30^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n})$, 2(16-21); SIO $58-307,15^{\circ} 45^{\prime} \mathrm{S} 112^{\circ} 07^{\prime} \mathrm{W}, 100(\mathrm{n}), 1(18)$; V $3663(50), 6^{\circ} 15^{\prime} \mathrm{S} 153^{\circ} 44^{\prime} \mathrm{E}, 8000,1(18)$; V $3849,20^{\circ} 33^{\prime} \mathrm{S} 168^{\circ} 38^{\prime} \mathrm{E}$, 6000, 2(18-19).

Equatorial North Pacific, southwest of the Hawaian Islands: SIO $56-127,13^{\circ} 03^{\prime} \mathrm{N} 166^{\circ} 04^{\prime} \mathrm{W}, 730(\mathrm{n}), 1(20)$.
Additional material: Western tropical Indian Ocean, off Madagascar: D $3929(2 \mathrm{~b}), 12^{\circ} 11^{\prime} \mathrm{S} 50^{\circ} 18^{\prime} \mathrm{E}$, $500 \mathrm{w} .(\mathrm{n})$, 2(12): D 3929(3), do., 400w.(n), 3 PL—AD(6-18); D 3929(4), do., 300w.(n), 1(15); D 3929(6), do., 300w.(n), 1 PL(-1): D $3930(3), 11^{\circ} 55^{\prime} \mathrm{S} 49^{\circ} 55^{\prime} \mathrm{E}, 300 \mathrm{w} .(\mathrm{n}), 1 \mathrm{PL}(6)$; D $3934(1+6+11), 11^{\circ} 24^{\prime} \mathrm{S} 50^{\circ} 05^{\prime} \mathrm{E}, 600 \mathrm{w} .(\mathrm{n})$, $5(13-15)$; D $3937(3)$, $9^{\circ} 26^{\prime} \mathrm{S} 46^{\circ} 05^{\prime} \mathrm{E}, 300 \mathrm{w} .(\mathrm{n}), 1(12)$; D 3941(1), $7^{\circ} 24^{\prime} \mathrm{S} 41^{\circ} 51^{\prime} \mathrm{E}, 600 \mathrm{w} .(\mathrm{n}), 1(12)$; D $3949(2), 11^{\circ} 33^{\prime} \mathrm{S} 41^{\circ} 44^{\prime} \mathrm{E}, 600 \mathrm{w} .(\mathrm{n})$, 1(12); D 3952(3), $15^{\circ} 05^{\prime} \mathrm{S} 41^{\circ} 53^{\prime} \mathrm{E}$, 300w.(n), 1(16); D 3959(2), $23^{\circ} 40^{\prime} \mathrm{S} 43^{\circ} 02^{\prime} \mathrm{E}$, 300w.(n), 1(15).

Eastern tropical Indian Ocean, southwest of Sumatra: D $3847(4), 12^{\circ} 02^{\prime} \mathrm{S} 96^{\circ} 43^{\prime} \mathrm{E}, 2000 \mathrm{w} .(\mathrm{n}), 3 \mathrm{PL}-\mathrm{YG}(10-12)$.
Throughout Indonesia and eastward to $145^{\circ} \mathrm{E}$ : D $3683(3), 4^{\circ} 03^{\prime} \mathrm{N} 123^{\circ} 26^{\prime} \mathrm{E}, 3000 \mathrm{w} .(\mathrm{d}), 1(12)$; D $3746(3), 3^{\circ} 50^{\prime}$ N $131^{\circ} 42^{\prime} \mathrm{E}, 300 \mathrm{w} .(\mathrm{n}), 1(11): \mathrm{D} 3751(2), 3^{\circ} 41^{\prime} \mathrm{N} 137^{\circ} 53^{\prime} \mathrm{E}, 600 \mathrm{w} .(\mathrm{n}), 12 \mathrm{PL}-\mathrm{YG}(10-11)$; D $3752(2), 2^{\circ} 10^{\prime} \mathrm{N} 138^{\circ} 20 \mathrm{E}$, $600 w .(n), 12 \mathrm{PL}-\mathrm{HG}(9-17)$; D $3768(8), 1^{\circ} 20^{\prime} \mathrm{S} 138^{\circ} 42^{\prime} \mathrm{E}, 500 \mathrm{w} .(\mathrm{n}), 3(11-13)$; D $3768(10), 1^{\circ} 20^{\prime} \mathrm{S} 138^{\circ} 42^{\prime} \mathrm{E}, 400 \mathrm{w} .(\mathrm{n}$. $3(11-19)$; D $3775(1), 0^{\circ} 02^{\prime} \mathrm{S} 131^{\circ} 18^{\prime} \mathrm{E}$, 400w.(n), 1(11).

Central and equatorial South Pacific, north of $30^{\circ} \mathrm{S}$, east of $150^{\circ} \mathrm{E}$, and west of $170^{\circ} \mathrm{W}: \mathrm{D} 3586(5), 9^{\circ} 43^{\prime} \mathrm{S} 170^{\circ} 40^{\prime} \mathrm{W}$, $200 \mathrm{w} .(\mathrm{n}), 2(11-12) ;$ D $3587(11), 11^{\circ} 00^{\prime} \mathrm{S} 172^{\circ} 37^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 1(15) ;$ D $3588(3), 13^{\circ} 10^{\prime} \mathrm{S} 173^{\circ} 20^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 1(12)$ : D $3593(8), 17^{\circ} 27^{\prime} \mathrm{S} 179^{\circ} 33^{\prime} \mathrm{E}, 300 \mathrm{w} .(\mathrm{n}), 2(12-13)$; D $3602(3), 20^{\circ} 00^{\prime} \mathrm{S} 174^{\circ} 29^{\prime} \mathrm{E}, 300 \mathrm{w} .(\mathrm{n}), 1(18) ; \mathrm{V} 3663(49), 6^{\circ} 15^{\prime}$ S $153^{\circ} 44^{\prime} \mathrm{E}, 5500,1(14)$; V $3663(51), 6^{\circ} 15^{\prime} \mathrm{S} 153^{\circ} 44^{\prime} \mathrm{E}, 3500,1(12)$.

## Melamphaes pumilus, new species. <br> Fig. 40.

Melamphaes microps (in part).—Bebbe, 1933: 181 ([see also M. typhlops and M. suborbitalis]; tabular compilation of specimens with depths of capture) ; 1937: 206 ( $\{$ see also M. microps, M. suborbitalis, and M. typhlops]; tabular summary of captures at $32^{\circ} 12^{\prime} \mathcal{N} 64^{\circ} 36^{\prime}$ W). Grey, 1955: 296 ([see also M. typhlops]; captures).

Melamphaes microps microps (misidentifications).-Parr, 1933: 16,17 (Bahama Ids. and off Bermuda; short diagnosis). Fowler, 1944: 441 (off Bahama Ids., after Parr).

Melamphaes microps subsp. (in part).—Parr, 1933: 17 ([see also M. suborbitalis]; Bahama Ids. and off Bermuda: comparisons).

## Distribution.

Abundant throughout its restricted range, M. pumilus occurs only in the western and central North Atlantic between $10^{\circ} \mathrm{N}$ and $40^{\circ} \mathrm{N}$ and west of 25 or $30^{\circ} \mathrm{W}$; the Sargasso Sea is its center of distribution (Fig. 48). Vertically at night, the postlarvac, young, and halfgrown occupy almost the same depth range, mainly below 50 meters; their greatest concentration is near 100 meters (Fig. 39). The adults, on the other hand, are seldom taken above 100 meters and are most common at 300-400 meters.

## Counts and measurements.

Counts: -The following counts are usually based on samples of 110 126. Dorsal rays, scale rows, and gill rakers on the upper first arch are further analyzed by locality under "Variation". Dorsal III, 14 1t
(14.87); anal I, 7-9 (7.97); caudal 4-5+10-9+3 - $(4.0+10.0-9.0+4.0)$; pectoral $14-16$ (14.99); pelvic I, $7-8$ (7.01); scale rows $30-33$ (31.81); scales in diagonal series 8 ; vertebrac $(\mathrm{n}=103)$ $27-28$ (27.75); gill rakers on first arch $3-4+12$ $14(3.68 \div 12.94)$; gill rakers on lower limb of fourth arch $7-9$ (7.93); mandibular pores 4-6 (4.97).

Proportions:--Based on 14 adults (19-22.5 mm .) from over the entire geographical range of the species, the following proportions may or may not he allometric: end of dorsal to caudal 298-335 (317); postdorsal 577-638 (604); postorbital 233260 (243); orbit to cheek ridge 71-84 (77); head Wepth 244-275 (258); head width 193-219 (201); interorbital 109-124 (116); length of frontal fossa 134 -i44 (139); width of frontal fossa 73-86 (79); prepectoral 333-377 (353); prepelvic 371-415 (386); isthmus to pelvic $320-346$ (332); pelvic to anal 288-332 (311); pectoral 297-311 (305); pelvic 208-239 (221); preanal 649-689 (666); anal to caudal 335-368 (353); length of caudal peduncle $233 \cdots 270$ (252); depth of caudal peduncle $91--99$ (95) ; snout length $89-97$ (94).


Fig. 39. Nocturnal vertical distribution of Melamphaes pumilus. Each circle, at the greatest depth attained by the particular haul (net not closed), represents one capture.

The following are proportions, based on samples of 125 , for which the data suggest little or no allometric change: body depth 247-308 (274); suborbital 48-69 (60)

Next are proportions for which the data suggest allometric change. Proportions are based on 60 adults (Ad) $18-22.5 \mathrm{~mm}$., 40 halfgrown ( Hg ) $13-18 \mathrm{~mm}$., and 25 young ( Yg ) $9-12.9 \mathrm{~mm}$.

|  | Predorsal | Head length | Snout to preopercle | Upper jaw |
| :---: | :---: | :---: | :---: | :---: |
| Ad | 409-456(428) | 352-389(370) | 237-268(256) | 158-183(169) |
| Hg | 413-460(434) | 349-397(374) | 240-270(260) | 156-182(173) |
| lig. | 418-484(447) | 363-393(377) | 243--300(268) | 173--200(186) |
|  |  | Orbitcheek angle | Eye |  |
|  | Ad | 111-125(118) | 39-47(43) |  |
|  | Hg | 106-126(115) | 43-55(48) |  |
|  | Yg. | 95-121(106) | 53-69(61) |  |
| Jescription. |  |  |  |  |

Body and head form:-The streamlined body narrows gradually from the anus to an especially long, tapered caudal peduncle, which is $2.5-3.0$ times as long as deep. From the dorsal origin to the frontal knob the profile descends almost straightly or in a very weakly convex arc. Almost symmetrically with the dorsal, the ventral contour of the head curves or angles slightly outward (with the apex under the cheek ridge) from the pelvic symphysis to the isthmus, where it abruptly bends up to the mandibular symphysis. The diameter of the relatively small eye measures only 0.75 times the suborbital width and about 0.45 times the snout length. From the premaxillary symphysis to the anterior end of the frontal knob is $0.80-0.83$ times the distance between the anterior nostrils.


Fig. 40. Melamphaes pumilus, n. sp. A, holotype, traced and modified from photograph (standard length 21.2 mm. ); B, young, D 88.3 (s. I. 10.1 mm ) ; C, postlarva, D 883 (s. 1.9 .8 mm ) ; D, postlarva, D 883 (s. 1.4 .0 mm .).

Head ridges:-Rounding and stubbing the side of the snout, the antorbital ridge is especially well developed and outstanding. A sharp angle in the frontal margin over the front of the pupil abruptly narrows the interorbital space. Between these angles, the interorbital width equals or measures slightly less than the distance from the orbit to the preopercular edge.

Sensory pores:-The pores in the group inside the cheek angle number 2 . Those in the group under the posteroventral angle of the orbit also number $2 ; 6$ of 26 counts is 1 . In the group on the supratemporal canal directly above the preopercle, the pores usually number $4 ; 6$ of 25 counts are 3 . In 10 counts the pores on the preopercle above the angle number $2-3+2-3+2-3+2-3$. On the outer margin of the mandible, from just behind the angle to the symphysis, the pores usually number $1+1+2+1$; occasionally they number $1-1+1+1$ and 6 of 109 counts are $1+2+2+1$. The pore on the outer surface of the mandible near the symphysis is $0.33-0.5$ times the size of its equivalent behind the symphysis.

Operculum:-At the preopercular angle a feeble projection marks the end of a weak ridge that originates near the cheek angle. A very weak ridge ending in a small projection at the angle traverses the posteroventral part of the interopercle; the last branchiostegal, however, is evenly rounded.

Jaws and teeth:-The maxillary overreaches by the lens diameter a vertical from the posterior edge of the bony orbit. The tooth formula is for adults $5-7 / 3-5$, for halfgrown 3-6/2-4, and for young $1-3 / 1-2$. Although in the expanded part of the premaxillary toothband the inner 2 or 3 rows are usually oblique, the outer rows, like the 2 or 3 rows in the mandible, align irregularly or nearly horizontally. Near the symphysis this band narrows to 1 or 2 rows. In adults the pharyngeal teeth number $8-15$ on the second pharyngobranchial, $22-36$ on the third, $7-11$ on the fourth, and $18-23$ on the third epibranchial.

Gill rakers:-The modal gill raker count is $4+13$; 44 of 124 counts are $3+13$ or $4+12,7$ are $3+12$ or $4+14$. On the first arch they are moderately long and slender, with the spaces between them about $1.67-$ -. 0 ) times the greatest width, near the middle, of the larger rakers. The longest raker, at the angle, measures about 1.5 times the diameter of the eye. The rakers on the lower fourth arch usually number 8 , less frequently 7 or 9.

Scales:-Usually represented entirely by pockets, the scale rows generally number 31 or 32 . Six to eight凹allops, between which end well-developed "radii" (formed of sharp bends in the circuli), render the anterior margin of a typical body scale irregular ; the posterior margin usually is eroded. The focus is nearest the anterior margin of the scale.

Fins:-The modal dorsal count is 1 II, $15 ; 24$ of 126 counts are III, 14, 9 are 1II, 16. The anal ravs almost always number 1,$8 ; 6$ of 126 counts are $1,7,2$ are 1,9 . Although in young the anal originates under the fifth or sixth from last dorsal ray, it is under the third or fourth from last in adults. The pectoral rays almost always number 15 ; only 6 of 122 counts are 14 or 16 .

Internal characters:--The modal vertebral count is $12+16$. Although only 6 of 103 precaudal counts are 11,20 caudal counts are 15 vertebrae, 2 are 17 . The rather slender haemal arch of the first caudal vertebra bears no spurs, but, slightly broadened distally, curves or angles into the slender, retrorse haemal spine. Anteriorly, the rete and gas gland of the well-developed gas-bladder occupy about a fifth or sixth of the entire structure. In the long, slender membranous bladder a few spaces, possibly gas pockets. are interspersed between extensive areas of adipose tissue. About 2.5 times as long as deep, the thick stomaeh is dark in front, but lightens toward the end of the blind sac; although the posterior dorsal surface is banded or mottled, the "wntral surface of the blind sac is almost unpigmented.

Color:-Although, due to abrasion, some scale pockets are lightest centrally, the integument is not generally mottled. The bases of the median fins usually are no darker than the rest of the body, which, with the head and fins, is never punctulate. The pharynx is dark brown to blackish, frequently with a superficial bluish sheen. Brown to blackish pigment mottles the coelomic peritoneum.

In color no distinguishing characters mark the young. The slender postlarvae, however, are distinctive. Whereas most of the body is colorless, distinct narrow bands of pigment or rows of melanophores in front of and on either side of the dorsal extend to the caudal fin. A broad band of pigment or scattered melanophores, darkest at the midlateral line, connects the top and bottom of the caudal peduncle just before the
caudal fin, which, in contrast with M. simus, never has a spot of pigment at the fork. Finally, melanophores and spots of pigment dot the head region: around the pharynx and pectoral fin, over the brain, and a few above the eye. Melanophores do not fleck the gill arches.

Sex ratio and size at maturity.
Among the 102 specimens sexed, there are 43 males and 36 females. Mature adults range in standard length from 18 to 22.5 mm .


Fig. 41. Geographical variation in selected counts and proportions of Melamphaes pumilus between 4 areas. Area A, far western North Atlantic, north of $21^{\circ} \mathrm{N}$ and west of $67^{\circ} \mathrm{W} ; \mathrm{B}$, central western North Atlantic, north of $21^{\circ} \mathrm{N}$, between $67^{\circ} \mathrm{W}$ and $59^{\circ} \mathrm{W}$; C, tropical North Atlantic, south of $21^{\circ} \mathrm{N}$; and D. central North Atlantic. north of $21^{\circ} \mathrm{N}$, between $59^{\circ} \mathrm{W}$ and $25^{\circ} \mathrm{W}$. For further explanation see Fig. 19.

## Geographical variation.

There is no significant morphological variation between samples of pumilus. Only numbers of scale rows, gill rakers on the upper first arch, and possibly values of predorsal length exhibit possible differences, though of no significance, between populations (Fig. 41). For these characters and soft dorsal rays, samples were analyzed from 4 localities: A) far western North Atlantic, (including the Cil ribbean Sea and Gulf of Mexico), north of $21^{\circ} \mathrm{N}$ and west of $67^{\circ} \mathrm{W}$; B) cemtral western North Atlantic, north if $21^{\circ} \mathrm{N}$, between $67^{\circ} \mathrm{W}$ and $59^{\circ} \mathrm{W}$
C) tropical North Atlantic, south if $21^{\circ} \mathrm{N}$; and D) central North Atlantic. north of $21^{\circ} \mathrm{N}$, between $59^{\circ} \mathrm{W}$ ant $25^{\mathrm{c}} \mathrm{W}$.

Considering the restricted range of M. pumilus, it is not surprising that it exhibits essentially no spacial variation. M. pumilus, therefore, is a genetically well-integraied species.

## Distinctions.

In having only 8 scales in a dias-
onal series, M. pumilus differs from the 3 other "dwarf" species, all of which usually have 10 . M. pumilus is further distinguished from M. simus, hubbsi, and danae in their species accounts.

## Derivation of name.

Derived from the Latin, the species name pumilus ("dwarfish") refers to the small size of the adults.
Specimens examined.- 1771 from 334 collections.
Holotype: SU 42838 (formerly NYZS 12988); near mature male ( 21.2 mm .); western North Atlantic, off Bermuda Island, $32^{\circ} 12^{\prime} \mathrm{N} 64^{\circ} 36^{\prime} \mathrm{W}$; capture 1829 meters (net number 414 ), bottom ca. 2380 meters; one-meter conical ring net: 3 September 1929; 0930 hours; M/V "Gladisfen", William Beebe.

Paratypes: Far western North Atlantic, north of $21^{\circ} \mathrm{N}$ and west of $67^{\circ} \mathrm{W}$ (area A): BOC $2831,24^{\circ} 11^{\prime} \mathrm{N} 75^{\circ} 37^{\prime} \mathrm{W}$. $2440,1(19)$; D $1229(1), 23^{\circ} 13^{\prime} \mathrm{N} 82^{\circ} 21^{\prime} \mathrm{W}, 1000 \mathrm{w} .(\mathrm{n}), 1(20)$; D $1231(1), 24^{\circ} 30^{\prime} \mathrm{N} 80^{\circ} 00^{\prime} \mathrm{W}, 1000 \mathrm{w} .(\mathrm{n}), 2(19-21):$ D 123 (2), $25^{\circ} 50^{\prime}$. $76^{\circ} 55^{\prime} \mathrm{W}$, $1200 \mathrm{w} .(\mathrm{n}), 17(9-19)$; D 1239(13), do., 3000 w .(d), 2(17-19); D 1239(14), do., 2500 w (d), $8\left(12-1^{4}\right.$ ) : D $1342(2), 34^{\circ} 00^{\prime} \mathrm{N} 70^{\circ} 01^{\prime} \mathrm{W}, 4000(\mathrm{~d}), 2(21)$; D $\left.1342(6), 34^{\circ} 00^{\prime} \mathrm{N} 70^{\circ} 01^{\prime} \mathrm{W}, 1000 \mathrm{w} .(\mathrm{n}), 1(21) ; \mathrm{D}\right) 1345(1), 35^{\circ} 07^{\prime} \times$ $72^{\circ} 38^{\prime} \mathrm{W}, 1000 \mathrm{w}(\mathrm{n}), 4(20-22)$.

Central western North Atlantic north of $21^{\circ} \mathrm{N}$ and between $67^{\circ} \mathrm{W}$ and $59^{\circ} \mathrm{W}$（area B）：BM（NH）1931．12．18．2， $32^{\prime} 12^{\prime} \mathrm{N} 64^{\circ} 36^{\prime} \mathrm{W}, 1280,1(22)$ ；BOC $2830,32^{\circ} 24^{\prime} \mathrm{N} 64^{\circ} 29^{\prime} \mathrm{W}, 3300,14(18-22)$ ；CNHM $49666,32^{\circ} 10^{\prime} \mathrm{N}^{\circ} 64^{\circ} 45^{\prime} \mathrm{W}$ ， 4，9（1）， $1(21)$ ；CNHM $49677,32^{\circ} 13^{\prime} \mathrm{N} 64^{\circ} 35^{\prime} \mathrm{W}, 1100(\mathrm{n}), 2(13-20)$ ；CNHM $49728,32^{\circ} 15^{\prime} \mathrm{N} 64^{\circ} 35^{\prime} \mathrm{W}, 2000(\mathrm{n}), 1(20)$ ； （NHM 49722， $32^{\circ} 06^{\prime} \mathrm{N} 65^{\circ} 20^{\prime} \mathrm{W}, 450(\mathrm{n}), 12(10-21)$ ；CNHM $49723,31^{\circ} 55^{\prime} \mathrm{N} 65^{\circ} 01^{\prime} \mathrm{W}, 1100(\mathrm{n}), 4(12-22)$ ；CNHM
 fí $43^{\prime} \mathrm{W}, 1000 \mathrm{w} .(\mathrm{n}), 8(22-23) ; \mathrm{D} 1356(1), 29^{\circ} 56^{\prime} \mathrm{N} 59^{\circ} 33^{\prime} \mathrm{W}, 1000 \mathrm{w} .(\mathrm{n}), 3(20-21)$ ；SU $42809,32^{\circ} 12^{\prime} \mathrm{N} 64^{\circ} 36^{\prime} \mathrm{W}$ ， 12s0（d），1（21）；SU 42817，do．，1829（d），1（21）；SU 42819，do．，1463（d），1（21）；SU 42831，do．，1829（d），1（21）；SU 42833， do．，1829（n），1（20）；SU 42841，do．，1646（d），2（21）；SU 42843，do．，1646（d），1（22）；SU 42844，do．，1646（d），1（21）；SU ！2904，do．，1463（d），3（18－20）；SU 42920，do．，1097（d），1（19）；SU 42922，do．，2195（d），1（20）；SU 42925，do．，1829（d）， $2(20)$ ．

Tropical North Atlantic，south of $21^{\circ} \mathrm{N}$（area C）：D） $849,19^{\circ} 00^{\prime} \mathrm{N} 63^{\circ} 53^{\prime} \mathrm{W}$ ， 500 w （n），1（19）；D $1186(7), 17^{\mathrm{c}} 59^{\prime} \mathrm{N}^{\text {（ }}$ $64^{\circ} 41^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 3(16-20)$ ；D $1189(7), 17^{\circ} 59^{\prime} \mathrm{N} 64^{\circ} 41^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 1(21) ; \mathrm{D} 1192(9), 17^{\circ} 43^{\prime} \mathrm{N} 64^{\circ} 54^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n})$ ， $1(20)$ ．

Central North Atlantic，north of $21^{\circ} \mathrm{N}$ and between $59^{\circ} \mathrm{W}$ and $25^{\circ} \mathrm{W}$（area D）：D 1323（7）， $27^{\circ} 17^{\prime} \mathrm{N}^{5} 54^{\circ} 35^{\prime} \mathrm{W}$ ，

 $2 x^{\prime} 15^{\prime} \mathrm{N} 56^{\circ} 00^{\prime} \mathrm{W}, 2000 \mathrm{w} .(\mathrm{d})$ ， $5(13-20)$ ；D $1365(1), 31^{\circ} 47^{\prime} \mathrm{N} 41^{\circ} 41^{\prime} \mathrm{W}, 1000 \mathrm{w} .(\mathrm{n}), 2(17-20)$ ；D $1365(13), 31^{\circ} 47^{\prime} \mathrm{B}$ $11^{\prime} 41^{\prime} \mathrm{W}, 2000 \mathrm{w} .(\mathrm{n}), 1(21)$ ．

Additional material：For series of nets on a particular＂Dana＂haul（e．g．D $1242(2,7,9,13,14,15)$ ），the meters of wire out and numbers of，with standard lengths of，specimens are grouped after the si：gle locality．

Far western North Atlantic，north of $21^{\circ} \mathrm{N}$ and west of $70^{\circ} \mathrm{W}$（area A）：BOC $2835,21^{\circ} 20^{\prime} \mathrm{N}^{\circ} 71^{\circ} 13^{\prime} \mathrm{W}, 1990,1(19)$ ； b） $891,29^{\circ} 28^{\prime} N 69^{\circ} 25^{\prime} \mathrm{W}, 200 \mathrm{w} .(\mathrm{n}), 11 \mathrm{PL}-\mathrm{HG}(8-13)$ ：D 948（1）， $22^{\circ} 14^{\prime} \mathrm{N}^{\circ} 67^{\circ} 22^{\prime} \mathrm{W}, 300 \mathrm{w} .(11), 3(10-11)$ ；D 948（2）， $22^{\circ} 14^{\prime} \mathrm{N} 67^{\circ} 22^{\prime} \mathrm{W}, 400 \mathrm{w} .(\mathrm{n}), 13(9-14) ; \mathrm{D} 1223(2), 22^{\circ} 06^{\prime} \mathrm{N}^{\circ} 84^{\circ} 58^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 1(18) ; \mathrm{D} 1238(1), 26^{\circ} 13^{\prime} \mathrm{N} 78^{\circ} 48^{\prime} \mathrm{W}$ ，

 $25^{\circ} 18^{\prime}$ N $74^{\circ} 00^{\prime} \mathrm{W}, 600,800 \mathrm{w} .(\mathrm{n}), 1(18), 2(12-18)$ ；D $1242(2,7,9,13,14,15), 24^{c} 05^{\prime} \mathrm{N} 74^{\prime} 36^{\prime} \mathrm{W}, 600,1200,800 \mathrm{w} .(\mathrm{n})$ ， $3010,2500,2000 \mathrm{w} .(\mathrm{d}), 5 \mathrm{PL}-\mathrm{AD}(5-20), 2(10-13), 3(10-19), 1(19), 1(17), 2(17) ; \mathrm{D} 1342(7,8,9), 34^{\circ} 00^{\prime} \times 70^{\circ} 01^{\prime} \mathrm{W}$ ，
 $29 \mathrm{PL}-\mathrm{Hg}(8-15)$ ； $1352(1), 35^{\circ} 42^{\prime} \mathrm{N} 73^{\circ} 43^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 24 \mathrm{PL}-\mathrm{Hg}(5-12)$ ．

Central western North Atlantic，north of $21^{\circ} \mathrm{N}$ and between $67^{\circ} \mathrm{W}$ and $59^{\circ} \mathrm{W}$（area B）：BOC $2836(4), 32^{\circ} 19^{\prime} \mathrm{N}$ $\therefore 133^{\prime} \mathrm{W}, 2440 \mathrm{~W}, 2(20-22)$ ；CNHM $49653,32^{\circ} 12^{\prime} \mathrm{N} 64^{\circ} 36^{\prime} \mathrm{W}, 1370(\mathrm{~d}), 2(10-15)$ ；CNHM $49654,32^{\circ} 14^{\prime} \mathrm{N} 64^{\circ} 33^{\prime} \mathrm{W}$ ，动（11）， $1(19)$ ；CNHM 49655， $32^{\circ} 00^{\prime} \mathrm{N} 64^{\circ} 52^{\prime} \mathrm{W}, 1100(\mathrm{n}), 2(10-14)$ ；CNHM 49657， $32^{\circ} 11^{\prime} \mathrm{N} 64^{\circ} 33^{\prime} \mathrm{W}, 820(\mathrm{~d}), 1(14)$ ；
 $: i 1^{\circ} 33^{\prime} \mathrm{N} 64^{\circ} 42^{\prime} \mathrm{W}, 1370(\mathrm{n}), 1(16)$ ；CNHM $49669,32^{\circ} 14^{\prime} \mathrm{N} 64^{\circ} 36^{\prime} \mathrm{W}, 1800(\mathrm{~d}), 1 \mathrm{PL}(9)$ ；CNHM $49670,32^{\circ} 15^{\prime} \mathrm{N} 64^{\circ} 36^{\prime} \mathrm{W}$ ， 1460（n）， $1(16)$ ；CNHM 49671， $32^{\circ} 11^{\prime} \mathrm{N} 65^{\circ} 04^{\prime} \mathrm{W}, 450(\mathrm{n}), 1(10) ;$ CNHM 49672， $32^{\circ} 13^{\prime} \mathrm{N} 64^{\circ} 35^{\prime} \mathrm{W}$ ， $820(\mathrm{n})$ ， 1 PL（9）； C．以НМ $49673,32^{\circ} 13^{\prime} \mathrm{N} 64^{\circ} 36^{\prime} \mathrm{W}, 550(n), 1(11)$ ；CNHM $49674,32^{\circ} 09^{\prime} \mathrm{N}^{\circ} 64^{\circ} 36^{\prime} \mathrm{W}, 275(\mathrm{n}), 2(10)$ ；CNHM $49675,32^{\circ} 13^{\prime} \mathrm{N}$ $1.37^{\prime} \mathrm{W}, 820(\mathrm{n}), 1(16)$ ；CNHM $49676,32^{\circ} 12^{\prime} \mathrm{N}^{\circ} 64^{\circ} 36^{\prime} \mathrm{W}, 820(\mathrm{n}), 1(11)$ ；CNHM $49678,32^{\circ} 13^{\prime} \mathrm{N}^{\circ} 64^{\circ} 41^{\prime} \mathrm{W}, 820(\mathrm{~d})$ ， $1+$ ）；CNHM 49679， $32^{\circ} 12^{\prime} \mathrm{N} 64^{\circ} 39 \mathrm{~W}, 1370(\mathrm{n}), 2 \mathrm{PL}-\mathrm{Hg}(10-14)$ ；CNHM 49681， $32^{\circ} 10^{\prime} \mathrm{N} 64^{\circ} 38^{\prime} \mathrm{W}, 200(\mathrm{n})$ ， $1(12)$ ；
 $17.18), 29^{\circ} 15^{\prime} \mathrm{N} 59^{\circ} 45^{\prime} \mathrm{W}, 150,200,300,500,150,150,100 \mathrm{w} .(\mathrm{n}), 4(+-13), 16(11-14), 2(11-12), 4(10-12), 8(10-18)$ ，

解；－14）， $15 \mathrm{PL}(6-10), 2(12-13) ; \mathrm{D} 859(1,2), 29^{\circ} 02^{\prime} \mathrm{N} 65^{\circ} 09^{\prime} \mathrm{W}, 200,150 \mathrm{w} .(\mathrm{n}), 3(14-19), 1(12) ; \mathrm{D} 864(1), 30^{\circ} 02^{\prime} \mathrm{N}$ （10＇W，150w．（n），2（11－12）；D 865（1，2，3）， $29^{\circ} 19^{\prime} \mathrm{N} 57^{\circ} 43^{\prime} \mathrm{W}, 200,150,100 \mathrm{w} .(\mathrm{n}), 7(11-15), 10(11-14), 1(11)$ ； 1） $577(1), 32^{\circ} 37^{\prime} \mathrm{N} 63^{\circ} 28^{\prime} \mathrm{W}, 150 \mathrm{w}$（n）， $70 \mathrm{PL}-\mathrm{Yg}(4-11)$ ；D $896(1,2), 39^{\circ} 44^{\prime} \mathrm{N} 57^{\circ} 21^{\prime} \mathrm{W}, 150,100 \mathrm{w}$（n）， $1(12), 1(12)$ ；
 $\mathrm{R}^{\circ} 10^{\prime} \mathrm{W}, 400,300 \mathrm{~W} .(\mathrm{n}), 5(12-14), 1(12) ; \mathrm{D} 945(1,2), 25^{\circ} 00^{\prime} \mathrm{N} 64^{\circ} 10^{\prime} \mathrm{W}, 400,300 \mathrm{w} .(\mathrm{n}), 3 \mathrm{PL}-\mathrm{Ad}(7-19), 4(12-13)$ ； 1） $446(1,2), 24^{\circ} 20^{\prime} \mathrm{N} 65^{\circ} 30^{\prime} \mathrm{W}, 400,300 \mathrm{w} .(\mathrm{n}), 6(9-17), 4(12-17) ; \mathrm{D} 947(1,2,6,7), 23^{\circ} 10^{\prime} \mathrm{N} 66^{\circ} 15^{\prime} \mathrm{W}, 400,360,1000$, ！＂川w，（n）， $7(11-18), 1(13), 2(+19), 5(14-19): D 949(3), 21^{\circ} 40^{\prime} \mathrm{N} 66^{\circ} 55^{\prime} \mathrm{W}, 200 \mathrm{w} .(1), 1(13) ; \mathrm{D} 1334(2,4,5), 27^{\circ} 28^{\prime} \mathrm{N}$
 ві＂， $300,200 \mathrm{w} .(\mathrm{n}), 2 \mathrm{PL} \quad \operatorname{Yg}(10-11), 17 \mathrm{PL}-\mathrm{Hg}(4-12), 80 \mathrm{PL}-\mathrm{Hg}(4-15) ; \mathrm{D} 133 \mathrm{~b}(3), 28^{\circ} 15^{\prime} \mathrm{N} 63^{\circ} 40^{\prime} \mathrm{W}, 300 \mathrm{w}$ ．（n），



All of the following captures are from the Stanford University collections（SU）and from the same locality， $32^{\circ} 12^{\prime}$ N $64^{\circ} 36^{\prime} \mathrm{W}$ ．Mostly taken in daytime hauls from $549-2195$ meters，these specimens（ $212 \mathrm{YG}-\mathrm{Ad}(9-22$ ）are listed by SU number，followed in parentheses by their collection－net number：42317（104），42802（699），42803（718），42804（234）， ！2806（588），42807（416），42808（177），42811（506），42812（263），42813（398），42814（657），42815（410），42816（487），42818（318）， $42820(1324), 42821(329), 42822(217), 42823(385), 42825(273), 42827(747), 42828(1260), 42829(555), 42830(552), 42832(486)$ ，

42834(135), 42836(213), 42837(1290), 42839(1155), 42840(379), 42842(358), 42847(494), 42848(512), 42849(104), 42898(173), 42899(698), 42900(427), 42901(373), 42902(391), 42903(326), 42905(511), 42906(567), 42907(505), 42908(496), 42909(638), $42910(435), 42911(1083), 42912(114), 42913(370), 42914(582), 42915(419), 42916(103), 42917(1304), 42918(368), 42919(627)$, 42921(1255), 42923(801), 42924(880), 42926(723), 42927(620), 42928(357), 42929(203), 42930(141), 42931(432), 42932(489), 42933(686), 42934(748), 42935(1102), 42936(683), 42937(844), 42938(690), 42940(1125), 42941(495), 42942(283), 42943(126), 42944(192), $42945(822), 42946(430), 43050(1511), 43051(513), 43052(1063), 43053(514), 43054(256), 43055(583)$, 4302ti; (1502), 43057(574), 43058(431), 43059(356).

Tropical North Atlantic, south of $21^{\circ} \mathrm{N}$ (area C): D 949(1, 2), $21^{\circ} 40^{\prime} \mathrm{N} 66^{\circ} 55^{\prime} \mathrm{W}, 400,300 \mathrm{w} .(\mathrm{n}), 1(17), 8(9-19)$; D $950(1), 20^{\circ} 50^{\prime} \mathrm{N} 66^{\circ} 30^{\prime} \mathrm{W}, 400 \mathrm{w} .(\mathrm{n}), 5(10-16)$; D $952(7), 17^{\circ} 55^{\prime} \mathrm{N} 64^{\circ} 48^{\prime} \mathrm{W}, 400 \mathrm{w} .(\mathrm{n}), 2(9) ; \mathrm{D} 1185(8,13), 17^{\circ} 41^{\prime} \mathrm{N}$ $60^{\circ} 58^{\prime} \mathrm{W}, 1000,4000 \mathrm{w} .(\mathrm{d}), 2(10-12), 1(11) ; \mathrm{D} 1186(4,6), 17^{\circ} 54^{\prime} \mathrm{N} 64^{\circ} 54^{\prime} \mathrm{W}, 2000,1000 \mathrm{w} .(\mathrm{n}), 1 \mathrm{PL}(10) ; 1(20)$; D 1189 (3, 8), $17^{\circ} 59^{\prime} \mathrm{N} 64^{\circ} 41^{\prime} \mathrm{W}, 3000 \mathrm{w}$.(d), $300 \mathrm{w} .(\mathrm{n}), 1(17), 4(11-13)$; D $1190(1,7), 17^{\circ} 59^{\prime} \mathrm{N} 64^{\circ} 45^{\prime} \mathrm{W}, 1000,300 \mathrm{w} .(\mathrm{n}), 2(12-16)$, $1(12)$; D $1195(3), 19^{\circ} 01^{\prime} \mathrm{N} 65^{\circ} 23^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 12(9-11)$; D $1214(3), 14^{\circ} 21^{\prime} \mathrm{N} 76^{\circ} 50^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 1(19)$; D $1250(2)$, $17^{\circ} 54^{\prime}$ N $67^{\circ} 30^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 2(11-21)$; D $1261(2,3,9), 19^{\circ} 04^{\prime} \mathrm{N} 65^{\circ} 43^{\prime} \mathrm{W}, 600,300,3000 \mathrm{w} .(\mathrm{n}), 1(19), 6 \mathrm{PL}-\mathrm{Hg}(8-14)$, $1 \mathrm{PL}(10)$; D $1269(9), 17^{\circ} 13^{\prime} \mathrm{N} 64^{\circ} 58^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 2 \mathrm{PL}(7-10)$; D $1278(4), 17^{\circ} 43^{\prime} \mathrm{N} 64^{\circ} 56^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 5 \mathrm{PL}-\mathrm{Yg}(\mathrm{ti})$ 10); D $1279(3), 17^{\circ} 43^{\prime} \mathrm{N} 64^{\circ} 56^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 1(9)$; D $1282(2), 16^{\circ} 03^{\prime} \mathrm{N} 62^{\circ} 29^{\prime} \mathrm{W}, 800 \mathrm{w} .(\mathrm{n}), 1(18)$; D $1292(2)$, $17^{\circ} 43^{\prime}$. $64^{\circ} 56^{\prime} \mathrm{W}, 800 \mathrm{w} .(\mathrm{n}), 3 \mathrm{PL}(10)$; D $1293(3), 17^{\circ} 43^{\prime} \mathrm{N} 64^{\circ} 56^{\prime} \mathrm{W}, 600 \mathrm{w} .(\mathrm{n}), 2 \mathrm{PL}(10)$; D $1296(2), 17^{\circ} 43^{\prime} \mathrm{N} 64^{\circ} 56^{\prime} \mathrm{W}, 800 \mathrm{w} .(\mathrm{n})$, 1(10).

Central North Atlantic, north of $21^{\circ} \mathrm{N}$ and between $59^{\circ} \mathrm{W}$ and $25^{\circ} \mathrm{W}$ (area D): D 831(1), $24^{\circ} 34^{\prime} \mathrm{N} 28^{\circ} 04^{\prime} \mathrm{W}, 300 \mathrm{w}$.(n). $1(11)$; D $836(1), 24^{\circ} 29^{\prime} \mathrm{N} 40^{\circ} 02^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 1(11) ; \mathrm{D} 844(1,2,4), 25^{\circ} 49^{\prime} \mathrm{N} 51^{\circ} 55^{\prime} \mathrm{W}, 300,200,100 \mathrm{w} .(\mathrm{n}), 2(11-12)$, 2(12-13), 1(14); D 845(1, 2), $24^{\circ} 46^{\prime} \mathrm{N} 54^{\circ} 08^{\prime} \mathrm{W}, 300,200 \mathrm{w}$.(n), 2(11-13), 3(11-12); D 867(1, 2), $28^{\circ} 15^{\prime} \mathrm{N} 56^{\circ} 29^{\prime}$ W. $150,100 \mathrm{w} .(\mathrm{n}), 1(15), 2(11-+)$; D $881(1), 34^{\circ} 42^{\prime} \mathrm{N} 54^{\circ} 00^{\prime} \mathrm{W}, 150 \mathrm{w} .(\mathrm{n}), 10 \mathrm{PL}(6-8) ; \mathrm{D} 883(1,2), 30^{\circ} 53^{\prime} \mathrm{N} 54^{\circ} 07^{\prime} \mathrm{W}, 100$, 150w.(n), $53 \mathrm{PL}(5-8), 54 \mathrm{PL} — \mathrm{Yg}(4 — 11)$; D 913(10), $23^{\circ} 37^{\prime} \mathrm{N} 55^{\circ} 45^{\prime} \mathrm{W}, 200 \mathrm{w} .(\mathrm{n}), 1(11)$; D $923(3), 22^{\circ} 47^{\prime} \mathrm{N} 48^{\circ} 53^{\prime} \mathrm{W}$, $200 \mathrm{w} .(\mathrm{n}), 1(10) ;$ D $924(2), 22^{\circ} 12^{\prime} \mathrm{N} 48^{\circ} 00^{\prime} \mathrm{W}, 200 \mathrm{w} .(\mathrm{n}), 2(10-11)$; D $925(5,7), 21^{\circ} 27^{\prime} \mathrm{N} 46^{\circ} 52^{\prime} \mathrm{W}, 300$, 200w.(n), $1(16)$, $6(11-16)$; D $926(1,2), 21^{\circ} 15^{\prime} \mathrm{N} 46^{\circ} 10^{\prime} \mathrm{W}, 300,200 \mathrm{w} .(\mathrm{n}), 4(10-16), 1(11) ; \mathrm{D} 928(2,3), 22^{\circ} 43^{\prime} \mathrm{N} 45^{\circ} 18^{\prime} \mathrm{W}, 200,150 \mathrm{w} .(\mathrm{n})$, $3(11-14), 1(11) ; D 931(1,2,4), 26^{\circ} 10^{\prime} \mathrm{N} 46^{\circ} 32^{\prime} \mathrm{W}, 300,200,150 \mathrm{w} .(\mathrm{n}), 2(11-12), 4(11-16), 1(16) ; \mathrm{D} 932(1,2,3)$, $27^{\circ} 23^{\prime} \mathrm{N} 46^{\circ} 24^{\prime} \mathrm{W}, 300,200,100 \mathrm{w} .(\mathrm{n}), 9(10-+), 18(10-15), 1(11) ; \mathrm{D} 933(1,2), 27^{\circ} 40^{\prime} \mathrm{N} 48^{\circ} 40^{\prime} \mathrm{W}, 300$, 200 w .(11), b(11-12), 1(11); D 934(1), $27^{\circ} 00^{\prime} \mathrm{N} 49^{\circ} 50^{\prime} \mathrm{W}, 300 \mathrm{w}$.(n), 2(10—11); D 935(1), $24^{\circ} 44^{\prime} \mathrm{N} 51^{\circ} 25^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 36 \mathrm{PL}-\mathrm{H}_{\mathrm{h}}$ ( $5-12$ ); D $937(2,3), 27^{\circ} 04^{\prime} \mathrm{N} 53^{\circ} 27^{\prime} \mathrm{W}, 400,300 \mathrm{w} .(\mathrm{n}), 1(10), 1(13) ; \mathrm{D} 939(1,3), 26^{\circ} 10^{\prime} \mathrm{N} 56^{\circ} 30^{\prime} \mathrm{W}, 400,200,1(11)$, $6(13-15)$; D $1320(2,4), 23^{\circ} 18^{\prime} \mathrm{N} 56^{\circ} 58^{\prime} \mathrm{W}, 800,300,1(18), 14 \mathrm{PL}-\mathrm{Hg}(5-11)$; D $1322(2,3,4,8,10,23,24,26,27,2 \mathrm{~s}$, $29,32,36$ ), $27^{\circ} 02^{\prime}$ N $53^{\circ} 39^{\prime} \mathrm{W}, 800,600,300,500,200 \mathrm{w} .(\mathrm{n}), 3000 \mathrm{w} .(\mathrm{d}), 2000 \mathrm{w} .(\mathrm{d}), 500,400,300,200,800$, 200 w .(n). $2(13-18), 4(13-16), 2(11-15), 1(18), 4(11-14), 1(14), 1(16), 1(16), 4(10-14), 1(15), 4(10-12), 1(12), 3(12-14) ;$ D $132: 3$ (8), $27^{\circ} 17^{\prime} \mathrm{N} 54^{\circ} 35^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 36 \mathrm{PL}-\mathrm{Hg}(4 — 15)$; D $1326(3,4), 27^{\circ} 14^{\prime} \mathrm{N} 51^{\circ} 25^{\prime} \mathrm{W}, 300,200 \mathrm{w} .(\mathrm{n}), 111 \mathrm{PL}-\mathrm{Hg}\left(4-1 \mathrm{H}^{\prime}\right.$, $22 \mathrm{PL}-\mathrm{Hg}(6-13) ; \mathrm{D} 1327(4,5), 27^{\circ} 34^{\prime} \mathrm{N} 51^{\circ} 47^{\prime} \mathrm{W}, 200,100 \mathrm{w} .(\mathrm{n}), 31 \mathrm{PL}-\mathrm{Hg}(5-13), 1(11) ; \mathrm{D} 1330(5)$, $26^{\circ} 37^{\prime} \quad \therefore$ $54^{\circ} 45^{\prime} \mathrm{W}, 400 \mathrm{w} .(\mathrm{n}), 4(11-12) ;$ D $1332(2,3,7,10,14,16), 26^{\circ} 58^{\prime} \mathrm{N} 56^{\circ} 58^{\prime} \mathrm{W}, 600,500,700,300,600,200 \mathrm{w} .(\mathrm{n}), 5(12-1 心 1$, $3(14-17), 3(14-17), 3(11-12), 2 \mathrm{PL}-\mathrm{Ad}(6-18), 19 \mathrm{PL}-\mathrm{Hg}(6-15) ; \mathrm{D} 1358(4,10,11,12), 28^{\circ} 15^{\prime} \mathrm{N} 56^{\circ} 00^{\prime} \mathrm{W}, 4000 \mathrm{w}$. (d), 300, 200, 150w.(n), 1(11), $33 \mathrm{PL}-\mathrm{Hg}(9 — 15), 33(11-15), 20(13-14) ; \mathrm{D} 1360(2,3,4), 26^{\circ} 56^{\prime} \mathrm{N} 53^{\circ} 09^{\prime} \mathrm{W}, 600,30 \mu$, 200w.(n), 1(17), $16 \mathrm{PL}-\mathrm{Hg}(6--17), 10 \mathrm{PL}-\mathrm{Hg}(6-14) ; 1362(1,3,4,5), 1000,300,200,150 \mathrm{w} .(\mathrm{n}), 1(18), 4(11-16)$, $12 \mathrm{PL}-\mathrm{Hg}(5-16), 2(12-14)$; D $1363(3), 30^{\circ} 25^{\prime} \mathrm{N} 44^{\circ} 46^{\prime} \mathrm{W}, 300 \mathrm{w} .(\mathrm{n}), 6 \mathrm{PL}-\mathrm{Hg}(9 — 14)$; MCZ ("Atlantis" sta. $1042 \cdots$ B 39), $37^{\circ} \mathrm{N} 57^{\circ} \mathrm{W}, 4(10-12)$; MCZ ("Atlantis" sta. 1052 ), ca. $37^{\circ} \mathrm{N} 57^{\circ} \mathrm{W}, 12(10-18)$.

## ZOOGEOGRAPHY AND SPECIATION

The following discussion of the zoogeography and differentiation of the species of Melamphaes and other bathypelagic fishes emphasizes the importance and influence of the water mass, as defined both physicochemically and biologically. Each species of Melamphaes is restricted to a certain area and a certain depth zunc of the oceans, occasionally to a single water mass. Their distributions, of course, are reflections of the nuvironmental parameters that vary from one oceanic region to another.

A zoogeographical study of bathypelagic fishes should test the significance of isolation within and adaptatims to subtly different envirouments. Because at present deep-sea fishes are not easiiy subject to experimental research, the reasons for their distributions can be suggested only through the descriptive approach, particularly through correlation between their distributions and various environmental features. It is realized that correlations do not necessarily prove causal relations, but when several such correlations are found, likely relationships may be hypothesized between the distribution of particular species and similarly distributed environmental parameters.

To investigate the distribution and speciation of bathypelagic fishes, all types of isolating mechanisms hould be examined, though in the present study special note is taken of those associated with water masses and their boundaries. The importance of the continents is obvious. In the South Atlantic and Indian oceans many tropical species circumflect the tip of Africa; the American continents, conversely, sharply separate the Atlantic and Pacific faunas. At the apex of the North Pacific the Bering Straits isolate the Aretic Ocean.

In her classic study of hathypelagic Vampyroteuthis infernalis Grice Pickforn (1946) showed the probable importance of density in controlling the distribution of this semi-planktonic soft-bodied cephalopod. However, for rapidly swimming nekton such as melamphaids, many species of which have well-developed gas-bladders, it is unlikely that the density of the surrounding water could be critical in determining their distributions. Currents (including gyres and zones of convergence) along with temperature distributions and to a lesser extent those of salinity, help limit and integrate bathypelagic populations. Recently the importance of biological limiting factors has also been realized. i emphasize biological factors in the discussion of zoogeographically important environmental parameters.

Finally, it is worthwhile to speculate on the mechanism of incipient stoppage of gene flow between !!pulations, which must precede the separation of closely related species within broadly connected bodies If water. With some insight into all these problems, the definite, predictable patterns in the distribution of bathypelagic fishes will seem clearer and more logical.

## WATER MASSES AND OCEANIC BOUNDARIES

Una (1959) observed that "Water masses are usually defined by a particular oceanographic property, wheh as temperature-salinity relation, phosphate, dissolved oxygen, etc... Then the boundaries of the water mass are in the region where the gradients of the property are maximum (i.e. the Polar Front, etc.)." Further, he realized that these physico-chemical boundaries are also biogeographical boundaries and ". . . correspond to lines of zoogeographical features of the shores and sea bottom." Many other oceanographers believe that, th be complete, a concept of the oceans and water masses should include both physical-chemical and biological 'haracteristics.

## Characteristics and Formation of Water Masses

According to Helland-Hassen (1918) and Sverdrep et al. (1942), water masses can be identified in the basis of their temperature-salinity characteristies; that is, an area is termed a water mass because of the consistency of the temperature-salinity relations within its boundaries. The relation of temperature to salinity in any water column, therefore, indexes the water mass. Non-conservative properties such as oxygen, phosphate, nitrate, and silicate concentrations also may be characteristic of water masses and may be used to identify them.

Recent studies show that the water mass should be more broadly defined, biologically as well as physically. McGowas (1960) aptly realized this when he stated, ". . . water masses, as defined by hydrographers, may also exist as biological entities. The water mass concept, which defines a three-dimensional unit of the ocean, thus provides us with an opportunity to compare plankton distributions with that of circumseribed volumes of water, each of which has a unique set of physical properties." Ressele (1935) first recognized the importance of distributions of "indicator species" of plankton to the identification of water masses and tracing of their movements. Hardy (1956) and Bary (1959) summarized the pertinent literature dealing with indicator species and related subjects. In the Pacific frequent, though not invarialle, associations of various organisms with physico-chemically defined water masses have been demonstrated: arrow worms (Chaetognatha), by Bump (1959) and Susd (1959); krill shrimp (Euphausiacea), by Briston (1958); pelagic tunicates, by Berver (1957), and pteropod mollusks by McGoway (personal communication). Clemexs (1958) postulated that certain fishes might be indicator species. Анох ( 1959,1960 ) found bathypelagic fishes, because of their relatively large size, very useful as indicators of water masses in the northeastern North Pacific.

Water masses differ biologically not only in their faunas, but also in factors such as dissolved metab, lites, productivity, and food supply. Hardy and Gëvtifer (1935), Ray (1958), Whsos (1958), and McGowss (1960) believe that the observed associations and distributions of many planktonic organism. make it appear unlikely that the conventionally measured physical parameters of the oceans constitut. the only limiting factors. McGowax showed that even though certain water types having the temperaturen and salinities characteristic of points in the Subarctic Water Mass occur in many parts of the world, the planktonic worm, Pooobius meseres Heath, occurs only in Subarctic Water or in waters that may have Subarctic components.

A water mass acquires its temperature-salinity properties primarily through changes at the surface of the ocean, by the processes of heating, cooling, evaporation, and precipitation. If these changes cause the surfar water to become denser than the underlying water, it sinks to depths corresponding to its density. Each parcel of water with the same temperature and salinity throughout is a water type, and corresponds to a single point on a temperature-salinity curve. Secondarily, as this water type moves away from its point of origin, it become mixed with other waters. The large bodies of water formed in this way are termed "water masses" and ar" characterized by similar temperature-salinity curves (Sverdrep et al., 1942; Haffnir, 1952). Currents play a large part in bringing about the unique temperature-salinity characteristics of water masses. For example. the large current gyres in the central oceanic areas condense the physical properties into a relatively narrow range (Bieri, 1959). It is clear, then, that the physico-chemical character of the water mass depends on thro factors: the latitude and climate of the region, its degree of isolation, and the associated currents (Sverdrep et al., 1942).

The biological constitution, of course, is ultimately dependent on the physico-chemical. Whereas the composition of a characteristic fauna may hinge upon the productivity and associated biological factors of it enclosing water mass, these factors are in turn a result not only of the temperature, salinity, oxygen content. and transparency of the water mass, but also of the horizontal currents and vertical mixing involved. Conversely biological factors, such as decay of plants and animals in the thermocline in highly productive area. may drastically alter the distributions of such properties as oxygen and nitrogen content (Brandhorst, 1959a).

## Physico-Chemical Identification of Water Masses

From the foregoing discussion we see that water masses can be identified through their temperaturesalinity characteristics. Density, however, which is mainly dependent on these, cannot be used for classification, because as temperature decreases and salinity increases, the density may remain the same; as a result water masses having approximately the same densities may have widely different temperatures and salinities. The temperature-salinity (or $\mathrm{T}-\mathrm{S}$ ) curve, however, precisely identifies the water mass. Temperature and salinity values in a water column vary with depth. In a given column, moreover, the temperature and salinities measured at several depths below $100-200$ meters, when plotted against each other, constitute a characteristic T-S curve, which summarizes the distribution of these properties for the immediate area surrounding the column. Each point on the T-S curve, then, corresponds to a water type so that the water mass is defined by the curve and not a single point (Sverdruep et al., 1942).

Below 100-200 meters T-S curves constructed from hydrographic data taken throughout a particular water mass fall within certain limits. These limits enclose the water mass envelope, which has a characteristic shape and can be used to identify the water mass and to indicate its integrity.

## Locations of Water Masses

Most water masses, especially those in the central and equatorial regions, exhibit consistent T-S distributions below 100 to 200 meters only, depending on the depth of the thermocline: considerably influenced by local dimate and surface currents, the surface layers vary greatly even within the boundaries of a particular water mass. The equatorial water masses are unique in that they are formed in situ by subsurface mixing. As a matter of fact, no water mass is formed at the sea surface in low latitudes. Considered together, the relatively hallow central water masses, which are formed at the regions of the subtropical convergences, are remarkable fir the similarity of their physico-chemical and biological structure. North Pacific Central Water, however, reflects the relatively Iow salinity of this ocean in general. In the southern oceans the central water masses give way at the Subtropical Convergence to a continous belt of Subantaretic water, but corresponding Subarctic Water forms only in the North Pacific. Both boreal water masses, in contrast with the Central, are charavterized by shallow thermocline, intense vertical mixing and high productivity (Sverdrip et al., 1942).

Intermediate water forms at the Antaretic Convergence in the Southern Hemisphere and in the western Ninth Pacific in the Northern Hemisphere; special types of intermediate water with relatively high temperatures and salinities emanate in the North Atlantic from the Mediterranean Sca and in the northwestern Indian Ocean from the Red Sea. These intermediate waters spread out under the Central Water masses at 500 imp) meters. Below this, conditions in the great depths that extend from about 1000 meters to the bottom are relatively uniform, both in time and space. The deep and bottom waters at these depths originate at the surface around Autarctica and in the North Atlantic off Greenland (Sverdrce et al., 1942).

Atlantic.--The Atlantic Ocean (Fig. 71), in contrast with the Pacific, is meridionally well circulated, is well oxygenated, and is generally low in productivity. No discrete equatorial water mass divides the Atlantic, hut only a zone of mixing centered at about 10 degrees north between the North and South Atlantic Central Water masses, each of which embodies a huge central current gyre. Another zone of convergence and mixing Secondary Polar Front) in the North Atlantic, lying between the mixed waters of the Gulf Stream to the north and the center of the Western Gyre to the South, extends across the ocean latitudinals between the $30^{\circ}$ and t 11 P parallels. Both boundary areas are the range limits of many bathypelagic fishes and other organisms. Arcumulated at the Woods Hole Oceanographic Institution, recent evidence shows there to be a deep south-warl-flowing countercurrent under the northward flowing Gulf Stream. This may account for the fact that ertain species, normally taken north of $40^{\circ} \mathrm{N}$ in the western North Atlantic, have been taken at greater depths near Bermuda Island. At 500-1000 meters relatively warm but highly saline Mediterrancan Water
spreads out from the Straits of Gibraltar and mixes with the shallower central waters and with the Antarctic Intermediate Water flowing north and centered at about 1000 meters. Lesser amounts of Intermediate Water form off Newfoundland, but the main contribution of the North Atlantic to the deep circulation is the formation off Greenland of Deep and Bottom Water, which flows south. Here it meets, overrides, and mixes with the Antarctic Bottom Water (Sverdrup et al., 1942). In the Atlantic even though the central waters are relatively sterile, areas of high productivity bound these waters to the north, to the south, and in the cool Benguela Current, which flows northward along the west coast of Africa. Hart and Currie (1960) described the areas of strong upwelling of deeper, nutrient-rich water in the Benguela. Characteristic of this current, these areas are regularly constricted shoreward by tongues of warmer, saltier Central Water invading from the west. The resulting increased productivity is so high that accumulation of decaying organic matter on the bottom account for localized anaerobic conditions nearshore. Even offshore the thermocline depth is relatively shallow and there is associated with it a fairly well developed (for the Atlantic) oxygen minimum layer. These highly productive areas in the Benguela invite comparison with similar, though more extensive, areas in the eastern tropical Pacific.

Indian Ocean, Indonesia, and central South Pacific.--The central water masses of the South Atlantic, Indian Ocean, and western South Pacific resemble each other in their physico-chemical and biological properties and, perhaps, should be considered for our purposes as one. All three are broadly interconnected, even around the tip of Africa, and have almost a common bathypelagic fish fauna. Western South Pacific Central Water is slightly cooler and less saline than the others. In the Tasman Sea the water to the north is a mixture of Equatorial and Western South Pacific Central waters; in the southwestern and central areas it is influenced by local changes and Subantarctic Water (Rochford, 1959). In zones of vertical mixing here (e.g., off New Zealand) the productivity is relatively high; the included fauna contains Central, Equatorial, and Sulbantarctic elements. In the northern Indian Ocean the Equatorial Water Mass, which vertically has a more constant salinity than the Central Water, is noticeably different from the Pacific Equatorial Water in its T-S relationships. Antarctic Intermediate Water underlies the Central Water, but to the north mixes with Equatorial Water and with an intermediate fan of highly saline Red Sea Water. The central waters are generallv low in productivity. In the Equatorial Water Mass productivity is highest near the equator off Madagascar, near the Continental shelf around India, and in upwelling areas off the Somali Coast (Figs. 71, 72).

The salinity of the Indonesian water masses is almost constant from 100 meters to the bottom. At about $34.5 \%$, it is lower than the salinity of the water masses described above, but higher than the salinity in much of the North Pacific. Much of this water probably originates by mixing of Western North lacific Central Water with Pacific Equatorial Water and locally formed water from semi-enclosed basins. The waters in these isolated basins (e.g. Sulu Sea) exhibit discrete distributions of temperature and salinity. In the Ind 1 nesian area nutrient run-off from the numerous land masses and upwellings increase the productivity (Haffeer, 1952; Graham, 1952; Hybbs, 1929).

North Pacific and equatorial Pacific.-The North Pacific differs from the North Atlantic in several important characteristics: the virtual closure of the Bering Strait causes the circulation to be mainly latitudinal instead of meridional; the salinity of the surface and intermediate waters is generally lower, especially to the north: vertical circulation is restricted so that no deep water is formed; since there is little exchange of water across the equator, the deep and bottom waters, which are far removed from their site of formation at the surfact. circulate sluggishly and consequently are relatively high in nutrients but low in oxygen; the overall concentration of nutrients is higher and, therefore, the productivity is higher (Flemeng, 1955); and the water masses are better defined.

A boundary near $40^{\circ} \mathrm{N}$ separates the Subarctic Water (modified or mixed water) to the north from thi" Central Water of higher temperature and salinity to the south (Uda, 1959; Flfaning, 1955). Even though physico-chemically this boundary is not usually as abrupt as the boundary between the Central and the Equatorial Water, it constitutes a major biological barrier, separating the Subarctic fauna from the Central (Bremt. 1959; Bekiemismey and Panis, 1960). Farther northward at about $47-50^{\circ} \mathrm{N}$ is the southern limit of the Gulf of Alaska Central Water (Alaskan Gyre) to the east and the Bering Sea Water (Western Gyre) to the
west. The Aleutian Islands separate these two counterclockwise gyres (Uda, 1959; Fleming, 1955). Just below the Gulf of Alaska, at the edge of the North Pacific Drift, is a well-marked zone of convergence at the the Gulf of Alaska Central Water might be considered a subdivision of the Subarctic, the Bering Sea Water thologically from the other two water masses (Fleming, 1955).

The Subarctic Water originates at the convergence of the cold, less saline Oyashio Current from the north and the warm, more saline Kuroshio Current from the south. The northern North Pacific, therefore, is divided into three oceanic regions by oceanic fronts of three Kuroshio extensions, which flow eastwardly. The middle whension (Aleutian or Subarctic Current) comprises this Subarctic Water of intermediate temperatures and salinities. Contributing to the Pacific Central Water and gyres, the southern extension (North Pacific Current) if warm water bends southward, leaving an intermediate region of mixing between it and the Aleutian Current. The northern extension (branch off Aleutian Current) continues northeast, eventually to form the Western Gure of Bering Sea Water. At the American coast another branch of the Aleutian Current is deflected northward and forms the Alaskan Gyre. This gyre comprises the Gulf of Alaska Central Water, which is warmer and more saline than Bering Sea Water (Kitano, 1958; Sverdiep et al., 1942).

Because of extensive vertical inixing, the Subarctic Water and associated water masses are abundantly replenished of nutrients from the deeper layers. This effects high production and, therefore, a large food supply for these waters, especially near the Aleutian Islands (Fleming, 1955). During the period of summer watification, Oксво (1958) found in the Subarctic Water a well-developed oxygen minimum ( $0.5-0.9 \mathrm{ml} / \mathrm{l}$ ), "hich is associated with this high productivity.

The Transitional Water along the coast of the Californias originates in the California Current, which is the southward deflection of the Aleutian Current. This current is further mixed with Central Water from the ast and with deep intrusions of diluted Equatorial Water flowing up at depth from the south. Near the coast, up welling of deep Transitional Water with both Subarctic and Equatorial components enriches the surface lavers (Reid et al., 1958).

The properties of the huge North Pacific Central Water Mass, which Sverdicp perhaps unjustifiably divided into eastern and western sections, contrast sharply with those of the Subarctic Water. Because this water has been warmed for a considerable time in the large central gyres, it has a stable thermocline and a decp mixed laver, which is relatively warm and saline. Since there is virtually no vertical mixing through the thermocline, the nutrients in the surface layer are almost exhausted and the productivity is low (Reid (ifl., 1958).

Although no deep or bottom water is formed in the North Pacific, a limited amount of mixed water sinks at the convergence of the Kuroshio and Oyashio currents northeast of Japan to form a relatively shallow laver of Intermediate Water. This water mass, which distributes nutrients produced in the high latitudes, dows southward and eastward at a depth of about 500 neters, below the Central Water and Kuroshio. Rerognized by a distinct salinity minimum, it overrides and mixes with intermediate masses from the south in the western Equatorial Pacific (Uds, 1958a, b).

A sharp stable boundary at about $20^{\circ}-25^{\circ} \mathrm{N}$, near the American continent and at about $10^{\circ} \mathrm{N}$ between in ngitudes $158^{\circ}$ and $172^{\circ} \mathrm{W}$, separates Transitional and Central Water from warmer, more saline Equatorial Water, which is formed in situ by advective mixing. At this boundary the thermocline, along with many associated properties, such as salinity, oxygen, and silicates, approaches the surface (Wooster and Cromwele, 19.38: Bnem, 1959 ; Acstin, 1960 ). This is the current divergence area between the North Equatorial Current and the Equatorial Counter Current. Off the coast of Central America the thermocline is relatively shallow and a lens of deep water approaches the surface. Because, as a consequence of the shallow thermocline the nutrient-rich deep water enriches the euphotic zone, these Central America waters are also highly productive. Hong the equator another current divergence within the South Equatorial Current induces upwelling (most intensely at about $130^{\circ} \mathrm{W}$ ) and, therefore, increased productivity in a relatively narrow belt west to $180^{\circ}$ (ir $170^{\circ}$ E (Wooster and Cromwelf, 1958; Chomwell, 1958; Sette, 1958; Acstin, 1960; ete.) (Fig. 72 ).

The equatorial current system is complex. Between the west-flowing North Equatorial and South Equatorial currents, the eastflowing Equatorial Counter Currents extends from about $5^{\circ} \mathrm{N}$ to $10^{\circ} \mathrm{N}$. According to Johs A. Kxarss, Vniversity of California, Seripps Institution of Oceanography (personal communication), in 1958 the Counter Current retained a measurable eastward component of velocity ( $5 \mathrm{~cm} / \mathrm{sec}$ ) at 1500 meters. He further suggested from a consideration of the conservation of mass, that the North and South Equatorial Currents may also extend to great depths. Flowing eastward below a shallow surface layer of west-flowing South Equatorial Current is the recently discovered Cromwell Current or Equatorial Undercurrent (Kxat ss and King, 1958). Located symmetrically about the Equator, this jet stream is about 240 miles wide at $140^{\circ} \mathrm{II}$. At its core, 100 meters, Kxatss measured a maximum velocity of 3.5 knots. Vertically, it extends from about 50 to 500 meters. These currents obviously present broad pathways of transit across the equatorial Pacitic; why bathypelagic fishes do not always take advantage of these thoroughfares is meat for speculation and will be discussed later.

Reid et al. (1958) described a deep countercurrent of Equatorial Water, below 200 meters, that slowly flows northward along the coasts of Baja California and Southern California, where it mixes with Transitional and Central waters. This water also fills the lower levels of the Gulf of California and, perhaps, allows some equatorial species to range further northward than otherwise would be possible. Similarly, in the Southern Hemisphere along the coasts of Peru and northern Chile, a southward flow may subtend the Peru Current (Brasdnokst, 1959b).

## LOCALIZATION OF SPECIES IN WATER MASSES

In most zoogeographical studies of bathypelagic fishes a single isotherm has been used to delimit distributions. However, inasmuch as species of Melamphaes and other bathypelagic fishes are distributed threrdimensionally between isotherms and other horizontal boundaries that periodically fluctuate, the vertical distribution of salinity with temperature (T-S curve) at each capture may better explain the distribution of these fishes. Though important, this T-S relation may not principally influence the range of a species, hut may index other more important biological parameters associated with this range. Fortunately the development of the water mass concept, which has as its basis the T-S curve, makes it possible to relate the di, tributions of particular species to those of certain water masses.

Because the depth of capture of most specimens of Melamphaes is uncertain, it is dif ficult to describe vertical distributions of species relative to the water masses. The available data, however, indicate that even though the four dwarf species are shallowest, three are as widely distributed as the most far-ranging decper forms. As a matter of fact, some of the deepest-water species studied, the adults of which live well below 1000 meters are narrowly restricted geographically (e.g., M. acanthomus). Having fragile skins, poorly ossificd skeletons, flabby muscles, and reduced eyes, they are morphologically adapted to the great depths. It seems probable that all species are vertically distributed relative to the depth of the thermocline rather than " absolute depth intervals. Where the thermocline approaches the surface, especially in the South Atlantic along the west coast of Africa, relatively shallow captures are the rule.

To locate species of Melamphaes in temperature-salinity-defined water masses, captures were not only plotted on surface distribution maps, but their associated T-S curves were superimposed on water mass envelopes. These distributions relative to water masses follow definite, predictable patterns, which are corr:borated by the distributions of many other bathypelagic fishes: the ranges of species coincide to form welldefined faunal regions--boreal, transitional, and tropical regions-which are restricted by the continents as well as water-mass boundaries.

Distribution maps:--For each species localities of capture were plotted on distribution maps, on which were indicated the horizontal extents of the various water masses. Only the positive stations-those where specimens were actually taken-were plotted. However, to estimate the reliability of the horizontal range of the specis, selected trawling series for each expedition that supplied specimens are plotted in Fig. 42.

T-S copture dingrams:--To locate captures in a particular water mass more precisely it is best to plot the entire segment of a $T$-S curve, constructed from hydrographic data taken concurrently at station, through the maximum possible depth range of capture. Grace Pickford (1946) originated this method in her study

-ig. 42. Series of net hauls taken on expeditions that supplied specimens for this investigation. Only those hauls deep enough to have caught melamphaids are included. Because other data were not available, only the hauls that caught melamphaids are plotted for the $1 \mathrm{k} / \mathrm{V}$ "Vitiaz", "Ob", "Galathea", and miscellaneous expeditions. For readability, only selected sta-
of the distribution of Vampyroteuthis infernalis. In her study envelopes from Sverdrep et al. were constructed for the major water masses of the Atlantic, Indian, and Pacific Oceans. On these graphs each capture was represented "... by three points: a maximum, probable and minimum, corresponding to temperatures and salinities, at one third, one half, and two thirds the tow line." This, of course, took in the entire probathe range of the greatest depths trawled, but made no provision for possible captures on the way up or down. With several shallower nets above the deepest, however, "Dana" trawls were always taken in series. Therefore, from the absence of specimens in shallow net tows she approximated depths of capture.

Haffer (1952) employed a similar method in locating the various species of Chauliodus in particular water masses. Here, however, for each capture he plotted but one point, which represented the temperature and salinity at a depth corresponding to half the number of meters of wire out for the particular "Dana" haul. Because ". . . representatives of a water mass may be selected as indicators of the water through the relationships demonstrated to temperature and salinity," Bany (1959) introduced his T-S-P (temperaturi-salinity-plankton) diagram. This method resembles the others, except that several species with numbers of individuals per capture are plotted on the same diagram. He assumed that diurnal migrations of the plankinn might alter their position with respect to the different water masses.

Jons A. Mc Gowan, Lniversity of California, Seripps Institution of Oceanography, ( 1960 ; personal communication), correctly criticized the above methods. He pointed out that because the entire segment of the T-s curve through the depth range of capture was not plotted, the plots were not entirely representative of the distribution of species. Since a water mass is indicated by a T-S curve and not a single T-S point, only the curve accurately locates the captures in a particular water mass.

First an upper depth-distributional limit for young and adults of most species was assumed from an examination of all trawl hauls containing these species to find the least depth at which they were taken. For earh capture, then, a T-S curve was constructed from hydrographic data taken from that depth to the presumed greatest depth of trawl. This T-S curve through the maximum possible depth range of a particular captite was used because it more completely defines the water mass in which the individuals lives. For each species these T-S segments were superimposed on water-mass envelopes for the oceans in which captures were matl. When the curves for a certain species mostly fall within a single envelope, the indications are that this specias inhabits only the water mass defined by this envelope. The diagrams were constructed as simply as possible and are designed to show only the presence or absence of each species in particular water masses. Consequently, only the water mass envelopes and T-S curves were constructed; sigma-t contours, etc. were omittect. Hydrographic data were obtained from the following sources:

Atlantic, Indian, Pacific Oceans-Deacon, 1937: Fleming et al., 1945; Thomsen, 1937.
Atlantic Ocean (and Gulf of Panama)-Bohnecke, 1936; Schmidt, 1929.
Central North Pacific Ocean-McGary et al., 1956; Stroctp, 1954.
Subarctic North Pacific Ocean and vicinity-Fleming and staff, 1958; 1959; University of California, Scripps Institutien of Oceanography (on file).
Eastern tropical Pacific and transitional regions—University of California, Scripps Institution of Oceanography 1951:t; 1951b; 1952; 1956a; 1957; 1958a; 1958b.

## Distributions Relative to Water Masses

It is difficult to indicate that bathypelagic organisms are distributed, as they are, three-dimensionally through the length and depth of a water mass. A consideration of both the T-S water mass diagram and of the horizontal plots is required to clarify the distribution of a species. Although Brivtos (1958) found the shallow est-living species of cuphausiids to be most narrowly restricted to water masses, no such generalization combl be made for the species of Melamphaes: as will be shown below, the shallowest and deepest dwellers apprar equally limited by oceanic boundaries; the horizontal geographical distributions of both types substantiatel their T-S capture diagrams. Studies of the distribution of the species of Chauliodus by Haprene (1952) ant of the lantern fishes of the genus Lampanyctus by Arow (1959) demonstrated the importance of vertical distri
butions in separating contiguous species, especially where horizontal distributions overlapped. This, of course, is especially true when comparing the horizontal distributions of shallow and deep-living species or of vertically eparated ontogenetic stages within a single species. In many melamphaids, for example, the larvae and young accur more shallowly than the adults; for some species the two groups may even live in different water masses.

The vertical diurnal migrations of many species of animals may obscure their distributions relative to particular water masses. Showing that they can be quite extensive, Hilary Moore (1958) summarized the pertinent literature on vertical migrations of various organisms. For speeies of Melamphaes, however, the data indicate relatively limited vertical migrations. Most of these species probably inhabit the same water mass both by day and by night. Furthermore, Anlstrow (1959) demonstrated that certain larvae and young of Metamphaidae migrate less extensively than corresponding growth stages of any 12 species of other families (1) bathypelagic fishes.

Certain species, although apparently localized within physico-chemically defined water masses, are not ahrays distributed throughout them; others are either distributed throughout a single such water mass or werlap two or more. Because this may have zoogeographical significance, the species of Melamphaes are here categorized as limited to a single physico-chemically defined water mass or to more than one. It should be remembered, however, that even though some species do overlap water masses, individuals often occupy approximately the same range of temperatures. This is expecially true of the central-tropical species. The agreement between species distributions and water masses is closest in the eastern tropical Pacific and in lureal regions. Biemi (1959), among others, confirmed this fact for some Crustacea and Chactognatha. The agrement is poorest in the Central-tropical Region. That here the species broadly cross the oceanic boundaries visgests great oceanographic and biological similarities between the constituent water masses.

Whereas most of the species that reach a relatively large size inhabit the highly productive boreal and castern tropical water masses, the 4 dwarf species (simus group) occur exclusively in the relatively sterile western equatorial and central water masses. Large species that do not entirely follow this pattern are M. typhlops (N. Atlantic Central Water), M. polylepis (central-tropical water masses), M. longiwelis (centraltripical), and M. indicus (central-tropical). The adults of 3 of these species, however, are slightly smaller than those of related species in the peripheral water masses. Also, the large adults of typhlops (East Atlantic) and indicus (Indonesia) are, in fact, congregated around productive areas.

Species limited to all or part of single water masses.--These species, most of which occur in the eastern Pacific, inhabit four types of water masses: Subarctic, Transitional, Central, and Equatorial.

Subarctic and Transitional species:-In the North Pacific M. lugubris occurs throughout Pacific Subarctic Water, including the Alaska Central Water, but does not extensively inhabit Bering Sea Water. Even though it extends south along the coasts of the Californias in mixed Transitional Water, it apparently does not to any great extent migrate Southward in the mixed Intermediate Water that sinks at the convergence at about $40^{\circ} \mathrm{N}$ (Figs. 43, 45). Young specimens, which were regularly taken in the transition region of mixing hetween the Subarctic and Central waters, were rarely taken in Central Water. Many other species of fishes and invertebrates, including the annelid Pooobius meseres, inhabit only Subarctic Water or Transitional and mixed waters (McGowan, 1960; Bieri, 1959; Brinton, 1957; Beklemishey and Parin, 1960). Although the distribution of Poeobius is abruptly halted at the boundary of the Central Water, it extends via the Tranitional Water to the equator, where, however, the planktonic worm is probably unable to reproduce (McGowav, 1960).

Melamphaes parvis of the typhlops group inhabits only Transitional Water in the eastern North Pacific wll the coasts of California and northern Baja California (Figs. 44, 46). According to Joun McGowax and Enwad Banton (personal communications), certain species of pteropod mollusks and cuphausiids also weur only in Transitional Water, some in transitional masses both off North and South America, but not in the intervening Equatorial Water.

Central species:- Although M. typhlops ranges throughout the North Atlantic Central Water Mass and is "en occasionally taken in mixed water or South Atlantic Central Water (Figs. 47, 49), M. pumilus of the simus group is narrowly confined to the western gyre of the North Allantic Central Water Mass in water of


Fig. 43. Distributions of the species in the Melamphaes lugubris species group. The hatched bands delimit relevant water masses (see Fig. 711 .


Fig. 44. I)istributions of 2 species in the Melamphaes typhlops species group. The hatched bands delimit relevant water masses (see Fig. 71 ),

4. 4. Temperature-salinity capture diagram for Melamphaes lugubris. The wat ines enclose water mass envelopes. The thin lines are temperature-salit! vements through the maximum possible depth ranges for each capture om ti:e presumed upper depth limit for the vertical distributions of adults d young to the maximum depth attained for each net haul); dashed lines are $r$ bung. solid lines for adults. The presumed upper depth limit for each species is in its species account (further explanation is in the text).


Fig. 46. Temperature-salinity capture diagram for Melamphaes parvus. For further explanation see Fig. 45.


Fig. 47. Distributions of 3 species in the Melamphaes typhlops species group. The hatched bands delimit relevant water masses (see Fig. 71).


Fig. 48 . Distributions in the Atlantic of 3 species in the Melamphaes simus species group. The hatched bands delimit the North and Sout! Atlantic Central Water masses (see Fig. 71).



Fig. 50. Temperature-salinity capture diagram for Melamphaes pumilus. For further explanation see Fig. 45.


Fig. 51. Temperature-salinity capture diagram for Melamphaes hubbsi. For further explanation see Fig. 45.


Fig. 52. Temperature-salinity caplure diagram for Melamphaes leprus. For further explanation see Fig. 45.


Fig. 53. Distributions of the species in the Melamphaes suborbitalis species group. The hatched bands delimit relevant water masses (see Fig. 71).


Fig. 54 . Distributions of the species in the Melamphaes spinifer species group. The hatched bands delimit relevant water masses (see Fig. 71).


Fig. 55. Distributions of the species in the Melamphaes macrocephalus species group. The hatched bands enclose the Pacific Equatorial Water Mass.


Fig. 56. Temperature-salinity capture diagram for Melamphaes laeviceps. For further explanation see Fig. 45.


Fig. 57. Temperature-salinity capture diagram for Melamphaes macrocephalus. For further explanation see Fig. 45.


Fig. 58. Temperature-salinity capture dlagram for Melamphaes spinifer. For further explanation see Fig. 45.
rlatively high temperature, high salinity, and low productivity characteristic of this gyre (Figs. 48, 50). That the range of closely related M. simus almost encircles pumilus is of special significance (Fig. 48). Whereas adults of M. typhlops occur deeply-probably even in Intermediate Water, Mediterranean Water, and Deep Water--mostly in the eastern North Atlantic, the young and larvae inhabit the overlying Central Water mainly in the western gyre. The adults of pumilus, on the other hand, overlap both the vertical and horizontal range If the young (Fig. 39).
M. hubbsi, also in the simus group, was taken only at two "Dana" stations in South Atlantic Central Water (Figs. 48, 51). Though M. leprus of the suborbitalis group also inhabits South Atlantic Central Water, it is areociated with the zone of mixing between this water and North Atlantic Central Water and, perhaps, with the highly productive Benguela Current off the west coast of Africa (Fig. 52).

Equatorial species:-All the equatorial species-M. laeviceps (suborbitalis group), M. macrocephalus, and M. spinifer-inhabit only the more highly productive eastern and central parts of the Pacific Equatorial Water Mass (Figs. 53,$56 ; 55,57 ; 54,58$ ). The deep-living adults reach relatively large size; the larvae and young wur more shallowly, probably in the upper 200-400 meters.

Species crossing water-mass boundaries:-The largest group under this heading comprises the centraltrepical species; these inhabit the warm, saline equatorial and central water masses, relatively low in proHetivity, which stretch from the central North Atlantic, around Africa through the equatorial and central regions of the Indian Oceans, to the western equatorial and central regions of the Pacific. That these species humld occur in more than one central-tropical water mass is not surprising because the boundaries between these biologically and physically similar water masses are relatively weak. Eкman (1953), recognizing this, called attention to the relatively free communication for pelagic organisms between the South Atlantic, Indian Occan, and the Western Pacific. The biological similarities between the central-tropical water masses are
particularly striking, even more so than the physico-chemical. Excepting the few areas (e.g., west coast of Africa and Indonesia) where upwelling and vertical mixing enrich the surface waters, the entire region is low in productivity.

Occurring in the North Atlantic and Subantarctic but not in the intervening tropics, two species are apparently antitropical. That these species are submergent in Intermediate or Deep Water across the tropics has never been demonstrated; most likely the cool currents that flow northward along the west coast of Africa have offered avenues for repeated invasion of favorable environments in the North Atlantic. Other speries of Melamphaes are either limited by proximity to land or exhibit peculiar disjunct distributions.

Central-tropical species:-M. polylepis (lugubris group) (Figs. 43, 59), M. longivelis (Fig. 44), and M. simus (Figs. 48, 61, 60) occur in central and equatorial water masses of the Atlantic, Indian, and western Pacific occans, but not in Equatorial Water of the eastern tropical Pacific. The other three central-tropical species, however, range less extensively. Whereas M. danae (sinus group) (Figs. 61, 62) and M. indicus (!y. phlops group) (Figs. 47, 63) inhabit neither the North nor South Atlantic Central Water, M. eulepis (spinifer group) occurs in the zone of mixing between these two water masses, mainly in South Atlantic Central Water types. M. eulepis also circumflects Africa into the water masses of the Indian Ocean, Indonesia, and central equatorial Pacific (Figs. 54, 64).

Excluded from Pacific Equatorial Water, two dwarf species, M. simus and M. danae, inhabit mainly the relatively shallow central waters, though both occur in Indian Equatorial and Indonesian waters. Taken regularly above $150-200$ meters, danae is the shallowest-living of all the species of Melamphaes; in fact, most of the T-S capture segments fall outside water mass envelopes and so indicate locally formed water types (Fig. 62). As in M. pumilus, the larvae, young, and adults are not well separated vertically. The adults of closely related simus, however, live at greater depth in water whose T-S curves fall within the upper parth, of water mass envelopes; the larvae and young occur more shallowly and probably overlap the vertical range of danae (Fig. 60). In the North Atlantic, simus occurs only in the more extensively mixed northern and eastern


Fig. 59. Temperature-salinity capture diagram for Melamphaes polylepis. For further explanation see Fig. 45.


Fig. 60. Temperature-salinity capture diagram for Melamphaes simus. For further explanation see Fig. 45.


Fin. til. Distributions of 2 species in the Melamphaes simus species group. The hatched bands delimil relevant water masses (see Fig. 71).


Fig. 62. Temperature-salinity capture diagram for Melamphaes danae. For further explanation see Fig. 45.




Fig. 64. Temperature-salinity capture diagram for Melamphaes eulepis. For further explanation see Fig. 45.


Fig. 65. Temperature-salinity capture diagram for Melamphaes suborbitalis. For further explanation see Fig. 45.
parts of the North Atlantic Central Water Mass, but apparently not in the intermediate masses. It surrounds, but does not greatly overlap, the distribution of pumilus (Fig. 48). M. simus may be subspecifically different in the central North Pacific.

Because few specimens are available of the other four species, their vertical and horizontal distributions relative to the water masses cannot be precisely defined. Although the larvae and young of M. longivelis, M. polylepis, and M. indicus probably live entirely within the upper layers of central and equatorial waters (excepting the Equatorial Water of the castern Pacific), the adults inhabit greater depths in the deeper central waters and the intermediate masses. M. polylepis is known mainly from larval and young specimens (partly because of the greater number of shallow net-tows taken). M. culepis was taken mainly in the upper anf meters of the upwelled, nutrient-rich water off the west coast of Africa.

Antitropical species:-M. suborbitalis (Figs. 53 , 65) and microps (Fig. 43) may be antitropical. Both are found in North Atlantic Central Water mainly north of the Secondary Polar Front and in the Subantarctic Water Mass or in areas of mixing, bevond its northern boundary (the North Atlantic population of microps, however, may be differentiated from the Subantarctic). From these southern populations only a few captures were available for distributional study. Although suborbitalis in the eastern North Atlantic ranges south into South Atlantic Central Water, the North Atlantic population of microps inhabits only North Atlantic Central Water mainly north of the Secondary Polar Front. Captures of "microps" and suborbitalis off Bermuda suggest that in the western North Atlantic individuals of both species may migrate southward in the deep counter current that flows under the Gulf Stream. Three specimens of a form closely resembling suborbitalis were trawled in the eastern North Pacific off Baja California near the boundary between Transitional Water and North lacific Central Water (Fig. 53), but, that these are conspecific with the other antitropical populations is uncertain.

Rolf L. Buln, Hopkins Marine Station, Stanford Lniversity (personal communication; 1959) show d that two lantern fishes (Myetophidae)-Lampanyctus pusillus and Hygophum hygomi-occur in the North Atlantic north of $20^{\circ} \mathrm{N}$, in the South Atlantic along the southwest tip of Africa, and in the Subantarctic to nll New Zealand, but not in the intervening tropical Atlantic. In the Atlantic the cool, nutrient-rich Benguta Current, by providing a suitable habitat for Subantarctic species, might transport individuals along the wet coast of Africa to the region of the equator. From here the South Equatorial Current, and finally the Gulf Strcam could carry them to the North Atlantic, where conditions again would be suitable for reproduction. Rass (1960) plotted the meridional distributions in the western Pacific ( $35^{\circ} \mathrm{N}-40^{\circ} \mathrm{S}$ along two transer $\mathrm{l}_{\mathrm{s}}$ between $160^{\circ} \mathrm{E}$ and $160^{\circ} \mathrm{W}$ ) of 10 antitropical lantern fishes. Two species (Lampanyctus blacki and Myctophum branchygnathos) were taken north of $20^{\circ} \mathrm{N}$ and south of $20^{\circ} \mathrm{S}$, but not between; others were nowe narrowly excluded from equatorial waters.

Species that have disjunct distributions other than antitropical:-There are two separated populations of M. janae, one in the eastern tropical Pacific and the other in the Indian Ocean (Figs. 47, 66i). The closely related M. indicus occupies the intervening western tropical Pacific and Indonesia. The eastern population of junue inhabits only the eastern and central parts of the Pacific Equatorial Water Mass, the western population mainly Indian Equatorial Water. The two populations differ mainly in sizes of mature adult, the standard lengths of individuals from the Indian Ocean averaging several millimeters the lesser. A few other fishes and invertebrates have similar distributions. According to Rolf L. Bolns (personal communi(eation), a species of lantern fish occurs in the castern tropical Pacific and in Indonesia, but not in the intervening western tropical Pacific. Edwabd Brintos, Scripps Institution of Occanography (personal communication), described for an euphausiid specie's a distribution even more nearly following M. janae. The caus of such disjunct distributions is unclear; perhaps various biologicat factors, including competition with intervening relatives, may partly explain these separations.
$S_{\text {pecies limited to }}$ near-continental shelf water:-M. actanthomus, which has been taken only along the Pacific coasts of North and Central America, is apparently confined to water near the continental shelf (Fig. 55). It inhabits both Pacific Equatorial Water south of the tip of Baja California and mixed Equatorial, Transitional, and Intermediate waters in the Gulf of California, off Baja California, and off Southern


Fig. 66. Temperature-salinity capture diagram for Melamphaes janae. For further explanation see Fig. 45.


Fig. 67. Temperature-salinity capture diagram for Melamphaes acanthomus. For further explanation see Fig. $4 \overline{5}$.

California (Fig. 67). The large individuals probably migrate northward along the coast in deep intrusions ,if Equatorial Water, which progressively loses its identity to the north. A few species of lantern fishes are also restricted to near shore regions. It may be that these species and M. acanthomus, the individuals of which usually attain relatively large sizes, are dependent for their livelihood on water enriched by nearby land masses.

## Distributional Patterns and Faunal Regions Relative to Water Masses

| REGIONS OF <br> WATER <br> MASSES | $\begin{aligned} & \text { en } \\ & \mathbf{n} \\ & 0 \\ & \mathbf{o} \\ & \underline{u} \\ & \mathbf{v} \end{aligned}$ |  |  |  |  |  | $\left\lvert\, \begin{aligned} & u \\ & \partial \\ & \dot{x} \\ & a \\ & \vdots \\ & \hline \end{aligned}\right.$ | $n$ <br> 0 <br> $u$ <br> $u$ <br> $\vdots$ <br> $\vdots$ <br> $u$ <br> $\vdots$ | $\left\|\begin{array}{l} a \\ w \\ \frac{u}{z} \\ \frac{a}{a} \\ i \end{array}\right\|$ | $\left\lvert\, \begin{aligned} & \frac{0}{a} \\ & u \\ & \vdots \\ & \vdots \\ & u \end{aligned}\right.$ |  | $\begin{aligned} & a \\ & j \\ & \vdots \\ & \frac{\alpha}{d} \\ & \alpha \end{aligned}$ | $\begin{aligned} & w \\ & \underset{z}{z} \\ & \underset{y}{2} \end{aligned}$ | $\left.\begin{aligned} & n \\ & J \\ & 0 \\ & 0 \\ & \underline{z} \end{aligned} \right\rvert\,$ | $\begin{aligned} & n \\ & a \\ & a \\ & a \\ & 1 \\ & a \\ & \vdots \\ & r \end{aligned}$ | $\begin{aligned} & n \\ & \frac{n}{2} \\ & \frac{2}{n} \end{aligned}$ | $\left\|\begin{array}{l} \bar{w} \\ \mathbf{m} \\ \mathbf{~} \\ \vec{x} \end{array}\right\|$ | $\begin{aligned} & u \\ & u \\ & z \\ & \vdots \\ & \vdots \end{aligned}$ | n |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\begin{aligned} & \text { GULF OF } \\ & \text { MEXICAN } \end{aligned}$ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| MEDITERRANEAN SEA |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| $\begin{aligned} & \hline \text { ATL. SUBARC (N } \\ & \text { SECOND POLAR } \\ & \text { FRONT-40 } \left.{ }^{\circ} \mathrm{N}\right) \\ & \hline \end{aligned}$ |  |  |  |  |  | $?$ |  |  |  |  |  |  |  |  |  | $?$ |  |  |  |
| WNATL CENTR. <br> GYRE (INCL <br> CARIB BEAN) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| E.N. ATL. CENTR (EAST OF $40^{\circ} \mathrm{W}$ ) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| ATLANTIC EQUATORIAL |  |  |  |  |  |  | $?$ |  |  |  |  |  |  |  |  | $?$ |  |  |  |
| ATL. TROPICAL (OFF W AFRICA) |  |  | $?$ |  |  |  |  |  |  |  |  |  |  |  | $?$ |  |  |  |  |
| SOUTH ATLANT. CENTRAL |  |  |  |  |  |  |  |  |  |  | $?$ |  |  |  |  |  |  |  |  |
| INDIAN CENTRAL |  |  | $?$ |  |  |  |  |  |  |  | $?$ |  |  |  |  | $?$ |  |  |  |
| INDIAN EQUATORIAL |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | $?$ |  |
| INDONESIAN |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| SOUTH PACIFIC CENTRAL |  |  |  |  |  |  |  |  |  |  |  |  |  | $?$ |  |  |  |  |  |
| NORTH PACIFIC CENTRAL |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| $\begin{aligned} & \text { W. PACIFIC } \\ & \text { EQUATORIAL } \end{aligned}$ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | $?$ |  | $?$ |  |
| $\begin{aligned} & \text { E PACIFIC } \\ & \text { EQUATORIAL } \end{aligned}$ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| NORTH PACIFIC TRANSITIONAL |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| $\begin{aligned} & \text { PACIFIC } \\ & \text { SUBARCTIC } \\ & \hline \end{aligned}$ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| GULF OF CALIFORNIAN |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| SUBANTARCTIC |  |  |  |  |  | ? |  |  |  |  |  |  |  |  |  |  |  |  |  |

Fig. 68. Occurrence (solid squares) of species of Melamphaes in various regions of water masses. If a species is assumed to occupy a certain region even though its occurrence is unverified by captures, the appropriate square is queried.

In their adherence to the water masses the species of Melamphaes follow a distributional pattern: central, equatirial, central-tropical, transitional, boreal, and antitropical. Some species are narrowly restricted to particular water masses; others, especially those in the comtral water masses and in the westom tropics, are not. In tallying the occurrence of the species in respect to water masses (Fig. 68), extended solid blowks are constituted by the wide-ranging em-tral-tropical species (i.e., M. polylegis, eulepis, longivelis, indicus, simus, and danae), whereas, typically, short, scattered blocks are represented by the carern equatorial and boreal species (i..... M. microps, lugubris, macrocephalus, actuthomus, suborbitalis, leprus, laevice?,", spinifer, parvus, typhlops, hubbsi, and pumilus).

It is dangerous, of course, to generaIize about such distributions on the sile basis of the ranges of fishes within the single genus Melamphaes. However, the ranges of many species in several familics generally coincide with those of specims of Melamphaes. Therefore, faunal regions, delimited primarily by horizontal boundaries of water masses, can be differentiated. These faunal regions, constructed on the basis of fish distributions, often concide with those for zooplankton. Beklemishey and Pahi (1960), indeed, found biogeographic zones that were common to both plankton and fishes in the North Pacific.

The faunal regions and subregions of the seas of the world are here delimited (Fig. 69) on the basis "if the percentage overlap across 15 boundaries of 135 species of bathypelagic fishes (comprising 27 generia, including Melamphaes, referred to 13 families). The following are families, genera, and references from which Fig. 69 was constructed ("SIO" means data from the fish collection at the Scripps Institution of Oceanugraphy; "PC" means data from personal discussions or correspondence): Bathylagidae (Bathylagus, Leur"-
glossus) Cohen 1958, SIO, PC (Daniel Cohen); Gonostomatidae (Gonostoma, Ichthyococcus, Viaciguerria) Norman 1930, Rechnitzer and Böhlke 1958, Ahlstrom and Counts 1958, SiO, PC (Marion Grey); Chauliodontidae (Chauliodus) Ege 1948, Haffner 1952, SIO, PC (James E. Morrow Jh.); Melanostomiatidae (Bathophilus, Tactostoma) Regan and Trewavas 1930, Aron and McChery 1958, SiO; Stomiatidac (Stomias) Fig: 1934, SIO; Scopelarchidae (Scopelarchus, Neoscopelarchoides) Marshall 1955, SIO; Evermannellidae (Eivermannella) SIO, PC (Robert R. Rofen); Omosudidae (Omosudis lowei) Ege 1958; Myctophidae (Benthusema, Electrona, Hierops, Hygophum, Lampanyctus, Tarletonbeania) Bolin 1959, Arox 1959, FraserBrever 1949, Wisner 1959, SiO, PC (Rolf L. Bolin, Whllam Aron); Paralepididae (Lestidium, MacroIturalepis, Paralepis) Ege 1953, Ege 1957, Harry 1953, Eutaeniophoridae (Eutaeniophorus, Parataeniophorus) bertelsen and Marshall 1958, SiO; Melamphaidae (Melamphaes, Scopelogadus (part); Zoarcidae (Melanustigma) Ekman 1953, SIO.

In constructing Fig. 69 all areas, generally following the water masses, that might have zoogeographical significance were listed on another chart and their boundaries set forth in graphic style. The range of each of the species was then added to this wernd chart as a straight line according to the technique used in Fig. 70. Xist, for each boundary was calculated the percentage of species whose sanges include the areas on cither side. These percentages of overlap for the fiameal boundaries are given in the left hand column of Fig. 69. It is on in ious that the greater the value of (li) percentage, the weaker the boundary so that, somewhat arbitrarily, the regions were divided into four classes, depending on the strength of their associated boundaries. These regions can be visualized by comparins this chart with Figs. 71-73 of the water masses, species distributions, and organic productivity.

Having no more than 17 per cent (1) the species transgressing their bumdaries, the primary regions are the North Atlantic Subarctic Region, north of the Secondary Polar Front; the vast Circumeentral-tropical Resinn, which extends from the Atlantic 1. the Pacific Ocean; the Eastern Parific Equatorial Region, which is the ligshly productive part of the Pacific Equatorial Water Mass; the North Pacific Subarctic-Transitional Resion, including the North Pacific Subarctic, Transitional, and Alaskan i.entral water masses; the Subantarc-


Fig. 69. Faunal boundaries, regions, and subregions associated with water masses and based on distributions of 135 species of bathypelagic fishes representing 18 genera, including Melamphaes. The percentages of overlap across faunal boundaries are found by extending the horizontal lines back to the percentage values on the left margin (further explanation in text).
tic Region, including only the Subantarctic Water Mass; and, possibly, the Mediterranean Sea (the polar regions were not investigated).

The Circumcentral-tropical Region can be further divided into secondary, tertiary, and quaternary subregions; but excepting the Subaretic-Transitional, the other primary regions, comprising boreal and eastern Pacific waters, are fairly homogenous and well isolated from each other.

The data preclude exact delimitations of subregions (some of the less certain are queried on Fig. 69). Secondary subregions (Gulf of Mexico, Atlantic Central, Indo-Pacific, North Pacific Transitional, and Parific Subarctic) by definition have 35-45 per cent of the species overlapping their weakest boundaries; tertiary subregions (Western North Atlantic Central, Eastern North Atlantic Central, Atlantic Tropical, and North Pacific Central(?)) have $58-63$ per cent; and quaternary subregions (Indian (?), Indonesian, and South Pacific Central (?)) have $68-75$ per cent.

These faunal divisions are, of course, tentative because they are based on only a small percentage of the total number of bathypelagic fishes. Furthermore, because of inadequate sampling in several areas, namy of the distributions that were taken from the literature are no doubt incomplete. For this reason, the percentage values of overlap across the sub-boundaries may be unrealistically low and, therefore, the regions may be somewhat artificial.

Regional differentiation in the eastern Pacific is especially noteworthy because of the distinctness of the included faunas and the sharpness of the boundaries. For this region the meridional distributions of 144 species of bathypelagic fishes (mostly from the collection at the Scripps Institution of Oceanography), representing 90 genera and 36 families, were plotted in Fig. 70 over meridionally oriented boundaries of water masses. In this graph coincidence of the range limits of many species, including 8 species of Melamphates, indicates boundaries of the faunal regions and subregions. Unfortunately, some of the data on ranges are probably based on incorrect identifications. However, the errors appear to be conservative; because two, species were most often lumped as one, fewer range limits per faunal break are recorded than actually occur.

One major break at $40-45^{\circ}$ N follows the boundary of the Pacific Subarctic Subregion to the north and the North Pacific Transitional Subregion and Central Subregion to the south (latitudinally, of course, there is a break between the Central Subregion to the west and the Transitional Subregion to the east). Since mest of the species involved are either Subarctic or Transitional (there are relatively few collections from Central Water), the 38 per cent overlap compares favorably with that of 36 per cent overlap in Fig. 69.

A second major faunal break occurs between $20^{\circ}$ and $33^{\circ} \mathrm{N}$; this zone represents the boundary between the Transitional Subregion to the north and the Eastern Pacific Equatorial Region to the south. Many of the ranges extend farther north than would be expected from an examination of the distribution of the watcr masses (Fig. 71). Several species (e.g., M. acanthomus) partly transcend this barrier in northward intrusions of Equatorial Water. Again the per cent of overlapping ranges ( 14 per cent) substantiates the value obtained in Fig. 69 ( 5 per cent).

Two other boundaries, which are biologically less well documented, separate the Equatorial Region (Equatorial Counter Current and South Equatorial Current areas) from the South Pacific Central Subregim. The relatively small number of captures recorded across these boundaries precludes a determination of the percentage overlap of ranges.

## Isolating and Integrating Mechanisms Associated with Water Masses

In reviewing the distributions of the species of Melamphaes we find that some follow the boundaries if physico-chemically defined water masses, whereas others do not. Those that do not may either overlap boundaries or localize within one water mass. We can conclude, therefore, that there is merely a tendency for species to associate with water masses that are strictly defined physico-chemically and, further, that the species are probally not limited by temperature and salinity alone, but also by currents, by non-conservative properties such as oxygen and nutrients, and by such associated biological factors as productivity and food
supply. Cognizant of this, Reid et al. (1958) suggested "... that an organism may be limited on one side of its distribution by temperature and on another side by some other properties, such as nutrients." The distribution of an organism relative to various environmental parameters is rarely simple. A species may either congregate about single optima or may follow different limiting factors at different parts of its range (Moone, 1958: 238). Certain factors may be more potent in their effect on the distributions of larvae and young than on those of the adults; thus the conditions that confine breeding areas may restrict the distribution of the whole species.

The T-S relationslip, however, may index more important biological limiting factors such as organic productivity and food supply. In turn these factors are ultimately controlled by temperature, salinity, solar radiation, and the replenishment of nutrients. Bogorov (1958) implied that surface areas of the oceans should be classified on the basis of their supply of food and production of plankton as well as on temperature. This coneept also applies to the bathypelagic zone, whose productivity must be related to that of the surface waters. ."The nature and abundance of the plankton of the upper water are undoubtedly reflected in the food reaching animals at deeper levels . . . and this in turn follows the local hydrographic conditions which lead to varying supplies of inorganic nutrients" (Moore, 1958: 134).

## Ontogenetic Distribution.

The larvae and young of many bathypelagic fishes live within relatively narrow depth ranges near the surface and are geographically limited to localized conditions to which they are specifically adapted. The derper dwelling adults, on the other hand, may range far from the breeding grounds. Marshall (1960:104) theught that the greater availability of the near surface food supply to the larvae was of primary importance in this ontogenetic separation. Other factors such as the vertical distributions of temperature and salinity may further restrict the suitable breeding habitat. It follows that the larval, young, or breeding stages may at tually limit and concentrate the distribution of the whole species, and that some of the wider-ranging adults may be expatriated and reproductively lost to the population. "Certainly in the sea we have many suggestions It:at the distribution of the species is much wider in many instances than the distribution of the breeding population" (Bullock, 1958). Ekmas (1953: 317), who discussed expatriation at length, elaborated ". . . the unfavorable region is . . . outside the real home of the species, and it is . . . possible to contrast the autochthonous main mass of the species which lives in the reproductive area with an allochthonous sterile expatriated contingent in an expatriation area."

Although larvac, young, and halfgrown of $M$. acanthonius, to cite one example, are restricted to upper Pacific Equatorial Water, the adults not only occur in deeper Equatorial Water, but range northward to off wuthern California and into the lower half of the Gulf of California. To be sure, they still inhabit northward intrusions of water influenced by the Equatorial Water Mass, but at the northern limits of their range this water has been mixed with adjacent masses, which considerably alter its constitution (Figs. 5.5, 67). Only large adults were taken in numerous trawls made in the Gulf of California, off Baja California, and off southern California, so acanthomus almost certainly does not breed in these areas. Individuals probably attain large $\checkmark$ izes as they travel slowly northward in the deep equatorial intrusions, but lose their reproductive potential at the northern limit of their range. Enough sexually mature adults remain in the Equatorial Water to perpetuate the species. The distribution of M. lugubris shows a similar ontogenetic separation (Fig. 45): adults were usually taken in Pacific Subaretic Water, though the young were almost always trawled in Transitional (mixed) Water (oceasionally even in Central Water) which lies to the south.

At the other extreme in ontogenetic distribution is M. pumilus: the larvae, young, and adults occupy almost the same area, though the adults usually descend to greater depths (Fig. 39). Perhaps the short life span of the small individuals in this "dwarf" species limits them to the integrating current gyre in which they live. The individuals of "giant" species such as M. acanthomus, however, probably can disperse from the breeding area for several years.

Although the adults of many myctophids undergo extensive diurnal migrations through a temperature range of as much as $15^{\circ} \mathrm{C}$, the larvae usually are restricted to the more uniform upper mixed layer above the thermocline (Rolf L. Bolin, personal communication). Having a life span of about four years, the adults


Fig. 70. Meridional (north-south) distributions in the eastern Pacific of 144 species of bathypelagic fishes, including 8 of Melamphaes. The blact the water masses designated by: SC, South Pacific Central Water; EQ, Pacific Equatorial Water, which includes the South Equatorial Current (SEC arctic and Alaskal

ars represent range limits on the latitudinal scale (number of captures is given to the right of each bar); shaded areas are boundaries between di the Equatorial Counter Current and associated northern boundaries (NEC); TR, C, North Pacific Transitional and Central Water; S.A, Subentral Water.
can wander far from the breeding area, but they either are expatriated or somehow return to breed. Bolin believes this restriction of the larvae establishes the surprisingly narrow range limits of some species. In discussing the distribution of the deep-sea grenadiers (Coryphaenoididac), Hubbs (1954) proposed that "the pelagic stages . . . seem to be more effective in limiting than in widely expanding the distribution of the species." Haffiner (1952) substantiated the fact that "smaller specimens" of species of Chauliodus occur at depths above the large adults. Although large adults of the deep-sea angler fish Ceratias holboeli have been taken only in boreal waters of the Atlantic Ocean, the larvae and young are restricted to the tropics (Clarke, 1950).

## Environmental Isolating Factors.

The parameters of the external environment that are discussed below directly or indirectly establish faunal boundaries within or between physico-chemically defined water masses. They can be divided into two categories: physico-chemical factors such as patterns of currents and the distributions of temperature or dissolved inorganic substances, and biological factors such as the magnitude of organic production and the availability of food.

## Physico-chemical factors.

Physico-chemical factors include current patterns, conservative parameters (temperature, salinity), and non-conservative parameters (oxygen, nutrients).

Current patterns:-Current gyres in the Atlantic and Pacific oceans undoubtedly integrate and concentrate populations of bathypelagic fishes. The gyres help form and maintain regimens of unique physicochemical and biological properties, which are optimal for their included faunas. Wisner (1959) suggested that a morphologically distinct population of the lantern fish Tarletonbeania taylori is confined by the Alaskan Gyre. The isolation of Melamphaes pumilus entirely within the western gyre of the North Atlantic again exemplifies this type of confinement. Cof (1946) emphaized the importance of oceanic eddies in the localization of populations of invertebrates.

The large horizontal currents present paths of faunal exchange and heIp concentrate populations within a given area. Russell, (1935) theorized that since deep currents in the Atlantic are more likely to carry deepliving bathypelagic animals southward to the Antaretic than northward, these currents may account for the greater number of species indigenous to the Antarctic. Moreover, Moore (1958:228), in a summary of the literature, described a regular cycle in the Antarctic in which shallow currents carry juveniles and adults of various plankters into lower latitudes and deeper water movements return their eggs to higher latitudes. This introduces the hypothesis of Alister Hardy (Hardy and Günther, 1935) that some animals may undergo diurnal vertical migrations partly to alter or maintain their horizontal ranges. Because these animals frequently pass through shallow and deep currents flowing in opposite directions, they could remain in the same general area or move normal to the flow simply by regulating their vertical migrations.

Convergences, divergences, and other mixing of waters at oceanic boundaries apparently accumulate or stimulate the growth of certain populations of pelagic organisms. Such mixing of waters, by altering the nutrient content, temperature, and concentrations of chemicals, enchances the propagation of many species (Hardy and Güxther, 1935). The several species of fishes (e.g., Melamphaes parvas) that are restricted to Pacific Transitional Water may exemplify this effect. B1eri (1959) noted that the arrow worm "Sagitla minimue seems to inhabit the regions between water masses or the regions of mixing of the water masses."

Conservative parameters (temperature, salinity):- Because bathypelagic fishes are not casily subject to experimentation, it is almost impossible to measure the direct effect of temperature and salinity on their physiology and the evaluation of the extent to which these two parameters control their distributions is not feasible. Even so, many authors, believing temperature to be the most inportant factor controlling the distribution of a species, have tried to account for distributions by encireling their record stations with particular isotherms-say $10^{\circ} \mathrm{C}$ at 200 meters.

A few authors, however, including Haffer (1952), Reid et al. (1958), and Fleming and Lafyaste (1956), recently noted that on logical grounds distributions of bathypelagic fishes and invertebrates are difficult to relate solely to temperature. Some species range across areas delineated by different isotherms, or do not entirely fill one such area; other animals undertake extensive diurnal migrations that carry them through greater differences of temperature than would ever be encountered at depth outside their horizontal range. The hypothesis that these diurnally migrating animals possess a dual enzymatic control, one system operative at depth and the other near the surface, completely lacks experimental confirmation. Leo D. Berver of the Scripps Institution of Occanography has informed me that although the distribution of a given species of Doliolida (Tunicata: Thaliacea) occasionally follows a particular isotherm, this isotherm differs from year to year, from season to season, or even from collection to collection. The isotherm, nevertheless, probably indexes a certain water mass, many characteristies of which control the distribution of the doliolid.

Varying only slightly from water mass to water mass, salinity is probably of less importance than temperature as a factor controlling distributions. Tucker (1959) pointed out, however, that since eggs of bathypelagic fishes probably are nearly isotonic with their environment, slight changes in salinity may disturl, this osmotic balance, and thus be a critical factor in limiting breeding areas. Furthermore, Fleming and Lateiste (1956) assumed that changes in salinity must directly influence the survival of species with buovant eggs.

Non-conservative parameters (axygen, nutrients):-Although Haffner (1952) thought that some species of Chauliodus are better adapted than others to particular ranges of oxygen tension, it seems improbable that the concentration of dissolved oxygen is often a critical factor limiting the distribution of bathypelagic organisms. Vast concentrations of fishes and invertebrates live within oxygen-minimum layers -probably the most oxygen-deficient waters in the open oceans-in the eastern tropical Pacific off Central America between 100 and 500 meters. Here the oxygen concentrations measure less than 0.1 ml ( Wooster and Cromwele, 1958; Brandhorst, 1958, 1959a; and others). Wildiam D. Clarhe of the Seripps Institution of Oceanography (personal communication), however, showed that a bathypelagic mysid shrimp (Gnathophausia gracilis) is generally excluded from these oxygen minima in the eastern Pacific. lt exhibits submergence, furthermore, in that it occurs in deeper, better oxygenated waters under these minima.

The frefuent replenishment of various inorganic nutrients (e.g., nitrates, phosphates, silicates) in the photosynthetic zone is prerequisite to high organic production. The importance of the rate of organic production (productivity) as one of the factors controlling the distribution of bathypelagic animals is discussed next.

## Biological factors.

Productivity, food supply, and the availability of certain dissolved metabolites are generally thought to influence the distributions of bathypelagic fishes and invertebrates. This appears to be particularly true for the species of Mclamphaes in the eastern Pacific.

Belun (1956h) suggested ". . . that the supply of food from the surface phytoplankton and drifting vegetation from the coasts may be an important factor in the distribution of deep sea fauna." He, anong others, attributed the disjunct distributions of many abyssal species to the disposition of surface productivity (Brits, 1956 a , etc.). Further, Bieri (1959) proposed that variation in numbers of individuals over the ranges of certain species of arrow worms might be due to differences in productivity between local areas comprising the total range. Both Sette (1958) and Brandhorst (1958) believe that productivity and food supply influence the aggregation and abundance of pelagic fishes. Sette showed how the abundance of yellowfin tuna in the equatorial eastern Pacific east of $150^{\circ} \mathrm{W}$ may be attributed to the increased productivity in this region. Perhaps the segregation of populations into regions of greater or lesser productivity intensifies their genctic isolation.

Factors affecting productivity:-Primary production of phytoplankton and therefore of the food supply in general is highest where the euphotic zone is replenished of the nutrients that have accumulated below the compensation depth (depth where photosynthesis just balances respiration). In these areas, then, assuming sufficient insolation for maximum photosynthesis and enough stability of the thermocline for most of the phytoplankters to remain above the compensation depth, photosynthesis will be maxinal. High productivity, therefore, occurs in areas of intense upwelling, in areas of vertical mixing and limited upwelling,
and near land. As pointed out by Aros (1959), however, the local areas of unstable water where vertical mixing is actually taking place may have a low standing crop of plankton, most of which is swept out of the photosynthetic zone. Estimations of the standing crop of zooplankton or of concentrations of chlorophyll " $a$ " provide indirect measurements of productivity. Direct methods measure rates of uptake by the phytoplankton of carbon 14 or compare the accumulation of oxygen in 2 samples, one in the dark, the other exposed to light (see reviews by Holmes, 1958 and by Holmes, Schaefer, and Shmada, 1957).

Distributional effects of biological factors:-Zoogeographically, the important result of increased primary production in a given water mass is the support of a fauna distinct from the faunas of adjacent, less productive areas. Because of their large supply of available food, these productive areas, perhaps, accommodate a relatively higher density of larger animals. A secondary effect is the formation of the oxygen minimum laver by the oxidation of dead organisms in the deeper thermocline.

Productivity varies considerably from the low values of the central water masses to the high values of the boreal and castern equatorial waters. For example, in the western Subarctic North Pacific the total daily production of organic matter is twenty times that in the warmer Kuroshio Current to the south (Bogorov, $1958 ; 1959$ ). Productivity, then, is correlated with the depth of the thermocline: in the relatively sterile central water masses the thermocline is deep and stable; in the rich peripheral areas it is shallower and less stable, allowing vertical mixing to the surface and, therefore, nutrient replenishment in the euphotic zone (BrandHORST, 1958).

Fleming and Labvaste (1956) contoured the organic production per year of the world oceans, in terms of grams of biologically fixed carbon under each square meter of sea surface. This diagram, modified in the eastern Pacific from data of Holmes, Schafefer, and Smmada (1957), forms the basis for the accompanying chart (Fig. 72) of the distribution of values of productivity. This chart agrees fairly well with a similar chart presented by Wafond (1958: Fig. 15), except that he probably underestimated the productivity in the western North Atlantic off the eastern United States, in the upper Gulf of Mexico, and in the Indian Ocean west of Sumatra.

ReId, (in press) has contoured the zooplankton volumes (displacement volume in cc/ $1000 \mathrm{~m}^{3}$ of water filtered through a conical meter net equipped with a flow meter) for the North and South Pacifie Oceans. Although this map generally substantiates the charts delineating organic productivity, it differs in important ways. First, whereas the belt of high productivity in the equatorial Pacific is centered about the equator and extends westward to $170-180^{\circ} \mathrm{W}$, a corresponding zone of high zooplankton volumes completely crosses the lacific to Indonesia and is centered slightly north of the equator, probably at the convergence between the South Equatorial Current and the Equatorial Counter Current. Secondly, the map shows within the zones of large zooplankton volumes in the equatorial and Subaretic Pacific, latitudinal belts of very low volumes, comparable to those in the sterile central water masses. In the Equatorial Water east of $160^{\circ} \mathrm{W}$ such a belt is centered, as would be expected, in the Counter Current between two convergences, one at the North Equatorial Current, the other just north of the South Equatorial Current. In the Subarctic Water a similar belt bounds the North Pacific Drift mainly between $50^{\circ}$ and $55^{\circ} N$ and extends northeastward into the Alaskan Gyre. High zooplankton volumes also surround island chains in the tropical Pacific.

On the average productivity is higher in the Indian Ocean and Pacific than in the Atlantic. The lowest values obtained during the R/V "Galathea" Expedition were from the Sargasso Sea in the western North Atlantic (Niflsex and Jexsex, 1997). Furthermore, owing to upwelling and vertical mixing the eastern parts of both the tropical Atlantic and Pacific are more productive than the central or western parts (Nielstex, 1954). Like the highly productive Peru Current off the Pacific Coast of South America, the Benguela Current, which flows northward along the west eoast of Africa in the South Atlantic, contains areas of intense upwelling and, therefore, high productivity (Niflsex and JEvsEx, 1957 ; Hart and Crbrie, 1960). Also analogous with the distribution of high profuctivity in the eastern Pacific, tongues of high productivity in the Atlantic extend westward just south of the equator and southwestward between $10^{\circ}$ and $20^{\circ} \mathrm{N}$. Between these tongues is an area of low productivity associated with the Equatorial Counter Current (Nielsen and Jevsen, 1957: Fig. 20e, f). In the Indian Ocean zones of upwelling and high productivity lie off the Somali Coast and in a
divergence associated with the boundary of the South Equatorial Current and the Equatorial Counter Current at $8^{\circ}-10^{\circ} \mathrm{S}$ (Nielsen and Jensen, 1957; Yamanaka and Anbaky, 1959). There are extensive areas of high productivity and zooplankton volumes in all boreal water masses.

Enriched by run-off from land, vertically mixed nearshore waters are usually productive (Fleming and Laevaste, 1956). In the South Pacific large concentrations of bathypelagic fishes around island chains and submerged ridges reflect the relatively high productivity of these areas. Hebss (1959) suggested that vertical currents associated with submerged seamounts and offshore banks enrich the upper waters, providing food for fishes and invertebrates that congregate here. The water in the Indonesian basins is rendered highly productive by run-off from many islands and supports large concentrations of zooplankton and of bathypelagic fishes.

In reviewing the literature on the importance of exocrines (external metabolites) in the sea, Lecas (1947) indicated that ". . . some dissolved organic substances may ... play a very important part relative to life in the sea" and, further, that increased growth near margins of waters of different origins ". . and the conduction of necessary metabolites from one region to another may . . . be essential for productivity in some places." For example, he believed the introduction from above into the bathypelagic area of carotenoids, vitamins, and other organic products may be necessary for the maintenance of the deep-sea fauna.

Biological factors as isolating mechanisms:-The ranges of species of Melamphaes generally follow the water masses, but where they depart it is usually to follow the contours of productivity (Figs. 72, 73). Therefore, it is likely that the distribution of organic productivity decidedly influences the distributions of bathypelagic fishes and invertebrates. To substantiate this hypothesis we first see whether species from the less productive central water masses share certain morphological traits that differ from similar traits in species from rich areas. In Melamphaes one such trait is absolute size; whereas the four dwarf species usually inhabit central waters of low food supply, most of the species that contain large individuals occur in the productive Subarctic, transitional, Indonesian, and eastern equatorial waters, all of which contain a larger supply of food, possibly comprising larger items. The adults of Melamphaes janae, a species with disjunct distribution (Fig. 47), are considerably larger in the eastern Pacific than in the central Indian Ocean, presumably because the eastern Pacific is the more productive. Likewise, Tortonese (1960) assumed scarcity of food partly to


Fig. 71. Water masses of the oceans, adapted from Sverdrup et. al., 1942. In the North Atlantic the dashed line vaguely coincides with the southern boundary of the Gulf Stream (sometimes termed the Secondary Polar Front). The Bering Sea and Alaskan gyre waters are omitted in the subarctic Pacific. Hatched bands delimit the major water masses; dotted lines indicate areas (convergences) of sinking of intermediate waters.


Fig. 72. Estimation of the organic production in the oceans, adapted from Fleming and Laevastu (1956). The contours are in grams of carbon biologically fixed under each square meter of sea surface per year. The area delineated by a dotted line in the central South Pacific -an area of many island chains-is probably more highly productive than indicated by the hatching.
account for the small size of several bathypelagic fishes in the Mediterranean Sea with respect to their close relatives in the Atlantic. Edward Brinton of the Scripps Institution of Oceanography informed me that the smallest species in certain genera of euphausiids occur only in central water masses.

Admittedly, the absolute abundance of food may be less significant than its availability; the dwarf species, by virtue of their small size, may be the more efficient feeders in the central water masses. A second alternate explanation concerns distribution with depth; the fact that many deep-water planktonic invertebrates are larger than relatives near the surface is probably related to the food relations in the "pyramids of numbers", rather than to the horizontal distribution of productivity (Hardy, 1956; etc.). Similarly, one might partly explain the size differences between species of Melamphaes, inasmuch as the "dwarfs" dwell in shallower waters than the "giants".

The fact that many species inhabiting the central water masses of the Atlantic also occur in the relatively sterile central waters of the Pacific supplies the next bit of evidence that organic productivity is one of the factors controlling the distribution of bathypelagic fishes. The productive Subantarctic, Subarctic, transitional, and eastern equatorial waters contain highly endemic faunas, which do not invade the central waters.

Why do not the same species occur on both sides (east and west) of the equatorial waters of the Pacific or Atlantic? The conservative properties (temperature and salinity) are similar on both sides and the equatorial currents would seem to provide broad pathways for faunal exchange in both directions. The sides do differ, however, in the related factors of thermocline depth, vertical replenishment of nutrients, productivity, and the associated development of oxygen minima. The greater productivity of the eastern tropics may help localize certain adaptive types there. Although the equatorial belt of large zooplankton volumes breaches the Pacific, the wide zone of high productivity apparently does not (Fig. 72). Furthermore, just as the area of high productivity and zooplankton volumes is much wider in the eastern than in the western part, the distribution of most bathypelagic fishes and invertebrates is wide in the east and attenuates to the west. The extensive current eddies off Central America probably help integrate this fauna.

Finally, we recall that in accordance with the enrichment of these waters by the influence of the adjacent land, several species of bathypelagic fishes (e.g., M. acanthomus) are restricted to nearshore waters.


A


B
Fig. 73. Composite of the distribution of: A (dark c oss hatching), the 7 species of Melamphaes that have the largest adult individuals; B (light hatching), the 4 species comprising the "dwarf" M. simus species group. The adults in A (of M. microps, M. lugubris, M. macrocephalus, M. acanthomus, M. suborbitalis, M. laeviceps, M. longivelis) often exceed 80 to 100 mm . standard length; those in B (of M. simus, M. hubbsi, M. danae, and M. pumilus) measure less than 25 to 28 mm .

## SPECIATION

The speciation of melamphaids and of other bathypelagic fishes relative to water masses is best described in three stages: (1) an initial period of dispersal, perhaps vertically as well as horizontally, followed by (2) the gradual cessation of gene flow between contiguous populations, and, finally, (3) by reinforcement of this initial isolation by competition between these populations.

## Dispersal.

We have seen that continental land masses, currents, and the properties associated with boundaries of water masses may serve bathypelagic organisms either as barriers to or as means of dispersal. Climatic changes in the geologic part, such as the alternate warming and cooling of the oceans during the Pleistocene, probably were important in breaking and erecting such barriers. Although more subtle than nearshore or terrestrial barriers to or means of dispersal, boundaries and colonization routes in the open ocean have helped elaborate the immense and varied bathypelagic fauna.

The possible center of origin of the Melamphaidae can be inferred in the light of these barriers to and means of dispersal. Darlingtox (1948) listed the kinds of clues that could indicate places of origin and dispersal routes of cold-blooded vertebrates groups. 1) The area where included genera and species are most numerous (for an expanding family).-The Melamphaidae are most numerous in both species and genera in the tropics. More species of Melamphaes were trawled in the lndo-Pacific than any other region (Fig. 68). Rolf L. Bolin (personal communication) observed that the lantern fishes (Myctophidae) are also speciose in the IndoPacific. 2) Degree of differentiation.-The included species and genera should be most distinct and exhibit most endemism where the family has been longest established. The species of Melamphaes are most easily distinguishable one from another in the eastern tropical and subtropical Pacific. 3) Extent and continuity of range.-The assumption that the area occupied by a family steadily increases with the family's age implies that the family's center of origin equals its center of distribution. This probably has value only in combination with other evidence. The center of distribution of the Melamphaidae is in the tropics, more particularly, the Indo-Pacific. The ranges of most included species are most continous in the extensive Circumcentraltropical Region (cf. Fig. 69). 4) Distributions of related, competing, or associated families.-The worldwide distribution of the closely related Stephanoberycidae is little known, except that numerous specimens have been trawled in deep water from the bottom in the North Atlantic and Gulf of Mexico. Most of the recent families (both shallow and deep water) of the Beryciformes are tropical. 5) Fossil record.-l know of only one fossil melamphaid, a Scopelogadus-like form from Miocene shale, Capistrano Palisades, north of San Diego, California, U.S.A. 6) Distribution of primitive forms.-This is probably the poorest criterion of all because the more primitive forms may as likely be near the original center of distribution of the family as at its periphery. Within Melamphaes most of the more primitive species (M. microps, lugubris, and suborbitalis) inhabit boreal or sub-boreal waters at the periphery of the ranges of more specialized species (e.g., Centraltropical species such as M. indicus, sinus and danae). Furthermore, Rolf L. Bolin (personal communication) found that the primitive myctophid genera (e.g., Electrona) usually inhabit polar or boreal waters at the periphery of the distribution of the family and that many species of the specialized genera occur in the tropical Indo-Pacific. 7) Evolutionary opportunities and availability of niches.-Although bathypelagic groups of fishes probably evolved initially through invasions of the depths from shallow water, a good deal of subsequent speciation and differentiation most likely occurred through dispersal between water masses (see under "Isolation" below). Because of the distinctness and separation of its water masses, the Pacific possibly offers the best opportunities for evolution of bathypelagic fishes. Haffner (1952) discovered incipient differentiation in Chauliodus (Stomiatidae) populations that inhabit semi-isolated ocean basins of Indonesia. He suggested that this might be the result of the complete isolation of the bathypelagic zones of these basins during the Pleistocene when the sea level was presumably lowered. Rolf L. Bolin (personal communication) suggested that the Indo-Pacific might have been the center of origin and dispersal of lantern fishes, partly because the prevailing currents provide transport away from, but generally not toward this area. In the Indian Ocean these are the North Equatorial and Agulhas currents, in the Atlantic the Benguela and Equatorial currents, and in the Pacific the Equatorial Counter Current and Lindercurrent (Cromwell Current).

In conclusion, most of the evidence points to the tropics as the center of origin and dispersal of the Melamphaidae. Furthermore, because many of the shore fishes, including berycoids, presumably have evolved from a large Indo-Pacific "mother fauna", it is reasonable to suggest that the lndo-Pacific is the center of origin of several bathypelagic families, including the Melamphaidae. The fact that living shallow-water Beryciformes are almost all tropical suggests that their ancestors were also tropical. Repeatedly giving rise
to forms adapted to the depths, these shallow-water ancestors were probably the progenators of the deep-sea berycomorphs (e.g., the Mclamphaidae). U'ndoubtedly, the heterogencity of the Pacific has been important in the speciation and generic differentiation of the Melamphaidae. Water masses and associated boundaries generally have been of great importance in their elaboration and dispersal, both horizontally and, perhaps, vertically.

## Isolation.

Buzzati-Traverso (1958) outlined a possible means whereby a mutant population of a bathypelagie species might become isolated in a water mass different from that inhabited by the parent population. This model incorporates both the "sweepstakes" method of colonization introduced by Simpsos (1944) and the concept of multiple invasions of a habitat suggested by Mayr (1942). If between two areas, A and B, there exists a continuous unidirectional current, individuals of a population restricted to A might be swept over to B. Most of these, not being suited to the different habitat, would die before reproduction. A few mutants, however, might be preadapted to survive, reproduce, and thus establish a second population in B. The process could be more subtle. In the population at $A$, certain mutations selected against might gain adrantage in B so that the mutant strain would competitively eliminate the original genotype from B. A steady inflow of genes into B from the population at A frnally could produce a condition of extreme selection against the unadlapted original combinations of genes that are immigrating. If the transport of mutants from $A$ to $B$ were sporadic, repeated invasions might establish in B two or more forms, all derived from the single population at A .

The population of Melamphaes janae in the eastern tropical Pacific may have originated as waifs from the eastern Indian Ocean, swept eastward in the Pacific Equatorial Counter Current and Undercurrent. At present the eastern Pacific population differs distinctly from that of the Indian Ocean only in the greater size of its mature adults. Later, however, as more mutations and recombinations accumulate that better adapt the individuals in the eastern Pacific to an area of abundant food supply, the two populations may diverge further. This model of speciation may be effective vertically as well as horizontally; repeated invasions of the depths ly coastal, pelagic, and shallow bathypelagic (mesopelagic) species probably played an important role in differentiating the bathypelagic fish fauna.

## Compretition.

To successfully colonize a new habitat organisms must not only survive, but must also reproduce and maintain their population density among natural predators and competitors (Rae, 1958; etc.). Therefore, competition (for dominance and niches) between contiguous populations in the zone of contact and the subsequent elimination of the less well adapted intermediates in this zone may reinforec the initial isolation of forms adapted to particular areas (Fixyen, 1959).

Haffyer (1922) believed that competition between various species of Chanliodus may account for their disjunct distributions. For example, in the Atlantic C. danae appears to exclude C. slounei from its optimal range, although both species occupy the same water mass. Two species of salmonoids, which inhabit the upper rivers in Japan, normally occur allopatrically with their ranges contiguous. Where one or the other is absent, however, the single species present will invade the habitat characteristic of the other. Each species, therefore, appears slightly the better adapted to its own home range (Mixam, 1958). Sucli competitive elimination of foreign species may have accelerated the formation of melamphaid endemies in the eastern tropical lacific.

## SUMMARY AND CONCLUSIONS

Melamphaes, one of the five bathypelagic genera into which the beryciform family Melamphaidae may be divided, comprises 19 or 20 species, 13 of which are new to science; these, in turn, are allotted to six species groups, one of which (M. simus group) contains only "dwarf species". Their geographical distributions were inferred from analyses of midwater trawl samples: five are restricted to Atlantic waters, four occur in the Atlantic and Indo-Pacific, two occur in the Indo-Pacific, and seven are restricted to the eastern Pacific. Occurring only in the North Atlantic and Subantarctic waters, two species are antitropical.

Since the species are not cosmopolitan, but are distributed into discrete areas within each ocean, their ranges are linked to the heterogeneity of the oceans. Within the oceans, zones where the currents diverge or converge bound discrete water masses, which can be characterized both physico-chemically and biologically. Because these water masses are usually identified by their conservative properties, curves of salinity plotted against temperature were constructed for each species from data obtained from hydrographic casts taken vertically at each locality of capture. These T-S capture curves, when superimposed on the water mass envelopes (the limits into which all curves for a particular water mass fall), show that certain species inhabit particular water masses and that the extent of these water masses generally coincides with the horizontal distributions of the species. Although some species are limited to all or part of single physico-chemically defined water masses, most of the forms cross one or more water-mass boundaries. The distributions of melamphaids and of many other groups of bathypelagic fishes generally coincide, so as to divide the bathypelagic realm into well-defined faunal regions and subregions.

Expatriated adults of some species range deeper and into higher latitudes than do the young and breeding stages, which are restricted to relatively shallow areas in the tropical thermocline. Although, for example, the adults of one eastern Pacific species (M. acanthomus) occur in deep water from the Gulf of Panama northward to Transitional Water off California, the larvae and young were taken more shallowly, above 500 meters, in the Gulf of Panama and immediate vicinity only. Here in the lower reaches of the thermocline the water is warmer, is more saline, and contains more food items suitable for the early ontogenetic stages than in the darker depths inhabited by the adults. It is suggested, therefore, that for these species the extent of the breeding grounds limits the distribution of the species as a whole.

Whereas members of the "dwarf" species group whose individuals seldom exceed one inch in standard length are limited to the relatively sterile central water masses, other species comprising relatively large individuals ( $4-6^{\prime \prime}$ ) inhabit peripheral water masses or parts of water masses of relatively high productivity. One species exhibits a peculiar disjunct distribution; one population occurs in the highly productive eastern Pacific Equatorial Water mass, the other in the less productive Indian Central Water. Interestingly, although morphologically the two populations are almost inscparable, mature adults from the Indian Ocean average 10 mm . standard length less than those of the eastern Pacific. It follows (as also suggested by others) that not only physico-chemical and geographical features, but also biological features such as the distribution of productivity and food supply control the distribution of melamphaids and, perhaps, many other bathypelagic organisms. Water masses, then, though usually defined by temperature-salinity curves, also should be considered biological entities with parameters of nutrient concentrations, productivity, and availability of food. The T-S relations, of course, index the distribution of biological factors.

Other isolating mechanisms frefuently are equally important in maintaining the faunal integrity. The latitudinal extent of the distributions of several species are limited by the continental Iand masses. Currents
and current gyres both distribute and isolate populations. A "dwarf" species, for example, is restricted to the western North Atlantic gyre centering in the Sargasso Sea. Physiologically, it is difficult to interpret the species' responses to temperature, salinity, and oxygen concentration. Even in the well-developed oxygen minimum layer of the eastern tropical Pacific, melamphaids were regularly and abundantly taken in trawl hauls.

The tropics, quite possibly the Indo-Pacific, were most likely the center of origin and dispersal of the Melamphaidae. More genera and species are tropical than temperate or boreat.
$S_{\text {peciation within the Melamphaidae as well as in other groups of bathypelagic animals probably occurs }}$ across physico-biologically defined water-mass boundaries, which, perhaps, filter through mutants preadapted to new envirommental regimens. Subsequent competition with contiguous populations of closely related forms may reinforce the initial partial isolation of the new population and, therefore, accelerate its evolutionary divergence. In the Pacific, the Equatorial Counter Current and Equatorial Lindercurrent may have repeatedly transported such preadapted waifs eastward to the highly productive eastern Pacific Equatorial Water mass, where, isolated from their western relatives, they evolved into the endemic melamphaid fauna of the eastern tropical Pacific.

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## APPENDIX

## Counts and Proportions of Holotypes

In the following tabulation there are listed for 19 nominal species of Melamphaes and for the one specimen to be designated as the neotype of M. typhlops: standard lengths in mm, proportions in thousands of standard length, and counts.

Most counts and proportions were taken by me directly from the holotypes; those in parentheses are from the literature or were taken by Canl L. Hubis. The few proportions calculated from measurements of the part into the whole are marked by an asterisk. The nonoriginal sources are: for M. lugubris, Gilbert 1890; for M. cavernosus (synonym of lugubris), Chapman 1939; for M. macrocephalus, Parr 1931; for M. suborbitalis, Gill 1883; for M. longivelis, Parr 1933; for M. typhlops, Carl L. Hubbs; for M. crassicauda (synonym of typhlops), Koefoed 1953. The counts and proportions for the holotype of M. microps are in its species account.

For all type specimens in the following table the caudal rays, if counted, number $4+10-9+4$ and the pelvic rays number $I, 7$ on both sides. Counts are given for both sides of pectoral rays, scale rows (horizontal and diagonal), gill rakers, cheek pores, and pores on supratemporal canal above the preopercle. The counts of pharyngeal teeth are presented in the same order as in the species descriptions.

| Holotype of |
| :--- |
|  |


|  | Post- <br> dorsal | Head length | Postorbital | Snout-preopercle | Orbitcheek ridge | Head depth |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 610 ? | 358 ? | 238 ? | $\ldots$ | $\ldots$ | 260 ? |
|  | 614 | 371 (*371) | 238 | $\ldots$ | $\ldots$ | 284 (*308) |
| po. | 617 | 373 | 260 | 245 | 72 | 269 |
| ma | 569 | 457 (470) | 300 | $\ldots$ | ... | 293 |
|  | 619 | 414 | 287 | 252 | 69 | 299 |
| su. | ... | 351 ? | 225 | ... | ... | 258 |
| le | 613 | 365 | 237 | 245 | 64 | 249 |
| la | 618 | 383 | 258 | 248 | 76 | 267 |
| sp | 585 | 374 | 239 | 269 | 73 | 294 |
| eu. | 624 | 370 | 261 | 259 | 70 | 294 |
| lo | 606 | 387 (380) | 260 | ... | . . | 252 |
| pa. | 601 | 364 | 235 | 248 | 64 | 265 |
| ja | 596 | 419 | 283 | 262 | 78 | 286 |
| in | 601 | 383 | 253 | 257 | 71 | 261 |
| ty | . . | (317) | ... | ... | ... | ... |
| cr | $\cdots$ | (*380) | $\cdots$ | . $\cdot$ | . ${ }^{\text {. }}$ | $\ldots$ |
| si | 611 | 360 | 251 | 240 | 76 | 251 |
| hu | 615 | 329 | 220 | 226 | 65 | 230 |
| da. | 599 | 358 | 236 | 231 | 67 | 250 |
| pu | 599 | 377 | 250 | 257 | 78 | 264 |


|  | Head width | Interorbital | Length frontal fossa | Width frontal fossa | Prepectoral | Prepelvic |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| lu. |  | 120 ? | $133 ?$ | 82 | 365 | 391 |
| ca. | 232 | 130 | 140 | 87 | 368 | 420 (*435) |
|  | 208 | 120 | 135 | 81 | 370 | 381 |
| ma | 222 | 140 | 157 | 87 | 433 | 435 |
|  | 239 | 135 | 132 | 85 | 401 | 409 |
| su. | 191 | 129 | 139 | 69 | 356 ? | 380 ? |
| le | 194 | 128 | 145 | 71 | 366 | 389 |
| la. | 198 | 118 | 142 | 71 | 374 | 395 |
| sp. | 210 | 125 | 164 | 83 | 383 | 409 |
| eu. | 210 | 134 | 160 | 94 | 387 | 393 |
| lo | 200 | 120 (125) | 154 | 72 | 382 | 399 |
| pa. | 202 | 115 | 144 | 78 | 366 | 390 |
| ja. | 204 | 117 | 140 | 81 | 387 | 389 |
| in. | 193 | 118 | 155 | 77 | 385 | 402 |
|  | $\ldots$ | ... | ... | . $\cdot$ | $\ldots$ | $\ldots$ |
|  | . $\cdot$ | $\ldots$ | . | . | . | $\cdots$ |
| si | 200 | 115 | 142 | 82 | 364 | 389 |
| hu | 175 | 107 | 129 | 75 | 341 | 369 |
| da. | 189 | 116 | 142 | 83 | 363 | 387 |
| pu | 212 | 116 | 142 | 80 | 377 | 415 |


|  | Isthmuspelvic | Pelvicanal | Pectoral | Pelvic | Preanal | Analcaudal |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 322 | $\cdots$ | ... | ... |  | $\ldots$ |
|  | 340 | 292 | (*313) | (*214) | 696 (*668) | 337 |
| po. | 332 | 307 | 326 | 232 | 665 | 360 |
| ma. | 380 | 287 | (360) | (250) | 704 (710) | 331 |
| ac | 352 | 292 | 321 | ... | 684 | 362 |
|  | 315 ? | 300 ? | ... | . . | 640 ? | $\ldots$ |
| le | 341 | 287 | 328 | 220 ? | 654 | 374 |
| la | 331 | 305 | 300 | 216 ? | 678 | 377 |
| sp.. | 341 | 351 | 327 | 256 | 739 | 302 |
| eu. | 346 | 343 | 333 | 259 | 702 | 333 |
| 10 | 334 | 341 | (300) | (230) | 710 (710) | 297 |
| pa. | 344 | 316 | 298 | 219 | 695 | 311 |
| ja | 342 | 360 | 323 | 236 ? | 724 | 315 |
| in | 347 | 371 | 342 | 253 | 751 | 296 |
|  | ... | $\ldots$ | $\ldots$ | ... |  | . . |
| er | $\cdots$ | . . | $\ldots$ | $\ldots$ | (*649) | $\ldots$ |
| si | 345 | 284 | 302 | 222 | 644 | 356 |
| hul | 321 | 290 | 302 | 211 | 635 | 369 |
| da. | 344 | 288 | 292 | 245 | 651 | 358 |
| pu | 340 | 288 | 307 | 231 | 660 | 368 |


|  | Length caudal ped. | Depth caudal ped. | Upper jaw | Orbitcheek angle | Snout length | Suborbital |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| lu |  | ... | ... | 110 | 96 | 50 |
| ca | 254 (*270) | 102 (*116) | 161 (*155) | 114 | 98 (*100) | 50 |
| po. | 266 | 109 | 169 | 115 | 93 | 46 |
| ma | 222 (220) | 106 (100) | 200 (200) | 131 | 106 (110) | 54 |
| ac | 237 | 122 | 184 | 137 | 107 | 53 |
| su. | $\ldots$ | 112 ? | 164 | 109 | 82 | 45 ? |
| le | 264 | 109 | 172 | 115 | 95 | 46 |
| la | 246 | 112 | 176 | 129 | 96 | 40 |
| sp. | 215 | 112 | 187 | 129 | 95 | 38 |
| eu. | 244 | 110 | 179 | 130 | 96 | 48 |
| 10 | 209 (200) | 113 (95) | 180 (180) | 125 | 91 (75) | 42 |
| pa. | 241 | 100 | 175 | 110 | 94 | 42 |
| ja | 217 | 97 | 182 | 134 | 103 | 51 |
| in | 216 | 110 | 179 | 128 | 93 | 47 |
| ty | (200) | $\ldots$ |  | ... | . | . |
| cr | (*210) | (*120) | (*200) | . | . | $\cdots$ |
| si | 251 | 100 | 155 | 115 | 88 | 62 |
| hu | 262 | 99 | 151 | 103 | 87 | 48 |
| da. | 255 | 97 | 151 | 101 | 94 | 59 |
| pu | 259 | 99 | 170 | 120 | 97 | 57 |


|  | Eye | Dorsal | Anal | Pectoral | Scale rows |
| :---: | :---: | :---: | :---: | :---: | :---: |
| lu | 52 | (III, 15) | ( I, 8) | 16-16 | 26( +6 ) |
| ca | 49 (*60) | III, 15 | I. 7 | 16-16 | 32-34? (29) |
| po. | 41 | III, 14 | I, 8 | 15-15 | $34-33$ ? |
| ma. | 46(50) | III, 14 (14) | I, 8 (8) | 14-14 (14) | 30-31 |
| ac | 48 | III, 15 | I, 8 | 15-15 | 32-31 |
| su | $52 ?$ | (III, 16) | I, 8 (8) | 15---15 | ... |
| le | 48 | III, 15 | I, 8 | 15-15 | 32-32 |
| la | 44 | III, 16 | I, 9 | 15-15 | 32-33 |
| sp. | 55 | III, 16 | I, 8 | 15-15 | 32-32 |
| eu. | 52 | III, 15 | I, 8 | 15-15 | 35--34 |
| lo | 55 (60) | III, 18 (17) | I, 9 | 15-15 | 32 ? |
| pa. | 50 | III, 14 | I, 8 | 15-15 | 33--33 |
| ja | 44 | III, 15 | I, 8 | $15-15$ | 31-31 |
| in | 49 | III, 15 | I, 8 | 15-15 | 31 ? |
| ty | (52) | (III, 15) | $(\mathrm{I}, 8)$ | . . . |  |
| cr | (*65) | (III, 15) | $(\mathrm{I}, 8)$ | 15 | (30) |
| si | 42 | III, 16 | I, 9 | 15-15 | 33?-33 |
| hu | 46 | III, 15 | I, 8 | 15-15 | 35-35 |
| da. | 45 | III, 15 | I, 8 | 15--15 | 32?-32 |
| pu | 42 | III, 15 | I, 8 | 15-15 | 32--32 |


|  | Scales diag. series | Vertebrae | Gill rakers, first arch | Gill rakers, fourth arch | Tooth <br> formula |
| :---: | :---: | :---: | :---: | :---: | :---: |
| lu | $\cdots$ | ... | $5+16$ | $\ldots$ | 4 or 5/3? |
| ca. | 9 | $11 ?+17$ | $6+16-5+16(15)$ | $\ldots$ | $4 / 2$ or 3 ? |
| po. | 9 | $11+18$ | $6+15-5+15$ | 10-11 | 6/3 |
| ma | 8 ? | ... | $6+15(15)-6+15$ |  | 4/3? |
| ac. | 8 | $11+16$ | $7+16-7 \div 16$ | 12-13 | 4/2 |
| su. | ... | ... | $5+15$ | ... | $59 / 3$ or 4 ? |
| le | 8 | $11+16$ | $5+16-5+16$ | 11-11 | 5/4 |
| la | 8 | $11+16$ | $5+14-5+13$ | $9-9$ | 6/4 |
| sp. | 8 | $12+15$ | $4+14-4+14$ | 9-8 | 7/4 |
| cu. | 8 | $12+17$ | $4+14-4+14$ | 8-9 | 8/6 |
| lo | 8 ? | $12+16$ | $4+15-4+15$ | 10 | $6 / 4$ or 5 |
| pa. | 8 | $12+16$ | $4+14-5+14$ | 8-8 | 6/4 |
| ja | 8 ? | $11+15$ | $4+13-4+13$ | 9-8 | 7/4 |
| in | 8 | $13+13$ | $4+13-4+13$ | 9-8 | 8/4 |
| ty. | $\ldots$ | . . | $(2+11-3+11)$ | ... | ... |
|  | $\cdots$ | $\cdots$ | (syntype) | $\cdots$ | $\cdots$ |
|  |  |  | $3+12-3+12$ |  |  |
| si | 10 ? | $12+18$ | $4+13-4+13$ | 8-9 | 5/4 |
| hu | 10 ? | $12+16$ | $4+12-3+12$ | 7-7 | 5/3 |
| da. | 10 | $11+16$ | $3+12-3+12$ | 7-7 | $5 / 3$ |
| pu. | 8 | $12+16$ | $4+13-4+13$ | 8-8 | 5/4 |

$\left.\begin{array}{lcccc}\hline & & & \\ \text { Pharyngeal } \\ \text { teeth }\end{array} \quad \begin{array}{c}\text { Mandibular } \\ \text { pores }\end{array} \quad \begin{array}{c}\text { Pores inside } \\ \text { cheek angle }\end{array} \begin{array}{c}\text { supratemporal } \\ \text { canal above } \\ \text { preopercle }\end{array}\right]$

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# THE CARLSBERG FOUNDATION'S <br> OCEANOGRAPHICAL EXPEDITION ROUND THE WORLD 1928-30 AND PREVIOUS "DANA"-EXPEDITIONS 

## DANA-REPORT No. 59.

LA COLLECTION DE PELAGOSPHAERA DU »DANA«<br>PAR<br>H. DAMAS<br>institut ed. van beneden<br>UNIVERSITÉ DE LIĖGE

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## INTRODUCTION

## Historique.

Pelagosphaera aloysii a été décrite en 1905 par R. Mingazzinı d'après un spécimen trouvé dans les collections planctoniques rapportées par le navire italien «Liguria». L'exemplaire, capturé à 500 m . de profondeur dans le Pacifique Sud, était une petite sphère transparente, de 6 mm . de diamètre. L'auteur y reconnaît la structure du groupe appelé alors les "Géphyriens». Il crût avoir affaire à un animal adulte, adapté à la vie pélagique et représentant une nouvelle famille de "Géphyriens».

L’année suivante, Senva retrouve dans les matériaux du "Liguria" plusieurs spécimens capturés dans d'autres régions du Pacifique, spécimens de 1,8 à $2,5 \mathrm{~mm}$ de diamètre, les uns sphériques, les autres piriformes. Une étude histologique et anatomique approfondie l'amène à conclure que Pelagosphaera n'est qu’une larve pélagique de Sipunculide. Les organes pris par Mingazzini pour des gonades correspondent aux glandes annexes de l'oesophage décrites dans les larves de Sipunculides par Hatscheck. D’autres caractères comme la présence d'une troque, l'absence d'organes de circulation et de reproduction démontrent la nature larvaire de cette forme. Le nom de Pelagosphaera ne peut donc servir à indiquer un genre nouveau mais simplement un type larvaire adapté à la vie planctonique.

Spengel (1907) est arrivé à la même conclusion par la comparaison des images de Mingazzini et des figures de Müller, Kröhs et Hatscheck sur le développement des Sipunculides. Il suggère qu'il s'agit de la larve du Sipunculus discrepans.

En 1910, Heath retrouve en Californie (baie de Monterey) deux spécimens de Pelagosphaera et les considère aussi comme des larves. Il ajoute quelques précisions sur leur structure.

En 1930, Dawydoff publie quelques observations sur l'animal capturé cette fois dans la baie de N'hatrang (Indochine) et observé en aquarium. Il décrit ses mouvements continuels, la dévagination d'une région céphalique munie d'une métatroque puissante, (à ce moment l'animal possède une "tête", un "cou" et un «thorax») et enfin sa métamorphose en un animal cylindrique, peu mobile dont l'adulte reste inconnu.

En 1947, W. K. Fisher considère comme larve de Sipunculus polynyotus, un certain nombre de Pelagosphaera capturées entre la Floride, les Bermudes et le Gulf-stream, au large du cap Hatteras. ll se base pour celà sur la disposition des muscles, qu'il étudie avec plus de précision que les autres auteurs. Il estime que le terme Pelagosphaera doit s'appliquer à des larves de plusieurs espèces.

A celà se borne, semble-t-il, la bibliographie relative à l'animal. On en concluerait aisément qu'il doit s'agir d'une forme relativement rare.

## Matériel étudié.

Or dans les collections du «Dana», figurent environ 1900 spécimens capturés à diverses profondeurs, devant la Floride, dans la mer des Caraïbes, le Golfe de Panama, le Pacifique oriental et central, les eaux de la Nouvelle Calédonie, de la Nouvelle Zélande, de l'Australie, la région d’Amboine, la mer des Célèbes, les mers de Chine, de Mindanao, le détroit de Macassar, l'océan Indien, le canal de Mozambique, l’Atlantique sud, les Canaries, les côtes du Maroc, le détroit de Messine. Ce type larvaire se rencontre donc sur la plus grande partie des océans (voir carte). L'étude de ces spécimens m'a été confiée par le Dr. Bertelsen que je remercie vivement de la confiance qu'il m'a ainsi témoignée. L'intérèt de cette étude est double: Pelagosphaera est une larve planctonique géante, adaptation temporaire à la vie pélagigue d'un animal benthique. Quels sont les organes nécessités par cette adaptation? D'autre part, l'étude de cette larve, encore énigmatique, ajoute-t-elle quelque chose à notre connaissance du groupe isolé des Sipunculides?

## ASPECT EXTÉRIEUR

Taille.

Les spécimens de la collection du "Dana" ont des tailles très variées. Le plus petit, parfaitement sphérique, a un diamètre de $0,7 \mathrm{~mm}$; le plus gros une longueur de $8,8 \mathrm{~mm}$ et un diamètre transversal de $7,7 \mathrm{~mm}$. La plupart des individus ont une taille voisine de 3 a 4 mm . La suite de la description montrera que ces chiffes n'ont pas de valeur absolue et doivent dépendre de l'état de contraction de l'animal lors de la fixation.


Iig. 1. Individus contractés. A. 13. C. ind. $4,1 \mathrm{~mm}$ long. (st. $35 \overline{5} 6 \mathrm{II}$ ) vues ant. lat. et dors. D. E. ind. $3,2 \mathrm{~mm}$ Iong. (st. 3830 VI ) vues lat. et dors. F. ind. 2 mm long. (st. 1328 III) vue lat.

## Forme.

La plupart des spécimens de la collection du "Dana» sont semblables à ceux décrits par Mixgazzini, SexNa, Hfatif et Fisher. Ils sont sphériques ou subsphériques, complètement transparents, el recouverts d'une cuticule parfaitement lisse (fig. 1). D’autres sont allongés, piriformes (fig. 2 D). D'autres sont même plus ou moins cordiformes. Certains sont marfués de bandelettes sombres (les muscles longitudinaux), la plupart non. Le massif viscéral n'occupe en général qu'une place restreinte dans la sphère, mais il peut en encombrer plus de la moitié (fig. 1 F ). L’introvert est souvent très long, aplati (fig. 1 A, B, C) ou
 etroit (fig. 2 E ) ou constituer une sorte dentonnoir (fig. 2 (i). Dans le premier cas, le carrefour buccal est quadrangulaire, dans le second globuleux. Toutes ces variations peuvent se rencontrer dans le produit d'une


Fig. 2. Individus contractés. A. ind. $3,5 \mathrm{~mm}$ long. ( $\mathrm{st} .3 \overline{5} 45 \mathrm{ll1}$ ) vue lat. 13. C. ind. $5,2 \mathrm{~mm}$ long. (st. 3545 ll ) vues lat. et ventr. I). ind. $4,5 \mathrm{~mm}$ long. (st. 1322 I ) vue lat. F. ind. 4 mm long. (st. $3861 \mathrm{II}+\mathrm{VI}$ ). F. ind. $4,5 \mathrm{~mm}$ long. (st. 3621 IV ). G. ind. 3.5 mm long. (st. 3822 I).
même pêche et n'ont d'autre valeur que celle de différences individuclles causées par la contraction plus ou moins forte des muscles superficiels (longitudinaux et circulares) et des muscles rétracteurs.

D'autres spécimens ont une forme plus curieuse et rappellent les aspects décrits par Dawroofr. A l'extrémité antéricure de l'animal, l'introvert fait saillie, soit en un petit cylindre soit en une collerette plus ou moins étalée (fig. 3). Il est peu probable qu’aucun des spécimens de la collection soit dans un état d’extension maximale. Celui qui s'en approche le plus est présenté dans la figure 4 . Il mesure ánm de l'extrémité antérieure á l'extrémité postéricure. En vue ventrale ou latérale ( $\mathrm{A}-\mathrm{C}$ ), il se présente comme une sphère sectionnée à l'avant et rattachée par un pédoncule étroit a une sorte de cône aplati. Sauf dans ses régions huccale et digestive, l'animal est parfaitement transparent. Les dessins ont été exécutés sans coloration préalable.

La sphère postéricure rappelle parfaitement les dessins de Pelagosphaera déjà publiés, sauf qu’elle ne contient pas l'introvert ni le carrefour buccal et ses annexes. Tous ces organes ont été déraginés en un cône chiffoné, dont le bord mince est garni d'une ligne sombre. Sur certains spécimens, s'observe à cet endroit l'un ou l'autre cil de grande taille (fig. 3 B ). Par conséquent, cette ligne sombre doit être la base de la métatroque décrite par Dawroorf. La comparaison de ces spécimens étalés avec les individus sphériques démontre d'ailleurs cette affirmation. La collerette, relativement épaisse sauf sur les bords, est creuse et sa cavité communique avee la cavité générale du corps. Pour s'eu convaincre, il suffit de presser la sphère postéricure d’un animal partiellement dévaginé: immédiatement la collerette se distend. Par conséquent, lors de la rétraction, la sphère postérieure doit absorber le liquide contenu dans la collerette et son diamètre augmenter en proportion.


Fig. 3. Individus partiellement étalés. st. 3861 ( $1+V I$ ). A. ind. $4,3 \mathrm{~mm}$ long. - les taches noires le long du cordon nerveux représentent des dépots probablement métaboliques. - 13 . ind. 2 mm . diam. vu de l'avant - 3 palettes ciliaires encore attachées à la métatroque. - C. un 3eme individu .... vue de l'avant - trompe.

Le sommet du cône est occupé par un organe massif, assez sombre, une trompe dont l'ouverture est dirigée vers l'avant (fig. $3 \mathrm{~A}, \mathrm{C}$ ) ou, après dévagination complète vers le côté ventral (fig. 4). Cet orifice est bordé de 3 lèvres, une dorsale, deux latérales dont la forme dépend de l'état de dévagination. Entre les lèvres ventrales s'avance un petit tentacule pointu, garni d'un sillon antérieur cilié (fig. 4 B).


Fig. 4. Individu complètement étalé - les cils de la métatroque tombés malheureusement - taille $5 \times 4,2 \mathrm{~mm}$. - st. 3768 XVI. A. vue ventrale. - B. vue antérieure. - C. vue latérale.


Fig. 5. Individu très avancé dans la métamorphose long. 4 mm . (st. 3860 VII ). - a. anus.

Fig. 6. Individu en métamorphose. long. $4,3 \mathrm{~mm}$. (st. $3861 \mathrm{II}+\mathrm{VI}$ ). - A. vue dorsale. B. vue ventrale de la tête et de la trompe; quelques cils sont demeurés sur la métatroque; le tentacule a un aspect cordiforme. C. vue latérale de la tête - la collerette se présente comme une série de replis. D. vue oblique.

# ETUDE ANATOMIQUE( ${ }^{1}$ ) 

Paroi du corps.

Elle a la constitution classique de celle des Siponcles: cuticule dure et imperméable, épiderme unistratifié, couche musculaire circulaire et longitudinale, péritoine. Quelques points méritent d'être soulignés.

La cuticule est toujours constituée de fines strates superposées. Elle est mince et lisse chez les larves typiques où elle s'épaissit uniquement au niveau de l'orifice de l'introvert. Contrairement à ce que dit Senva, elle a, déjà à ce stade, l'aspect irisé de la cuticule du Siponcle. Chez les larves en métamorphose, elle devient beaucoup plus épaisse, verruqueuse. La collerette et la trompe des individus dévaginés (même ceux en cours de métamorphose), la partie profonde de l'introvert des individus contractés en sont pratiquement dépourvues.

L'épiderme adhère fortement à la cuticule. Il est constitué d'une couche de grandes cellules pavimenteuses parmi lesquelles s'intercalent des amas de petites cellules et de cellules chargées de grosses granulations. Il s'agit évidemment des ébauches des tubercules et des glandes de l'adulte.

Au niveau du pôle postérieur de l'animal, l'épiderme cubique est remplacé subitement par une zône relativement petite de hautes cellules dont les extrémités paraissent porter des cils qui traversent la cuticule. A cet endroit, la paroi du corps est généralement marquée d’une petite dépression. Cette zone ciliée est reliée à l'extrémité du cordon nerveux ventral. Il s'agit probablement d'un organe des sens. Hatscheck a figuré la même structure chez la larve de Sipunculus nudus (fig. 58, pl. 5, fig. 69, 70 et 71, pl. VI). Senva (p. 67) admet que cet organe fait normalement une légère protubérance sur le corps. Or, chez l'exemplaire le plus dilaté (fig. 5) il est encore invaginé. Cela indique probablement que le spécimen en question n'était pas dévaginé au maximum.

Sur la collerette, l'épiderme est particulièrement plat. Lorsque l'introvert est invaginé, cette région est extrèmement plissée. Le bord externe de la collerette est constitué d'une seule rangée d'énormes cellules très aplaties dont la taille dépasse parfois $60 \times 10 \times 5 \mu$ (fig. 7). A côté des cellules épidermiques banales, elles apparaissent gigantesques. Elles sont toutes orientées parallèlement à la longueur de l'animal. Leur forme est grossièrement trapézoïdale: elles s'enfoncent entre le mésoderme et l'épiderme voisis de sorte qu'un tiers seulement de leur longueur est en contact avec le milieu externe. Leur noyau, très grand, est rejeté tout à fait à l'extérieur. Leur protoplasme basal est vacuoleux mais sur leur plus grande hauteur, ces cellules sont remplies par des fins filaments, bases des cils vibratiles. Ceux-ci, toujours tombés sur les individus étalés, semblent ètre groupés en palettes dans les coupes d’individus contractés. Leur longueur est difficile à préciser. A en juger par les mesures sur coupes d'individus contractés (mais dans ce cas les cils sont toujours plissés) leur longueur paraît être de 0,2 à $0,4 \mathrm{~mm}$ suivant la taille de la larve. La collerette était donc garnie d'une très forte bande ciliée, la métatroque décrite par Dawydoff.

En dehors du cerveau et des organes annexes du tube digestif qui seront décrits plus loin, la trompe est recouverte d'un épithélium très épais, où se mélangent de hautes cellules, les unes muqueuses, les autres ciliées, dont les corps s'étagent à divers niveaux.

La couche musculaire n'est que très lâchement unie à l'épiderme. Elle s'en décolle très aisément. Il ne semble pas cependant exister chez les larves globuleuses, de canaux coelomiques interposés entre l'épiderme et les muscles. Chez les larves en cours de métamorphose, des lacunes existent à ce niveau, lacunes qui
( ${ }^{1}$ ) Il faut signaler ici que ces spécimens, flxés en vrac sur le bateau d'exploration et conservés dans le formol dilué depuis 1930 . étaient dans un état médiocre au point de vue histologique. Cela n'a pas permis de pousser l'étude aussi loin qu'il était désirable. D'autre part, la description de Senna est à peu près parfaite. II suffira donc de signaier les observations nouvelles.
correspondent aux replis de la surface du corps. Mais sur les médiocres préparations qu'il fut possible de réaliser, je n'ai pu observer ni revêtement péritonéal de ces lacunes, ni communication entre elles et le coelome (voir cependant page 15).

La couche des muscles circulaires est régulière et continue chez les larves plus ou moins sphériques. La paroi de l'introvert invaginé est garnie d'une forte gaine de fibres circulaires, surtout à son extrémité antérieure. Mais lorsqu'elle se dévagine en une collerette, ces muscles se dispersent et la musculature apparaît très faible. Par contre, chez les larves en cours de métamorphose, la collerette même dé-


Fig. 7. Coupe sagittale de la métatroque -- ind. en métamorphose (voir fig. 6) 1.- ectoderme. 2.-cel. de la métatroque (cils malheureusement tombés) 3.-- couche péritonéale. vaginée possède une paroi musculaire très épaisse, due semble-t-il à une augnentation de fibres longitudinales comme des fibres transversales.

Les muscles longitudinaux ne sont pas toujours aisément visibles. Ils semblent être encore en une couche continue chez certains spécimens très transparents. Chez d'autres, ils se montrent comme des bandes méridiennes plus sombres (fig. 1 A, $B, C$. . Le nombre de ces bandes est assez variable. D'ailleurs, les muscles se fusionnent ou se dichotomisent parfois. Comme le nombre des muscles longitudinaux a grande importance en systématique, ils ont été comptés dans plusicurs spécimens préalablement colorés légèrement à l'hématoxyline, en particulier chez 58 individus provenant de la station $3861 \mathrm{II}+\mathrm{VI}, 300-350 \mathrm{~m}$ de câble, dont la taille variait de 1,9 à $4,4 \mathrm{~mm}$. Le résultat de cette énumération s'établit comme suit:

| Nombre de bandes <br> musculaires | Nonibre d'individus | Renarques |
| :---: | :---: | :--- |
| $?$ | 30 | indéchiffrables |
| 36 | 2 | 22 bandes droites et 16 gauches |
| 38 | 1 |  |
| 39 | 3 |  |
| 40 | 1 |  |
| 42 | 2 |  |
| 43 | 3 |  |
| 44 | 1 |  |
| 45 | 3 |  |
| 47 | 2 |  |
| 49 | 4 | 29 bandes droites et 25 gauches |
| 50 | 1 |  |
| 54 |  |  |

On voit que dans le produit d'une même pêche, la variabilité est très grande et que de plus, les individus ne sont pas toujours symétriques. La conclusion en a été tirée qu'à ce stade de la vie de l'animal, le nombre de bandes n'était pas fixé, ce qui rend malheureusement illusoire tout essai d'attribuer la larve à une espèce déterminée. Cependant tout indique que, dans ce cas particulier, l'expèce doit posséder à l'état adulte un grand nombre de muscles longitudinaux.

Dans aucun spécimen en cours de métamorphose, il n'a été possible de compter avec certitude le nombre de muscles longitudinaux.

## Muscles rétracteurs.

De la paroi du corps, un certain nombre de rétracteurs se dirigent vers la base de la trompe ou vers l'extrémité invaginée de l'introvert. Il s'agit ou bien de véritables muscles composés de plusieurs fibres parallèles ou bien de filaments très minces constitués probablement d'une seule fibre. Fisher a déjà fait la même observation sur des spécimens récoltés au large de la Floride. La disposition de ces fibres pouvant être intéressante au point de vue systématique, elle a été étudiée en détail sur 213 spécimens provenant de la station 3861 - spécimens capturés de 200 à 350 m de câble. Dans cette population, le nombre de muscles rétracteurs variait de 6 à 14 . Le tableau suivant résume la variabilité constatée. Les majuscules indiquent des muscles épais, les minuscules des muscles réduits à une fibre. A côté des muscles rétracteurs dorsaux ( $D$ et $d$ ) ou ventraux ( $V$ et $v$ ) classiques, il a fallu créer une catégorie de muscles frontaux (f), peut-être protracteurs, pour quelques fibres s'insérant au voisinage du plan équatorial d'un individu contracté.

|  | Formule musculaire |  |  |  | Nombre d'individus |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 2 V | 4 V | $2 f$ | 2D | 2d | 3 |
| 2V | 2v | 2 f | 4D | 2d | 35 |
| 2 V | 2 V | 2 f | 2D | 4 d | 5 |
| 2 V | 2v | 2 f | 4D |  | 76 |
| 2 V | 2 v | 4 f | 4 D | 2d | 2 |
| 2 V | 2 v | 4 f | 4D |  | 1 |
| 4 V |  | 2f | 4D | 2d | 1 |
| 2 V | 2 V | $2 f$ | 2 D | 2d | 12 |
| 4 V |  |  | 4D | 2d | 1 |
| 2 V | 2 v |  | 4D | 2d | 1 |
| 2 V |  | 21 | 4D |  | 10 |
| 2 V | 2 V |  | 4D |  | 15 |
| 2V | 2 V |  | 2D | 2d | 8 |
| 2 V |  | 2 f | 4D |  | 5 |
| 2 V |  |  | 4D |  | 16 |
| 2 V |  |  | 2D | 2d | 6 |
| 2 V | 2 v |  | 2D |  | 1 |
|  |  |  |  |  | 198 symétriques |
| 2 V | 2 V | 3 f | 4D | 2 d | 1 |
| 2 V | 2 v | 2 f | 3D | 3d | , |
| 2 V | 2 V | 1 f | 4D | 2d | 1 |
| 2 V | 2 V | 2 f | 3 D | 1 d | 1 |
| 2 V | 2 v | 11 | 4D |  | 1 |
| 2 V | 2 V | 2 f | 2 D | 1 d | 1 |
| 2 V | 2 v | 2 f | 3 D |  | 1 |
| 2 V | 2 V | 2 f |  | 3d | 1 |
| 2 V | 2 v | 11 | 3D |  | 1 |
| 2 V | 2 v |  | 3D | 1 d | 2 |
| 2 V |  |  | 3D |  | 4 |
|  |  |  |  |  | 15 asymétriques |

Comme on le voit, la variation est très ample dans la même population et ce n'est pas en se basant sur ce caractère qu'il serait possible de classer les larves de la collection en groupes correspondant à des espèces différentes. Aussi, la tentative a été abandonnée.

Il n'a pas été possible de trouver une relation entre la taille des larves et leur formule musculaire, pas plus qu'il n'existait de relation évidente entre la taille et le nombre de muscles longitudinaux.

De plus, l'asymétrie des muscles rétracteurs n’est pas toujours révélée par le tableau ci-contre. Ainsi dans un individu (station 3860 IX $\times$ XIII), il existe 4 gros rétracteurs dorsaux de longueurs inégales. A droite, le long rétracteur dorsal est ventral par rapport au rétracteur court. A gauche, le même muscle se divise en deux faisceaux dont l'un passe au dessus, le second en dessous de l'autre rétracteur. L'individu complètement dévaginé (fig. 4 A ) est un bon exemple de la disposition asymétrique des rétracteurs.

Les larves proches de la métamorphose qui ont été disséquées ( 3 en tout) montraient une paire de gros rétracteurs dorsaux et une paire de gros rétracteurs ventraux, ce qui correspond bien à la formule du Sipunculus; mais un d'eux possédait en plus une paire de rétracteurs dorsaux accessoires. Hatscheck a déjà signalé, à propos de Sipunculus nudus, qu'au cours du développement se forment des fibres musculaires accessoires qui disparaissent à la métamorphose.

Les diagnoses des genres et des espèces de Sipunculides précisent à quels muscles longitudinaux s'attachent les muscles rétracteurs. Mais, dans le cas présent, il a paru inutile de chercher à préciscr les rapports entre deux structures dont l'une - les bandelettes longitudinales - n'a pas encore atteint sa disposition définitive, et l'autre - les muscles rétracteurs - se résorbera en partie au cours de la métamorphose.

Plus intéressante est la question des attaches antérieures des muscles. Senva a déjà signalé que les 6 muscles rétracteurs principaux ( 4 D 2 V ) se réunissent en 4 groupes avant de s'unir à la paroi du carrefour buccal. Celui-ci est ainsi forcé de prendre une allure quadrangulaire. Mais les rapports s'analysent mieux sur les individus dévaginés. D'après les coupes, (entre autres celles d'un individu capturé à la station 3904 IV), des deux muscles dorsaux principaux, le plus court et le plus fort s'insère sur la paroi de la trompe un peu en arrière et en dehors du verveau. Le long rétracteur dorsal se divise en faisceaux au moment où il pénètre dans la cavité de la collerette. Ses fibres s'attachent indépendamment les unes des autres sur la paroi antérieure de la collerette entre le cerveau et la métatroque. Le rétracteur ventral principal s'insère, quant à lui, plus en avant, sur les parois latéro-ventrales de la trompe en dehors de l'organe accessoire de la bouche nommé «Schlundkopf" par Hatscheck.

Les muscles accessoires (dorsaux et ventraux) qu'il fut possible de suivre sur coupes, bien que constitués d'une seule fibre semble-t-il, se divisent en pénétrant dans la cavité de la collerette. Ils se perdent dans un lacis très lâche de fibres isolées qui traversent cette cavité. Il semble que leur insertion finale se trouve sur la paroi antérieure de la collerette, entre la métatroque et la trompe.

## Système nerveux et organes des sens.

Le cerveau (très gros, presque bilobé) est situé dorsalement, en surface sur la trompe. Il comprend déjà des cellules de plusieurs types: une ou deux paires de gros neurones situés profondément dans la région dorsale et de nombreuses petites cellules constituant une couche superficielle épaisse. Sous cette couche, se trouve un lit de fibres nerveuses, entre autres trois gros cordons dont l'un au moins se continue dans les nerfs du collier périoesophagien. Une fine cuticule, semblable à celle qui recouvre l'épiderme, revêt le cerveau.

Sur le cerveau des individus dévaginés, s'aperçoivent, en position très latérales, 2 trainées brunâtres, les ocelles. Senna décrit l'existence dans ses spécimens, de 2 paires d'ocelles: une grosse et une petite. Mais aussi bien sur les individus dévaginés que sur les spécimens sectionnés de la collection du «Dana", il n’a été possible d'en apercevoir qu'une seule paire. Peut-être s'agit-il là d'une différence spécifique?

Au niveau des ocelles, la surface du cerveau est plane et la cuticule s'amincit. Les ocelles sont simplement constituées de cellules étirées dont les cols, réfringeants dans les préparations, convergent vers la dépression (fig. 8, 1). Autour des noyaux cellulaires, Ie protoplasme est entouré de granules pigmentaires si nombreux qu'ils masquent tout autre structure. Il est probable que ces cellules rétiniennes ont des prolongements allant assez loin dans la masse cérébrale. C'est du moins ainsi que s'interprètent le plus aisément les trainées de granules noires qui parcourent le cerveau. L'ocelle est donc beaucoup plus simple que celui du Siponcle adulte.

$\longmapsto 0,05 \mathrm{~mm}$.
Fig. 8. Coupe frontale à travers le cerveau au niveau de la tache oculaire. (coll. Armauer Hansen). 1.- terminaisons étirées des cellules rétiniennes. 2.- bande ciliée péricérébrale.

Dans deux individus capturés lors de la croisière 1922 du bateau norvégien "Armauer Hansen», existent dans la masse cérébrale, un peu en dedans des ocelles, deux paires de formations énigmatiques. Une cellule sphérique réduite - sauf au niveau du noyau - à une pellicule entourant une cavité remplie d'un précipité, est accolée, peut-être même enveloppée complètement, par un très gros neurône à fort noyau réticulé. Dans les spécimens du "Dana", moins bien conservés au point de vue histologique, ces formations n'ont pas été retrouvées mais à leur place existent des cellules nettement plus grandes que la moyenne. Il est impossible d'attribuer une signification à ces structures inconnues jusqu'à présent chez les Siponcles aussi bien larvaires qu'adultes.

Le cerveau est bordé dorsalement et sur les côtés, d'une séric de cellules qui rappellent, en plus petit, les cellules ciliées de la métatroque (fig. 8,2 ). Cette bande correspond certainement à la bande ciliaire transversale figurée par Натscheck (fig. $\mathbf{5 1} 1,58$, pl. 6) sur la larve de Sipunculus nudus, mais ici elle est en fer à cheval. Comme le cerveau des Siponcles dérive de la plaque ciliaire apicale de la Trochophore, il est possible de voir dans cette bande le reste de la ciliature de l'organe syncipital.

L'état histologique des spécimens n'a pas permis de suivre les cordons nerveux émanant du cerveau. Seuls sont reconnaissables les deux gros cordons constituant ce que les auteurs appellent l'anneau périoesophagien. Contrairement à ce que Senva (p.67) déclare avoir constaté dans les spécimens de Pelagosphaera à sa disposition, les cordons périoesophagiens ont été retrouvés dans tous les spécimens sectionnés, ceux de la croisière de l'"Armauer Hansen" comme ceux du "Dana". On peut, avec grande vraisemblance, attribuer à une fixation médiocre l'observation de l'auteur italien. Chez un animal dévaginé, ces deux cordons quittent le cerveau vers le bas et l'avant, entre les muqueuses de la trompe et le péritoine, contournent les organes annexes du tube digestif, passent en dedans de l'attache antérieure des rétracteurs ventraux et se réunissent sous le canal excréteur de la glande annexe où ils se continuent dans le cordon ventral. Celui-ci
a déjà la constitution classique du cordon nerveux des Sipunculides. A l'extrémité postérieure, chez les individus intacts, il présente toujours un double ressaut et se termine perpendiculairement à l'épiderme au niveau d'un renfoncement peut-être sensoriel.

## Organes annexes de la bouche.

Un animal entièrement étalé, examiné de l'avant ou par la face ventrale, montre entre les deux lèvres de la trompe, un tentacule court, pointu, triangulaire à base large, creusé en gouttière ciliée sur la face antérieure (fig. 3 et 4). Il s'agit du canal excréteur d'une grosse glande bilobée suspendue dans la cavité coelomique, sous l'intestin antérieur. Dans un individu invaginé, cette glande semble accrochée au massif buccal, a l'endroit où y pénètre le cordon nerveux ventral.

Extérieurement la glande paraît double. En fait, comme Senna l'a montré, elle est constituée de deux masses cellulaires appendues à l'extrémité interne du canal excréteur. Vers ce point convergent toutes les cellules glandulaires, très hautes, disposées en éventail. Malgré la médiocre conservation histologique, ces cellules donnent encore une faible réaction au P.A.S. Il s'agit donc probablement d'une glande muqueuse dont le produit est conduit par un canal cilié vers la face supérieure du tentacule et de là déversé sur le bord ventral de la collerette.

Jusqu'à son extrémité interne, le canal excréteur est bordé de cellules plus ou moins cubiques, fortement ciliées. Leur protoplasme est souvent surchargé de granulations qui dans certaines colorations se teintent de brun. Senva, qui a déjà fait cette observation, y a vu un signe de dégénérescence. La chose est peu probable, puisque l'organe existe encore à l'état parfait chez les individus les plus proches de la métamorphose. Dans les individus contractés, la lumière du tube excréteur est dilatće. Peut-être joue-t-elle le rôle de lieu d'accumulation durant les périodes où la larve affecte une forme sphérique et ne peut rejeter le produit de secrétion.

Cette glande correspond à «l'Anhangsdrüse des Oesophagus" de Hatscheck. Senva a déjà fait remarquer que, comme l'organe dont il va être question, elle est en fait prébuccale.

Dans l'espace entre le tentacule et la trompe, entre les deux lèvres de celle-ci, s'ouvre une fente transversale qui, ventralement est recouverte d'un épithélium très différent de celui du reste du corps. Les cellules $y$ sont hautes, cylindriques, à protoplasme dense. Elles forment une surface arquée très lisse garnie d'une forte couche cuticulaire. Sous cet épithélium existe une masse de tissu d'aspect turgescent, une sorte de coussin oblong transversal, constitué de cavités à parois bien nettes. Sous l'épithélium et dans les parois séparant les cavités courent de nombreuses fibres musculaires transversales. Sur un organisme contracté, l'organe en question s'aperçoit comme une masse quadrangulaire transparente appliquée à la face ventrale du carrefour buccal.

Chez la larve de Sipunculus nudus Hatscheck a décrit au même endroit, sous le nom de "Schlundkopf" un repli transversal de l'épithélium entourant une vésicule mésodermique. Le mot de "Schlundkopf» ne paraît pas opportun pour un organe situé sur la face externe de l'animal mais Hatscheck admet que cette structure est formée aux dépens de l'oesophage embryonnaire. La question mériterait d'être revue. De plus, les dessins de l'auteur viennois indiquent à la face profonde de l'organe en question, une invagination ectodermique parallèle à la surface et des cellules glandulaires qui n'existent pas chez Pelagosphera. Cette discordance dans la constitution de ce coussin turgescent et musculaire serait la seule différence anatomique entre les larves de Sipunculus nudus et Pelagosphaera.

La question se pose de savoir si, chez Pelagosphaera, l'organe passerait d'abord par le stade dessiné par Hatscheck, pour se modifier ensuite fortement ou si les observations de Hatscheck, appuyées par des dessins très schématiques, correspondent bien à la réalité.

La signification fonctionelle de cet organe est difticile à imaginer. Les renseignements sur le mode de vie et la métamorphose des larves de Sipunculiens sont malheureusement presqu'inexistants. Dans les coupes frontales de Pelagosphaera contractées, lorgane est placé comme un bouchon à l'entrée du tube digestif.

Peut-être durant la vie, la contraction de ses fibres musculaires transversales le fait-il basculer dans la bouche et pousser à l'intérieur de l'œesophage les aliments agglomérés devant lui'? L'organe servirait en somme de machoire inférieure, jouerait done un rôle analogue à celui du mastax des Rotifères.


Fig. 9. Coupe parasagittale de la trompe d'un individu en métamorphose (ind. de la fig. 5). - 1.- collerette très plissée. 2.- cils de la métatroque. 3.- cellules de la métatroque. 4.- cerveau. 5.- zöne glandulaire de la trompe. 6.— glandes annexes de la bouche (touchées tangentiellement). 7.- màchoire (touchée tang.). 8.- syt. nerveux ventral (touchée tang.). 9.- bouche.

Ces deux organes - glande et "machoire" - sont considérés comme larvaires et disparaissent chez le Siponcle adulte (Hatscheck p. 85). Chez Pelagosphaera, ils existent encore chez les individus les plus avancés de la collection du «Dana» (fig. 9). Chez ceux-ci, la collerette est devenue plus musculeuse, ne paraît plus capable de s'étendre aussi fort mais les organes annexes du tube digestif ne sont pas réduits.

## Tube digestif.

L'état de conservation des spécimens ne permet pas d’ajouter grand chose aux descriptions de Senna. Dans les individus contractés et sphériques, le tube digestif quitte la partie gauche du carrefour buccal, dessine une spirale vers la gauche, l'arrière puis le dos et l'avant. L'anus peut se trouver bien en avant du carrefour buccal. La spirale est encore visible dans les spécimens dévaginés: elle est simplement étirée. Mais dans les individus proches de la métamorphose, le tube digestif, en $V$, est situé pratiquement dans un seul plan.

Sur l'animal entier, la limite oesophage-estomac est toujours bien visible. Celle qui sépare l'estomac de l'intestin postérieur s'aperçoit surtout chez les individus bourrés de nourriture. Dans le magma remplissant l'estomac, les tests de Diatomées et les spicules de Radiolaires abondent. Comme il fallait s'y attendre, l'animal est planctonophage.

De très fines brides suspendent le tube digestif au centre de l'animal (fig. 4). Elles sont si minces qu'elles demeurent peu visibles sans coloration préalable.

## Néphridies.

Tandis que Senna a décrit (et figuré) les néphridies comme ouvertes dans la cavité générale par un néphrostome, Heath et Dawydoff les considèrent comme des protonéphridies closes. En fait, dans tout les spécimens sectionnés, il a été possible de trouver le néphrostome et parfois l'entonnoir cilié (fig. 10).


Fig. 10. Coupe parasagittale dans la néphridie - l'épiderme a été décollé sauf au niveau du néphridiopore. - 1. - néphrostome. 2.- néphridiopore. 3.- zône musculaire de la peau.

L'erreur des deux auteurs précités s'explique par le fait que le néphrostome est minuscule, que l'entonnoir est plaqué contre la paroi et juxtaposé au néphridiopore. Les deux orifices se trouvent fréquemment dans deux coupes successives.

L'organe est en fait, identique à celui que Hatscheck a décrit chez la larve de Sipunculus.

## Liquide coelomique.

Beaucoup de spécimens ont une partie de la cavité coelomique encombrée d'un précipité granuleux où se trouvent des cellules sanguines de diverses tailles. La qualité de la fixation n'a malheureusement pas permis de chercher à savoir si déjà sont différenciés les divers types cellulaires caractéristiques des Siponcles. Dans les spécimens fixés ces éléments libres sont souvent accumulés, par suite de leur poids, en un point déterminé de l'animal (fig. $2 \mathbf{b}, \mathrm{c}$ ) ce qui peut faire croire - abusivement - à un développement du mésenchyme.

Ln certain nombre de spécimens présentent de plus des taches blanchâtres plus ou inoins nombreuses sur le revêtement péritonéal du tube digestif ou du cordon nerveux (fig. 3) et entre l'épiderme et la couche musculaire. A cet endroit, ces taches alfectent la forme étoilće de cellules pigmentaires et s'orientent parallèlement aux muscles. Ces taches, blanchâtres par réflexion, sont brunâtres lorsqu'elles sont examinées par trausparence. Il s'agit d'amas d'aiguilles flexueuses. Elles disparaissent dans les préparations microscopiques car elles se dissolvent dans l'alcool. La présence de pareils dépôts (d'origine métabolique?) entre les muscles cutanés et l'épiderme aussi bien que sur la paroi péritonéale suggère l'existence de fentes coelomiques en cet endroit, bien qu'aucune trace de revêtement péritonéal de semblables lacunes (caractéristiques des Siponcles) n'ait pu être constaté.

Organes génitaux et Système circulatoire.
Pas plus que les spécimens étudiés par Senna, Heath ou Fisher, les exemplaires de la collection du "Dana" ne montrent de trace d'organes génitaux ou de vaisseaux sanguins, pas même les individus à cuticule épaisse, proches de la métamorphose.

## SYSTÉMATIQUE

Les deseriptions de Sexai, Heati, Fisher sont entièrement confirmées par l'étude du matériel du "Dana". Il est induhitable que Pelagosphaera est une larve de Siponculide. Il suffit, pour s'en convaincre. de comparer les dessins actuels aver ceux publiés par Hatscheck sur l'embryologie de Sipunculus nudus spécialement arec ses figures 51,56 et 58 ( pl . V').

Peu de différences peuvent être relevées: la taille, le développement de la zone métatrochale en une collerette, le gonflement en une bulle plus ou moins sphérique de la région abdominale, enfin la structure de lorgane buccal nommé "Schlundkopf" par Hatscueck. Les trois premières témoignent d'une prolongation de la période larvaire, qui sera discutée plus loin. Morphologiquement parlant, elles sont sans signification. La dernière devrait être confirmée par une étude nouvelle de l'embryologie de Sipunculus, ainsi qu'il a été signalé plus haut (page 13).

Pelagosphera est done, sans doute possible, la larve d'une forme très voisine de Sipunculus. Le fait que 2 sur 3 des individus proches de la métamorphose examinés n’avaient conservé que 4 muscles rétracteurs ce qui est la formule de Sipunculus - confirme cette interprétation.

Actuellement il parait prématuré de vouloir préciser davantage car les caractères utilisés habituellement pour caractériser les espèces et les genres ne peuvent servir ici. Ou bien les structures invoquées en l'occurrence ne sont pas discernables avec certitude; ou bien la variabilité de ces structures dans des spécimens provenant d'une même pêche - et done probablement d'une même population -- montre que dans la croissance ultérieure et la métamorphose, elles sont réorganisées. C'est la cas en particulier des muscles longitudinaux et des muscles rétracteurs. Tant que manqueront les stades de métamorphose jusqu’à l'animal constitué sur le type de l'adulte, il sera illusoire de tenter de rapporter Pelagosphnera à une espèce déterminée et même avec certitude au genre Sipunculus, bien que ce dernier point soit probable.

D'autre part, le matériel rapporté par le "Dana» est si important et provient de tant d'endroits des océans, qu'il parait à priori peu vraisemblable que Pelagosphaera soit la larve d'une seule espèce de Sipunculide. Celle-ci devrait en effet être répandue dans le monde entier. Seul Sipunculus nudus répond à cette exigence. Mais la larve a été décrite par Hatscueck et elle se métamorphose sans atteindre la grande taille, ou l'allure globulcuse de Pelagosphaera.

## RÉPARTITION GÉOGRAPHIQUE

La planisphère situe toutes les localités connues par l'auteur, où furent capturés des Pelagosphaera. Au cours des croisières successives du «Dana», cette larve fut capturée en 98 endroits. Les travaux de Mingazzini, de Sema, de Heatio, de Fisier, de Dawyooff, les collections de la croisière de l’«Armauer Hansen" 1922 permettent d'y ajouter 16 autres localités.


En somme, pratiquement toutes les mers visitées par le «Dana» ont fourni des Pelagosphaera. Plus de la moitié des larves capturées (1213) l'ont été sur la côte sud de Sumatra et le détroit de Malacea (station 3814 à 3904). Mais la densité de pêche à cet endroit a été beaucoup plus intense que n'importe où ailleurs. Aussi impressionnante est la capture, dans le Pacifique oriental, à la seule station 35.56 , de 109 spécimens ou celle de 137 spécimens au large des côtes du Maroc (stations 4005 ì 4019 ).

Il serait difficile, sur la base des récoltes actuelles de déeider en quel endroit du globe Pelagosphera est le plus abondant. Lors de sa croisière autour du globe, le "Dana" est passé à 3 reprises dans la mer des Célèbes. Chaque fois, il a capturé des Pelagosphera, au total t² spécimens. Mais de deux pêches faites pratiquement au même endroit (station 3683 et 3739 ), la première n'en a pas rapporté et la seconde en a capturé 3 . Le fait qu'un spéeimen a été capturé dans la mer Thyrrhénienne, pas très loin en somme de la station zoolosique de Naples, indique bien cue la chance doit jouer dans ces captures.

La carte indique que Pelagosphaera a été pêché aussi bien à proximité des côtes qu’en plein océan, dans l'Atlantique comme dans le Pacifíque ou dans l'Océan lndien. La densité des captures effectuées à proximité des côtes, dans l'Archipel de la Sonde, autour des Célèbes ou le long des côtes du Maroc ne doit pas impressionner autre mesure. Elle est à mettre en relation bien plus avee l'itinéraire suivi par l'expédition du "Dana" (qu’avee la répartition géographique de l'animal.

## BIOLOGIE DE L'ANIMAL

La structure de Pelagosphaera est en fait un exemple parfait d'adaptation planctonique. Lorsqu'elle est étalée, elle fait immédiatement songer à la larve veliger des Mollusques. Cette bulle distendue a évidemment pratiquement la densité dé l'eau et sa métatroque lui fournit un organe de locomotion suffisant. On peut imaginer d'ailleurs que cette bande ciliée lui sert également à capturer la nourriture. ll est permis, en effet, de concevoir que cet animal capture les organismes flottants dont il se nourrit (Diatomées et Radiolaires d'après le contenu du tube digestif) par le jeu combiné de la glande prébuccale, de la paratroque et d'une "machoire» (l'organe décrit sous le nom de "Schlundkopf" par Hatscneck).

D’après les préparations, la volumineuse glande prébuccale déverse son contenu - probablement muqueux - devant le bord inférieur de la collerette garni de la métatroque (voir fig. 3 et 4). Le mucus, entrainé par le mouvement ciliaire englue probablement les organismes planctoniques et les réunit en une masse que la "machoire" en se contractant, pousse dans la trompe. C'est du moins ainsi que, sur préparations et pièces fixées, il est possible de se représenter le mode d'alimentation de Pelagosphaera.

Sur les 1923 spécimens des collections du «Dana», 1702 ont été capturés par des instruments tirés par un cable d'une longueur maximale de 650 mètres c'est à dire pêchant dans les 300 premiers mètres d'eau. Pelagosphaera vit donc dans les couches superficielles de l'océan.

Les captures suggèrent que l'adulte, encore inconnu, vit au contraire à grande profondeur. 142 spécimens seulement ont été pris au dessus de fonds de moins de 1000 mètres tandis que 1332 proviennent d'endroits où la profondeur de l'eau dépassait 2000 mètres. Certes des larves pélagiques peuvent être transportées au loin par les courants. D'autre part, le "Dana" a prospecté spécialement les eaux profondes. Mais parmi les stations autour de l'Archipel de la Sonde, beaucoup furent faites à profondeur relativement faible et n'ont pas rapporté de Pelagosphaera.

Un certain nombre de captures ont d'ailleurs été faites en plein Océan, par exemple à la station 3561 en plein Pacifique, et bien que plusieurs se trouvent sur le trajet de grands courants marins elles conduisent aussi à penser que l'adulte doit être capable de vivre à grande profondeur.

Pelagosphaera apparait donc comme la larve planctonique d'un animal faisant partie du benthos abyssal. Tandis que l'adulte vit dans la boue, éventuellement à plusieurs kilomètres de la surface, la larve vient se nourrir dans les couches éclairées, habitées par le microplancton. Elle devra y grandir suffisamment pour être capable d'effectuer la migration verticale qui la ramènera sur le fond. Ce voyage est probablement simplement le résultat de l'augmentation de la densité de l'animal au moment de sa métamorphose. Tous les spécimens approchant de la métamorphose figurant dans les collections du "Dana», mesurent au maximum $4,5 \times 2 \mathrm{~mm}$ alors que Pelagosphaera atteint 8 à 9 mm de diamètre. La métamorphose est donc accompagnée d'une réduction de volume, probablement sans perte de sustance, c'est à dire d'une augmentation de la densité. La descente vers le fond en résulte fatalement, ce qui explique que les spécimens en métamorphose sont relativement rares dans les collections.

Pour obtenir la quantité de substance nécessaire à l'acquisition du poids qui fera descendre l'animal, une vie larvaire prolongée est nécessaire. C'est pourquoi Pelagosphaera diffère essentiellement de la larve de Sipunculus nudus par sa taille.

Pelagosphaera est donc certainement une larve gigantesque d'un animal de grande profondeur. Elle montre, en les exagérant même, les caractères parfaits d'un animal adapté à la vie planctonique. Mais il s'agit d'une adaptation transitoire préparant le retour de l'adulte dans le benthos abyssal. On connait d'autres cas semblables: les larves pélagiques d'Echiuriens abyssaux et surtout Pelagosphaera pelagica Spenger., larve pélagique d'un Entéropneuste inconnu.

## INTERPRÉTATION MORPHOLOGIQUE

Pelagosphaera est, il faut le rappeler, construite essentiellement sur le même plan que la larve de Sipunculus nudus décrite par Hatscheck. Celle-ci est interprétée comme une trochophore fortement allongée. Cependant Hatscheck faisait déjà observer que par la perte de la couronne ciliée préorale, l'exagération de la portion post-trochale, l'existence d'un coelome véritable et d'une paire de métanéphridies, cette larve a, en fait, déjà dépassé le stade trochophore. "Die sind aber Eigenthümlichkeiten, welche auch in den andere Thieren das Trocophore Stadium überdauern und in den späteren Stadien, je zum Theil sogar in erwachsenen Zustande, sich erhalten.» (p. 61).

La larve de Sipunculus nudus est donc une trochophore avancée, hautement adaptée à la vie pélagique. Pelagosphaera exagère encore ces caractères adaptatifs. Sa taille plus grande, (jusqu'à 9 mm ), l'expansion en collerette puissante de la région portant la métatroque, le développement des organes annexes de la bouche, l'expansion en sphère de la région abdominale sont tous caractères temporaires, destinés à se réduire ou disparaitre lors de la métamorphose.

D'autre part, les spécimens de la présente collection même ceux chez qui débute la métamorphose, ont encore tous conservés toutes ces structures larvaires: les organes annexes de la bouche sont encore en parfait état histologique, la métatroque est toujours aussi puissante. Ces faits suggèrent que la métamorphose de Pelagosphaera est plus progressive et plus lente que celle de Sipunculus nudus décrite par Hatscheck.

Un seul organe larvaire montre quelques transformations: la collerette est envahie par des fibres musculaires. Elle ne semble plus capable de s'étaler aussi fort qu'autrefois. Elle forme toujours un bourrelet annulaire post-céphalique, bourrelet orné de replis longitudinaux juxtaposés (fig. 6). Cependant les grandes cellules de la métatroque existent toujours (fig. 9). Le battement de leurs cils maintient probablement quelque temps, entre deux eaux, la larve en métamorphose dont la densité s'accroit.

La collerette qui s'épaissit, va-t-elle être simplement incorporée à la paroi du corps? Les replis parallèles qui le marquent sur l'exemplaire représenté dans la figure 6 font penser immédiatement qu'elle va se transformer et donner naissance aux tentacules buccaux de l'adulte.

Les études embryologiques de Hatscheck et Gerould s'opposent à cette manière de voir. Le premier spécialement souligne «dass der Flimmerkranz mit der Bildung des Mundlippen nicht zu thun hat sondern einer viel weiter nach rückwarts gelegenen Körperzone entspricht. Der Flimmerkranz hat also auch nicht mit der Bildung des Tentakeln zu thun, die sich von der Mundlippen aus entwicklen» (p. ã5). Mais Нatsckeck parle en même temps d'un déplacement de la région buccale vers l'avant et ses figures 69, 71, 73 (pl. V), très schématiques, montrent une modification totale des rapports entre les organes. Le cerveau, par exemple, cesse d'être superficiel et pivote de $180^{\circ}$ vers l'arrière. Ce mouvement pourrait très bien être lié à une progression vers l'avant de toute la région précédant la métatroque, région qui interviendrait ainsi dans la formation de la garniture buccale et des lèvres.

Les dessins de Gerould sur le développement de Golfingia gouldii, spécialement la comparaison de ses figures 54 ( pl .7 ) et 71 ( pl .9 ), montrent le même remaniement de toute la région antérieure: progression de l'orifice buccal, invagination de la région cérébrale. Les figures des auteurs amènent donc à douter de leurs affirmations. En fait, les rapports réels entre la métatroque de la larve et la région buccale des Sipunculides, devraient être précisés par une étude nouvelle de la métamorphose, étude qui utiliserait des techniques telles que celles des marques colorées, car le point de repère véritable - les grands cils de la métatroque -- tombent au cours de la métamorphose de Sipunculus nudus ou de Golfingia gouldii, a vant l'apparition des tentacules.

L'obtention de tous les stades de la métamorphose de Pelagosphaera trancherait plus aisément ce problème
dont l'intérèt est évident: si comme le suggèrent les stades les plus avancés de Pelagosphaera, les tentacules. dérivent de la collerette et par conséquent de la métatroque, la même structure serait utilisée, mais de deux façons différentes, chez la larve et chez l'adulte.

Hatscheck signalait déjà que les particularités de la trochophore des Sipunculides sont déjà des traits de structure caractéristiques de l'état adulte. En d’autre terme, dans leur évolution ontogénétique, les Sipunculides ne dépasseraient guère le stade trochophore. Cette remarque semble se vérifier chez Pelagosphaerı qui utilise peut-ètre la région de la métatroque comme organe locomoteur it l'élat larvaire, comme tentacules buccaux à I’état adulte. Il semble permis, par conséquent, de considérer les Sipunculides comme des Trochophores transformées et adaplées à la vie benthique. Cette hypothèse expliquerait la position isolée du groupe.

## ENGLISH SUMMARY

1.- More than 1900 specimens of Pelagosphaera were collected during the "Dana» Expedition. They were caught in all explored seas.
2.- In addition to contracted specimens which have already been described by previous authors, a few intlated individuals were found. In front of a spherical body, these Iarvae present a conical collar with a strong metatroch (fallen in fixed specimens) and a proboscis orientated ventrally.
3.- The anatomical features of the larvae are exactly similar to those described by previous authors. The number of longitudinal muscles as well of retractor muscles is so variable that it is even impossible to try to class the larvae in a definitive species. But it is highly probable that they belong to a Sipunculus.
4.- Some anatomical features are described with more precision, especially the structure of the accessory organs of the mouth and of the nephridia which are metanephridia.
5.- Some 15 individuals were at the beginning of metamorphosis, but they still retained all the larval organs. The metatroch, in particular, is in a perfect state. The collar is invaded by a lot of muscle fibers and is fringed, so that it seems to be the origin of the tentacles of the adult.
6.- Many Radiolarians and Diatoms were found in the gut of Pelagosphaera.
7.- Pelagosphaera is a trochophore highly adapted to pelagic life. It was caught mostly in the upper 300 metres but above depths of 2000 metres or more.
8.- The study of Pelagosphaera, especially of the specimens in metamorphosis, suggests that the Sipunculids are trochophores adapted to benthic life.

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# MELAMPHAIDAE III SYSTEMATICS AND DISTRIBUTION OF THE SPECIES IN THE BATHYPELAGIC FISH gEnus SCOPELOGADUS VAILLANT 

BY<br>ALFRED W. EBELING and<br>WALTER H. WEED III

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$\qquad$
WITH 23 FIGURES IN THE TEXT
$\qquad$

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# MELAMPHAIDAE III <br> SYSTEMATICS AND DISTRIBUTION OF <br> THE SPECIES IN THE BATHYPELAGIC FISH gEnus scopelogadus vaillant 

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# I NTRODUCTION 

Scopelogadus Vaillant, Melamphaes Gnth., Sio Moss, Poromitra Goode and Bean, and Scopeloberyx Zugmayer comprise the Melamphaidae, a bathypelagic family of beryciform-like fishes referable to the Stephanoberyciformes. Ebeling (1962) incladed in his revision of Melamphaes an account of the family, with suggested relationships and a key to these 5 genera. Sio Moss, 1962, is the most recently described genus; Poromitra and Scopeloberyx will be subjects of later revisions.

Like other deep-dwelling bathypelagic fishes the 3 species, including 2 subspecies, in Scopelogadus are closely adapted to the cold, aphotosynthetic, and almost lightless abyssal depths, where pressures exceed 1000 p.s.i., food is relatively scarce, and swift currents are rare. Under these conditions the structure of fishes reflects an "economy of life" (as coined by Marshall, 1960). To maintain their population biomass in this rigorous environment there must be a conservation of metabolic energy in the form of any or most of the following: reduction of ossification, eye size, and gill surface; degeneration of gas-bladder, photophores, pseudobranchiae, and various bones of the head; decrease in density of flesh; increase in jaw size (to seize large prey, which are relatively few and far between); and elimination of countershading (Marshall, 1954, 1960; Denton and Marshall, 1958; Walters, 1961). Any adaptations that decrease the density of body tissues will, of course, enable fishes to approximate neutral buoyancy with a minimum expenditure of energy. Similarly, individuals of Scopelogadus, relative to other melamphaids, have a weak skeleton (as shown by radiographs), reduced gill surfaces, a degenerate or lost gas-bladder, occasionally a reduced pseudobranch, soft flesh with epidermis and scales especially fragile and easily lost, and broad head sensory canals bounded by delicate leaflike bone. The eye size, however, is normal for the genus.

In the present study we compare the systematics and distributions of Scopelogadus taxa, whose members are closely adapted to the bathypelagic environment, with others in Sio and Melamphaes, whose species include more "normal" individuals, frequently shallower dwelling and morphologically less completely attuned to an economy of life. We pose the following questions. How many forms comprise the resurrected genus Scopelogadus? How can these morphologically similar, but fragile and damaged specimens best be differentiated? Statistically, how is Scopelogadus related to the previously revised genera Melamphaes and Sio? How are the 3 species distributed relative to the physicochemically defined oceanic water masses? Are they distributed according to established bathypelagic faunal regions (see Ebeling, 1962) and, if not, how do they differ? Are their distributions analogous to distributions of some species in Sio and Melamphaes? For those species that occupy several water masses, are there morphological differences that suggest raciation or incipient speciation between the populations that inhabit these different oceanic regions, and are the observed patterns of variation similar to those within the species of Melamphaes?

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We acknowledge with gratitude the Danish Carlsberg Foundation, which supplied most of the specimens, and other institutions for loaning the remaining material. The following are museums and other institutions, together with their code abbreviations and responsible staff.
amNH, American Museum of Natural History: Charles M. Breder, Vladimir Walters.
bmnh, British Museum (Natural History): N. B. Marshall, Denys W. Tucker.
BOC, Bingham Oceanographic Collection, Peabody Museum, Yale University.
BZM, University of Bergen Zoological Museum: Hans Brattström, Johan Fr. Willgohs.
CNHM, Chicago Natural History Museum: Marion Grey, Pearl Sonada.
CZM, University of Copenhagen Zoological Museum: Anton Fr. Bruun, J. R. Pfaff.
D, R/V "Dana" collections of the Danish Carlsberg Foundation, Charlottenlund Slot: Å. Vedel Tåing, Erik Bertelsen.
G, R/V "Galathea" collections of the Copenhagen Zoological Museum: Anton Fr. Bruun, J. R. Pfaff.
GNM, Göteborg Natural History Museum: Orvar Nybelin.
IFAN, Institut Français d'Afrique Noire, Dakar: J. Cadenat.
MCZ, Museum of Comparative Zoology, Harvard University: William C. Schroeder, Giles W. Mead, Myvanify M. Dick.
NYZS, Collections of the New York Zoological Society, made from the M/V "Arcturus" by William Beebe, in the Stanford University collections, but uncataloged as such.
$\mathrm{Ob}, \mathrm{R} / \mathrm{V}$ " Ob " collections of the Zoological Institute at the U.S.S.R. Academy of Sciences, Leningrad: A. P. Andriashev.

POFI, U.S. Bureau of Commercial Fisheries, Biological Laboratory, Honolulu: Donald W. Strasburg.
SiO, Scripps Institution of Oceanography, University of California, San Diego: Carl L. Hubbs, Richard H. Rosenblatt.

SU, Natural History Museum, Stanford University: George S. Myers, Margaret H. Storey.
USNM, United States National Museum: Leonard P. Schultz, Ernest A. Lachner, Daniel M. Cohen.
UW, Department of Oceanography, University of Washington: William Aron, Peter McCrery.
V, R/V "Vitjaz" collections of the Institute of Oceanology, Academy of Sciences of the U.S.S.R., Moscow: Theodor S. Rass, Nicolas V. Parin.
WHOI, Woods Hole Oceanographic Institution: Richard H. Backes.
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## SYSTEMATICS

This section treats the 3 species including the 2 subspecies comprising Scopelogadus, which previously had been in synonymy with Melamphaes (see "Remarks"). Before the present study, 5 nominal species referable to Scopelogadus had been described: Scopelus mizolepis Günther, 1878; Melamphaes beanii Günther, 1887; Scopelogadus cocles Valllant, 1888; Melamphaes eurylepis Hollt and Byrne 1906; and M. bispinosus Gilbert, 1915. Of these Norman (1929: 156, 166-168) recognized as valid only 2, beanii and mizolepis. Parr (1931: 41, 43-45), using supposed differences in head length and eye diameter, however, resurrected bispinosus, which had been tentatively synonymized with mizolepis by Norman, as the third species in a group of relatively large-scaled melamphaids. In the most recent major treatment of the family, Koefoed (1953:32-34) identified all his North Atlantic specimens of Scopelogadus as Melamphaes mizolepis, not mentioning beanii, which in fact was the predominant species in his material. We recognize the following: S. mizolepis mizolepis (Günther), S. mizolepis bispinosus (Gilbert), S. unispinis, n.sp., and S. beanii (Günther). During the present study 2311 specimens from 693 collections were examined; of these 380 were analyzed meristically and morphometrically.

## METHODS

Most procedures and collection data were presented in detail in Ebeling (1962). Certain modifications and clarifications as applied to Scopelogadus are given below.

Collections and condition of specimens:-Most of the expeditions and oceanographic cruises taking specimens (Fig. 15) were listed in Ebeling (1962: Table I). To this should be added cruises by the Institut Français d'Afrique Noire, off West Africa at $14-15^{\circ} \mathrm{N}$ and two expeditions of the Scripps Institution of Oceanography: "Tethys", 1960, ship, R/V "Spencer F. Baird", eastern tropical Pacific west to Hawaii, and "Monsoon", 1961, ship, R/V "Argo", Indian Ocean to western and central tropical Pacific. For the R/V "Dana" collections the actual depth trawled was taken as half the given number of meters of wire out.

Inasmuch as they belong to a genus of comparatively fragile melamphaids, most of the specimens were in very poor condition. The scales were almost always missing, the superficial tissues of the head were damaged or destroyed, and the fin rays were usually broken near the tips. This caused some inaccuracy in the measurements, many of which were defined by reference points obscured in tissue damage. For example, the points associated with the posterior extremities of the head and the ridges thereon were often impossible to find. This made for a greater variability in measurements than might be expected of more solidly built species.

Counts and measurements:-All measurements (in the proportion, thousandths of standard length) and counts are presented as ranges followed by the mean in parentheses. Unusual variation in counts is further analyzed in the descriptions. All except those taken according to Hubbs and Lagler (1949) are defined as follows: caudal rays, all procurrent and principal rays (usually $4+10-9+4$ ); pectoral rays, all except the small bony splint just above first (unbranched) ray; vertebrae, all centra including the urostyle (the atlas has a slightly shorter centrum than the second precaudal vertebra and has associated with it an easily visible neural spine; the first caudal vertebra has a complete arch and has its haemal spine located just behind the elongate pterygiophore associated with the base of the anal spine); gill rakers on lower limb of fourth arch, all rudiments and stumps, but excluding the small spinose patches between the rakers, and the rakers at or above the angle of the arch; pharyngeal teeth counts, see Fig. 3 for location of tooth patches; body depth, insertion of pelvic, vertically upward; postdorsal, base of first dorsal spine to caudal base; end of dorsal to caudal, base of last dorsal ray to caudal base; snout to preopercle, tip of snout horizontally to edge of preopercle; orbit to cheek ridge, posterior edge of bony orbit on line with middle
of eye to edge of cheek ridge (line of fusion of hyomandibular bone with preopercle); head depth, occiput (directly over preopercle) vertically to ventral edge of preopercle; interorbital, between wide margins of frontal bones directly over middle of eye; length of frontal fossa, anterodorsal edge of frontal knob (leaflike protuberance at top of snout) to line between posterior extremities of paired ridges on top of head; width of frontal fossa, greatest width between these paired ridges; prepectoral, tip of snout to base of first pectoral ray; prepelvic, tip of snout to base of pelvic spine; isthmus to pelvic, midpoint of angle in ventral profile of mandible under nostrils (marked by the second sensory placode in from tip of jaw) to base of pelvic spine; pelvic to anal, base of pelvic spine to base of anal spine; width between pelvics, greatest width between bases of spines; preanal, tip of snout to base of anal spine; anal to caudal, base of anal spine to caudal base; orbit to cheek angle, posteroventral margin of fleshy orbit to recess between 2 spinelets at angle of cheek ridge (with dividers lightly pressed against the fleshy orbit); suborbital, greatest width of bone taken at mid-gape perpendicularly upward to bony orbital flange (below front half of eye).

Allometric growth :-As in Melamphaes, the criteria for defining the young, halfgrown, and adult growth stanzas used in presenting allometric proportions (e.g., predorsal, head length, length of upper jaw, suborbital) are based on curves of these plotted against standard length. In Scopelogadus m. mizolepis and S. m. bispinosus two growth inflections described a U-shaped curve, with the dip (area of smallest values) restricted to halfgrown; values within the left leg of the " $U$ " were of young and values within the right were of adults. The curves for S. unispinis were almost straight with slopes of about minus one, so that "inflection points" were arbitrarily determined. $S$. beanii was intermediate in that the curves were exponential; the inflection between young and halfgrown was clearer than that between halfgrown and adults.

Sex determinations:-Superficial examination revealed two categories of gonads: obvious ovaries with well formed, easily discernible eggs and smaller, often poorly preserved gonads, which could not be identified as to sex. Accurate sex ratios, therefore, could not be calculated.

Vertical distributions:-The upper depth limits of adults, halfgrown, and young equaled the shallowest haul or hauls in which each was taken because, in general, closing nets were not used (i.e., open net depths indicate the shallowmost limit of a species or age group, but not the deepest).

Presentation of systematic data:-Characters common to all 3 species are restricted to the genus description. Also, descriptive excerpts common to both subspecies of $S$. mizolepis occur only once, preceding both accounts. Diagnoses and comparisons of all included species and subspecies are given in the keys or tabulated (Tables I, V). Unless otherwise stated, the written descriptions are based only on adults and nearadults. Lists of specimens examined other than types (holotype, syntypes, and paratypes) are in Appendix II. For the paratypes, collection data are presented in the following order: collection or catalog number (e.g., D 2417 (6) means sixth net from bottom in "Dana" collection 2417); locality by position; greatest depth trawled (all depths are in meters; the suffix "w" means meters of wire out) and time of capture (N, means night; D, day; ND, trawl beginning at night and ending at day); and number of specimens, followed in parentheses by size range in millimeters of standard length (e.g., 7(13-42) - if postlarvae are included, they are so identified, e.g. 7 PL-HG(13-42)). Available counts and proportions of holotypes and syntypes are in Appendix I.

## Scopelogadus Vaillant, 1888.

Scopelogadus Vaillant, 1888: 141-142, 385, 386, 403 (type species, Scopelogadus cocles Vaillant 1888, by monotypy; description, relationships). Alcock, 1899: 37 (equals Melamphaes Günther, 1864). Brauer, 1906: 280 (equals Melamphaes). Kotthaus and Krefft, 1957: 173, 187 (listed as "M. (Scopelogadus) mizolepis'’). Ebeling, 1962: 18 (validity).

Distribution.
Scopelogadus occurs throughout all major oceans except the Arctic and Antarctic ${ }^{1}$. All species except $S$. beanii are entirely tropical. The adults and halfgrown usually inhabit the bathypelagic region below 100-200 meters; the larvae and young were taken at lesser depths.
${ }^{1}$ However, like all other melamphaids it does not inhabit the Mediterranean Sea.

Table 1. Counts and proportions of the taxa in Scopelogadus.
The mean is given in parentheses, following the range. All proportions are in thousandths of standard length. The proportions, which are based on a sample of 12 adults from over the entire range of the species, may or may not be allometric (other proportions calculated from large samples of representative growth stages are analyzed either as allometric or non-allometric in the species accounts and are tabulated as frequency distributions by locality in Table V).

|  | S. m. mizolepis | S. m. bispinosus | S. unispinis | S. beanii |
| :---: | :---: | :---: | :---: | :---: |
| Counts |  |  |  |  |
| Number. | 10-12, *67-72 | 12, *135-138 | 12, * 46-49 | 12, *88 |
| Dorsal. | * II, 10-12 (11.00) | * II, 10-12 (10.90) | *I, 10-11 (10.96) | *II, 10-11 (10.89) |
| Anal. | *I, 8-9 (8.07) | *I, 7-9 (8.00) | *I, 7-9 (7.96) | * I, 7-9 (8.02) |
| Gill rakers on first arch. | *6-8+15-18 | *6-9+15-18 | *7-9 + 17-20 | * $8-10+18-22$ |
|  | $(7.09+16.21)$ | (7.10-16.30) | $(8.25+18.25)$ | $(8.69+19.02)$ |
| Total vertebrae. | *24-26 (24.96) | *24-26 (24.90) | *23-24 (23.02) | *25-27 (26.00) |
| Caudal | ** $4+10+9+3$ | $4+10+9+3-4$ | $3-4+10+9+3$ | $3-4+10+9+3-5$ |
| Pectoral. | 14-16 | 14-15 | 14-15 | 14-16 |
| Pelvic. . | I, 7 | I, 7 | I, 7 | I, 7 |
| Gill rakers on lower limb of 4th arch. | 10 | 9-11 (10.0) | 10-11 (10.5) | 11-12 (11.7) |
| Teeth on second pharyngobranchial.. | 54-90 | 38-108 | 29-57 | ***30-65 |
| Teeth on third pharyngobranchial ... | 46-96 | 49-125 | 40-72 | ***47-77 |
| Teeth on fourth pharyngobranchial.. | 29-51 | 25-57 | 21-44 | ***26-47 |
| Teeth on third epibranchial. . . . . . . . | 53-88 | 30-106 | 30-66 | ***46-75 |
| Proportions |  |  |  |  |
| Number. | 10-12 | 10-12 | 10-13 | 10-12 |
| Standard length. | 62.9-93.7 | 71.1-95.0 | 69.7-95.3 | 61.0-122.0 |
| Postdorsal. . | 544-591 (565) | 545-597(566) | 548-563 (557) | 562-598(582) |
| End of dorsal to caudal. | 335-372 (352) | 341-381 (357) | 319-367(345) | 356-396(379) |
| Postorbital length of head. | 219-249(237) | 219-300(258) | 193-246(220) | 189-235(210) |
| Snout to preopercle. | 235-257 (246) | 223-276(253) | 221-248(236) | 189-218(203) |
| Orbit to cheek ridge | 36-54 (44) | 33-54 (45) | 29-47 (35) | 27-39 (32) |
| Head depth. | 236-273(251) | 256-295(274) | 258-301 (279) | 260-289(275) |
| Head width. | 191-229 (203) | 187-223(209) | 182-233(206) | 185-229(206) |
| Interorbital. | 149-174(164) | 135-185(157) | 158-211 (187) | 151-183(163) |
| length of frontal fossa | 174-189(181) | 169-200(184) | 159-179(170) | 123-160(144) |
| Width of frontal fossa. | 75-92 (85) | 73-107(95) | 75-98 (89) | 65-85 (77) |
| Prepectoral. | 369-400 (386) | 378-432(408) | 375-404 (385) | 344-398(372) |
| Prepelvic. | 366-404 (386) | 389-417(404) | 386-441 (412) | 352-404 (382) |
| Isthmus to pelvic. | 342-391 (362) | 349-377(363) | 355-405(375) | 306-373(342) |
| Pelvic to anal. | 200-241 (222) | 194-225(210) | 213-275(243) | 185-228(207) |
| Pectoral length. | 261-312 (280) | 302-348(326) | 336-385(356) | 297-356(331) |
| Pelvic length (approx.) | 113-156(134) | 106-142(124) | 114-148(132) | 115-129(123) |
| Width between pelvics. | 32-50 (42) | 31-55 (41) | 40-82 (63) | 41-68 (53) |
| Preanal. | 575-630(607) | 586-624(605) | 599-659(628) | 554-590(568) |
| Anal to caudal. | 411-467(442) | 395-464(430) | 410-452 (427) | 444-498(471) |
| Depth of caudal peduncle. | 98-121 (109) | 90-117(106) | 118-141(126) | 98-117(111) |
| Orbit to cheek angle. | 86-104 (94) | 91-111(103) | 93-121(107) | 97-118(106) |
| Snout length.. | 95-110(102) | 98-121(108) | 95-111(103) | 87-108(97) |

[^9]
## Diagnosis.

Melamphaids with 11-14 dorsal fin elements (total), including 1-2 spines; less than 17 scale rows (from pe to caudal base - 12 or less from end of posttemporal bone to caudal base); 5 pyloric caeca; no cheek scales; no antrorse spur on the haemal arch of the first caudal vertebra; the oral teeth usually uniserial; 8 branchiostegal rays; no supramaxillary bone; no conspicuous internarial spine; a relatively smooth or secondarily uneven head (frontal ridges not serrate, but epidermis seldom intact); and head pores of variable size, minute to moderate, usually single, occasionally randomly distributed (the pores are seldom discernible because the head epidermis is usually missing). Scopelogadus can be distinguished from all other melamphaids by the large body scales, absence of cheek scales, and absence of a supramaxillary.

## Description.

In addition to the diagnostic features the following description includes characters that are common to all species.

Body and head form :-Contour behind dorsal slopes unevenly or almost straightly to caudal peduncle,
which is slightly tapered. Profile from dorsal origin to frontal knob almost straight to preopercle, then, above eye, abruptly angles downward to frontal knob and descends only slightly more steeply to upper jaw (i.e.. the forehead is not obviously angular). Ventral contour straighter than dorsal, but markedly concave from pelvic fin to anus. Nostrils crescent-shaped, on each side anterior and posterior openings set close together (with epidermis missing, they appear as one cavity with a transverse septum of nasal epithelium between them), bordered by a slightly exserted rim, which anteriorly forms the forward projection of the antorbita! ridge. Diameter of eye varies from $0.50-1.00$ times suborbital width.

Head spines and ridges :-Frontal ridges normally with margins smooth. However, they are frequently damaged and secondarily jagged because of their delicate structure. Short spinelike ridges at cheek angle fragile, often missing; posteroventrally they are divergent or parallel. Frontal knob leaflike, projects anterodorsally between nostrils, divided medially into 2 lateral wings. Internarial spine inconspicuous or absent (the upper area of the nasal symphysis, however, is hard and pointed for support of the frontal knob). Lateral frontal margin over eye very thin, straight or evenly rounded; interorbital width, measured across the frontal margins between the centers of the eyes, twice or more distance from orbit to end of preopercle. Posteroventral section of preopercle with weak ridges radiating from cheek angle to end at margin as weak serrations. Branchiostegals thin, unsculptured. Operculum tissue-thin, pliant, slightly expanded posteriorly; horizontal ridge and serrate dorsal border very weak and pliant. Posttemporal with smooth margins, i.e., no shoulder spines.

Head epidermis and sensory pores:-Head epidermis fragile, often badly damaged or lost so that head appears deeply sculptured. Embossed lines usually missing with epidermis; extremely thin, barely discernible, widely spaced (spaces between sometimes equal lens diameter (of eye) in width); darker than surrounding epidermis. Because the embossed lines are relatively few and widely spaced, the branching superficial nerves that supply them are relatively few and thinly distributed. The lines and nerves are most easily seen on the cheek. Sensory pores randomly or linearly arranged, never in well defined and constant groups of 2 or more; vary in size from minute, barely visible pinpricks to relatively large pores about 0.33 lens diameter in width; with rims slightly exserted and darker than surrounding tissue.

Jaws and teeth :-Jaws equal; upper jaw rounded, lower jaw somewhat pointed with distinct symphyseal knob. In side view gape extends obliquely to vertical from front of eye or lens; maxillary to back of pupil. Lips narrow; almost entire length of upper jaw except symphyseal area covered by suborbitals. Supramaxillary absent. Teeth mostly uniserial in both jaws, minute, conical. Greatest width of pharyngeal tooth patches in number of tooth rows: second and fourth pharyngobranchials 3-7, third pharyngobranchial 5-10, and third epibranchial 4-9; teeth on lower pharyngeal bone in long narrow patch hidden by fourth gill arch.

Gill rakers and branchiostegal rays:-Gill rakers on first arch long, well developed: length of longest equal to or slightly less than horizontal width of orbit, width equal to space between adjacent rakers. Rakers on fourth arch well developed: longest equals width of adjacent section of ceratobranchial; spines on most spinose raker 14-20. Branchiostegal rays 8 , with trailing edges smooth and even.

Scales:-About $12-16$ pockets in longitudinal series from nape to caudal base. Only one specimen (S. beanii, Bergens Zoological Museum 2599, standard length 61.5 mm .) had most of its scales intact (Fig. 12A). These numbered 13 in longitudinal series from nape to caudal base, 4 in diagonal series from dorsal origin to anus (including scales on mid dorsum and mid venter), and 3 on the opercle, interopercle, and subopercle; cheek scales were absent. Generally, scales very large, thin, imbricate, deciduous and almost always missing, leaving shaggy scale pockets. Cheek scales absent.

Fins :-Longest dorsal ray slightly longer than frontal fossa. Longest anal ray 2-3 times distance orbit to edge of preopercle. Dorsal count low: spines 1-2, weak; soft rays almost always 11, only 36 of 367 counts 10 or 12. Anal typically I, 8; originates under dorsal ray 3-6 from end. Pectoral typically 14-15; reaches to end of dorsal. Pelvics always I, 7; originate at or before vertical from pectoral insertion. Dorsal and ventral procurrent caudal rays typically 4; 2 longest ventral procurrents completely fused in S. unispinis.

Internal characters:-Haemal arch of first caudal vertebra without anteroventrally directed spurs. Pyloric caeca 5, longest shorter than stomach. Gas-bladder, when present, rudimentary; sits above stomach; recognizable only by small spherical remnant of rete mirabile and gas gland (Fig. 1A-B). Stomach usually
about twice as long as deep; blind sac short and blunt, only about 0.2 times length of whole stomach, slopes aenly into pyloris (Fig. 1).

Color of adults:-Brown to dark brown in alcohol or formalin, darkest on operculum; body and head never finely speckled or flecked. Interradial membranes of fins almost transparent (perhaps due to abrasion during capture), rays darker. Gill arches and pharynx light to dark brown, arches lightest ; no iridescent bluish sheen. Branchiostegals blackish.

Larvae and young:--Preopercle of larva with 3 faint spines. Body robust, laterally compressed. pigmentation distinctive: much of body and head punctulate with melanophores, over background of evenly pigmented blotehes; no distinctive pigment bands on either side of dorsal fin. Coelomic peritoneum and spaces between vertebral spines often darkish. Young of ail species, except $S$. mizolepis bispinosus, as adults, but lighter; in bispinosus larval pigmentation is carried to subsequent ontogenetic stages.

## Remarks.

Although Scopelogadus Vaillant has been thought to be a synonym of Melamphaes Günther for more than half a century, the three included species share so many salient characters that Ebeling (1962), preserving Vallant's name, listed them as a separate genus. Subsequent investigations have reinforced our belief in the reality of Scopelogadus.

Vallant ( $1888: 141-142$ ) gave no diagnostic characters for the genus except that the type species, $S$. cocles Vallant was covered by large scales. If adequately described, of course, this large scaled condition clearly sparates the species of Scopelogadus from all other melamphaids. He underestimated the importance of this 'haracter, however, when he suggested ( p .403 ) the possible identity of $S$. cocles with Melamphaes microps ( ( $\ddot{\text { Önther }}$ ), which has many more scales in longitudinal series. Goode and Bean (1895:181-182) in describing the scales of Scopelogadus as "moderate", also overlooked the generic importance of this character. In fairness to these ichthyologists, however, it should be remembered that because the scales are almost always missing and, therefore, are represented by ragged, poorly defined scale pockets, accurate estimates of their numbers we usually unobtainable. The other distinguishing characters given by Goodis and Bean (short head, comparatively small mouth, rudimentary eye, short dorsal and anal fins), even when taken together, are misleading and never diagnostic. The "comparatively small mouth" is suggestive of Scopelogadus, but species in other melamphaid genera, especially Sio and Melamphaes also have relatively small mouths.

Both Alcock (1899:37) and Brater (1906: 280) believed Scopelogadus to be a synonym of Melamphaes, although Brater showed that S. cocles was quite distinct from M. microps. Even though the species in Scopelogadus form a morphologically well-defined unit, this synonymy has held through the most complete treatments of the Melamphaidae: Norman, 1929; Parr, 1931, 1933; Cnapman, 1939; Koefoed, 1953. However, we feel that Scopelogadus as a genus should most certainly be preserved because of the large number of characters that associate the included 3 species (see "Diagnosis"). Further, there is no question as to the generic identity of $S$. cocles. Its having only II, 11 dorsal rays and fewer than 15 or 20 scale rows clearly places it with S. mizolepis, S. unispinis, and S. beanii.

## Characters.

Since most specimens were damaged (see "Collections and Condition of Specimens") they were identified by using protected or durable characters such as those associated with the pharynx, vertebral column, and intestinal tract, or measurements defined by stable reference points. Further, with exception of dorsal spines, the fin ray counts were more or less constant throughout all species, and damage obscured any possible interspecific differences in numbers of scale rows. Even though head length, for example, varied interspecifically, length of caudal peduncle could often be used more reliably in identification; the delicate section of the operculum forming the back end of the head was often damaged, but the reference points for caudal peduncle length (end of anal, caudal base) were almost always intact. In the key to species, therefore, the following characters are used: counts of gill rakers on first arch, vertebrae, and spines in dorsal fin; proportions of caudal peduncle length, suborbital width, body depth, and, secondarily, head length; conditions
of spine development on interspaces between rakers on fourth gill arch, rakers on fifth arch, gill filament development on first arch, stomach pigmentation, and gas-bladder development; measurement of angle with apex at center of eye and sides extending through dorsal fin origin and pelvic insertion (Fig. 2).

## Analysis of species.

In many characters $S$. unispinis is morphologically intermediate between $S$. mizolepis and $S$. beanii; the latter is apparently the species most completely adapted to life in the deep bathypelagic region, i.e., the head of beanii is blunt and unstreamlined and the gill surface on the first arch is the least of all 3 species. Substantiating this is the fact that adults of S. beanii were never taken as shallow as the other species. The following analytical keys diagnose these 3 species, including 2 subspecies of $S$. mizolepis.

## Adults and Halfgrown.

1 a . Total gill rakers on first arch almost always 25 or fewer (8 of 231 counts 26 -27). Stomach noticeably darkened posteriorly about blind sac (Fig. 1A) (S. mizolepis). . 2.
b. Total gill rakers on first arch almost always 26 or more (5 of 137 counts 25 ). Stomach not noticeably darkened posteriorly about blind sac (Fig. 1B-C)


Fig. 1. Stomach and gas-bladder. A, Indonesian specimen of Scopelogadus m. mizolepis (standard length 90 mm .); B, Scopelogadus unispinis (s.I. 93 mm .) ; C, Scopelogadus beanii ( s .1 .81 mm .). B, darkened tip of blind sac; M, remnant of membranous sac; RG, regressed rete mirabile and gas gland; S, stomach. Hatching marks the top of the coelom.

2a. Angle $\theta$ usually 44-51 degrees (Fig. 2). Ranges in thousandths of standard length: suborbital 44-76, body depth 232-274, head length 344-409 (Table V). Teeth on third pharyngobranchial characteristically $65-125$ (Fig. 3). First gill arch with longest of pair of filaments opposite first raker below angle usually less than 0.6 times ( $0.33-0.63$ ) length of this raker (Fig. 4A)
S. mizolepis mizolepis. Tropical Atlantic, Indian, and western Pacific oceans.
b. Angle $\theta$ usually $50-60$ degrees (Fig. 2). Ranges in thousandths of standard length: suborbital 53-86, body depth $235-335$, head length $363-465$ (Table V). Teeth on third pharyngobranchial characteristically 24-65 (Fig. 3). First gill arch with longest of pair of filaments opposite first raker below angle usually more than 0.6 times ( $0.58-0.70$ ) length of this raker (Fig. 4 B )
S. mizolepis bispinosus. Tropical eastern and central Pacific Ocean.

3a. Dorsal spine 1. Total vertebrae almost always 23 (one of 46 counts 24 ). Length of caudal peduncle 275-327, head length (adults only) 345-409 thousandths of standard length. Lower fourth gill arch with proportion of spinose interspaces usually $0.5-1.0$ (Fig. 5 A ); rudimentary rakers on fifth arch mostly well formed stubs (Fig. 6A). Gas-bladder remnant of rete mirabile and gas gland present (Fig. 1B)....
S. unispinis. Indo-Pacific, between latitudes 13 degrees north and south.

3b. Dorsal spines 2. Total vertebrae 25-27. Length of caudal peduncle 334-383, head length 325380 thousandths of standard length. Lower fourth gill arch with proportion of spinose interspaces usually $0.0-0.2$ (Fig. 5 B ); rudimentary rakers on fifth arch mostly reduced to spinose patches or single spines (Fig. 6B). Gasbladder remnant of rete mirabile and gas gland apparently absent (Fig. 1C)......... . S. beanii. Atlantic: Gulf Stream and west coast of Africa. Southern oceans: probably circumglobal south of $30-33^{\circ} \mathrm{S}$.

## Larvae and Young.

1a. Snout (palatoethmoid region) with dark pigment wedge extending to eye (Fig. 12 D ). Total vertebrae usually $26-27$ (rarely 25 )

Scopelogadus beanii.
b. Snout without dark wedge in front of eye (palate, however, may be faintly dusky) (Figs. 9D, $10 \mathrm{D})$. Total vertebrae $23-25$
2 a . Total vertebrae 23. Dorsal spine 1

## S. unispinis.

b. Total vertebrae 24-25. Dorsal spines 2. ...... (S. mizolepis)
3.

3a. Melanophores always abundant on body and head; some retained in young to $25-30 \mathrm{~mm}$. standard length (Fig. 10B-D)

> S. mizolepis bispinosus.
b. Melanophores abundant or thinly scattered on body and head, frequently undeveloped on cheeks and operculum; none retained in young longer than $8-9 \mathrm{~mm}$. standard length (Fig. $9 \mathrm{~B}-\mathrm{E}$ ) . . . . . . . . . . . . . . S. mizolepis mizolepis.


Fig. 2. Front half of Scopelogadus mizolepis bispinosus, showing angle $\theta$, which has its apex at the center of the eye lens and its sides extending through the origins of the dorsal and pelvic fins.


Fig. 3. Patches of pharyugeal teeth on the left side only of the roof of the pharynx of Melamphaes lugubris (the arrangement of patches is similar in all melamphaids). Gill arches 2 and 3 are shown parted. The arrows indicate discrete patches of teeth: E3, patch of teeth on third epibranchial; P2, on second pharyngobranchial; P3, on third pharyngobranchial; P4, on fourth pharyngobranchial. A fifth patch of teeth on the lower pharyngeal bone is not visible in the view illustrated.


A


B

Fig. 4. Segment near the angle of the flrst gill arch, showing the relative gill raker and gill filament lengths. A, Sargasso Sea specimen of Scopelogadus m. mizolepis (standard length of specimen 56 mm .) ; B, Gulf of Panama specimen of Scopelogadus m. bispinosus (s. 1.61 mm .).


A


B

Fig. 5. Lower limb of fourth gill arch, showing spinose and empty interspaces between the rudimentary gill rakers. A, Scopelogadus unispinis: (standard length of specimen 94 mm .) ; B, Scopelogadus beanii (s.l. 100 mm .). The arrow indicates a patch of spines in an interspace.


A


B

Fig. 6. Left fifth gill arch (lower pharyngeal bone), showing the rudimentary gill rakers ( $r$ ) and associated patch of pharyngeal teeth ( $p$ ). A, Scopelogadus unispinis (standard length of specimen 94 mm .) ; B, Scopelogadus beanii (s.l. 100 mm .).

## Scopelogadus mizolepis.

Correctly listed as circumtropical by Bhiggs (1960), S. mizolepis ranges from the Sargasso and Caribbean seas in the western North Atlantic, through the Indian Ocean, to the western and central Pacific. Interestingly, however, unlike S. beanii it apparently does not occur around southern Africa, which constitutes the only gap in an otherwise continuous distribution.
S. mizolepis exhibits considerable morphological variation, especially in the Pacific; so much so, in fact, that until counts and measurements of morphologically intermediate specimens from the central North Pacific and equatorial Pacific were obtained and analyzed, we thought that this single species was actually two: mizolepis in the tropical Atlantic and Indo-Pacific, bispinosus in the eastern tropical and equatorial Pacific. As shown below, however, all possibly diagnostic characters, except one, showed intergradation in specimens
from the equatorial and central Pacific. Only the fact that $S$. mizolepis bispinosus retains larval patterns of pigmentation through subsequent growth stages seems to separate it completely from $S . m$ mizolepis. This is probably an artificial separation, however, due to the lack of collections containing early ontogenetic series from the area of overlapping distributions.

An angle ( $\theta$ ), with apex at the center of the eye and sides extending through the dorsal origin and pelvic insertion (Fig. 2) was often used in identifying the 2 subspecies (Fig. 7 A ). To test the usefulness of this character, 108 specimens from the Atlantic, Indian, and Pacific oceans, including the area of morphological intergradation, were first identified by their general appearance as $S . m$ mizolepis, $S$. m. bispinosus, or as intermediate between the two. Then by using a separation value of 50.5 degrees, over 90 percent of the specimens identified as bispinosus ( $51-60^{\circ}$ ) could be separated from 100 percent of mizolepis ( $39-50^{\circ}$ ). Including the intermediates, then, about 23 percent of the specimens could not be identified to subspecies by using only values of this angle, which, incidently, showed little or no allometric change with standard length. The count if pharyngeal teeth on the pad associated with the third pharyngobranchial (Fig. 3) was also used to identify most of a similar sample of 145 specimens, including those in the previous sample (Fig. 7 B ). Although the rount increased with standard length, the values fell within 2 regression modes, between which about 22 percent were diagnostic of neither subspecies. Atlantic and some Indian Ocean specimens of $S$. m. mizolepis had weakly dereloped gill filaments, castern Pacific specimens of $S . m$. bispinosus had them relatively well developed, but Indo-western Pacific specimens were more or less intermediate. Further, from the subspecies' descriptions can be assembled several other characters that intergrade similarly: e.g., development of rakers on the fifth gill arch (lower pharyngeal bone), proportion of inter-raker teeth on the fourth arch, angle of divergence between the back preopercular margin and the cheek ridge.


Fig. 7. Scattergrams of A, angle $\theta$ and $B$, teeth on the third pharyngobranchial as functions of standard length. . Scopelogadus m. mizolepis; $\Theta$, intermediates; O, Scopelogadus m. bispinosus.


Fig. 8 . Geographical variation of Scopelognalus mizolepis in selected proportions between areas of water masses. Area AB, Atlantic; C, Indo-Pacific: D-H, central and eastern tropical Pacific (see Table ${ }^{-}$ for a more complete description of these areas). A-C. S. m. mizolepis; D-H. S. m. hispinosus, including a few intermediates. In each diagram the base line indicates the range; the small vertical line, the mean; the whole black-centered bar, 2 standard deviations, one on either side of the mean: and the black bar, 4 standard errors, 2 on either side of the mean. The number to the right of each base line is the sample number. The scales are in thousandths of standard length.

Frequency distributions among class intervals of body depth, head length, and width of suborbital also illustrate the cast-west variability of $S$. mizolepis (Table V). When 2 standard deviations, one on either side of the mean, were calculated for sampl-, of specimens identified as $S$. m. mizolepis and intermediates from 2 localities and of specimens identified as $S . m$. bispinosus and intermediates from 5 lm calities, however, there was no instance of a complete non-overlap of these standard deviation intervals between any 2 adjacent populations of the two subspecies (Fig. 8). Suborbital width, however, showed the greatest separation: there was almost a complete non-overlap of the standard deviation intervals between a sample from the Indo-western Pacific and another from the Gulf of Panama and adjacent regions. The non-overlap of standard deviation intervals simply implies that more than $8:$ percent of one sample is distinguishable on the basis of that character from 84 percent of the other. Generally, however, less than 84 percent of specimens from one subspecies could be separated from 84 percent of the other on the basis of these 3 characters. This 84 percent level of divergence was suggested by Hebrs and Perlmutter (1942), by Hubbs and Hybbs (1953), and by Pinentel (1958). as indicating possible subspecific difference for an given character. Hubss and Hubbs thought that thi level of divergence could be adequately represented for this character (assuming the sample size was near 30 or more), by the non-overlap between 2 samples of 2 standard deviations, one on either side of th. mean. Pimentel correctly criticized this method by reminding its users that the 84 percent separation is va lid only if the standard deviations of the samples equal that of the population universe from which they wer: drawn, an unlikely occurrence in nature. To estimate the population standard deviation, therefore, its 9.1 percent confidence limits, which are based on the $X^{2}$ distribution, should be calculated from the samplvariances. Necessarily, however, because our samples are biased and occasionally exhibit extraordinarily large variances, the standard deviations were graphed simply to indicate possible trends in variation rather than precise estimates of the population paraneters. Pimentel believed, furthermore, that to indicate th. existence of subspecies, several characters should show concordance in divergence. In the present study th additional morphometric data, therefore, probably serve best to reinforce the conclusions drawn from the foregoing consideration of the primary subspecies characters (the magnitude of angle $\theta$, larval pigmentation, and number of pharyngeal teeth on the third pharyngobranchial).

Accounts, including complete synonymies, of each subspecies follow descriptive excerpts common to both.
Body and head form :-Body somewhat fusiform, with greatest depth at pelvic insertion; contour along base of dorsal straight. Caudal peduncle moderate in length, depth about 0.29-0.40 its length. Head depth about $0.62-0.74$ its length. Profile from frontal knob to premaxillary symphysis noticeably slanting. Ventral contour from pelvic insertion to mandibular symphysis rounded, becoming steeper at isthmus.

Head ridges and operculum:-Frontal fossa with bottom of expanded part (excluding delicate marginal ridges) flat or slightly concave. Preopercle with its ridges, radiating from cheek angle, somewhat ir-
regularly spaced above the angle. Cheek ridge nearly vertical, usually slightly divergent from preopercular margin. Operculum with posterior margin somewhat angular, with apex at point of subopercle, which projects hackward above pectoral fin for a distance about $0.4-0.7$ eye diameter.

Fins:-Pelvic usually inserts slightly before pectoral insertion. Caudal with the two ventral procurrent , ines that are adjacent to the principal rays incompletely fused, usually separable; the ventral procurrent count, therefore, usually appears to be 4.

Internal characters:-Vertebral mode $10+15 ; 28$ of $239,10+14 ; 8$ precaudal counts $11 ; 34$ caudal counts it, 12 counts 16,2 counts 17 (the counts of 17 are from Pacific specimens from about the Galapagos Is.). Is described by Marsmalis (1960) in an Atlantic specimen of $S$. mizolepis mizolepis, the gas-bladder is represented by a small sphere of yellowish tissue (the remnant of the gas gland and rete mirabile), which lies just above the junction of the esophagus and stomach. Stomach with blind sac noticeably darkened posteriorly (Fig. 1A).

Color of young and larvae in formalin:-The palatoethmoid region is not noticeably pigmented (i.e., the preocular area is relatively light).

Scopelogadus mizolepis mizolepis (Güvther, 1878).
Fig. 9.
Scopelus mizolepis Günther, 1878: 185 (original description; South of New Guinea, "Challenger" St. 191).
Melamphaes mizolepis. Günther, 1887: 28-29 (new combination; short description). Alcock, 1890: 201-202 $18^{\prime} 26^{\prime}$ N., $85^{\circ} 24^{\prime}$ E., 1310 fms.). Goode and Bean, 1895: 178 (affinity with "Plectromus', [misspelled 'myzolepis']). ilcock, 1896: 314 (Bay of Bengal after Alcock, 1890); 1899, 37-38 (brief description; range; Bay of Bengal after \lcock, 1890 ; Indian Mus. Calcutta No. 12834). Lönnberg, 1905 : 59 (comparison with Sio nordenskjöldii (Lönnberg)). ; Pracer, 1906: 279, 280-281, Pl. 13, Fig. 1 (description; tropical Atlantic and Indian Ocean captures; synonymy; range; entification; stomach contents; in key). Holt and Byrne, 1906: 20-21 (comparison with Melamphaes eurylepis [- Scopelogadus beanii] Holt and Byrne). Mlrray and Hjort, 1912: 609, 614, 625, 627, 682-683 (range; vertical distribution). Nusbaum-Hilarowicz, 1923; 33-40, Pl. 3, Figs. 12-14 (alimentary canal). Fowler, 1928: 96 (diagnosis; $\because$ pe locality). Beebe, 1929: 18 (North Atlantic captures, ca. $39^{\circ}$ N., $72^{\circ}$ W.; [specimens possibly Scopelogadus beanii]). Xorman, 1929:156, 166, 168 (in part [see S. beanii]; description; Atlantic captures off West Africa; notes and comparisons; in key; synonymy). Weber and de Beaufort, 1929: 263-264, Fig. 70 (description after Günther and Brauer; Indo:acific range; depth; synonymy). Norman, 1930, 347 (in part [see S. beanii]; Atlantic captures off West Africa; range). Parr, 1931: 39, 41-44 (distinguished from S. bispinosus; tabular morphometrics; in key). Beebe, 1933: 181 ( $32^{\circ} 12^{\prime}$ N., ' $4^{\prime} 36^{\prime}$ W.; depth and abundance). Parr, 1933: 15, 22-25, Fig. 10 (in part [sce S. beanii]; description; western North Allantic captures; distinguished from S. beanii; variation in eye size; tabular morphometrics; in key). de Buen, 1935: - (Spain: region Gallega). Fowler, 1936b: 1264, 1266-1267 (in part after others [see S. mizolepis bispinosus]; range; i: key; synonymy). Barnard, 1937: 52 (validity). Beebe, 1937: 206 ( $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime}$ W., 300-1000 fms.). Belloc, :!38: 301-302, Fig. 22 (in part [see S. beanii]; $14^{\circ} 54^{\prime}$ N., $23^{\circ} 16^{\prime} \mathrm{W}$.). Norman, 1939: 4 (Arabian Sea, 3385 m. ; range). :owler, 1944: 441, 495 (in part [see S. mizolepis bispinosus]; 21-25 N., $71-77^{\circ} \mathrm{W}$., 6500-10000 ft.). Lozano y Rey, 1!52: 38, 44-46, Fig. 4 (description; range; in key). Ekman, 1953: 367 (list; range). Koefoed, 1953: 33-34, Table 16 in part [see S. beanii]; North Atlantic captures; M.eurylepis Holt and Byrne conspecific, comparisons; tabular morphometrics; stomach contents). Poll, 1954: 18-19, 389, Fig. 4 ( $11^{\circ} 53^{\prime}$ S., $13^{\circ} 20^{\prime}$ E., $480-510 \mathrm{~m}$. ). Grey, 1955 : 297 (captures off Bermuda, 1000-1370 nı.-day, 500-550 m.-night). Fowler, 1956: 210, Fig. 110 (description and figure atter Norman and Brauer; Arabian Sea). Mardyama, 1957: 33 (N. Pacific, but not yet from Japan). Briggs, 1960 : 176 (circumtropical, but possibly replaced in eastern Pacific). Marshall, 1960: 47, Fig. 28B-1) (swimbladder structure). $\therefore$ idenat, 1961 (in part [see S.beanii]; Sénégal, W. Africa).

Scopelogadus cocles Vaillant, 1888: 13, 143-146, 385-386, 403, Pl. 26, Figs. 6a-e (original description; Banc d'Arguin, ,ff Cape Verde Is., 1090 m .; anatomy). Goode and Bean, 1895: 181-182, Pl. 53, Fig. 199 (brief description after Vailinit). Norman, 1929: 166, 167, 168 (equals S. beanii, types examined). Borodin, 1931: 80 (equals S. beanii after入orman). Fowler, 1936 b: 1266 (equals S. beanii after Norman). Ebeling, 1962:18 (listed as type species of Scopelogadus).

Melamphaes cocles. Garman, 1899:383 (new combination; listed). Brader, 1906: 279-280 (distinguished from MelamThaes microps (Günther); in key). Fowler, 1936a: 534-535 (description after Vaillant; in key).

Plectromus mizolepis. Jordan, Evermann, and Clark, 1930: 233 (in part [sce S. mizolepis bispinosus]; new combination; in eheck list). Koefoed, 1953: 33 (equals Melamphaes mizolepis).

Scopelogadus mizolepis. Ebeling, 1962: 18 (new combination).
Melamphaes beanii (misidentification in part). Norman, 1929: 166-168 [see S. beanii].


Fig. 9. Scopelogadus mizolepis mizolepis (Günther). A, adult specimen (standard length 83 mm .), D 3913 (1); B, young (s. 1.14 .6 mm .1 D 1322 (9); C, young (s.l. 8.5 mm .), D $1322(9)$; D, postlarva (s.I. 5.0 mm .), D 1291 (3). Fig. 9 A was traced and modified from a photograph. Head epidermis, scales, and sensory pores are generally missing.

## Distribution.

S. mizolepis mizolepis occurs in the tropical Atlantic, Indian, and Pacific oceans. The N. Atlantic population, almost circumscribed by the distribution of $S$. beanii (Fig. 23), is partly associated with the Sargasso (western central gyre) and Caribbean seas, but extends to West Africa mainly in the region of the equatorial currents. Off West Africa records extend southward to $20^{\circ} \mathrm{S}$. Apparently separated from the Atlantic population by South Africa, the Indo-Pacific population ranges from East Africa through Indonesia and the western tropical Pacific, mainly between latitudes $20-25$ degrees north and south. A few isolated captures were made in the central tropical Pacific where it intergrades with S. mizolepis bispinosus (Fig. 16). Vertically, the upper limit of adults is about 500 m . and of halfgrown about $150-300 \mathrm{~m}$. Apparently, there is little difference in vertical distribution of populations from the central N . Atlantic, the region off West Africa, and the Indo-Pacific. The greatest proportion of shallow records, however, was from off West Africa, while the smallest proportion was from the Sargasso Sea, where only one "adult" was taken ( 1200 m . trawl). The upper limit of postlarvae and young is about $75-100 \mathrm{~m}$. in the Sargasso and Caribbean seas, $25-50 \mathrm{~m}$. uf West Africa, and 150 m . in the Indo-Pacific, from where relatively few records were available.

## Counts and proportions.

The proportion, "length of caudal peduncle" suggests little or no allometric change: 295-370(332), $!=69$. Suggesting allometric change, the proportions listed below are based on 21 "adults" (Ad) $66.4-93.7 \mathrm{~mm}$., 35 halfgrown $(\mathrm{Hg}) 33.5-63.0 \mathrm{~mm}$., and 16 young ( Yg ) 21.5-30.3 mm.

|  | Body depth | Predorsal | Head length |
| :---: | :---: | :---: | :---: |
|  | 239-274(257) | 438-495 (465) | 379-398(388) |
|  | 232-274(257) | 439-489 (459) | 344-409(372) |
| Yg. | 256-308(281) | 463-537 (492) | 356-458(402) |
|  | Length of upper jaw | Suborbital | Eye |
|  | 122-162(143) | 44-76(58) | 38-68(50) |
| Yg. | 141-195(164) | 49-102 (74) | 50-69(59) |

## 'Sescription.

Body and head form :-Body relatively slender, pointed anteriorly; contour along base of dorsal barely loping. Dorsal profile curves evenly downward anteriorly; snout pointed. Eye diameter about 0.83-1.13 cuborbital width, about $0.41-0.51$ snout length. Greatest width of gape about $0.60-0.70$ maxillary length.

Head Ridges and operculum :-Frontal fossa width $0.42-0.51$ its length, edges angling inward above ye. Preopercle with posterior margin sloping from vertical backward at about $7-12$ degrees.

Gill arches :-Rakers on first arch $3+12$ in 5.7 mm . postlarva, $4+13$ in two 7.5 mm . postlarvae, $4+14$ in $9.2-9.7 \mathrm{~mm}$. postlarvac, $7+16 \mathrm{in} 15.2 \mathrm{~mm}$. young, and $7+15-17$ in $20-30 \mathrm{~mm}$. young. Apparently the full compliment develops between 10 and 15 mm . standard length. Gill filaments on first areh relatively short and weakly developed or fairly well developed : the longest of the pair of filaments opposite the first raker below the angle usually measures $0.33-0.63$ times the length of this raker ( $0.33-0.48 \mathrm{in}$ Atlantic and western lndian Ocean specimens, $0.47-0.63$ in Indo-Pacific specimens). On the lower fourth gill arch the inter-raker spaces that contain spines are more numerous than those without spinose patches (not counting the space after the last raker, but including the space between the angle and the first raker); the usual proportion of spinose interspaces in $0.60-0.92$. The largest spinose patch (usually 2 or 3 spaces below angle) contains about $2-4$ pines (rarely as many as 6). The rudimentary rakers on the fifth arch, although usually less than half the length of those on the fourth arch, are in Indo-Pacilic specimens mostly well-formed stubs, i.e., seldom is the majority reduced to spinose patches or single spines. Commonly in the Atlantic specimens, however, especially those from the Sargasso Sea, the majority is reduced to spinose patches.


!ig. 10. Scopelogadus mizolepis bispinosus (Gilbert). A, adult specimen (standard length 92 mm .), SIO 52-363; B, young (s.l. 28.4 mm.) $\therefore$ ㄱS (uncat.); C, postlarva (s.l. 18.8 mm .), D $1208(8)$; D, postlarva (s.1. 8.5 mm .), D $1208(6)$; E, postlarva (s.l. 7.5 mm .), D $3548(6)$. Fig. 10A was traced and modifled from a photograph. Head epidermis, scales, and sensory pores are generally missing.

Fins :-Anal originates under fourth to sixth ray from end of dorsal, usually under fifth. Pectoral mode 14 ; $i s$ of 51 are 15 , one 16.

Color of young and larvae in formalin :-Young, even as small as $8.5-10 \mathrm{~mm}$., similar to halfgrown and adults, though somewhat lighter; uniformly brownish, but darker at margins of the few remaining scale pockets, in branchial-opercular region, and in peritoneal cavity; body without stippled or spotted areas of melanophores. On a postlarva 5.0 mm . numerous discrete melanophores, superimposed on areas of uniform ;igmentation, stipple the body and upper head; these melanophores were much less numerous, especially al mid-body, on a specimen 6.5 mm .
vize at maturity.
The 36 mature or near mature females ranged in standard length from 40 to 94 mm .
hemarks.
Although the type specimens of the nominal species Scopelogadus cocles Vaillant, 1888 were taken off West Africa, where both S. m. mizolepis and S. beanii occur, counts from a specimen labelled "paratopo"ype" (Paris Museum National d'Histoire Naturelle No. 84-1076) indicate cocles to be a synonym of mizolepis. Kindly made by Dr. Carl L. Hubbs of the Scripps Institution of Oceanography, gill raker counts of $7+15$, i. ft and $7+15$, right, though characteristic of mizolepis, are much too low for beanii. The holotype (PMHN $\therefore 1-1075$ ) could not be found.

Specimens examined.-1001 from 333 collections.
Holotype of S. mizolepis: (examined by Dr. Carl L. Hubbs) - BMNH 1887. 12.7.9; halfgrown ( 60.9 mm .); western ropical Pacific, S. of New Guinea, off Aru Is.; $5^{\circ} 41^{\prime} \mathrm{S} ., 134^{\circ} 4^{\prime} 30^{\prime \prime}$ E.; capture, $0-800 \mathrm{fms}$. (bottom); 13 ft . beam trawl; 23 Sept. 1874; 1010-1720 hrs.; R/V "Challenger", St. 191.

Holotype of S. cocles: (lost?) - Paris Mus. Hist. Nat.; 84-1075; adult (80 mm.); eastern N. Atlantic, N. Africa, NE. of Cape Verde Is., Banc d'Arguin, ca. $20^{\circ}$ N., $20^{\circ}$ W.; capture, 1090 m . ; dredge; R/V "Travailleur et Talisman" dredge no. 94.

Paratypes of S. cocles: PMHN 84-1076 (examined by Dr. Hubrs), (labelled "paratopotype") data as for holotype, $3655 \mathrm{~m} ., 1$ (42.5). PMHN 84-1076? (lost?), (same collection as above; no length given).

Scopelogadus mizolepis bispinosus (Gilbert, 1915).
Fig. 10.
Melamphaes bispinosus Gllbert, 1915; 325-326, Pl. 15, Fig. 5 (original description; California, off Coronado I., inif fms.; comparisons; paratypes). Ulrey and Greeley, 1928: 6 (listed after Gilbert). Norman, 1929: 168 (equals S. mizolepis?). Parr, $1931: 39,41,43-45$, Fig. 17 (eastern tropical North Pacific captures: tabular distinctions of holo-
type from S. mizolepis; notes, in key); Fowler, 1944: 495 (eastern tropical North Pacific). Maruyama, 1957: 33 (North Pacific, but not yet recorded from Japan; [misspelled "biopinosus"]). Morrow, 1957: 59, 69 ( $4^{\circ} 48^{\prime} \mathrm{S} ., 81^{\circ} 51^{\prime} \mathrm{W} ., 73 \mathrm{fms}$. ।. Munz, 1957: 1142-1143 (analysis of retinal pigment); 1958: 221 (analysis of retinal pigment). Aron, 1960 (captures off California).

Plectromus bispinosus. Jordan, Evermann, and Clark, 1930: 233 (new combination; listed after Gilbert). Barahart, 1936: 33, Fig. 112 (diagnosis; range).

Scopelogadus bispinosus. Ebeling, 1962: 18 (new combination).
Melamphaes mizolepis (misidentifications). Garman, 1899: 62-63, 383, 409, 412-413 (captures in Gulf of Panama and vicinity ; description; notes; etc.). Morrow, 1957: 59-60, 69 (Peru captures).

Melamphaes mizolepis (probable misidentifications). Beebe, 1926: 409-410 ( $6^{\circ} 25^{\prime} \mathrm{N} ., 85^{\circ} 06^{\prime} \mathrm{W} ., 600 \mathrm{fms} . ; 6^{\circ} 15^{\prime} \mathrm{N}_{\text {. }}$, $86^{\circ} 46^{\prime}$ W., 600 fms .). Fowler, 1936: 1264, 1266-1267 (in part [see S.m. mizolepis]); 1944: 495 (in part [see $S$. m. mizolepis]).

Plectromus mizolepis (probable misidentification in part). Jordan, Evermann, and Clark, 1930: 233 [see S.m. mizolepis].

Plectromus cristiceps (misidentification in part). Townsend and Nichols, 1925: 12-13 (capture off California; [als" Poromitra cristiceps (Ghbert, 1890)]).

Plectromus maxillaris (misidentification in part). Townsend and Nichols, 1925; 12 (capture off Californias; [alsn Scopeloberyx maxillaris (Garman, 1899)]).

## Distribution.

$S$. mizolepis bispinosus occurs mainly in the eastern tropical Pacific between $40^{\circ} \mathrm{N}$ and $20^{\circ} \mathrm{S}$. To the westward it ranges across the equatorial Pacific, where it intergrades with S.m. mizolepis (Fig. 16). Vertically, the upper limit of adults is about $400-500$ meters; the young and halfgrown occur more shallowly, up to 120 . 130 m .

## Counts and proportions.

These proportions suggest little or no allometric change : length of caudal peduncle ( $\mathrm{n}=135$ ) 279-360(319); length of upper jaw $(n=137) 134-193(155)$. Suggesting allometric change, the proportions listed below are based on 25 adults (Ad) $69.0-102.0 \mathrm{~mm}$., 91 halfgrown ( Hg ) $39.0-67.8 \mathrm{~mm}$., and 32 young ( Yg ) $17.8-38.9 \mathrm{~mm}$.

|  | Body depth | Predorsal | Suborbital |
| :---: | :---: | :---: | :---: |
| Ad ... 272-335 (290) |  |  | 53-86(69) |
|  |  | 435-537(472) |  |
|  | 234-316(275) | 449-529 (485) | 57-101 (75) |
|  | Head length | Eye |  |
| Ad | 383-454(415) | 37-51(44) |  |
| Hg | 363-465(415) | 39-60(47) |  |
| Yg. | 379-490(428) | 43-62 (52) |  |

## Description.

Body and head form :-Body stout; contour along base of dorsal slopes gently. Dorsal profile evenly rounded; snout not obviously blunt. Eye diameter about $0.53-0.91$ suborbital width, about $0.37-0.47$ snout length. Greatest width of gape about $0.65-0.81$ maxillary length.

Head ridges and operculum :-Frontal fossa with width usually $0.43-0.61$ its length, edges anglins inward or, less frequently, somewhat rounded above eye. Preopercle with posterior margin sloping fron? vertical backward at about 12-17 degrees.

Gill arches:-Rakers on first arch $5+13$ in 8.5 mm . postlarva, $6+14$ in 12.4 mm . young, $6+15$ in 14.1 mm . young, and $6-7+16-17$ in $17.8-27.7 \mathrm{~mm}$. young. Apparently the full compliment develops between 18 and 25 mm . standard length. Gill filaments on first arch relatively long and well developed; the longest of the filaments opposite the first raker below the angle usually measures $0.58-0.70$ times the length of this raker.

On the lower fourth arch the inter-raker spaces that contain spines are equal in number to or more numerous than those without spinose patches (not counting the space after the last raker, but including the space between the angle and the first raker); the usual proportion of spinose interspaces is $0.50-0.70$. The largest spinose patch contains $2-3$ spines. The rudimentary rakers on the fifth arch, although usually less than half the length of those on the fourth, are mostly well-formed stubs; i.e. seldom is the majority reduced to spinose patches or single spines.

Fins :-Anal originates under third to fifth ray from end of dorsal, usually between fourth and fifth. Pectoral mode 14,10 of 86 are 15.

Color of young and larvae in formalin:-Young as large as 30 mm . stippled or spotted with melanophores, which also characterize smaller young and larvae. Adult pigmentation seldom developed on specimens shorter than small halfgrown. That this is also true in the region of geographical overlap and intergradation with $S . m$. mizolepis could not be determined.

On a postlarva 8.5 mm . scattered patches of discrete melanophores, superimposed on areas of uniform piginentation, stipple parts of the head and body; this stippling is more extensive on larger postlarvae and young.

## Size at maturity.

The 43 mature or near mature females ranged in standard length from 50 to 102 mm .
Specimens examined.-709 from 148 collections.
Holotype: USNM 75809 ; adult ( 74.5 mm .) ; eastern N. Pacific, Mexico, off Baja California del Norte, South Point Coronado Is.; bottom 1194 m. ; 18 March 1904; R/V "Albatross" St. 4382.

Probable paratypes (eastern N. Pacific, off southern California): SU 22972, San Clemente I., 986 (D), 1 (86); SU 29983, Pt. Loma, 1212 (D), 1 (65) ; SU 22984, do., 965 (D), 1 (57); SU 22989, N. Coronado I., 1212 (D), 1 (55).

Scopelogadus unispinis, n.sp.

## Distribution.

Fig. 11.
S. unispinis is mainly restricted to the western Pacific within and about the Indo-Australian Archipelago, and the Indian Ocean. All captures were made between latitudes 15 degrees north and south. The east-west houndaries are the $175^{\circ} \mathrm{W}$ meridian and East Africa (Fig. 20). Vertically, the upper limit of adults and halfgrown is about $300-500 \mathrm{~m}$.; the young occur more shallowly, up to $150-200 \mathrm{~m}$.

## Proportions.

The following are proportions for which the data suggest little or no allometric change : body depth ( $n=43$ ) ${ }^{2} 52-333(292)$; suborbital $(\mathrm{n}=27) 64-95(77)$. Next are proportions for which the data suggest allometric change. These are based on 23 adults (Ad) $78.3-95.3 \mathrm{~mm}$., 18 halfgrown ( Hg ) $40.0-74.3 \mathrm{~mm}$., and 8 young (Yg) $14.7-34.4 \mathrm{~mm}$.

|  | Predorsal | Head length | Length of caudal peduncle |
| :---: | :---: | :---: | :---: |
| Ad | 458-509(488) | 345-409(370) | 275-327(300) |
| Hg | 472-513(496) | 363-406(385) |  |
| Yg. | 531-558(545) | 430-455 (440) | 259-295 (280) |
|  | Upper jaw | Eye |  |
|  | 138-173(155) | 44-58(52) |  |
| Hg | 158-200(177) | 44-58(52) |  |
| Yg. | 194-208(203) | 53-61 (56) |  |



Fig. 11. Scopelogadus unispinis, n. sp. A, holotype (standard length 84 mm .), D 3678(4); B, young specimen (s.l. 14.7 mm .), D 3909(4): C, young or metamorphosing postlarva ( 5.1 .8 .5 mm .), D $3906(3)$. Fig. 11 A was traced and modified from a photograph. Head epidermis. scales, and sensory pores are generally missing.

## Description.

Body and head form :-Body stout, somewhat fusiform, greatest depth at pelvic insertion; contour along base of dorsal slightly rounded, relatively steep. Caudal peduncle relatively short, depth about $0.40-0.51$ its length. Head depth about $0.69-0.81$ its length; dorsal profile evenly rounded; snout not obviously blunt (i.e., profile from frontal knob to premaxillary symphysis noticeably slanting). Ventral contour from pelvic insertion to mandibular symphysis rounded, becoming steeper at isthmus. Eye diameter about 0.60-0.80 suborbital width, about $0.46-0.55$ snout length. Greatest width of gape about $0.62-0.72$ maxillary length.

Head ridges and operculum:-Frontal fossa with width usually $0.50-0.60$ its length, edges slightly rounded above eye; bottom of expanded part (excluding delicate marginal ridges) flat or slightly concave.

Preopercle with posterior margin sloping from vertical backward at about 15-20 degrees; its ridges, radiating from the cheek angle, are more or less evenly spaced. Cheek ridge vertical, noticeably diverging from pre"percular margin. Operculum with posterior margin rounded, except for point of subopercle, which projects backward, above pectoral fin, for distance measuring about 0.67 eye diameter.

Gill arches:-Rakers on first arch $5+15$ in 8.5 mm . postlarva, $5+15$ in 10.0 mm . young, $6+15$ in it. 7 mm . young, $7+17-7+18$ in $19-20 \mathrm{~mm}$. young, and $7+18$ in 24 mm . young. Apparently the full compliment develops between 20 and 25 mm . standard length. Gill filaments on first arch relatively short and weakly developed; the longest of the pair of filaments opposite the first raker below the angle usually measures nly 0.33-0.40 times the length of this raker. On the lower fourth gill arch the inter-raker spaces that contain spines are equal in number to or more numerous than those without spinose patches (not counting the space after the last raker, but including the space between the angle and the first raker); the usual proportion of ,pinose interspaces is $0.50-1.00$. The largest spinose patch contains about $4-8$ spines. The rudimentary rakers on the fifth arch, although usually less than half the length of those on the fourth arch, are mostly well-formed stubs; i.e., seldom is the majority reduced to spinose patches or single spines.

Fins :-Anal usually originates under fourth or fifth ray from end of dorsal. Pectoral mode 15, 11 of 23 are 14 (some counts questionable). Pelvic usually inserts directly below or slightly in front of pectoral insertion. Caudal with the two ventral procurrent spines that are adjacent to the principai rays almost completely fused; the ventral procurrent spine count, therefore, without microscopic examination, usually appears to be 3 .

Interinal characters:-Vertebrae almost constant at $10+13$; one of 46 caudal counts 14 . The gashladder is represented by a small sphere of yellowish tissue (the remnant of the gas gland and rete mirabile), which lies just above the juncture of the esophagus and stomach. Stomach with blind sac not noticeably darkned posteriorly (Fig. 1B).

Color of young and larvae in formalin :-Young, even as small as $10-12 \mathrm{~mm}$., similar to halfurown and adults, though somewhat lighter; uniformly brownish, but darker at margins of the few remaining scale pockets, in branchial-opercular region, and in peritoneal cavity; body without stippled or spotted areas if melanophores. A single metamorphosing specimen, 8.5 mm ., was uniformly light brownish or tan (i.e., $110 t$ stippled with melanophores), but had dark scale pockets; otherwise its color was as above. Its palatoethmoid region was not noticeably pigmented (i.e., the preocular area was relatively light).

Size at maturity.
The 4 mature or near mature females ranged in standard length from 82 to 97 mm .
Derivation of name.
Derived from the Latin, the species name unispinis refers to the diagnostic single dorsal spine.
Specimens examined.-97 from 57 collections.
Holotype: D $3678(4)$; immature male $?\left(84.0 \mathrm{~mm}\right.$.) ; Indonesia, $4^{\circ} 05^{\prime} \mathrm{N} ., 128^{\circ} 16^{\prime}$ E.; capture, 2000 meters wire, bot! $1 \mathrm{~m} 4700 \mathrm{~m} . ; 1.5$ meter stramin net ; 24 March 1929; 1840 hours; R/V 'Dana".

## Paratypes:

Indian Ocean, east of $70^{\circ} \mathrm{E}$ :
D $3828(10), 1^{\circ} 22^{\prime}$ N., $96^{\circ} 06.5^{\prime}$ E., 3000 w (D), $1(85)$

1) 3847 (3), $12^{\circ} 02^{\prime}$ S., $96^{\circ} 43^{\prime} \quad$ E., 2500 w (N), $2(52-70$ )

D $3847(5), 12^{\circ} 02^{\prime}$ S., $96^{\circ} 43^{\prime} \quad$ E.., $1500 \mathrm{w}(\mathrm{N}), 2(52-57)$
D $3909(1), 5^{\circ} 21^{\prime} \mathrm{N} ., 80^{\circ} 38^{\prime} \quad$ E., $4500 \mathrm{w}(\mathrm{N}), 3(22-49)$
D $3909(3), 5^{\circ} 21^{\prime} \mathrm{N} ., 80^{\circ} 38^{\prime}$ E., 3500 w (N), 1 ( 96.5 )
D 3909(5), $5^{\circ} 21^{\prime}$ N., $80^{\circ} 38^{\prime}$ E., 2500 w (N), 4 (10.8-70.8)
D 3912(1), $6^{\circ} 52^{\prime}$ N., $79^{\circ} 30^{\prime}$ E., 1000 w (N), 1 ( 91.5 )
D $3915(1), 3^{\circ} 14^{\prime}$ N., $75^{\circ} 21^{\prime}$ E., 1000 w (N), 2(40.0-65.5)
$\begin{array}{lllll}\text { G 282, } & 5^{\circ} 32^{\prime} \text { N., } 78^{\circ} 41^{\prime} & \text { E., } 4040 & \text { (D), } 2(65.0-98.5)\end{array}$


D $3678(1), 4^{\circ} 05^{\prime}$ S., $128^{\circ} 16^{\prime} \mathrm{E} ., 5000 \mathrm{w}(\mathrm{N}), 1$ (49.3)
D $3678(6), 4^{\circ} 05^{\prime}$ S., $128^{\circ} 16^{\prime}$ E., 1000 w (N), 1 (55.8)
D $3682(1), 1^{\circ} 42^{\prime}$ N., $124^{\circ} 29^{\prime}$ E., $1000 \mathrm{w}(\mathrm{N}), 1(83.5)$
D 3683 (1), $4^{\circ} 03^{\prime}$ N., $123^{\circ} 26^{\prime}$ E., 5000 w (D), 1 (82.8)
D $3683(6), 4^{\circ} 08^{\prime}$ N., $123^{\circ} 00^{\prime}$ E., $1000 \mathrm{w}(\mathrm{N}), 1$ (74.0)

## Scopelogadus beanii (Günther, 1887).

Fig. 12.
Plectromus crassiceps (not Scopelus crassiceps Günther, 1878) Bean, 1885: 73-74 (original description; 3 syntyp* from western North Atla'tic, Albatross Sta. $2075,41^{\circ} 40^{\prime} \mathrm{N} ., 65^{\circ} 35^{\prime} \mathrm{W} ., 855 \mathrm{fms} .$, Sta. $2094,39^{\circ} 44^{\prime} \mathrm{N}^{\prime}, 7^{\circ} 04^{\prime} \mathrm{W}$. 1022 fms., Sta. $2106,37^{\circ} 41^{\prime} \mathrm{N} ., 73^{\circ} 03^{\prime} \mathrm{W} ., 1497 \mathrm{fms}$. [An additioral specimen, LSNM $33553,48 \mathrm{~mm}$., is Scopelobery. opisthopterus (Parr, 1933)]). Jordan, 1885: 862 (Gulf Stream). Goode and Bean, 1895: 179 (preoccupied). Jordas a 4 Evermann, 1896a: 843 ('quals Plectromus beanii, after Günther). Norman, 1929: 166 (equals Melamphaes beanii, after Gǜther). Fowler, 1936: 1266 (equals M. beanii, after Günther).

Melamphaes bea.शii Günther, 1887: 29-30 (substitute name for preoccupied Plectromus crassiceps [not Scopelis crassiceps Günther, 1878] Bean. Garman, 1899: 383 (listed). Lönnberg, 1905: 59 (comparison with M. nordenskjöldii). Bracer, 1906: 279 (in key; authored as "Goode and Bean" sic). Gilbert, 1915: 325-326 (measurements; comparisoh with M. bispinosus). Norman, 1929: 156, 162, 166-168 (in part [see S. mizolepis]; description; Atlantic captures; rang extension - S. Atlantic; in key; synonymy); 1930: 346 (S. Atlantic captures). Borodin, 1931: 57-58, 80 (N. Atlanti captures; synonymy). Parr, 1931: 41 (in key); 1933: 15, 24-25, Fig. 11 (tabular morphometric comparisons with M. mizor lepis; S. Atlantic capture; in key). Fowler, 1936: 1264, 1266 (range; synonymy; in key). Jenkins, 1936: 353, 38 ; (W. of Ireland). Nybelin, 1948: 73 (N. Atlantic capture; comparison with S. mizolepis). Kotthaus and Krefft, 1957: 173 (identification with N. Atlantic specimens).

Plectromus beanii. Goode and Bean, 1895: 179-180, Pl. 54, Fig. 202 (in part [USNM $=33553$ is Scopelobery.: opisthopterus (Parr)]) ; new combination; description; synonymy; N. Atlantic captures including syntypes). Jorda: and Evermann, 1896a: 841-843 (description after Bean; Gulf Stream, deep water; synonymy); 1896 b: 337 (Gulf Stream) Barnard, 1925: 369 (comparison with Melamphaes coronatus). Jordan, Evermann, and Clark, 1930: 233 (check list i.

Melamphaes eurylepis Holt and Byrne, 1906: 19-21, 24, Pl. 1, Figs. 1-2 (original description; holotype and : "cotypes"; north of Ireland, 0-700 fms.); 1910: 6 (Irish Atlantic Slope). Norman, 1929: 166-167 (equals Melamphaes beanii Gǘxther, holotype examined). Koefoed, 1953: 33 (equals Melamphaes mizolepis (Günther) type examined: comparisons). Ebeling, 1962: 18 (equals Scopelogadus beanii).

Scopelogadus beanii. Ebeling, 1962: 18 (new combination).
Melamphaes mizolepis (misidentifications). Norman, 1929: 168 (in part [see Scopelogadus mizolepis]); 1930: 347 (in part [see S. mizolepis]). Borodin, 1931: 57-58, 80 (N. Atlantic Gulf Strean captures, notes). Park, 1933: 22-2: (in part [see S. mizolepis]). Koefoed, 1953: 33-34 (in part [see S. mizolepis]). Cadenat, 1961: bet. 231-245 (in part [see S. mizolepis]).

Melamphaes mizolepis (probable misidentifications). Zegmayer, 1911: 96-97, Pl. 5, Fig. 1 (N. Atlantic captures north of $40^{\circ}$ N. ; description; range). Rocle, 1919: 44 (capture, $42^{\circ} 18^{\prime} \mathrm{N} ., 12^{\circ} 08^{\prime}$ W.). Roule and Angel, 1933 : 66 (captur:, $44^{\circ} 24^{\prime}$ N., $11^{\circ} 36^{\prime}$ W.; identification). Belloc, 1938: 301-302 (in part [see S. mizolepis]). Smith, 1949: 148, Fig. 28:(diagnosis; off Cape of Good Hope after Gilchrist, 1922, 500 fms.; in key). Kotthaus and Krefft, 1957: 173, 187 (identification with specimens from N. Atlantic [see Scopelogadus, sp. below]).


Fig. 12. Scopelogadus beanii (Günther). A, halfgrown with scales and cephalic sensory pores (s. 1.61 .5 mm .), BZM 2599.


Fig. 12 cont. Scopelogadus beanii (Günther). B, adult specimen (standard length 81.2 mm. ), D $230 €(8)$; C, young (s.l. 13.3 mm .), D $1342(8)$; D, postlarva (s.1. 8.1 mm ), D 4007 (11); E, postlarva (s.l. 5.1 mm .), D 4201 (13). Fig. 12 B was traced and modified from a photograph. Head epidermis, scales, and sensory pores are generally missing; a few head pores, however, are reconstructed.

Plectromus mizolepis (probable misidentifications). Gilchist, 1922: 65-66 (capture, $33^{\circ} 46^{\prime} \mathrm{S} ., 17^{\circ} 13^{\prime} \mathrm{E} ., 500 \mathrm{fms}$; notes on head cavities, sensory organs, nerve endings). Barnard, 1925: 368-369 (diagnosis; references; range; off Table Bay, after Gilchrist; in key).

Melamphaes, sp. (probable misidentifications). Norman, 1930: 347 (in part; captures from N. and S. Atlantic! Brandes, Kotthals, and Krefft, 1957: 54 (capture, $65^{\circ} \mathrm{N} ., 35^{\circ} \mathrm{W}$. - range extension; identifies with Scopelogadus; notes). Kotthaus and Krefft, 1957: 173, 187 (capture, $64^{\circ} 52^{\prime} \mathrm{N} ., 35^{\circ} 08^{\prime} \mathrm{W} ., 350-385 \mathrm{~m}$. - range extension; bris I description; notes, identifies with Scopelogadus).

## Distribution.

S. beanii occurs in the Atlantic, southern Indian, and western South Pacific oceans. Except for a few recort, of larvae from the western Sargasso Sea, the Atlantic population is associated with the Gulf Stream system and the region off the west coast of Africa. The Indian Ocean and western Pacific captures were made south of $30^{\circ} \mathrm{S}$ (Figs. 20, 23). Vertically, the upper limit of adults is $800-1000 \mathrm{~m}$., halfgrown $500-600 \mathrm{~m}$., and young about 150 m . Apparently there is little or no difference in vertical distribution between the North Atlanti;; West African, and Indo-Pacific captures; the latter, however, were poorly represented by larval and yours specimens.

## Counts and proportions.

The proportion, "eye diameter" suggests little or no allometric change: 44-65 (51), $\mathrm{n}=78$. Suggesting all()metric change, the proportions listed below are based on 53 adults (Ad) $81.2-122 \mathrm{~mm}$., 28 halfgrown ( Hg ) $43.5-78.9 \mathrm{~mm}$., and 15 young ( Yg ) $18.0-41.5 \mathrm{~mm}$.

|  | Body depth | Predorsal | Head Iength |
| :--- | :---: | :---: | :---: |
| Ad $\ldots$ |  | $268-310(293)$ | $430-479(450)$ |
| Hg $\ldots$ |  | $325-380(346)$ |  |
| Yg. . | $273-347(306)$ | $464-567(512)$ | $342-479(404)$ |


|  | Depth of <br> caudal <br> peduncle | Length of <br> upper jaw | Suborbital |
| :---: | :---: | :---: | :---: |
| $\mathrm{Ad} \ldots$ | $334-383(360)$ | $131-157(144)$ | $52-76(62)$ |
| $\mathrm{Hg} \ldots$ | $330-374(355)$ | $138-182(158)$ | $56-90(71)$ |
| $\mathrm{Yg} \ldots$ | $300-372(336)$ | $171-217(192)$ | $63-123(93)$ |

Description.
Body and head form:-Body moderately stout, blunted anteriorly, appearing club-shaped; greates depth at pelvic insertion or at mid opercle; contour along base of dorsal straight, sloping gently. Caudal peduncle relatively long, depth about $0.28-0.37$ its length. Head depth about $0.74-0.85$ its length; dorsal profile curvin! sharply downward anteriorly; snout blunt (i.e., profile from frontal knob to premaxillary symphysis almos vertical). Ventral contour from pelvic insertion to mandibular symphysis weakly angular at isthnus, where it bends up to the mandibular symphysis. Eye diameter about $0.70-0.87$ suborbital width, about $0.48-0.5^{-7}$ snout length. Greatest width of gape about $0.74-0.85$ maxiltary length.

Head ridges and operculum :--Frontal fossa with width usually $0.47-0.58$ its length, edges anglin; inward above eve; bottom of expanded part (excluding delicate marginal ridges) noticeably concave. Preopercle with posterior margin sloping from vertical backward at about $15-20$ degrees; its ridges, radiating from the cheek angle, are more or less evenly spaced. Cheek ridge angling backward, diverging little frons preopercular margin, frequently almost paralleling it. Operculum with posterior margin broadly rounded: point of subopercle barely projects backward, above pectoral fin, for distance measuring less than 0.25-0.30 eye diameter.

Gill arches :-Rakers on first arch $4-5+13-14$ in 6.7 mm . postlarvae, $5+15$ in 8.1 mm . postlarva, $\therefore 6+15$ in 10.0 mm . postlarvae, $8+18-19$ in $18-32 \mathrm{~mm}$. young, and $9+19-20$ in $37-38 \mathrm{~mm}$. young. Apparently the full compliment develops between 30 and 35 mm . standard length. Gill filaments on first arch relatively short and weakly developed; the longest of the pair of filaments opposite the first raker below the angle usually measures only $0.25-0.47$ times the length of this raker (the specimens from the south lndian and western $S$. l'acific occans had the lower values: $0.25-0.33$ ). On the lower fourth gill arch the inter-raker spaces that contain spines (usually $2-3$ spaces below angle) number less than a third those without spinose patches (not counting the space after the last raker, but including the space between the angle and the first raker) ; the usual proportion of spinose interspaces is $0-0.2$. The largest spinose patch (when present) contains mly $1-3$ spines. The rudimentary rakers on the fifth arch are mostly reduced to spinose patches or single uines; at most only $2-3$ well-formed stubs are present.

Fins :-Anal usually originates under fifth or sixth ray fromend of dorsal, most commonly under the sixth. Pectoral mode 15,37 of 78 are 14 , one 16 (some counts questionable). Pelvic usually inserts slightly in front "f pectoral insertion. Caudal with the two ventral procurrent spines that are adjacent to the principal ravs incompletely fused, frequently separable; the ventral procurrent count, therefore, usually appears to be 4.

Internal characters :-Vertebral mode $10+16 ; 7$ of 95 are $10+15 ; 5$ are $10+17$; one is $11+15$. The Gas-bladder is apparently completely or almost completely regressed; in 5 specimens examined, no, or possibly very little, remnant of the gas gland, rete mirabile, or membranous sac could be found. Stomach with blind sac not noticeably darkened posteriorly (Fig. 1C); stomachs of 2 specimens from the southern Indian Ocean were relatively weakly pigmented.

Color of young and larvae in formalin :-Young, even as small as $12-13 \mathrm{~mm}$., similar to halfgrown and adults, though somewhat lighter; uniformly brownish, but darker at margins of the few remaining scale mokets, in branchial-opercular region, and in peritoneal cavity; body without stippled or spotted areas of :aclanophores. Postlarvae $4-5 \mathrm{~mm}$. may be uniformly, but lightly pigmented in the interspinal segments of the vertebral column, branchial arches, and operculum; very few discrete melanophores, however, stipple ite body or head. In the $6-10 \mathrm{~mm}$. stages, however, numerous discrete melanophores, superimposed on reas of uniform pigmentation stipple the body and uppewhead. Apparently diagnostic of $S$. beanii, the palaHethmoid region, which appears as a salient dark wedge ifs a preocular area, is noticeably pigmented.

Yiie at maturity.
The 24 mature or near mature females ranged in standard length from 84 to 122 mm .

Remarks.
The three syntypes of S. beanii were originally described as Plectromus crassiceps (not Günther, 1878) Bean, 1885. Günther (1887: 29), however, implied that the nominal genus Plectromus Gill, 1883 was a ,ynonym of Melamphaes Güntrer, 1864 when he listed P. crassiceps Bean under Melamphaes beanii Gënmer. Obviously beanii was introduced as a substitute name for the subjective junior homonym Melamphaes rassiceps (Bean), which would have been preoccupied by Melamphaes crassiceps (Günther, 1878), a distinct species now included by Ebeling (1962) in another genus, Poromitra. Goode and Bean (1895: 178-179), athough erroneously considering Plectromus distinct from Melamphaes, correctly used the species name beanii as valid in the combination "Plectromus beanii, (Günther), Goode and Bean" (Günther, of course, is the author of beanii). Even though Poromitra crassiceps (Günther, 1878) has been placed in a genus other than copelogadus, the species name beanii remains valid: according to Article 36 of the Rules of Zoological Nomen"lature, "Rejected homonyms can never be used again."

An examination of Bean's syntypes (USNM $33378,33509,34835$ ) of $S$. beanii proved them conspecific. GOode and Bfan (1895: 180) erred in listing as "type specimen" of the species the specimen, USNM 33553. This small individual ( 48 mm . T. L.), although listed in the original description, was not designated a syntype and is, in fact Scopeloberyx opisthopterus (Parr, 1933).

Concurring with Norman (1929), we believe the evidence to be overwheImingly in favor of synonymizing
the nominal species Melamphaes eurylepis Holt and Byrne with S. beanii. The excellent illustrations (Holt and Byrne, 1906: Pl. 1, Figs. 1-2) agree with beanii in every detail, especially in the relatively short head, blunt snout, rounded posterior margin of operculum, and long caudal peduncle. The following characters from the original description are characteristic of $S$. beanii: length of caudal peduncle into head length about 1.0, depth of caudal peduncle into its length more than 3.5. In the comparison of M. eurylepis with M. mizolepis, Holt and Byrxe also noted, among other characters, that whereas a feeble angular projection pointed the posterior margin of the operculum in mizolepis, this margin was rounded in eurylepis (the rounded posterior margin is typical of S. beanii). All capturcs were north of Ircland, where there occurs, to our knowledge, no species in Scopelogadus but beanii. Typical of Scopelogadus, the dorsal count was given as II, 10-11; the scale rows $13-15$ in longitudinal series, 3 in transverse series.

Kindly supplied by the British Museum (Natural History), photographs of the holotype of M. eurylepis (BMNH 1907.11.1.1) substantiate these findings: the head is relatively short and blunted anteriorly, the bacl: margin of the operculum is evenly rounded, the caudal peduncle is 4 times as long as deep, longer than in any other species, and the cheek ridge and posterior margin of the preopercle slant backward almost paralle! to each other. Dr. Carl L. Hebbs, University of California, Scripps Institution of Oceanography, kindly counted the gill rakers of the holotype as $9+19$ (left) $-9+19$ (right), which agrees with S. beanii.

Koefond (1953) erroneously synomized M. eurylepis with S. mizolepis because ". . a comparison of their description with that given by Brauer and Zugmayer and with the measurements of the "Michael Sars" specimens shows that 'the chief points of difference' according to Holt and Byrne (1906: 20) may be united in the same specimen or transitional features may be found." He then discussed these 5 differences (i.e.. length of caudal peduncle, eve size, distance from anal origin to base of caudal peduncle, roundness of the. posterior border of the operculum, and pectoral fin length). For "eye size" he is correct in that the proportion "diameter of eye as percent of standard length" is variable and intergrades between all 4 species in Scopelogadus. Similarly, the pectoral fin extends to the end of the dorsal or occasionally even bevond in all species. Admittedly, the characters of caudal peduncle length and roundness of opercular margin are usually diagnostic of S. beanii. His entire discussion of comparisons, however, probably is misleading because the data on "M. mizolepis" were from specimens from widely scattered localities in the Atlantic and Indian oceans ("Valdivia", Monaco, and "Michael Sars" expeditions) and, therefore, probably contained unsorted values for both $S$. beanii and $S$. mizolepis.

Specimens examined.-460 from 146 collections.
Syntypes of S. beanii: CSNM 33378 ; adult ( 103.4 mm .) ; western Atlantic, $41^{\circ} 40^{\prime} 30^{\prime \prime}$ N., $65^{\circ} 35^{\prime}$ W.; bottom, 855 fms. : 3 September 1883 ; R/V "Albatross" Sta. 2075. USNM 33509 ; adult ( 94.5 mm .) ; $39^{\circ} 44^{\prime} 30^{\prime \prime}$ N., $71^{\circ} 04^{\prime} 00^{\prime \prime}$ W.; bottom 1022 fms.; 21 September 1883 ; R/V "Albatross" Sta. 2094. USNM 34835 ; adult ( 101.5 mm .) ; $37^{\circ} 41^{\prime} 20^{\prime \prime} \mathrm{N} . \mathrm{N}^{\circ} 73^{\circ} 03^{\prime} 20^{\prime \prime} \mathrm{W}$.; bottom, 1497 fms.; 6 November 1883; R/V "Albatross", Sta. 2106.

Holotype of Melamphaes eurylepis: (examined by Dr. Carl L. Hubrs). BMNH 1907.11.1.1; adult (64.2 mm.): eastern N. Atlantic, off NW. Ireland, $54^{\circ} 57^{\prime} \mathrm{N} ., 10^{\circ} 05^{\prime} \mathrm{W}$.; capture $600-700 \mathrm{fms}$.; "large open tow net"; 12 February 1905; "S.R." Sta. 197.

Paratype ("cotype") of M. eurylepis: (not examined). Locality as for holotype, 1150 fms.; $1(76$, total length).

## MORPHOLOGICAL RELATIONS

Recently revived by Sokal and Michexer (1958), numerical taxonomy-a valuable tool in systematic analysis-objectively evaluates morphological (or other) affinities between taxa by simultaneously comparing many characters between all possible pairs. The resulting correlation coefficients, one for each pair if taxa, are arranged in a matrix where they can be grouped according to their magnitudes (i.e., degree of , imilarity between pairs). Because large numbers of characters coded into unweighted value-states yield the most promising results, IBM sorters are frequently employed to evaluate the vast amount of counts and measurements used in the analysis (see Sveati, 1961).

Fager (1957) described an objective method for the formation of recurrent ecological or geographical groups of organisms, based on a set of rules for grouping species in terms of their affinities with other species. iffinity can be measured by any dichotomous index, significant versus non-significant correlation cocfficients, m-occurrence more than $x \%$ of the time versus co-occurrence less than $x \%$ of the time, etc. The method can, therefore, use morphological information as well as the presence and absence data for which it was originally designed. Its only fault is that affinity must be considered as "all or none"; degrees of difference, which can be analyzed by the nore sophisticated methods, are not evaluated.

In this study monotypic Sio (see Moss, 1962), 19 species comprising Melamphaes (see Ebeling, 1962), and the 4 species and subspecies of Scopelogadus are grouped on the basis of 41 , mostly uncorrelated, characters (Table II). The range in values of each character was divided into 3 to 5 equal coded states and the rode number (1-5) for each character was listed for each taxon; these were designated by a letter, A-X ('Table III).

Punch cards were prepared in order to make it easier to compare all possible pairs of taxa (276) by states "f 41 characters. A card was made for each taxon, then punched according to a "master" or "template" card on which positions for all scored states for each character were indicated. To compare any pair of taxa, therefore, the two cards were aligned and the number of coincident punches were counted. The numbers of joint "ccurrences of equal states were used to determine whether species showed affinity.

The index of affinity used was originally the following: the proportion of joint occurrences of equal states (the geometric mean, which is usually employed, simplifies to this in this case) between the two taxa minus a sample size correction factor,

$$
\mathrm{l}=\frac{\mathrm{J}}{\mathrm{~N}}-\frac{1}{2 \mathrm{~N}} \text {, where: }
$$

I, Index of affinity,
$J$, Number of joint occurrences of character states,
N, Number of characters used (41).
The value of I necessary for affinity was first set at greater than or equal to 0.50 ; the equation was solved for J ; although 24 coincident punches were needed to satisfy the requirement, 27 afforded a more meaningful -eparation. This is because several character states that remain constant through large groups of species were used; an index of 0.50 would allow separation of large groups and genera, but smaller intrageneric groupings would remain hidden. Solving the equation for 1 , using J at 27 , therefore, the final index used was 0.59 ; i.e., pairs of taxa with 27 or more coincident character states were considered to show affinity.

Table II. Coded states of 41 characters for Melamphaes, Scopelogadus, and Sio.

| Index | Character | Expression | State codes and class intervals |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | 1 | 2 | 3 | 4 | 5 |
| I | Dorsal suft rave | Average number | 16-18 | 13-15 | 10-12 | 9 | - |
| 2 | Dorsal spines | Average number | 1 | 2 | 3 | - | -- |
| 3 | Scale rows | Average number | 33-36 | 32-33 | 30-32 | 10-20 | - |
| 4 | Precaudal vertebrac | Modal number | 12 | 11 | 10 | - | - |
| 5 | Caudal vertebrae | Modal number | 17-18 | 16 | 15 | 14 | 13 |
| 6 | Opercular scales | Number | 8 | - | 4 | - | - |
| 7 | Spur on 1st caudal vertebra | Development | Well-dev. | Rudim. | Absent | - | - |
| 8 | losittemporal spine | Development | Well-dev. | Rudim. | Absent | - | - |
| 9 | Gill rakers. lower 1st arch | Average number | 18-20 | 15-17 | 13-15 | 11-12 | - |
| 10 | Sculpturing of scales | Posterior groove width anterior grove width; or description | 4-12 times | 1-3 times | Post. field smooth | Large, irregular | - |
| 11 | Gill rakers, th arch | Development | Well-formed stumps | Shurt nubbins | Spinous patches | $\stackrel{-}{\square}$ | . |
| 12 | Durability of squamation | Relative proportion intact | Almost 1.0 | 0.33 or more | $\begin{aligned} & 0.33 \text { or } \\ & \text { less } \end{aligned}$ | Almost 0.0 | - |
| 13 | Teeth | Rows in upper jaw | 1-2 | 3-5 | 5-7 | 6-9 | - |
| 14 | Gas-bladder development | Dev. of entire organ | Very well | Fairly well, fatty | Rudimentary | Absent | - |
| 15 | Position pelvic origin relative to pectoral | Placement, $(+)=$ before, $( \pm)=$ under, $(-)=$ behind | Well (-) | Ca. ( $\pm$ ) | Slight ( + ) | Well ( + ) | - |
| 16 | Position anal origin relative to dorsal | Placement, under which ray from end of fin, or as above | 5-6 | 2-5 | Ca. (土) | Well (-) | - |
| 17 | Epidermis | Condition | Intact | Partly missing | Missing | - | - |
| 18 | Spines on preopercle | Development | Large, strong | Small, weaker | Absent | - | - |
| 19 | Eye diameter | Average, thousandths SL | 53-60 | 49-52 | 45-48 | 35-44 | - |
| 20 | Head length | Average, thousandths SL | 320-360 | 361-380 | 381-400 | 401-425 | - |
| 21 | Superficial head bones | Expansion, development of reticulate bone | Expanded, much ret. bone | Not exp., but ret. bone | Thin, no ret. bone | - | - |
| 22 | Size of adults | "Dwarf"-"Giant" | Giant | Large | Small | Dwarf | - |
| 23 | Pelvic rays | Modal number | 8 | - | 7 | - | - |
| 24 | Gill rakers, flrst arch | Development, relative width | Long, wide | Fairly long, slender | Short, slender | Almost <br> rudi- <br> mentary | - |
| 25 | Interraker spines, lower 4th gill arch | Proportion spinose patches/naked interspaces | $0.0-0.2$ | $0.3-0.5$ | 0.6-0.8 | 0.9-1.0 | -- |
| 26 | Antorbital ridge | Development | Weakly dev. | Weak to moderate | Strongly dev. | - | - |
| 27 | Teeth on 3rd pharyngobranchial | Usual number | 23-38 | 39-54 | 55-70 | 71-85 | - |
| 28 | Pyloric caeca | Number | 7 | -- | 5 | - | - |
| 29 | Length of caudal peduncle | Average, thousandths SL | 207-245 | 246-284 | 285-323 | 324-360 | - |
| 30 | Length of upper jaw | Average, thousandths SL | 133-147 | 148-163 | 164-179 | 180-194 | - |
| 31 | Supramaxillary | Presence | Present | - | Absent | - | -- |
| 32 | Predorsal | Average, thousandths SL | 405-425 | 426-446 | 447-467 | 468-488 | - |
| 33 | Cheek scales | Number | 3-4 | 2 | 0 | -- | - |
| 34 | Suborbital | Average, thousandths SL | 30-41 | 42-53 | 54-65 | 66-77 | -- |
| 35 | Length of gill flaments on 1st arch | Length of longest filament of pair opposite longest raker length of this raker | .88-1.1 | .67-.87 | .46-. 66 | .25-. 45 | - |
| 36 | Color of larvac | Melanophore pattern | Dorsal patch | Dorsalanal band | Colorless | Spotted | - |
| 37 | Body depth | Average, thousandths SL. | 253-268 | 269-284 | 285-300 | 301-317 | $\cdots$ |
| 38 | Snout form | Slant | Gently sloping | Steeply sloping | Subvertical | - | . |
| 39 | Head pores | Modal number on mandible | 4 | ${ }_{5}-6$ | 6-7 | Variable | - |
| 40 41 | Orbit to cheek angle Branchiostegal rays | Average, thousandths SL Modal number | $99-108$ 8 | 109-118 | 119-128 7 | 129-139 | - |

Table III. Coded states for each of 41 characters, listed for the species of Melamphaes, Sio, and Scopelogadus. Characters are designated by index number only (see Table II); letters refer to species and subspecies.


With the number of affinities for each taxon thereby known, the largest possible group, all members of which have affinities with all other members, was assembled following the rules set forth by Fager (1957). The taxa were counted off in order of their number of affinities with others (highest number first) until the number of taxa counted exceeded the number of affinities (Y) of the previous taxon. The largest possible sroup, therefore, could contain $\mathrm{Y}-1$ members (in this case 5). After arrangement of the counted taxa in a trellis liagram (matrix of comparisons), however, it was found that there was no group of 5 all having affinities with each other. Those species with 3 affinities were next included in the trellis diagram. Groups of 4 could he formed. Smaller groups were constructed from the remaining taxa. The taxa having 0 or 1 affinities were omitted from the trellis diagram because they could only occur singly or in groups of 2 . When a choice be-


Fig. 13. Morphological groupings within and between Melamphaes, Sio, and Scopelogadus. A, determined by analysis of recurrent grou $;$ (the thickness of the line connecting groups is proportional to their morphological affinity); B, determined subjectively before the statisticia analysis (connecting lines simply indicate some degree of close morphological relationship). Solid lines enclose species groups, dashed lines enclose genera. For further explanation see the text.


Fig. 14. Diagrammatic representation of the matrix of comparisons between all pairs of taxa of Melamphaes, Sio, and Scopelogadus. The squares are shaded according to the number of coincident character states between each species pair. For further explanation see the text and Table III.
tween groupings existed, the largest group that contained no common members was accepted (Rule 3. Fager, 1957). Fig. 13A shows the groups and indicates the intergroup relationships; lines connect taxa sharing 27 or more common character states. The numbers on the lines represent the realized fractions of possible affinities between groups; e.g., th suborbitalis-leprus-laeviceps group could have a possible total of $6(3 \times 2)$ affinities with the acanth:-mus-macrocephalus group, whereas only 2 were ac tually observed.

This arrangement was compared with another (Fig. 13B) which was subjectively determined 0! the basis of relatively few characters and constructed before the present analysis was undertaker For Melamphaes both arrangements are similar, ex cept that the large typhlops species group exhibit; more heterogeneity in the statistical analysis; M. typhlops (Lowe) has no affinities with others in th: genus and the janae-indicus and longivelis-parvis: pairs are separated. Although the microps, suborbilalis, and simus groups show many intergroup affinities among themselves and with the janae and: longivelis pairs of the typhlops group, the spinife:
group, like M. typhlops, while showing close intergroup affinities in the subjective analysis, was relatively isolated in the statistical groupings.

Both Sio and Scopelogadus were isolated from all species of Melamphaes though, subjectively, Sio was Hought to be the more closely related to Melamphaes. Statistically, Scopelogadus beanii was separated from its 3 congeners though it was previously subjectively grouped with $S$. unispinis.

Adapted from Sneath (1961), another graphical method represented more closely the degrees of morpholasical difference between the 2 species. In a matrix of species comparisons, squares were shaded according (1) 4 categories of difference (Fig. 14). The relative distinctness of Melamphaes typhlops from wher congeners was again clearly demonstrated. In contrast with the previous analysis, however, the shaded areas showed sio nordenskjoldii (Lönnberg) to be more similar to the species in Melamphaes than to those in Scopelogadus, : morphologically well integrated but distinctly separate unit.

## DISTRIBUTION

The 4 forms in Scopelogadus, like the 20 species in Melamphaes and Sio, are distributed according to patlurns that are related to the heterogeneity of the oceans. Oceanic zones where currents converge or diverge, and land areas bound water masses, which though defined classically by their temperature-salinity relationships, intse unique biological (non-conservative) properties. Ebeling (1962) discussed at length the zoogeography rlative to water masses of Melamphaes species and other bathypelagic fishes. He emphasized biological actors, primarily organic productivity, as possibly accounting for certain recurrent distributional patterns, which were used to define various faunal regions.

To find correspondence, if any, between Scopelogadus distributions and water masses, curves of salinity fotted against temperature were constructed for each species using data taken from hydrographic casts made vertically at or near each locality and time of capture (see Ebeling, 1962 for literature references to this jrocedure). These data were collected from the following sources: Discovery Committee, 1929; Rakestraw - al., 1960; Schmidt, 1929; Thomsex, 1937; Lniversity of California, Scripps Institution of Oceanography (1n file). These "T-S capture" curves were superimposed on the appropriate water mass envelopes, which are curves delimiting the area into which all T-S curves from a particular water mass will fall. Suvd (1961) recently used this technique to describe the ecology and distribution of arrow worms (Chaetognatha) in the "astern tropical Pacific. He not only superimposed T-S capture curves on water mass envelopes, but also incorporated temperature-oxygen capture curves into his analysis.

In each diagram of the present study, T-S capture curves for adults and halfgrown (solid lines) were compared with those for larvae and young (broken lines). The upper depth limit for each species or ontosenetic stage was taken as the depth of the shallowest of all trawl hauls that captured it. The lower limit of the T-S curve was simply the greatest depth of the particular trawl for which the curve was drawn. The T-S rapture diagrams compliment maps of geographical distributions, on which are shaded boundaries of the rincipal water masses (after Sverdrup et al., 1942). The areas sampled are indicated by the plotted trawling lations for all species (Fig. 15). Ebeling, ( 1962 - after Sverdicp et al. and other authors) briefly surveyed the distributions of the major water masses. Also, Tebble (1960) presented an excellent discussion of the water nasses in the South Atlantic and contiguous Antarctic oceans. McGary et al. (1961) showed by T-S eurves a comparatively gradual transition between North Pacific Central Water and Pacific Subarctic Water to the north. They suggested that albacore were, therefore, influenced in their northward movement by the productivity of this zone, rather than an abrupt temperature break.

## Vertical distributions.

The vertical diurnal migrations of many bathypelagic fishes obscure their distributions relative to particular vertically separated water masses. To examine the possibility of species of Scopelogadus migrating vertically, lifferences in depths of capture between these species and also between day and night hauls were subjected (:) a Chi Square analysis of variance based on ranked values (using Friedman's $W^{r}$ distribution). Two ontoge-

Dana-Report No. 60. 1963.


netic groups-large young to adults and postlarvae to small young-were compared, each among all four taxa (Table IV). Using the .05 or smaller level of probability to indicate significance, there was little or no differance between average depth of captures among species ( $.25>\mathrm{P}>.1$ ), but the night captures were significantly deeper than the day ( $.05>\mathrm{P}>.025$ ). Although this might indicate diurnal migrations to greater depths, the possibility that the average "Dana" day trawl was significantly deeper than the night trawl was explored. A random sample of 200 "Dana" trawl notations was taken from lists in Schmidt (1929) and Anonymous -lyana-Report Number 1 (1934). Of these, 149 were night hauls averaging 150 meters and the remaining

Table IV. Average depth of trawls capturing Scopelogadus.


#### Abstract

PL-Yg, postlarvae and small young; Yg-Ad, large young to adults; n, number of trawls from which the mean depth was calculated. The data were taken mostly from R/V "Dana" trawls, but for S. mizolepis bispinosus, Bingham Oceanographic Collection, tanford University, and United States National Museum records were added. Mean depth is in meters.


| Growth Stages | Time | S. m. mizolepis |  | S. m. bispinosus |  | S. unispinis |  | S. beanii |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | n | Mean depth | 11 | Mean depth | n | Mean depth | $n$ | Mean depth |
| ! $1 . \mathrm{Yg}$ | Night Day | 59 12 | 268 533 | 4 | 468 800 | - | - | 10 9 | $\begin{aligned} & 214 \\ & 621 \end{aligned}$ |
| in-Ad. | Night Day | $\begin{array}{r} 129 \\ 44 \end{array}$ | $\begin{array}{r} 447 \\ 1150 \end{array}$ | 21 13 | $\begin{array}{r} 714 \\ 1550 \end{array}$ | 26 16 | $\begin{array}{r} 961 \\ 1734 \end{array}$ | 9 35 | $\begin{array}{r} 539 \\ 1687 \end{array}$ |

. 11 were day hauls averaging 717 meters; i.e., almost 3 times more night hauls were taken, but day hauls were usually 4 or 5 times as deep. Then, was the proportion of day hauls (.26) similar to the proportion of day captures for the four taxa? For all species this proportion was . 52 , which was significantly different from .26 (Independent Sample Proportion Chi Square Test, $\mathrm{P}<.005$ ). The Chi Square values, however, varied conviderably between the taxa. Between "Dana" hauls and Scopelogadus m. mizolepis, the difference in proprtions was not significant (Chi Square, 0.48 ; . $75>\mathrm{P}>.50$ ), but for $S$. m. bispinosus (Chi Square, 4.9; $4.5>\mathrm{P}>.025$ ), $S$. unispinis (Chi Square, $3.6 ; \mathrm{P}=.05$ ), and $S$. beanii (Chi Square, $48.0 ; \mathrm{P} \ll .005$ ), this'difference "as significant, with Chi Squares increasing by two orders of magnitude. Finally, the ratio of average depth - f night captures to average depth of all captures for all sipecies significantly differed from the ratio of night tauls to all hauls, calculated from the random sampling of "Dana" trawls (Chi Square, 23.0; P<.005).

We concluded that much of the difference between depths of day and night captures is artificial due to mon-random sampling. Although the difference in average depths of capture between all species was not significant at the .05 level, the $P$ value obtained ( $.25>P>.1$ ) suggests possible significance, which might be shown in a parametric test of random samples. Admittedly, for all species day captures were significantly deeper than night captures. This might at first glance indicate diurnal vertical migrations, were it not for the fact that, in general, "Dana" day hauls were significantly deeper than night, and many more night hauls were taken, increasing the chance of capturing shallow stragglers. Interestingly, the proportion of day captures was significantly greater than the randomly sampled proportion of "Dana" day trawls. The night trawls, however, included many shallow ( $30-75 \mathrm{~m}$.) hauls, which rarely took species of Scopelogadus. Further, night hauls "rere significantly shallower than day hauls and the commonest night captures were of the two shallowest forms (as determined by the upper distributional limits of either adults or larvae), the subspecies of $S$. mizolepis. in fact, the proportion of day captures of $S$ : mizolepis, the shallowest, did not significantly differ from the randomly sampled proportion of all hauls, whereas that of $S$. beanii, the deepest, showed the greatest differince, most of the captures actually being by day. That adult beanii were caught in more day hauls than night is most simply explained by the fact that it is a relatively deep species, whose adult bathyphilic populations rould be most frequently sampled by the significantly deeper day hauls (see species account, "Distribution" Table IV is misleading in that young and adults are grouped together). Vertical diurnal migrations, therefore, although possible, are probably not extensive.

## Ontogenetic distributions.

The larvae and young of all species in Scopelogadus occur more shallowly than do the adults. Because in the three dimensional oceanic environment water masses are vertically as well as geographically separated, the two ontogenetic groups may live in different water masses. This is particularly true for many individuals of S. beanii and S. m. bispinosus (Figs. 18, 22). Ontogenetic groups may also be geographically separatel. As were the young of Sio nordenskjoldii (see Moss, 1962), the larvae and young of the southern population of Scopelogadus beanii were commonly taken between 30 and $40^{\circ} \mathrm{S}$ in the southern Indian Ocean and in the Tasman Sea, well within the central water masses. Adults were taken at greater depths below the youn!, and most likely also inhabit Antarctic Intermediate Water and Deep Water. Similarly, in the North Atlantic the larvac and young of S. beanii were trawled regularly at the inner edge of the Gulf Stream in water characteristic of the Sargasso Sea, while adults were usually taken farther northward in deeper water, the N. Atlantic Deep, Intermediate, and N. Atlantic Central waters.

In this connection, Ebelivg (1962) discussed in detail the problem of discontinuous ontogenetic distributions of bathypelagic fishes, with special reference to Melamphaes acanthomus, an eastern tropical Pacifir species. Non-breeding, expatriated adults of this species were taken far from the breeding area. Also, in the North Pacific, young of $M$. lugubris Gilbert were taken in the northern parts of the central and underlyinis intermediate water masses, although adults were usually taken farther north in the Subarctic Water. Generally, throughout the species of Melamphaes, Sio, and Scopelogadus, the nursery area is shallower, often more salinc, wariner, and more closely associated with the thermocline than is the adult habitat.

## Disiributions relative to water masses.

To show that bathypelagic fishes are distributed three dimensionally through the length and depth of water masses necessitates a consideration of both T-S water mass diagrams and geographical distributions. Unlike equatorial and boreal species of Melamphaes, no species of Scopelogadus is restricted to a single physicochemically defined water mass.

The circumcentral-tropical species Scopelogadus mizolepis inhabits central, equatorial, and intermedial water masses of the Atlantic, Indian, and Pacific oceans (see Ebeling, 1962 for discussion of faunal regions). Larvae and young generally occur in central waters, upper equatorial waters, or, in the case of $S$. m. bispinosus. in mixed North Pacific Transitional Water; many adults apparently live at greater depths in the underlying intermediate or deep waters (Figs. 16, 23, 17-19). S. m. mizolepis is common in North Atlantic Central Water off West Africa, in equatorial water having properties intermediate between the two Atlantic central water masses, and, as adults, in the underlying Antarctic Intermediate Water, which is characterized by a distinc| salinity minimum. Interestingly, it apparently avoids the Mediterranean Water, which is relatively warni and salty (Fig. 17). In the North Atlantic, S. mizolepis "excludes" S. beanii from the Sargasso Sea (western gyre) and the Caribbean region. In fact, beanii, which is associated with the Gulf Stream in this area, completely surrounds mizolepis at its northern boundaries, though off the west coast of Africa north of $20^{\circ} S$ the two species are sympatric (Fig. 23). Specimens of S. m. mizolepis from the Sargasso and Caribbean seas are smaller on the average than those from off West Africa. Similarly, the dwarf species Melamphaes pumilus Ebeling is restricted mainly to these seas and is surrounded to the north and east by its dwarf sibling M. simus Ebeling, which inhabits waters in or underlying the Gulf Stream and Canary Current (Ebeling, 1962). Here the similarity ends; unlike M. pumilus, M. simus extends southward off West Africa, so that the two species are almost completely allopatric. S. m. mizolepis is common in Indian Equatorial Water and isohaline water of the Indonesian region. It also invades Indian Central and western North and South Pacific Central waters. much the same as Melamphaes polylepis Ebeling and M. longivelis Parr. Melamphaes simus and M. danas Ebeling have similar Indo-Pacific distributions, but live at lesser depths. In contrast with M. simus and M. danae, however, S. m. mizolepis invades central and western parts of the Pacific Equatorial Water, where, as well as in North Pacific Central Water, it intergrades with $S$. m. bispinosus.

Scopelogadus m. bispinosus (Figs. 16, 18), which replaces S. m. mizolepis in the eastern and central tropical Pacific, is distributed analogously to, but more widely than, the eastern Pacific equatorial species Melamphaes


Fig. 16. Distributions of: Scopelogadus mizolepis mizolepis; $\theta$, intermediates; and O, S. m. bispinosus. The dark bands delimit central and equatorial water masses; off the west coast of North America north of $20^{\circ} \mathrm{N}$ is North Pacific Transitional Water.


Fig. 17. Temperature-salinity capture diagram for Scopelogadus mizolepis mizolepis. The broad lines enclose water mass envelopes, mostly from Sverdrup et al., 1942. The thin lines are temperature-salinity segments through the maximum possible depth range for each capture (from the presumed upper depth limit of adults or young to the maximum depth attained for each net haul); dashed lines are for postlarvae and young, solid lines for adults and halfgrown. The presumed upper depth limit for each species is in its species account. For further explanation see the text.


Fig. 18. Temperature-salinity capture diagram for Scopelogadus mizolepis bispinosus. For further explanation see Fig. 17.


Fig. 19. Temperature-salinity capture diagram for morphological intermediates between the two subspecies of Scopelogadus mizolepis. For further explanation see Fig. 17.
acanthomus Ebeling, M. macrocephalus Parr, M. laeviceps Ebeling, and M. spinifer Ebeling. As does M. acanthomus, S. m. bispinosus occupies N. Pacific Transitional Water to the north, but unlike acanthomus it breeds there and extends northward to almost $40^{\circ} \mathrm{N}$. It ranges westward with M. laeviceps in Pacific Equaiurial Water to the central equatorial Pacific. Unlike all these species of Melamphaes, however, it regularly accurs in Eastern N. Pacific Central and N. Pacific Intermediate waters to the north and in Eastern South Pacific Central Water and water intermediate between this water mass and Pacific Equatorial Water to the ...uth. This tropical subspecies is completely excluded from Pacific Subarctic Water (Fig. 18). Intergrades between S.m. mizolepis and S. m. bispinosus were usually taken in mixed waters having characteristics of Western S. Pacific Central, Pacific Equatorial, and Eastern North Pacific Central waters and at greater depths, Intarctic and Pacific Intermediate waters (Fig. 19).

The distribution of Scopelogadus unispinis (Figs. 20, 21) is analogous to that of Melamphaes indicus Ebeling. Both occur in the tropical Indian Ocean, Indonesia northward to the Philippines, and the western Pacific. Their water mass distributions are also similar; both species were taken commonly in Indonesian and Indian iequatorial waters (frequently mixed with Indian Central Water) and, more rarely, in the central water masses. Adults of both species probably occur in northward intrusions of Antarctic Intermediate Water, but are, perhaps, excluded from much of the Indian Central Water. This distributional pattern is characteristic of -veral species of bathypelagic fishes. For example, Schultz (1961) gave the range for the hatchetfish Argyrorelecus lychnus sladeni Regan as Indian and western Pacific oceans.


Fig. 20. Distributions of:
Scopelogadus unispinis; and O , Scopelogadus beanii. The dark bands delimit central and Indo-Paciflc equatorial water masses.

Were it not for its occurrence along tropical West Africa, Scopelogadus beanii (Figs. 20, 22, 23) would be classified as antitropical (North Atlantic and southern oceans) as are, among other bathypelagic fishes, Melamphaes microps (Günther) and Melamphaes suborbitalis (Gill). Adults of S. beanii are common in North Atlantic Deep Water and mixed N. Atlantic Central Water in the region of the Gulf Stream. They may not be excluded, as are several other species of bathypelagic fishes, from Mediterranean Water. Invading the periphery of the Sargasso Sea, some larvae and young were taken in N. Atlantic Central Water (Fig. 22). As mentioned previously, however, S. beanii as a whole is excluded from most of the Sargasso and Caribbean seas by S. m. mizolepis (Fig. 23). Several captures of both young and adults were made along the west coast of Africa in water intermediate in character between North and South Atlantic Central waters. These captures, of course, bridge the gap in an otherwise "antitropical" pattern. Young and some adults were taken in $S$.


Fig. 21. Temparaturesalinity capture diagram for Scopelogadus unispinis. For further explanation see Fig. 17.

Atlantic, Indian, and Western South Pacific Central water masses; adults are probably more common in th: underlying Antarctic Intermediate or mixed waters. Interestingly, however, the southern population, like that of Sio nordenshjoldii (Lövberg) is seemingly associated with the Subtropical Convergence at about $40^{\circ} S$ (see Moss, 1962). For both species the lack of captures from Subantarctic Water may simply be due to th. scarcity of trawl hauls from this water mass. It may be, however, that the breeding area of these species i, restricted to central water just north of the convergence. Both Scopelogadus beanii and Sio nordenskjoldii occu! south of $30-35^{\circ} \mathrm{S}$ in the Indian Ocean, but work their way northward in the Tasman Sea and other areas oli New Zealand (Fig. 20). The young of Sio also inhabit the southern fringes of the central water masses in the Southern Hemisphere, from the South Atlantic eastward to the Western South Pacific Central Water.

## GEOGRAPHICAL VARIATION

Samples of specimens from the areas of water masses defined in Table $V$ were analyzed for morphometric and meristic variation between these areas. Frequency distributions of 11 counts and proportions compare populations of the 3 Scopelogadus species. The sample size of counts was usually about 30 , though a few samples were as small as 11 or as large as 50 . Because of allometric growth, body proportions from only halfgrown and adults were tabulated. This usually reduced their sample size by 8 or 10 .


Fig. 22. Temperature-salinity capture diagram for Scopelogadus beanii. For further explanation see Fiz 17.

The rationale for establishing the 2 subspecies of $S$. mizolepis is discussed in its species account. Scatter diagrams (Fig. 7), graphs (Fig. 8), and frequency tables (Table V) help distinguish the subspecies. One subspecies inhabits equatorial and adjacent water masses of the eastern thopical Pacific, the other inhabits central, equatorial, and adjacent water masses of the Indo-Pacific and Atlantic. Ebeling (1962) described the eastern tropical Pacific as a "primary zoogeographical region" with a highly endemic bathypelagic fish fauna. The tropical IndoPacific and Atlantie, however, were shown to be part of a vast Circumcentral-tropical Region, comprising many similar water masses and extending from the tropical Atlantic to the Pacific. Reflecting the similarity of the Circumeentral-tropical water


Fig. 23. North Atlantic distributions of: O. Scopelogadus mizolepis mizolepis; and O, Scopelogadus beanii. masses, the included bathypelagic fish fauna exhibits little endemism or variation between these water masses. There are, nevertheless, a number of exceptions. For example, the stomiatoid fish Chauliodus sloani B cocn and Schneider, exhibits considerable variation between water masses of the tropical Atlantic and Indo-Pacific (Ege, 1948; Haffaer, 1952; Mohrow, 1961). Also, the Indian Ocean form of S. unispinis is morphologically distinguishable from the northern East Indian form.

Table V. Frequency distributions of selected counts and proportions for geographical groups of the species and subspecies of Scopelogadus.

A-C, S.m. mizolepis: A, from the Sargasso Sea (western gyre of the North Allantic Central Water) and Caribbean region; b. from productive equatorial and central waters off West Africa; C, from the Indo-Pacific (a few western Pacifle specimens wer, morphologically internediate between the 2 subspecies). D-H, S. m. bispinosus: D, from the eastern Pacifle, north of $20^{\circ}$ N (mainly from North Pacific Transitional Water in the region of the California Current; E, from near the Galapagos Is.; F, central tropicei Pacific, west of $100^{\circ} \mathrm{W}$ and mainly between 2 and $20^{\circ} \mathrm{N}$ (mainly from the Equatorial Counter Current, productive region of th South Equatorial Curaent, and associated deeper waters - several specimens fom areas I), E, and F were morphologically intos mediate between the two subspecies); G, from the Gulf of Panama and vicinity, 4-20 N and $78-90^{\circ} \mathrm{W}$ (productive Pacific Equatorial Watei); H, from off Peru, south of $3^{c}$ S. I, S. unispinis. J-L, S.beanii: J, North Atlantic Gulf Stream System and associated deeper waters, mainly north of $30-35^{2} \mathrm{~N} ; \mathrm{K}$, fom productive equatorial and central waters off West Africa between $30^{\circ}$, and $25^{\circ} \mathrm{S}$; L, from mainly south of $30^{\circ} \mathrm{S}$ in the South Atlantic, South Indian, and weste.n South Pacific oceans (vicinity of or just north of the Subtropical Convergence). Proportions, in thousandths of standard length, are for adults and halfgrown only.


|  | Length of caudal peduncle |  |  |  |  |  | Length of upper jaw |  |  |  |  |  |  |  | Suborbital |  |  |  |  |  | Eye |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 270 289 | 290 309 | 310 | 330- | $\left\lvert\, \begin{gathered} 350- \\ 369 \end{gathered}\right.$ | 370 <br> 389 | 120 | $130-$ | $140-$ | 150 159 | 160 | $170-$ 179 | $\begin{gathered} 180 \\ 189 \end{gathered}$ | $\begin{array}{\|l} 190- \\ 200 \end{array}$ | $\begin{aligned} & 40- \\ & 49 \end{aligned}$ | $\begin{aligned} & 50- \\ & 59 \end{aligned}$ | 60 69 | $\begin{aligned} & 70- \\ & 79 \end{aligned}$ | $\begin{aligned} & 80- \\ & 89 \end{aligned}$ | $90-$ 99 | $\begin{gathered} 30 \\ 39 \end{gathered}$ | $40-$ 49 | $50-$ 59 | $\begin{gathered} 60- \\ 69 \end{gathered}$ |
| 1 | - | - | 4 | 5 | 4 | - | 4 | 8 | 5 | 1 | - | -- | - | - | 4 | 13 | - | - | - | - | 1 | 6 | 5 | - |
| ! | - | - | 3 | 6 | 1 | - | - | - | 6 | 5 | 1 | - | - | - | 2 | 4 | 6 | - | - | - | - | - | - | - |
| C. | - | 5 | 11 | 7 | 2 | - | - | 4 | 18 | 3 | - | - | - | - | 1 | 13 | 7. | 5 | - | - | - | 10 | 12 | 1 |
| 1). | 2 | 6 | 6 | 15 | 2 | - | - | 3 | 7 | 13 | 2 | - | - | - | - | 5 | 21 | 2 | - | - | 2 | 13 | 4 | - |
| 8 | - | 5 | 5. | 12 | - | - | - | - | 14 | 8 | - | - | - | - | - | - | 4 | 14 | 4 | - | 4 | 10 | 2 | - |
| ! | 3 | 9 | 14 | 7 | - | - | - | 1 | 11 | 3 | 8 | 9 | 1 | - | - | - | 9 | 15 | 1 | - | 2 | 10 | 6 | 1 |
| ; . . | 3 | 9 | 10 | 3 | - | - | - | 3 | 13 | i3 | 2 | 1 | - | - | - | - | 8 | 16 | 2 | - | - | 14 | 6 | - |
| 11 | - | 4 | 11 | 8 | - | - | - | - | 9 | E | 3 | 1 | 1 | - | - | - | 3 | 1 | 1 | - | 1 | 8 | 2 | - |
| 1. | 9 | 22 | 8 | - | - | - | - | 1 | 5 | 11 | 9 | 5 | 2 | 2 | - | - | 3 | 13 | 7 | 3 | - | 8 | 23 | - |
| 1 | - | - | - | 6 | 22 | 3 | - | 4 | 16 | 5 | 2 | - | - | - | - | 5 | 23 | 3 | - | - | - | 14 | 17 | 1 |
| $\cdots$ | -- | - | - | 8 | 14 | 3 | - | 2 | 10 | 7 | 1 | 4 | 2 | - | - | 10 | 6 | 8 | 3 | - | - | 12 | 14 | 1 |
|  | - | - | - | 6 | 6 | 1 | - | 4 | 5 | 3 | 1 |  | - | - | - | 1 | 9 | 2 | 1 | 1 | - | 6 | 9 | - |

Of the 3 species of Scopelogadus, S. mizolepis showed the most intraspecific variation. Several east-west morphological clines were noted in the species account. Perhaps the most interesting of these are the clines of lecrease in gill surface on the first gill arch and the reduction of raker size on the fifth arch; both occurred between $S$. m. bispinosus in the eastern Pacific and $S$. m. mizolepis in the Atlantic.

Indo-Pacific specimens of $S . m$. mizolepis, which are separated from Atlantic specimens by the southern tip uf Africa, had on the average a significantly longer predorsal and wider suborbital (Fig. 8). The counts revealed no significant intraspecific differences (significant difference was adjudged the wide non-overlap of \& standard errors, two on either side of the mean - see the species account of $S$. mizolepis). A few characters indicated the Sargasso Sea and Caribbean specimens to be distinct from others, even Atlantic equatorial and W'est African specimens. Sexable females were noticeably smaller: 12 specimens averaged only 57.4 mm . in standard length, compared with 74.3 mm . for 9 from West Africa and 68.5 mm . for 15 from the lndo-Pacific. Further, characters that vary within and between the 2 subspecies appeared in Sargasso and Caribbean spec:mens in their most extreme states relative to the morphology of $S$. m. bispinosus. The gill filaments were hortest, the rakers of the fifth arch were least well developed, the upper jaw was shortest, the suborbital was narrowest, the head was shortest (Table V), and the pharyngeal teeth were most numerous.

Within $S . m$. bispinosus, samples varied significantly in numbers of gill rakers and proportions of body lepth, head length, predorsal length, length of caudal peduncle, and suborbital width (Fig. 8, Table V). These distributions of characters revealed two kinds of populations. Specimens from the Gulf of Panama and vicinity (area Gr in table and figure legends) and from off Peru (H) tended to be most "bispinosus-like", whereas pecimens from north of $20^{\circ} \mathrm{N}$ (D) and from near the Galapagos Is. (E) on the average more closely resemhled S. m. mizolepis. The only characters that did not bear this out were body depth from area D, predorsal from G, and suborbital from $E$ and $F$. Interestingly, characters from samples taken in the central tropical 'acific ( $F$ ) had either bimodal distributions or near normal distributions with relatively large variances (or standard deviations). A recheck of these specimens showed that, indeed, about half the specimens were trpically bispinosus, while the other half tended to be intergrades.

That $S$. unispinis comprises 2 morphotypes was indicated by the bimodal distribution of proportions of hody depth and by relatively large variances of numbers of gill rakers and proportions of upper jaw length. Re-examination showed that specimens from the Indian Ocean generally were, in fact, deeper bodied than ihose from northern Indonesia and the Philippines.

Antitropical populations of Melamphaes microps-one in the Northern, the other in the Southern Hemi-sphere-were morphologically distinguishable (Ebeling, 1962). Similarly, the northern population of S. beanii, from the region of the Gulf Stream, differed meristically and, perhaps, morphometrically from the southern population, inhabiting central and intermediate water masses near the Subtropical (Subantarctic) Convergence. North Atlantic specimens had significantly fewer gill rakers. Unlike antitropical species, however, these populations are connected off West Africa. Moreover, the West African specimens, as might be expected were on the average morphologically intermediate.

The species of Melamphaes and Scopelogadus that inhabited the greatest number of water masses usually showed the largest percentage of geographical variation (Table VI). Occurring in more water masses than the other species analyzed, S. mizolepis and Melamphaes simus Ebeling also had the highest percentages of significant variation, 54 and 42, respectively. S. mizolepis has split subspecifically between 2 primary faunal regions (defined in Ebeling, 1962), the Eastern Pacific Equatorial and Circumcentral-tropical. M. simus, however, which inhabits only the Circumcentral-tropical Region showed little evidence of subspeciation.

Table VI. Relationship of occurrences in different water masses to percentage of significant intraspecific variation for 8 species of Scopelogadus and Melamphaes.

Data for Melamphaes were taken from Ebeling (1962) and unpublished counts and measurements. The percentage of significant variation is based only on the characters that were analyzed geographically. Within Melamphaes the characters were not at ways the same fo: each species, but were selected as possibly showing significant geographical variability. Generally, the same ch: racters were used throughout Scop l gadus. Significant difference between means was taken as the wide non-overlap of 4 standar; errors, 2 on either side of the mean. Subspecies characters had non-overlapping standard deviations, one on either side of the meati. Sample size was usually between 20 and 40 . "Prima y zoogeographical regions" we:e defined by Ebeling.

|  | Total no. water masses from which recorded | No. primary zoogeographical regions from which commonly recorded | Total no. geographically analyzed characters | Percent significant variation | No. "subspecies characters" |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Scopelogadus mizolepis | 8 or 9 | 2 | 13 | 54 | 3 or 4 |
| Melamphaes simus. . | 7 or 8 | 1 | 19 | 42 | 1 (?) |
| M. danae. | 5 | 1 | 18 | 0 | 0 |
| S. beanii. . | 4 or 5 | 2 or 3 | 12 | 25 | 0 |
| S. unispinis. | 3 or 4 | 1 | 12 | 17 | 0 |
| M. lugubris. | 2 or 3 | 1 | 18 | 11 | 0 |
| M. janae . | 2 or 3 | 2 | 18 | 11 | 1 (?) |
| M. pumilus. | 1 | 1 | 18 | 0 | 0 |

Melamphaes danae Ebeling showed no significant intraspecific variation even though it was taken in i water masses. Its range throughout the similar water masses of the Indo-Pacific may allow a thorough mixin: of populations within the species (Ebeling, 1962). But other species, such as S. unispinis and Chauliodux sloani, that inhabit much the same area can be divided into series of geographical variants (Ege, 1948). Haffner (1952) showed how the degree of past isolation of the East Indian basins like the Sulu Sea might have influenced the morphological divergence of Indo-Pacific populations of C. sloani. Shallower dwelling Melamphaes danae, on the other hand, could have, perhaps, more freely intercommunicated across the shallou sills separating the basins than could have either deeper living $S$. unispinis or C. sloani.

In the North Atlantic Scopelogadus beanii is distributed in much the same way as the North Pacific species Melamphaes lugubris Gilbert. As do many other bathypelagic fishes of the North Atlantic, however, S. beanii transgresses the tropics and also inhabits waters about the Subtropical Convergence in the Southern Hemisphere. However, M. lugubris is restricted to the North Pacific as are most other N. Pacific Subarctic species (Ebeling, 1962). This may account for the greater intraspecific variability in wider ranging S. beanii (Table VI): although the range of $S$. beanii is constricted along the west coast of Africa, all populations of M. lugubris ar" broadly interconnected.

Melamphaes pumilus Ebeling is mainly confined to the western gyre (Sargasso Sea) and Caribbean region of North Atlantic Central Water. Expectedly, therefore, it showed no significant geographical variation (Ebeling, 1962); the whole species is probably one panmictic population.

The foregoing suggests the importance of water mass boundaries, especially those that limit primary faunal regions, in intraspecific variation and perhaps, therefore, in speciation of bathypelagic fishes. For example, until central Pacific internediates of Scopelogadus mizolepis were found, we thought that it was two distinct species, one in the Indo-Pacific and tropical Atlantic, the other in the eastern tropical Pacific.

## DISCUSSION AND CONCLUSIONS

Comprising only 3 species, Scopelogadus is the second smallest of 5 genera in the bathypelagic fish family Melamphaidae. S. beanii ranges from the North Atlantic southward, along the west coast of Africa, to the southern oceans. S. unispinis is restricted to the Indo-Pacific. S. mizolepis is circumtropical, but has diverged into two subspecies: $S$. m. mizolepis in the tropical Atlantic and Indo-Pacific, $S . m$. bispinosus in the castern tropical Pacific. All 3 species are morphologically very similar, which probably reflects the relative homoseneity of their deep bathypelagic environments.

Most of the specimens were in poor condition. Abrasion during capture usually rendered the delicate cxternal parts, such as head epidermis and scales, unusable as distinguishing characters. To separate the 4 vimilar taxa, therefore, we had to rely on countable, measurable, or internal structures that were not destroyed "r severely altered. This, of course, greatly restricted the number of taxonomic characters with only slightly ur non-overlapping ranges between the taxa. Within S. mizolepis, for example, several morphoclines initially had us considering the one species as two, before we had examined intermediate specimens from the central tropical Pacific. One interesting cline was expressed as gill filament length. On the first arch, gill filaments of specimens of S.m. mizolepis from the Sargasso Sea were short, those of S. m. bispinosus from the Gulf of lanama were relatively long, while those of specimens of $S$. m. mizolepis from the intervening lndo-Pacific and from off West Africa were intermediate in length. In contrast with the structure of the shallowest bathy!elagic (mesopelagic) fishes, the structure of the deeper bathypelagic fishes suggests for them a lower metaholism and a less active life. Gill surface, for example, is considerably reduced (Marshall, 1960; Walters, 1961 , etc.). Marshall noted an intrageneric trend in reduction of gill surface among 3 species of the bathypelagic fish Gonostoma, whose shallowest species had the greatest gill surface. However, for S. mizolepis the differences in amount of gill surface on the first arch could not be correlated with mean depth of capture of the included subspecies; the Atlantic specimens were not taken significantly deeper than the Pacific specimens. These differences may be related to the concentrations of oxygen in the habitats. The oxygen content of the western North Atlantic habitat of $S$. m. mizolepis is relatively high (about $3-6 \mathrm{ml} / \mathrm{L}$ ), whereas that of most of the eastern tropical Pacific habitat of $S$. m. bispinosus is low (less than 0.1 to $2 \mathrm{ml} / \mathrm{L}$ ), so low, in fact, that part of the depth range of bispinosus, which lives mostly between 200 and 2000 meters, is termed an oxygen minimum layer (Sverdrup et al., 1942; Wooster and Cromweli., 1958). The increased gill surface, therefore, may reflect a more efficient utilization of oxygen in oxygen-poor waters. Interestingly, specimens of another melamphaid, Poromitra megalops (Lëткек), from the eastern tropical Pacific have noticeably more gill surface than do specimens from the North Atlantic.

Morphologically, Scopelogadus is a discrete and well integrated unit, quite distinct from the previously revised genera Melamphaes Günther and Sio Moss (see Ebellng, 1962; Moss, 1962). Also, Scopelogadus appears to be the melamphaid genus most completely adapted to a bathypelagic existence; its included species have relatively delicate external tissues, low density bones (as determined by radiographs), small gill surfaces, and a completely regressed gas-bladder. Scopelogadus is intermediate between Sio and Melamphaes in number of included species. Sio is monotypic and Melamphaes comprises 19 or 20 species. Though Melamphaes can be separated into several species groups, the 3 species in Scopelogadus are all closely interrelated, with S. unispinis, in some ways, intermediate between $S$. mizolepis and S. beanii. S. beanii appears morphologically to be the species most completely adapted to deep bathypelagic life and, in fact, was trawled at greater depths than S. mizolepis.

The species of Scopelogadus are not, in contrast with a few species of Melamphaes, strictly confined by the boundaries of physicochemically defined water masses. They do, however, mostly follow the distribution:l scheme of bathypelagic fishes suggested by Ebeling (1962). S. beanii is an "almost" antitropical specio. whose distribution is comparable to that of apparently antitropical Melamphaes microps and M. suborbitulis (Gill). Whereas S. beanii extends uninterrupted from the North Atlantic along the West African coast to tlun southern oceans, however, M. microps and M. suborbitalis apparently do not; they are excluded from the equatorial Atlantic. The southern distributions of S. beanii and, to a certain extent, of Melamphaes suborbitalis and M. microps coincide with the main range of Sio nordenskjoldii (see Ebeling, 1962; Moss, 1962). In the Southern Hemisphere, all 3 species inhabit Antarctic Intermediate Water and central waters that are in the vicinity of the Subtropical Convergence. All except M. microps were also trawled from the Tasman Sea ant from off northern New Zealand. These species, with the possible exception of M. microps, define a faunal region associated with the Subtropical Convergence (Subantarctic Convergence). Evidence obtained by ploiting T-S capture curves suggests that the larvae and young inhabit the shallower parts of the warm central waters to the north of the convergence. Adults, however, live deeper and also inhabit Antarctic Intermediat Water and underlying Deep Water; some possibly work their way southward past the convergence.

The Indo-Pacific species S. unispinis occurs throughout Indian Equatorial Water, Central Water, and Indonesian water in much the same way as Melamphaes indicus. In fact, several genera (e.g., the melamphai $\}$ genera Melamphaes, Scopelogadus, and, perhaps, Poromitra) each contain a species that is restricted to all or part of this region. Circumtropical S. mizolepis, on the other hand, ranges throughout the tropics. Its division into 2 subspecies, however, implies an initial conformity to the primary faunal regions: S.m. mizolepis inhabits, as do Melamphaes eulepis and M. simus, most of the equatorial, central, and underlying intermediat: water masses of the Circumcentral-tropical Region, from the Atlantic to the Pacific; S. m. bispinosus is restricte : mainly to Equatorial and adjacent waters of the eastern tropical Pacific. Although the range of bispinosus includes central and transitional as well as equatorial water masses, most E. Pacific Equatorial species of Melamphaes (M.spinifer, M. laeviceps, and M. macrocephalus) are restricted to Pacific Equatorial Water. The distribution of the somewhat "dwarf" population of S. m. mizolepis from the western North Atlanti(western gyre of North Atlantic Central Water, including the Caribbean Sea and underlying intermediat: water) is analogous with that of the dwarf species Melamphaes pumilus, which is mainly restricted to th: Sargasso and Caribbean seas.

Analysis of intraspecific geographical variation between several areas of water masses revealed significant morphological differences both within and between the Circumcentral-tropical and Eastern Pacific Equatorial primary faunal regions. Even though between these regions $S$. mizolepis has diverged subspecifically, within the regions only infrasubspecific differences between populations were observed. These regions are broadly contiguous in the central Pacific. They have, however, fewer common species than the Atlantic Subarcti(northern Gulf Stream) and the Subantarctic (or region of the Subtropical Convergence). Though the latter two are separated in the west by the central gyres of the North and South Atlantic, they are similar in both their physicochemical and biological (as measured by primary productivity) properties and are partly interconnected in the eastern North Atlantic and along the west coast of Africa.

As might be expected, the species of both Scopelogadus and Melamphaes that occur in the greatest number of water masses show, with some exceptions, the most geographical variation. This is especially true of the species whose ranges include 2 primary faunal regions. For example, the ranges of Melamphaes simus and Scopelogadus mizolepis are comparable. Both species occur throughout most of the vast Circumcentral-tropical Region, from the Atlantic, through the Indian Ocean, to the central water masses of the Pacific. S. mizolepis, however, inhabits the primary E. Pacific Equatorial Region; M. sinus does not. Further, S. mizolepis comprises two well documented subspecies, one Circumcentral-tropical, the other mainly limited to the E. Pacific Equatorial Region. On the other hand, M. simus, though showing considerable geographical variation, has not subspeciated. Perhaps the distributions of the two subspecies of S. mizolepis are analogous with those of largely Circumcentral-tropical Melamphaes eulepis, and its close relative, Eastern Pacific Equatorial M. spinifer. Their ranges apparently do not overlap. Perhaps in their past morphological divergence these species had passed
through an evolutionary stage similar to the present subspecies stage of $S$. mizolepis, which may be in the process of incipient speciation. Morrow (1961) described similar distributions within the stomiatoid genus Chauliodus. C. sloani Bloch and Schneider, which Morrow believed to be the ". . . most basic form among the modern species of the genus," is Circumcentral-tropical, but exhibits considerable intraspecific morphologiral variation, especially in the Indo-Pacific. Two species occurring within the Circumcentral-tropical Region and morphologically very similar to C. sloani-C. pammelas Alcock (northern Indian Ocean) and C. schmidti EGi: (eastern tropical Atlantic)-"... appear to have been derived directly from it." The tropical Atlantic pecies C.danae Regan and Trewavas, and N. Pacific Subarctic-transitional species C.macouni Bean, have, perhaps, more remote origins. The E. Pacific Equatorial species C. barbatus Garman, is morphologically farthest from the basic type (Mornow, 1961). In other words, although all close siblings of C. sloani occur within the Circumcentral-tropical Region, 2 of 3 species that are more remote from the basic C. sloani morpho!rpe inhabit other, peripheral primary regions. Three evolutionary stages, therefore, are represented within the genus: geographical variation between populations, incipient speciation of siblings, and distinct species firmation. Ebeling (1962) described a similar distributional pattern in Melamphaes. A dwarf group of 4 -jecies contains one wide ranging Circumcentral-tropical species (M. simus) and 3 possibly derived siblings from within this region, but most of the larger, morphologically quite distinct species inhabit other primary regions on the periphery, some of which contain several species. The dwarf species, however, are more ypecialized than their larger congeners.

The morphological diversification of Melamphaes as compared with Scopelogadus and Sio is great. Melamhaes contains 19 species, Scopelogadus 3, and Sio is monotypic. Why? Brinton (1957) thought that the shallowest euphausiid (krill shrimp) species exhibited the greatest amount of latitudinal morphological variability, the deepest the least. This is understandable when it is remembered that between water masses the surface liscontinuity is the sharpest. Further, Breri (1959:24) stated that at surface boundary regions, the nearsurface individuals of a species are eliminated first, leaving the deeper members to define the total range. Gould the hypothesis that deeper dwelling genera are wide ranging, but less speciose than shallower apply !. Scopelogadus, Melamphaes, and Sio? The average depth of trawls taking individuals of Scopelogadus was $\therefore i 5 \mathrm{~m}$. for halfgrown and adults, and 130 m . for larvae and young; of Melamphaes, 375 m . for halfgrown and : dults and 130 m . for young; of Sio, 150 m . for young only. This might suggest acceptance of the hypothesis were it not for the fact that M. simus, one of the shallowest dwelling species of Melamphaes, is more widely distributed than all but one Scopelogadus, S. mizolepis. Within a particular genus it would be interesting to see if the deepest living species would show less geographical variation than the shallowest one that has about the -ame extent of geographical range. In Scopelogadus both $S$. beanii and $S$. mizolepis inhabit 2 primary faunal regions. On the average $S$. beanii was taken deeper than $S$. mizolepis, which is geographically the more variable "f the two.

Another explanation of the difference in sizes of melamphaid genera is that relative to Melamphaes, Scopeingadus may be a "young" genus, in that each of its constituent species may represent a whole species group of Melamphaes. Scopelogadus is more completely adapted to the bathypelagic environment, and, therefore, ierhaps more recently evolved; i.e., Scopelogadus is more specialized than Melamphaes and has less latitude for diversification.

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## APPENDIXI. COUNTS AND PROPORTIONS OF TYPES

The counts and proportions for the holotypes of Scopelogadus mizolepis bispinosus (Gilbert) and S. unispinis, n.sp., and for the syntypes of $S$. beanii Güstiner were taken directly from the specimens. Counts and a few measurements for the holotypes of S.m. mizolepis (Günther) and Melamphaes eurylepis Holt and Byra. were kindly made by Dr. Cari. L. Hubbs, Scripps Institution of Oceanography and by Dr. Eric G. Sila, Central Marine Fisheries Research Institute, Mandapam Camp, India; other measurements were either takia from the original descriptions or, as proportions, off photographs supplied by the British Museum (Natural History). Counts and measurements of a paratype of Scopelogadus cocles Valleane were made by Dr. Hubbs: the holotype could not be located. Pharyngeal teeth counts are listed in the same order as in text Table :. Standard lengths are in millimeters; proportions are in thousandths of standard length.

|  | $\begin{gathered} \text { S. m. mizo- } \\ \text { lepis } \\ \text { (holotype) } \\ \text { BMNHH } \\ 1887.12 .7 .9 \end{gathered}$ | $\begin{aligned} & \text { S.cocles } \\ & \text { (paratype) } \\ & \text { Paris Mus } \\ & \text { 84-1076 } \end{aligned}$ | $\begin{gathered} \text { S.m. bispi- } \\ \text { nosus } \\ \text { (holotype) } \\ \text { CSNMI } \\ 78809 \end{gathered}$ | $\begin{aligned} & \text { S. unispinis } \\ & \text { (holotype) } \\ & \text { D } 3678(4) \end{aligned}$ | S. beanii (syntype) USNM 33378 | $\begin{gathered} \text { S. beanii } \\ \text { (syntype) } \\ \text { USNM } \\ 35509 \end{gathered}$ | $\begin{gathered} \text { S. beanii } \\ \text { (syntype) } \\ \text { USNM } \\ 34835 \end{gathered}$ | M.enrylepis (holotype BMNH 1907.11.1.1 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Counts |  |  |  |  |  |  |  |  |
| Dorsal. | II, 11 | II, 11 | II, 11 | I, 11 | II, 11 | II, 11 | II, 11 | II, 11 |
| Anal. | I, 8 | I, 8 | I, 8 | I, 8 | I, 8 | I, 8 | I, 8 | I, 8 |
| Gill rakers on first arch. | $7+17$ | $7+15$ | $7+17$ | $8+18$ | $8+18$ | $8+18$ | $8+18$ | $9+19$ |
| Rakers on lower fourth arch. |  |  |  | 11 |  |  |  |  |
| Total vertebrae. |  |  | 25 | 23 | 26 | 26 | 26 |  |
| Caudal. |  |  | $10+9$ | $\begin{gathered} 4+10 \\ 9+3 \end{gathered}$ | . . | $10+8$ ? | $10+9$ | ... |
| Pectoral. |  |  | 14 | 15 |  | 14 | 15 |  |
| Pelvic. |  |  | I, 7 | I, 7 | I, 7 | I, 7 |  |  |
| Pharyngeal teeth |  |  |  | $\begin{gathered} 28+54+ \\ 27+46 \end{gathered}$ | . . . | ... |  | $\ldots$ |
| Scale rows. | $\begin{aligned} & \text { (less } \\ & \text { than } 20 \text { ) } \end{aligned}$ | $\begin{gathered} \text { (less } \\ \text { than } 20 \text { ) } \end{gathered}$ | $\begin{gathered} \text { (less } \\ \text { than } 20 \text { ) } \end{gathered}$ | $\begin{gathered} \text { (less } \\ \text { than } 20 \text { ) } \end{gathered}$ | $\ldots$ | $\cdots$ | ca. 15 | ca. 13 |
| Vertical scale rows. |  |  |  | ... | $\cdots$ | $\cdots$ |  | ca. 4 |
| Teeth (rows upper jaw rows lower).. | 1/1 |  | 1/1 | 1/1 | 1/1 | 1/1 | 1/1 | 1/1 |
| Branchiostegal rays. . . . . . . . . . . . |  | 8 | 8 | 8 | 8 | 8 | 8 |  |
| Proportions |  |  |  |  |  |  |  |  |
| Standard length. | 60.9 | 42.5 | 74.5 | 80.4 | 103.4 | 94.5 | 101.5 | 64.2 |
| I3ody depth. | 269 | ... | 288 | 324 | 279 | 271 | 280 | 287 |
| Predorssl. | 478 | $\ldots$ | 488 | 482 | 475 | 452 | 458 | 470 |
| Postdorsal. | 569 | $\cdots$ | 572 | 550 | 598 | 597 | 587 | 591 |
| End of dorsal to caudal. | $\ldots$ | $\cdots$ |  | 343 | $\ldots$ | 397 | 388 | 389 |
| Head length. | 375 | 369 | 443 | 367 | 369 | 344 | 340 | 360 |
| Postorbital length of head | . . | . . | 268 | 219 | 207 | 207 | 218 | 227 |
| Snout to preopercle. | 252 | ... | 265 | 240 | 190 | 216 | 180 | 218 |
| Orbit to cheek ridge. | 43 | $\ldots$ | 54 | 32 | ... | . . |  | 30 |
| Head depth........ | 268 | . . . | 272 | 293 | 273 | 264 | 272 | 290 |
| Head width. | . . | $\ldots$ | 205 | 219 | 179 | 185 | 185 | . |
| Interorbital. | . . . | . . . | 157 | 186 | 160 | 150 | 148 | . |
| Length of frontal fossa | . . . | . . . | 170 | 179 | 125 | . . . | . . . | . . |
| Width of frontal fossa.. | $\ldots$ | . . | 94 | $\cdots$ | 60 | $\cdots$ | S | $\cdots$ |
| Prepectora!. | 369 | . | 405 | 382 | 362 | 343 | 362 | 397 |
| Prepelvic. | 406 | . . | 409 | 395 | 346 | 366 | 371 | 397 |
| Isthmus to pelvic | 365 | . . . | 368 | 362 | 306 | 318 | 341 |  |
| Pelvic to anal... | 221 | . $\cdot$ | 215 | 220 | 218 | 226 | 213 | 175 |
| Pectoral length. | ... | . . . | . . . | 364 | . . . | . . | . . . | . . . |
| Width between pelvics. | ... | $\ldots$ | $\cdots$ | 79 | - . |  |  |  |
| Preanal.... | 590 | . . . | 597 | 613 | 552 | 541 | 566 | 563 |
| Anal to caudal. | 405 | . . . | 421 | 446 | 481 | 477 | 476 | 470 |
| Depth of caudal peduncle. | 124 | . . | 115 | 126 | 106 | 101 | 108 | 94 |
| Length of caudal peduncle. | 321 | ... | 315 | 319 | 356 | 351 | 369 | 370 |
| Length of upper jaw....... | 145 | $\ldots$ | 162 | 170 | 139 | 140 | 142 | 146 |
| Orbit to cheek angle. | 104 | ... | 97 | 100 | 90 | 99 | 101 | 109 |
| Snout length...... | 100 | $\ldots$ | 111 | 106 | 90 | 86 | 88 | $\cdots$ |
| Suborbital. . | 55 | . . | 71 | 76 | 66 | 62 | 65 | 60 |
| Eye. . . . . . . . . . . . . . . . . . . . . . . . . . | 57 |  | $\cdots$ | 54 | $\cdots$ | $\cdots$ | $\ldots$ | 57 |
| Pelvic origin relative to pectoral...... | + 2 mm . | . $\cdot$ | + 2 mm . | + 1 mm . | +3 mm . | + 3 mm . | +2 mm . | + 2 mm . |
| Anal origin under which (number) ray from end of dorsal | 5th | $\ldots$ | 5th | 5th | 6th | 6th | 5th | 6th |

# APPENDIXII. LIST BY LOCALITY OF SPECIMENS EXAMINED OTHER THAN TYPES 

Abbreviations of institutions that supplied the specimens are: AMNH, American Museum of Natural History; BMNH, British Museum (Natural History); BOC, Bingham Oceanographic Collection, Yale Cniv.; BZM, University of Bergen Zoological Museum; CNHM, Chicago Natural History Museum; CZM, Eniversity "f Copenhagen Zoological Museum; D, R/V "Dana" Collections; G, R/V "Galathea" Collections of the Univ. of Copenhagen Zoological Museum; GNM, Natural History Museum of Göteborg; IFAN, Institut Français d'Afrique Noire, Dakar, Sénégal; MCZ, Museum of Comparative Zoology, Harvard Univ.; Ob, R/V "Ob" Collections, Zoological Institute at the Academy of Sciences, Leningrad; POFI, L.S. Bureau of Commercial Fisheries Biological Laboratory, Honolulu; SIO, University of California, Scripps Institution of Oceanography; sl, Natural History Museum, Stanford Univ.; USNM, United States National Museum; UW, Department of Oceanography, Univ. of Washington; V, R/V "Vitjaz" Collections, Institute of Oceanology, U.S.S.K. icademy of Sciences, Moscow; WHOI, Woods Hole Oceanographic Institution.

The "Catalog no." may be either a catalog or a collection number of the institution. For "Dana" hauls, the haul number is in parentheses following the collection number. "Depth" is greatest depth of trawl, either in meters of wire out (designated "w") or approximated actual depth in meters (no designation). "Time" "f capture is N (night), D (day), or combinations of these. "Specimens" are listed as number of individuals in the collection, followed in parentheses by their size range in mm . standard length. If the collection contained Imstlarvae, the individuals are so designated ("PL").

Scopelogadus mizolepis mizolepis.


| In-stitution | Cat- alog no. | Depth | Time | Specimens | $\begin{aligned} & \text { In- } \\ & \text { stl- } \\ & \text { tution } \end{aligned}$ | Cat- <br> alog <br> no. | Locality | Depth | Time | $\begin{aligned} & \text { Syec- } \\ & \text { imens } \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| D | 1185 (2) $17^{\circ} 41^{\prime}$ N., $60^{\circ} 58^{\prime} \mathrm{W}$. | 600 w | N | 1 PL (8) | D | 1342(4) | $34^{\circ} 00^{\prime}$ N., $70^{\circ} 01^{\prime} \mathrm{W}$. | 2000 w | D | 1 (12) |
| - | (3) $17^{\circ} 41^{\prime} \mathrm{N} ., 60^{\circ} 58^{\prime} \mathrm{W}$. | 300 w | N | 3 (8-13) | - |  | $34^{\circ} 00^{\prime}$ N., $70^{\circ} 01^{\prime} \mathrm{W}$. | 1000 w | N | 1 (2b) |
| - | (11) $17^{\circ} 41^{\prime} \mathrm{N} .60^{\circ} 58^{\prime} \mathrm{W}$. | 6000 w | 1) | 1 (45) | $\rightarrow$ | 1345 (2) | $35^{\circ} 07^{\prime} \mathrm{N} .{ }^{7} 2^{\circ} 38^{\prime} \mathrm{W}$. | 600 w | N | 1 Pl , (f) |
| - | (14) $17^{\circ} 41^{\prime} \mathrm{N} ., 60^{\circ} 58^{\prime} \mathrm{W}$. | 3000 w | D) | $\begin{gathered} 2 \text { PL-Yg } \\ (7-28) \end{gathered}$ | - | 1353(7) | $33^{\circ} 51^{\prime}$ N., $666^{\circ} 43^{\prime} \mathrm{W}$ | 300 w | N | $3 \mathrm{Pl}$ $(8 \mathrm{~lm})$ |
| - | $1186(7) 17^{\circ} 58.5^{\prime}$ N., $64^{\circ} 41^{\prime} \mathrm{W}$. | 600 w | $N$ | 1 (21) | - | 1356(2) | $29^{\circ} 56^{\prime}$ N., $59^{\circ} 33^{\prime} \mathrm{W}$. | 600 w | N | 1 (1×1 |
| - | 1188 (4) $17^{\circ} 43.7^{\prime} \mathrm{N} . .64^{\circ} 57^{\prime} \mathrm{W}$. | 300 w | N | 1 (11) | - | 1358(1) | $28^{\circ} 15^{\prime} \mathrm{N} ., 56^{\circ} 00^{\prime} \mathrm{W}$. | 7000 w | D | 1 (5): |
| - | 1189 (7) $17^{\circ} 58.5^{\prime} \mathrm{N} ., 64^{\circ}+1^{\prime} \mathrm{W}$. | 600 w | N | 3(24-25) | - | (6) | $28^{\circ} 15^{\prime} \mathrm{N} ., 56^{\circ} 00^{\prime} \mathrm{W}$. | 2000 w | D | $2(15)$ |
| - | 1198 (2) $17^{\circ} 43^{\prime} \mathrm{N} ., 64^{\circ} 56^{\prime} \mathrm{W}$. | 800 w | N | 1 (38) | - |  | $28^{\circ} 15^{\prime} \mathrm{N} ., 56^{\circ} 00^{\prime} \mathrm{W}$. | 600 w | N | 1 (5: |
| - | 1214 (1) $14^{\circ} 21^{\prime}$ N., $76^{\circ} 50^{\prime} \mathrm{W}$. | 1200 w | N | 2(38-62) | - | 1360 (2) | $26^{\circ} 56^{\prime} \mathrm{N} ., 53^{\circ} 09^{\prime} \mathrm{W}$. | 600 w | N |  |
| - | (4) $14^{\circ} 21^{\prime}$ N.. $76^{\circ} 50^{\prime} \mathrm{W}$. | 300w | N | 2(9-10) |  |  |  |  |  | $(6.12)$ |
| - | 1215 (2) $16^{\circ} 06^{\prime}$ N., $76^{\circ} 02^{\prime} \mathrm{W}$. | 1000 w | N | $1 \mathrm{PL}(8)$ | - | 1361 (1) | $27^{\circ} 07^{\prime} \mathrm{N} ., 51^{\circ} 10^{\prime} \mathrm{W}$. | 1000 w | N | 1 (61) |
| - | (4) $16^{\circ} 06^{\prime}$ N., $76^{\circ} 02^{\prime} \mathrm{W}$. | 300 w | N | 2(18-20) | - | 1362(1) | $28^{\circ} 57^{\prime} \mathrm{N} ., 47^{\circ} 24^{\prime} \mathrm{W}$ | 1000 w | N | 2(4) |
| - | 1216 (2) $18^{\circ} 22^{\prime} \mathrm{N} . .78^{\circ} 38^{\prime} \mathrm{W}$. | 600 w | N | 2(28-36) | - | 1365 (1) | $31^{\circ} 47^{\prime} \mathrm{N} ., 41^{\circ} 41^{\prime} \mathrm{W}$ | 1000 w | N | 1 (6\%) |
| - | (3) $18^{\circ} 22^{\prime} \mathrm{N} ., 78^{\circ} 38^{\prime} \mathrm{W}$. | 300 w | N | 5(16-18) | -- | (9) | $31^{\circ} 47^{\prime} N ., 41^{\circ} 41^{\prime} \mathrm{W}$ | 5000 w | D | 1 (5) |
|  | 1217 (4) $18^{\circ} 50^{\prime} \mathrm{N} .{ }^{\prime}, 79^{\circ} 07^{\prime} \mathrm{W}$. | 2500 w | D | 1 (40) | - | 3545 (4) | $14^{\circ} 37^{\prime} \mathrm{N} ., 61^{\circ} 17^{\prime} \mathrm{W}$. | 2000 w | N | $2(4236)$ |
| - | 1223(1) $22^{\circ} 06^{\prime}$ N., $84^{\circ} 58^{\prime} \mathrm{W}$. | 1000 w | N | 1 (31) | - | 4004 (1) | $10^{\circ} 21^{\prime}$ N., $17^{\circ} 59^{\prime} \mathrm{W}$. | 1000 w |  | 11 (1; i3) |
| - | (2) $22^{\circ} 06^{\prime} \mathrm{N}, 84^{\circ} 58^{\prime} \mathrm{W}$. | 600 w | N | 1 (13) | - | (2) | $10^{\circ} 21^{\prime} \mathrm{N} ., 17^{\circ} 59^{\prime} \mathrm{W}$ | 600 w |  | $13(1 ; 52)$ |
| - | (5) $22^{\circ} 06^{\prime}$ N., $84^{\circ} 58^{\prime} \mathrm{W}$. | 600 w | N | 3(38-59) | - |  | $10^{\circ} 21^{\prime} \mathrm{N} ., 17^{\circ} 59^{\prime} \mathrm{W}$ | 300 w |  | $40(1 \times 37)$ |
| - | 1225 (3) $23^{\circ} 58^{\prime}$ N., $83^{\circ} 22^{\prime} \mathrm{W}$. | 300 w | D) | $2(8-15)$ | - |  | $10^{\circ} 21^{\prime} \mathrm{N} ., 17^{\circ} 59^{\prime} \mathrm{W}$ | 50 w | D | 1(13: |
| - | 1228 (1) $23^{\circ} 35^{\prime}$ N., $81^{\circ} 54^{\prime} \mathrm{W}$. | 1000 w | N | 1 (30) | - | 4005 (4) | $13^{\circ} 31^{\prime}$ N., $18^{\circ} 03^{\prime} \mathrm{W}$. | 2500 w | D | $2(11-15)$ |
| - | (2) $23^{\circ} 35^{\prime} \mathrm{N} ., 81^{\circ} 54^{\prime} \mathrm{W}$. | 600 w | N | $2(13-42)$ | - |  | $13^{\circ} 31^{\prime} \mathrm{N} ., 18^{\circ} 03^{\prime} \mathrm{W}$. | 2000 w | D | $7(1123)$ |
| - | $1229(1) 23^{\circ} 13^{\prime} \mathrm{N} ., 82^{\circ} 21^{\prime} \mathrm{W}$. | 1000 w | N | 1 (62) | - | (7) | $13^{\circ} 31^{\prime} \mathrm{N} ., 18^{\circ} 03^{\prime} \mathrm{W}$. | 1000 w | N | $3(7 \cdots 5)$ |
| - | 1230 (6) $23^{\circ} 13^{\prime}$ N., $82^{\circ} 21^{\prime} \mathrm{W}$. | 1500 w | N | 2(14-29) | IFAN | 59-(199 |  |  |  |  |
| - | 1231 (1) $24^{\circ} 30^{\prime}$ N., $80^{\circ} 00^{\prime} \mathrm{W}$. | 1000 w | N | 1 (24) |  | -206) | $14^{\circ} 52^{\prime} \mathrm{N} ., 18^{\circ} 15^{\prime} \mathrm{W}$ | 700 | -• | $8(21-38)$ |
| - | 1239 (13) $25^{\circ} 50^{\prime}$ N., $76^{\circ} 55^{\prime} \mathrm{W}$. | 3000 w | D | $4(11-24)$ | - | 59-(207 |  |  |  |  |
| - | $1242(1) 24^{\circ} 05^{\prime} \times ., 74^{\circ} 36^{\prime} \mathrm{W}$. | 1000 w | N | 1 (44) |  | -9) | $15^{\circ} 57^{\prime}$ N., $20^{\circ} 39^{\prime} \mathbf{W}$. | 1000 | . | 3(21-31) |
| - | (2) $24^{\circ} 05^{\prime} N ., 74^{\circ} 36^{\prime} \mathrm{W}$. | 600 w | N | 1 (15) |  | 59-(211 |  |  |  |  |
| - | (3) $24^{\circ} 05^{\prime} \mathrm{N} .74^{\circ} 36^{\prime} \mathrm{W}$. | 300 w | N | 1 (16) |  | -13) | $15^{\circ} 25^{\prime} \mathrm{N} ., 18^{\circ} 40^{\prime} \mathrm{W}$. | 1000 | . | $3(14.36)$ |
| - | (14) $24^{\circ} 05^{\prime} \mathrm{N}, 74^{\circ} 36^{\prime} \mathrm{W}$. | 2500 w | D | $4(7-18)$ |  | 59-214 | $15^{\circ} 25^{\prime} \mathrm{N} ., 18^{\circ} 40^{\prime} \mathrm{W}$. | 1000 | . | 1 (45) |
| - | (15) $24^{\circ} 05^{\prime} \mathrm{N}, 74^{\circ} 36^{\prime} \mathrm{W}$. | 2000 w | D | 3(7-16) | - | 59-216 | $14^{\circ} 58^{\prime} \mathrm{N} ., 18^{\circ} 43^{\prime} \mathrm{W}$. | 2000 | . . | 1 (63) |
| -- | 1245 (2) $19^{\circ} 35^{\prime}$ N., 73 $3^{\circ} 27^{\prime} \mathrm{W}$. | 600 w | N | $2 \mathrm{PL} \cdot \mathrm{Yg}$ | MCZ | "Oregon" |  |  |  |  |
| $\cdots$ | (3) $19^{\circ} 35^{\prime}$ N., $73^{\circ} 27^{\prime} \mathrm{W}$. | 300 w | N |  | - S | t. 2576 34248 | 26 $6^{\circ} 33^{\prime}$ N., $\mathrm{N}^{\circ} 76^{\circ} 52^{\prime} \mathrm{W}$. | 1665 | . | 1(4) |
| - | 1253(3) $17^{\circ} 43^{\prime} \mathrm{N} ., 64^{\circ} 56^{\prime} \mathrm{W}$. | 300 w | N | 1 (9) | NYZS | 14721 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1463 | D | $1(19)$ |
| $\pm$ | 1261 (3) $19^{\circ} 04^{\prime}$ N., $65^{\circ} 43^{\prime} \mathrm{W}$. | 300 w | N | 6(12-22) | -- | 16856 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1280 | D | 1(12) |
| - | (8) $19^{\circ} 04^{\prime}$ N., $65^{\circ} 43^{\prime} \mathrm{W}$. | 3500 w | N | 1 (15) | SL' | 42215 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1829 | D | 1(12) |
| - | (10) $19^{\circ} 04^{\prime}$ N., $65^{\circ} 43^{\prime} \mathrm{W}$. | 2500 w | D | 1 (12) | - | 42216 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1463 | D | 1 (2.) |
| - | 1266 (3) $17^{\circ} 45^{\prime}$ N., $64^{\circ} 55.5^{\prime} \mathrm{W}$. | 600 w | N | $3 P L$ (6-7) | - | 42217 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1646 | D | 1 (11) |
| - | 1269 (1) $17^{\circ} 13^{\prime} \mathrm{N}, 6^{\circ} 4^{\circ} 58^{\prime} \mathrm{W}$. | 4500 w | DN | 1 (23) | - | 42218 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 914 | D | 1 (10. |
| - | $1279(4) 17^{\circ} 43^{\prime} \mathrm{N}, 64^{\circ} 56^{\prime} \mathrm{W}$. | 300 w | N | 1 (9) | - | 42219 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1097 | D | 1 (13) |
| - | 1280 (3) $17^{\circ} 43^{\prime} \times ., 64^{\circ} 56^{\prime} \mathrm{W}$. | 600 w | N | 4 PL (6) | - | 42220 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1280 | N | 1 (14) |
| - | 1283(10) $14^{\circ} 38^{\prime}$ N., $61^{\circ} 16^{\prime}$ W. | 2000 w | D | 1 (9) | - | 42221 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1280 | N | 1 (13, |
| - | 1292(3) $17^{\circ} 43^{\prime}$ N., $64^{\circ} 56^{\prime} \mathrm{W}$ (4). | 600 w | N | 1 (10) | - | 42222 | $32^{\circ} 12^{\prime} \mathrm{N} ., 64^{\circ} 36^{\prime} \mathrm{W}$. | 1097 | D | 1 (22) |
| - | (4) $17^{\circ} 43^{\prime}$ N., $64^{\circ} 56^{\prime} \mathrm{W}$. | 300 w | N | 2 PL (3-6) | - | 42223 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1280 | D | 1 (26) |
| - | 1293(3) $17^{\circ} 43^{\prime} \mathrm{N} ., 64^{\circ} 56^{\prime} \mathrm{W}$. | 600 w | N | 2 PL (4) | - | 42224 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1463 | D | 1 (21) |
| - | 1294 (5) $17^{\circ} 43^{\prime} \mathrm{N} ., 64^{\circ} 56^{\prime} \mathrm{W}$. | 100 w | N | $1 \mathrm{PL}(4)$ | - | 42225 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1097 | D | 1 (10) |
| - | 1296(4) $17^{\circ} 43^{\prime} \mathrm{N} ., 64^{\circ} 56^{\prime} \mathrm{W}$. | 300 w | N | 1 (10) | - | 42226 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36$ : W. | 1463 | D | 1 (12) |
| - | 1314(5) $17^{\circ} 43^{\prime} \mathrm{N} ., 64^{\circ} 56^{\prime} \mathrm{W}$. | 100 w | N | 1 PL (5) | - | 42227 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1463 | D | 1 (9) |
| - | 1320 (1) $23^{\circ} 18^{\prime}$ N., $56^{\circ} 58^{\prime} \mathrm{W}$. | 1000 w | N | 2 (25) | - | 42228 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 914 | D | 1 (9) |
| -- | (2) $23^{\circ} 18^{\prime} \mathrm{N} ., 56^{\circ} 58^{\prime} \mathrm{W}$. | 800 w | N | 3(8-22) | - | 42229 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1280 | D | 1 (24) |
| - | (3) $23^{\circ} 18^{\prime}$ N., $56^{\circ} 58^{\prime} \mathrm{W}$. | 600 w | N | 3(19-24) | - | 42230 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1280 | D | 1 (2). |
| - | 1322(1) $27^{2} 122^{\prime}$ N., $53^{\circ} 39^{\prime}$ W. | 1000 w | N | 1 (24) | - | 42231 | $32^{\circ} 12^{\prime}$ N. $64^{\circ} 36^{\prime} \mathrm{W}$. | 914 | D | 1 (10): |
| - | (4) $27^{\circ} 02^{\prime}$ N., $53^{\circ} 39^{\prime} \mathrm{W}$. | 300 w | N | 10(16-32) | - | 42232 | $32^{\circ} 12^{\prime} \mathrm{N} ., 64^{\circ} 36^{\prime} \mathrm{W}$. | 1463 | D | 1 (10): |
| - | (9) $27^{\circ} 112^{\prime}$ N., $53^{\circ} 39^{\prime} \mathrm{W}$. | 400 w | N | $15 \mathrm{PL}-\mathrm{Yg}$ | - | 42233 42234 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. $32^{\circ} 12^{\prime} \mathrm{N} ., 64^{\circ} 36^{\prime} \mathrm{W}$. | 1646 | D | $1(15$ $1(25)$ |
| - | (12) $27^{\circ} 02^{\prime}$ N., $53^{\circ} 39^{\prime} \mathrm{W}$. | 2300w | N | 1 (18) | - | 42235 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1463 | D | 1 (35) |
| - | (15) $27^{\circ} 02^{\prime}$ N., $53^{\circ} 39^{\prime} \mathrm{W}$. | 1300 w | N | 1 (22) | - | 42236 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1463 | D | 2 (19-21) |
| - | (24) $27^{\circ} 02^{\prime}$ N., $53^{\circ} 39^{\prime} \mathrm{W}$. | 2000 w | D | 1 (57) | - | 42237 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1463 | N | 1 (25) |
| - | (25) $27^{\circ} 02^{\prime}$ N., $53^{\circ} 39^{\prime} \mathrm{W}$. | 700 w | N | $2(16-19)$ | - | 42238 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1097 | D | 1 (18) |
| - | (27) $27^{\circ} 02^{\prime}$ N.. $53^{\circ} 39^{\prime} \mathrm{W}$. | 400w | N | 1 (16) | -- | 42239 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1097 | D | 1 (20! |
| - | (30) $27^{\circ} 022^{\prime} \mathrm{N}, 53^{\circ} 39^{\prime} \mathrm{W}$. | 1100 w | N | 1 (25) | - | 42240 | $32^{\circ} 12^{\prime} \mathrm{N} ., 64^{\circ} 36^{\prime} \mathrm{W}$. | 1097 | D | 1 (9) |
| - | 1323(1) $27^{\circ} 17^{\prime} \times ., 54^{\circ} 35^{\prime} \mathrm{W}$. | 700 w | D | 1 PL (7) | - | 42241 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1280 | D | 1 (11) |
| - | (7) $27^{2} 17^{\prime} \times . .54^{\circ} 35^{\prime} \mathrm{W}$. | 700 w | N | 1 (16) | - | 42242 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 914 | D | 2(11-14) |
| - | (14) $27^{\circ} 17^{\prime}$ N., $54^{\circ} 35^{\prime} \mathrm{W}$. | 700 w | N | 1 (22) | - | 42243 | $32^{\circ} 12^{\prime} \mathrm{N} ., 64^{\circ} 36^{\prime} \mathrm{W}$. | 914 | D | 1(14) |
| - ${ }^{\text {- }}$ | 1326 (4) $27^{\circ} 14^{\prime} \mathrm{N}, ., 51^{\circ} 25^{\prime} \mathrm{W}$. | 200w | N | 1 PL, (8) | - | 42244 | $32^{\circ} 12^{\prime} \mathrm{N} ., 64^{\circ} 36^{\prime} \mathrm{W}$. | 549 | D | $1(1+1)$ |
| -- | 1327 (1) $27^{\circ} 34^{\prime} \mathrm{N} ., 51^{\circ} 47^{\prime} \mathrm{W}$. | 1100 w | N | 1 (34) | - | 42245 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 732 | D | 1 (8) |
| - | 1328 (6) $27^{\circ} 05^{\prime} \mathrm{N} ., 52^{c} 11^{\prime} \mathrm{W}$. | 1100 w | N | 2(22-51) | - | 42246 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 732 | D | 1 (8) |
| - | (9) $27^{c} 05^{\prime} \mathrm{N}, 52^{\circ} 11^{\prime} \mathrm{W}$. | 800 w | N | $1(17)$ | - | 42247 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime}$ W. | 914 | D | 2 (22-2i) |
| - | 1329(1) $26^{\circ} 37^{\prime} \mathrm{N} ., 53^{\circ} 22^{\prime} \mathrm{W}$. | 700 w | D | $1 \mathrm{PL}(6)$ | - | 42248 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1280 | D | 1 (12) |
| $\cdots$ | 1330(1) $26^{\circ} 37^{\prime} \mathrm{N}, 54^{\circ} 45^{\prime} \mathrm{W}$. | 1000w | N | 1 (22) | -- | 42249 | $32^{\circ} 12^{\prime} \mathrm{N}, 64^{\circ} 36^{\prime} \mathrm{W}$. | 1829 | D | 1(40) |
| - | (3) $26^{c} 37 \prime N ., 54^{\circ} 45^{\prime} \mathrm{W}$. | 600 w | N | 1 (13) | -- | 42250 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1646 | N | $1(32)$ |
| -- | 1332 (7) $26^{\circ} 58^{\prime} \mathrm{N} ., 56^{\circ} 58^{\prime} \mathrm{W}$. | 700 w | N | 4(25-58) | .. | 42251 | $32^{\circ} 12^{\prime} \mathrm{N} ., 64^{\circ} 36^{\prime} \mathrm{W}$. | 1829 | D | 1 (24) |
| - | (14) $26^{\circ} 58^{\prime}$ N., $56^{\circ} 58^{\prime} \mathrm{W}$. | 600 w | N | 1 (10) | - | 42252 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1280 | D | $1(13)$ |
| - | 1334 (2) $27^{\circ} 28^{\prime}$ N., $59^{\circ} 29^{\prime} \mathrm{W}$. | 600 w | N | 2 (8) | - | 42253 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1646 | D | 1 (4.4) |
| - | 1339 (3) $30^{\circ} 00^{\prime}$ N., $54^{\circ} 38^{\prime} \mathrm{W}$. | 300 w | N | 1 PL (4) | - | 42254 | $32^{\circ} 12^{\prime} \mathrm{N} ., 64^{\circ} 36^{\prime} \mathrm{W}$. | 1829 | N | 1 (20) |


| $\begin{aligned} & \text { In- } \\ & \text { sti- } \\ & \text { thtion } \end{aligned}$ | Catalog no. | Locality | Depth | Time | Specimens |
| :---: | :---: | :---: | :---: | :---: | :---: |
| S | 42255 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1097 | D | 1 (44) |
| -- | 42256 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 732 | D | 1 PL (6) |
| . | 12257 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1829 | D | 1 (50) |
| - | 42258 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 914 | D | 1 (10) |
|  | 42259 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1829 | D | 1 (39) |
|  | 42260 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 914 | D | 1 (30) |
|  | 12261 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1097 | D | 1 (29) |
| - | 12262 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1280 | D | 1 (10) |
| - | 42263 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1097 | D | 1 (43) |
| - | 42354 | $32^{\circ} 12^{\prime}$ N., $64^{\circ} 36^{\prime} \mathrm{W}$. | 1829 | D | 1 (14) |
| - | 46356 | $30^{\circ} 01^{\prime} \mathrm{N}, \mathrm{E}^{6} 0^{\circ} 03^{\prime} \mathrm{W}$. | . . |  | 1 (59) |
| WI: 1 | I Atl.-1052 | $37^{\circ} \mathrm{N},{ }^{5} 57^{\circ} \mathrm{W}$. |  | $\cdots$ | 1 (16) |
| - P | RHB.-451 | $39^{\circ} 45^{\prime} \mathrm{N} ., 71^{\circ} 08^{\prime} \mathrm{W}$. | 70 | N | 1 (24) |
| F | RHB.-572 | $20^{\circ} 17^{\prime} \mathrm{N} ., 60^{\circ} 02^{\prime} \mathrm{W}$. | 800 | N |  |
| I | RHB.-588 | $26^{\circ} 18^{\prime}$ N., $76^{\circ} 05^{\prime} \mathrm{W}$. | 800 | N | 7 |
| . Whatic, south of $10^{\circ} \mathrm{N}$ (mostly Area B of Table V): |  |  |  |  |  |
| Bri\%: | 2696 | $2^{\circ} 43.5^{\prime} \mathrm{N} ., 0^{\circ} 56.5^{\prime} \mathrm{W}$. | 175 |  | 1 (45) |
| MW. | $\begin{gathered} \text { H 1930.1.12. } \\ 1027-8 \end{gathered}$ | $5^{\circ} 54^{\prime}$ S., $11^{\circ} 19^{\prime}$ E. | 150 |  | $2(26-30)$ |
| - | $\begin{aligned} & \text { 1930.1.12. } \\ & 1029 \end{aligned}$ | $0^{\circ} 46^{\prime} \mathrm{S},{ }^{\prime} 5^{\circ} 49^{\prime} \mathrm{E}$. | $850-950$ |  | 1 (18) |
| - | $\begin{aligned} & 1930.1 .12 . \\ & 1030 \end{aligned}$ | $0^{\circ} 56^{\prime} \mathrm{S} ., 14^{\circ} 09^{\prime} \mathrm{W}$. | 100 |  | 1 (12) |
| - | $\begin{aligned} & 1930.1 .12 . \\ & 1031-40 \end{aligned}$ | $0^{\circ} 56^{\prime} \mathrm{S} ., 14^{\circ} 08^{\prime} \mathrm{W}$. | 250 |  | $28(15-63)$ |
| - | $\begin{aligned} & 1930.1 .12 . \\ & 1041-46 \end{aligned}$ | $2^{\circ} 44^{\prime} \mathrm{S} ., 0^{\circ} 57^{\prime} \mathrm{W}$. | 125-175 |  | 6(20-48) |
| CXI) | (uncat.) | $15^{\circ} 52^{\prime} \mathrm{S} ., 6^{\circ} 02^{\prime} \mathrm{W}$. |  |  | 8(32-38) |
| $\stackrel{\square}{\text { F }}$ | 1171 (4) | $8^{\circ} 19^{\prime}$ N., $44^{\circ} 35^{\prime} \mathrm{W}$. | 300 w | N | 4 PL(12) |
| - | (12) | $8^{\circ} 19^{\prime}$ N., $44^{\circ} 35^{\prime} \mathrm{W}$. | 2000 w | D | 1 (15) |
| - | 3981 (1) | $19^{\circ} 16^{\prime} \mathrm{S} ., 1^{\circ} 48^{\prime} \mathrm{W}$. | 1000 w | N | 2(19-52) |
| - | 3996 (6) | $15^{\circ} 41^{\prime} \mathrm{S} ., \quad 5^{\circ} 50^{\prime} \mathrm{W}$ | 1000 w | N | 3(45-73) |
| - | 3997 (2) | $11^{\circ} 00^{\prime}$ S., $7^{\circ} 36^{\prime} \mathrm{W}$. | 600 w | N | 5(8-56) |
| - | 3998 (1) | $7^{\circ} 34^{\prime} \mathrm{S} ., 8^{\circ} 48^{\prime} \mathrm{W}$. | 1000 w | N | 3(28-44) |
| -- | (2) | $7^{\circ} 34^{\prime}$ S., $8^{\circ} 48^{\prime} \mathrm{W}$. | 600 w | N | 6(8-47) |
| - | (3) | $7^{\circ} 34^{\prime}$ S., $8^{\circ} 48^{\prime}$ W. | 300 w | N | $10(8-25)$ |
| - | 3999 (1) | $3^{\circ} 45^{\prime}$ S., $10^{\circ} 00^{\prime} \mathrm{W}$. | 1000 w | N | 12(14-84) |
| - | (2) | $3^{\circ} 45^{\prime} \mathrm{S} ., 10^{\circ} 00^{\prime} \mathrm{W}$. | 600 w | N | $57 \mathrm{PL}-\mathrm{HG}$ |
| - | (3) | $3^{\circ} 45^{\prime} \mathrm{S} ., 10^{\circ} 00^{\prime} \mathrm{W}$. | 300 w | N | $\begin{gathered} 31 \text { PL-Yg } \\ (4-14) \end{gathered}$ |
| - | 4000 (1) | $0^{\circ} 31^{\prime} \mathrm{S} ., 11^{\circ} 02^{\prime} \mathrm{W}$. | 1000 w | N | $8(20-68)$ |
| - | (2) | $0^{\circ} 31^{\prime} \mathrm{S} ., 11^{\circ} 02^{\prime} \mathrm{W}$. | 600 w | N | $\begin{array}{r} 9 \mathrm{PL}-\mathrm{Yg} \\ (13-28) \end{array}$ |
| - | (3) | $0^{\circ} 31^{\prime} \mathrm{S} ., 11^{\circ} 02^{\prime} \mathrm{W}$. | 300 w |  | 26(9-12) |
| - | (6) | $0^{\circ} 31^{\prime} \mathrm{S} ., 11^{\circ} 02^{\prime} \mathrm{W}$. | 6000 w | ND | $2(30-47)$ |
| - | 4001 (1) | $3^{\circ} 56^{\prime} \mathrm{N} ., 12^{\circ} 32.5^{\prime} \mathrm{W}$. | 1000 w | N | $9(16-82)$ |
| - | (2) | $3^{\circ} 56^{\prime}$ N., $12^{\circ} 32.5^{\prime} \mathrm{W}$. | 600 T | N | 10(18-34) |
| - | (3) | $3^{\circ} 56^{\prime}$ N., $12^{\circ} 32.5^{\prime} \mathrm{W}$. | 300w | N | $\begin{gathered} 17 \text { PL -HG } \\ (10-30) \end{gathered}$ |
| - | 4003(1) | $8^{\circ} 26^{\prime}$ N., $15^{\circ} 11^{\prime} \mathrm{W}$. | 6000 w | D | 3(21-50) |
| - | (5) | $8^{\circ} 26^{\prime} \mathrm{N},{ }^{\prime} 15^{\circ} 11^{\prime} \mathrm{W}$. | 2000w | D | 1 (46) |
| - | (7) | $8^{\circ} 26^{\prime}$ N., $15^{\circ} 11^{\prime} \mathrm{W}$. | 1000 w | N | 18(12-71) |
| - | (8) | $8^{\circ} 26^{\prime}$ N., $15^{\circ} 11^{\prime} \mathrm{W}$. | 600 w | N | 2(7) |
| - | (9) | $8^{\circ} 26^{\prime}$ N., $15^{\circ} 11^{\prime} \mathrm{W}$. | 300 w | N | 7 PL $(5-8)$ |
| G | 66 | $4^{\circ} 00^{\prime}$ S., $10^{c} 25^{\prime} \mathrm{E}$. | 4120 | 1) | 1 (42) |
| $15 \times M$ | 89252 | $2^{\circ} 43^{\prime}$ S., $0^{\circ} 56^{\prime} \mathrm{W}$. | 125-175 |  | $2(41-44)$ |

Trepical Indian Ocean, between $40^{\circ}$ and $100^{\circ} \mathrm{E}$ (part of Area C, Tathe V):
BKNH 1939.5.24

| 821 | Arabian Sea | 3385 | $\ldots$ | $1(37)$ |
| ---: | :--- | ---: | :--- | :--- |
| $3850(1)$ | $6^{\circ} 01^{\prime} \mathrm{S} ., 93^{\circ} 12^{\prime} \mathrm{E}$. | 600 w | N | $3 \mathrm{PL}(4-6)$ |
| $3860(20)$ | $2^{\circ} 57^{\prime} \mathrm{S} ., 99^{\circ} 36^{\prime} \mathrm{E}$. | 600 w | N | $1(12)$ |
| $3904(1)$ | $5^{\circ} 18^{\prime} \mathrm{N} ., 90^{\circ} 55^{\prime} \mathrm{E}$. | 3500 w | D | $4(28-34)$ |
| $3906(3)$ | $4^{\circ} 26.5^{\prime} \mathrm{N} ., 85^{\circ} 21^{\prime} \mathrm{E}$. | 400 w | N | $1(49)$ |
| $3909(4)$ | $5^{\circ} 21^{\prime} \mathrm{N}, 80^{\circ} 38^{\prime} \mathrm{E}$. | 3000 w | N | $2(15-24)$ |
| $3912(1)$ | $6^{\circ} 52^{\prime} \mathrm{N} ., 79^{\circ} 30^{\prime} \mathrm{E}$. | 1000 w | N | $1(86)$ |
| $(2)$ | $6^{\circ} 52^{\prime} \mathrm{N} ., 79^{\circ} 30^{\prime} \mathrm{E}$. | 600 w | N | $2(14-19)$ |
| $3913(1)$ | $6^{\circ} 36^{\prime} \mathrm{N} ., 79^{\circ} 06^{\prime} \mathrm{E}$. | 1000 w | N | $1(83)$ |
| $(2)$ | $6^{\circ} 36^{\prime} \mathrm{N} ., 79^{\circ} 06^{\prime} \mathrm{E}$. | 600 w | N | $1(10)$ |
| $(3)$ | $6^{\circ} 36^{\prime} \mathrm{N} ., 79^{\circ} 06^{\prime} \mathrm{E}$. | 300 w | N | $12(9-19)$ |
| $3914(3)$ | $4^{\circ} 52^{\prime} \mathrm{N} ., 77^{\circ} 08^{\prime} \mathrm{E}$. | 300 w | N | $13 \mathrm{PL}-\mathrm{Yg}$ |

(6-15)

| In-stitution | Catalog no. | Locality | Depth | Time | Specimens |
| :---: | :---: | :---: | :---: | :---: | :---: |
| D | 3915 (2) | $3^{\circ} 14^{\prime}$ N., $75^{\circ} 21^{\prime} \mathrm{E}$. | 600 w | N | 1 PL (6) |
| - | 3916(1) | $1^{\circ} 45^{\prime}$ N., $73^{\circ} 03^{\prime} \mathrm{E}$. | 1000 w | $N$ | 1(18) |
| - | (3) | $1^{\circ} 45^{\prime}$ N., $73^{\circ} 03^{\prime} \mathrm{E}$. | 300 w | N | $3(10-16)$ |
| - | 3917(5) | $1^{\circ} 45^{\prime}$ N., $71^{\circ} 05^{\prime} \mathrm{E}$. | 1200 w | DN | 5(14-21) |
| - | (6) | $1^{\circ} 45^{\prime}$ N., $71^{\circ} 05^{\prime} \mathrm{E}$. | 1000 w | N | 2(59-92) |
| - | (7) | $1^{\circ} 45^{\prime}$ N., $71^{\circ} 05^{\prime} \mathrm{E}$. | 600 w | N | 1 (61) |
| - | 3918(3) | $0^{\circ} 35^{\prime}$ N., $66^{\circ} 09^{\prime}$ E. | 300 w | N | 3 PL (3-4) |
| - | 3919 (2) | $0^{\circ} 07^{\prime}$ S., $63^{\circ} 56^{\prime}$ E. | 600w | N | $2 \mathrm{PL}(8)$ |
| - | (3) | $0^{\circ} 07^{\prime}$ S., $63^{\circ} 56^{\prime} \mathrm{E}$. | 300 w | N | $2 \mathrm{PL}(4-6)$ |
| - | 3920 (5) | $1^{\circ} 06^{\prime} \mathrm{S} ., 6^{\circ} 25^{\prime} \mathrm{E}$. | 2000 w | ND | $\begin{gathered} 2 \mathrm{PL}-\mathrm{Yg} \\ (8-26) \end{gathered}$ |
| - | (8) | $1^{\circ} 12^{\prime} \mathrm{S} .,{ }^{\text {6 }} 62^{\circ} 19^{\prime} \mathrm{E}$. | 300 w | N | $\begin{gathered} 4 \text { PI-Yg } \\ (4-11) \end{gathered}$ |
| - | 3922(1) | $3^{\circ} 45^{\prime}$ S., $56^{\circ} 33^{\prime}$ E. | 1000 w | N | 1 (91) |
| - | 3924 (1) | $5^{\circ} 01^{\prime} \mathrm{S} ., 54^{\circ} 46^{\prime} \mathrm{E}$. | 1000 w | N | 2(35-44) |
| - | 3933 (3) | $11^{\circ} 18^{\prime} \mathrm{S} ., 50^{\circ} 03^{\prime} \mathrm{E}$. | 3000 w | D | 1 (9) |
| - | 3941 (2) | $7^{\circ} 24^{\prime} \mathrm{S} ., 41^{\circ} 51^{\prime} \mathrm{E}$. | 400 w | N | 1 PL (5) |
| - | 3956(2) | $21^{\circ} 13^{\prime} \mathrm{S} ., 4^{\circ} 26^{\prime} \mathrm{E}$. | 300 w | N | $1 \mathrm{PL}(6)$ |
| G | 234 | $5^{\circ} 25^{\prime}$ S., $47^{\circ} 09^{\prime} \mathrm{E}$. | 4940 | D | $4(43-94)$ |
| - | 263 | $4^{\circ} 14^{\prime} \mathrm{S} ., 44^{\circ} 52^{\prime} \mathrm{E}$. | 4770 | D | 2(37-44) |
| - | 314 | $15^{\circ} 54^{\prime}$ N., $90^{\circ} 17^{\prime} \mathrm{E}$. | 2610 | N | 1 (41) |
| - | 316 | $12^{\circ} 43^{\prime}$ N., $91^{\circ} 17^{\prime}$ E. | 1800-3230 | D | 4 (36-92) |
| S 10 | 61-33 | $10^{\circ} 39^{\prime}$ S., $98^{\circ} 51^{\prime} \mathrm{E}$. | 1408 | N | 1 (29) |
| - | 61-34 | $18^{\circ} 49^{\prime} \mathrm{S} ., 88^{\circ} 05^{\prime} \mathrm{E}$. | 1643 | N | 1(67) |

Indo-west Pacific, between $105^{\circ}$ and $140^{\circ} \mathrm{E}$ (part of Area C, Table V):

| D | 3676(6) | $5^{\circ} 52^{\prime}$ S., $131^{\circ} 14^{\prime} \mathrm{E}$. | 6000 w | N | 2(16-38) |
| :---: | :---: | :---: | :---: | :---: | :---: |
| - | (7) | $5^{\circ} 52^{\prime}$ S., $131^{\circ} 14^{\prime} \mathrm{E}$. | 5000 w | D | 1 (30) |
| - | 3677(3) | $5^{\circ} 28^{\prime}$ S., $130^{\circ} 39^{\prime}$ E. | 3000 w | D | $1 \mathrm{PL}(+)$ |
| - | 3683 (4) | $4^{\circ} 03^{\prime}$ N., $123{ }^{\circ} 26^{\prime} \mathrm{E}$. | 2000 w | D | 4(5-9) |
| - | (8) | $4^{\circ} 08^{\prime}$ Ṅ., $123{ }^{\circ} 00^{\prime} \mathrm{E}$. | 300 w | D | 1 (9) |
| - | 3685(2) | $7^{\circ} 22^{\prime}$ N., $121^{\circ} 16^{\prime} \mathrm{E}$. | 600 w | D | $3(11-26)$ |
| - | (3) | $7^{\circ} 22^{\prime}$ N., $121^{\circ} 16^{\prime} \mathrm{E}$. | 300 w | N | 3(9-15) |
| - | (9) | $7^{\circ} 22^{\prime}$ N., $121^{\circ} 16^{\prime} \mathrm{E}$. | 2000 w | D | 3(13-30) |
| - | 3686 (3) | $8^{\circ} 34^{\prime}$ N., $119^{\circ} 55^{\prime} \mathrm{E}$. | 300 w | N | 1 (13) |
| - | (6) | $8^{\circ} 34^{\prime}$ N., $119^{\circ} 55^{\prime} \mathrm{E}$. | 4000 w | D | 1 (56) |
| - | 3687 (2) | $7^{\circ} 14^{\prime}$ N., $115^{\circ} 23^{\prime} \mathrm{E}$. | 600 w | D | $\begin{gathered} 6 \text { PL-Yg } \\ (9-20) \end{gathered}$ |
| - | 3688(3) | $6^{\circ} 55^{\prime}$ N., $114^{\circ} 02^{\prime} \mathrm{E}$. | 3000 w | D | 3(12-35) |
| - | (4) | $6^{\circ} 55^{\prime}$ N., $114^{\circ} 02^{\prime} \mathrm{E}$. | 2000w | D | 3(13-24) |
| - | (5) | $6^{\circ} 55^{\prime}$ N., $114^{\circ} 02^{\prime} \mathrm{E}$. | 1000 w | D | $2(8-15)$ |
| - | 3689 (1) | $7^{\circ} 13.5^{\prime}$ N., $111^{\circ} 49^{\prime}$ E. | 3000 w | D | 1 (43) |
| - | (4) | $7^{\circ} 13.5^{\prime}$ N., $111^{\circ} 49^{\prime}$ E. | 1500 w | D | 1 (11) |
| - | (8) | $7^{\circ} 13.5^{\prime}$ N., $111^{\circ} 49^{\prime} \mathrm{E}$. | 300 w | N | 3(15-18) |
| - | (11) | $7^{\circ} 13.5^{\prime}$ N., $111^{\circ} 49^{\prime}$ E. | 1500 w | N | 1 (63) |
| - | 3713(1) | $13^{\circ} 7^{\prime} N ., 112^{\circ} 45^{\prime} \mathrm{E}$. | 1000w | N | 1 (80) |
| - | 3714 (1) | $15^{\circ} 22^{\prime}$ N., $115^{\circ} 20^{\prime} \mathrm{E}$. | 1000 w | N | $2(26-50)$ |
| - | 3731 (1) | $14^{\circ} 37^{\prime} \mathrm{N} ., 119^{\circ} 52^{\prime} \mathrm{E}$. | 1000 w | N | 1 ( + ) |
| - | (6) | $14^{\circ} 37^{\prime} \mathrm{N} ., 119^{\circ} 52^{\prime} \mathrm{E}$ | 1000 w | N | 4(19-44) |
| - | (10) | $14^{\circ} 37^{\prime}$ N., $119^{\circ} 52^{\prime} \mathrm{E}$. | 4000 w | D | 2(41-56) |
| - | 3736(4) | $9^{\circ} 17^{\prime}$ N., $123^{\circ} 58^{\prime} \mathrm{E}$. | 1000 w | DN | $1 \mathrm{PL}(7)$ |
| - | (7) | $9^{\circ} 17^{\prime}$ N., $123^{\circ} 58^{\prime} \mathrm{E}$. | 300 w | N | 1 (10) |
| - | 3746(2) | $3^{\circ} 50^{\prime}$ N., $131^{\circ} 42^{\prime}$ E. | 600 w | N | 2(30-37) |
| - | 3751 (7) | $3^{\circ} 40.5^{\prime}$ N., $137^{\circ} 53^{\prime} \mathrm{E}$. | 3000 w | D | 2(+) |
| $\rightarrow$ | 3752 (2) | $2^{\circ} 10^{\prime}$ N., $138^{\circ} 20^{\prime} \mathrm{E}$. | 600 w | N | 1 (57) |
| - | 3768 (1) | $1^{\circ} 20^{\prime}$ S., $138^{\circ} 42^{\prime}$ E. | 4000 w | D | 2(38-52) |
| - | (3) | $1^{\circ} 20^{\prime} \mathrm{S} ., 138^{\circ} 42^{\prime} \mathrm{E}$. | 3000 w | D) | 2(64-66) |
| - | 3804 (3) | $9^{\circ} 09^{\prime} \mathrm{S} ., 114^{\circ} 47^{\prime} \mathrm{E}$. | 300w | N | $\begin{gathered} 15 \mathrm{PL}-\mathrm{Yg} \\ (6-13) \end{gathered}$ |
| - | 3809(1) | $6^{\circ} 22^{\prime}$ S., $105^{\circ} 12^{\prime} \mathrm{E}$. | 600 w | D | $1(15)$ |
| G | 444 | $7^{\circ} 54^{\prime}$ N., $121^{\circ} 30^{\prime}$ E. | 5200 | N | 1 (51) |
| - | 472 | $10^{\circ} 24^{\prime}$ S., $114^{\circ} 07^{\prime} \mathrm{E}$. | 2535 | D | 1 (53) |
| $V$ | 3750 | $20^{\circ} 04^{\prime}$ N., $126^{\circ} 58^{\prime} \mathrm{E}$. | 1000 | . | 1 (52) |

Tropical central Pacific, between $160^{\circ} \mathrm{E}$ and $130^{\circ} \mathrm{W}$ (part of Area C, Table V):

|  |  |  |  |  |  |  |  |
| :--- | :---: | :---: | :--- | :--- | :--- | :--- | :--- |
| D | $3563(1)$ | $7^{\circ} 455^{\prime}$ | S., | $131^{\circ} 22^{\prime}$ | W. | 1000 w | N |


|  | Catalog no. | Locality | Depth | Time | Specimens |
| :---: | :---: | :---: | :---: | :---: | :---: |
| V | 3802 | $3^{\circ} 19^{\prime}$ N., $173^{\circ} 14^{\prime}$ W. | 4100 |  | 1 (70) |
| - | 3869 | $9^{\circ} 23^{\prime}$ N., $173{ }^{\circ} 35^{\prime} \mathrm{E}$. | 1000 |  | 1 (29) |
| - | 3871 | $12^{\circ} 23^{\prime}$ N., $173^{\circ} 19^{\prime} \mathrm{E}$. | 1000 |  | 1 (33) |
| - | 3879 | $25^{\circ} 56^{\prime}$ N., $171^{\circ} 14^{\prime}$ E. | 1000 |  | 1 (51) |

## Morphological intermediates between

Scopelogadus m. mizolepis and S. m. bispinosus.
(This category excludes records of specimens that were intermediate in one or more characters, hut that on the basis of ali characters were most similar to one or the other subspecies. These records are included with each subspecies).

| Tropical central and equatorial Pacific: |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| D | 3558 (1) | $0^{\circ} 18^{\prime} \mathrm{S} ., 99^{\circ} 07^{\prime} \mathrm{W}$. | 4000 w | D | 7 (35-98) |
| - | (5) | $0^{\circ} 18^{\prime}$ S., $99^{\circ} 07^{\prime} \mathrm{W}$. | 1000 w | N | $2(56-58)$ |
| POFI | 1823 | $23^{\circ} 38^{\prime}$ ․, $161^{\circ} 20^{\prime} \mathrm{W}$. |  | N | 3(22-45) |
| SIO | 52-409 | $1^{\circ} 1.5^{\prime}$ N., $91^{\circ} 46^{\prime} \mathrm{W}$. | 1090 | N | $24(50-84)$ |
| - | 60-245 | $12^{\circ} 07^{\prime}$ N., $148^{\circ} 35^{\prime} \mathrm{W}$. | 2100 | N | 3(18-51) |
| - | 60-249 | $17^{\circ} 09^{\prime} \mathrm{N} ., 153^{\circ} 57^{\prime} \mathrm{W}$. | 2100 | DN | 1 (42) |
| - | 60-278 | $25^{\circ} 21^{\prime}$ N., $144^{\circ} 45^{\prime} \mathrm{W}$. | 3000 | N | $2(22-39)$ |
| - | 60-284 | $29^{\circ} 01^{\prime}$ N., $132^{\circ} 09^{\prime} \mathrm{W}$. | 3000 | DN | 1 (51) |
| UW | 14542 | $36^{\circ} 44^{\prime}$ N., $130^{\circ} 51^{\prime} \mathrm{W}$. | 800w | N | 1 (75) |

Scopelogadus mizolepis bispinosus.

| Eastern North Pacific, north of $20^{\circ} \mathrm{N}$ (Area D of Table V): |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| AMNH | 12815 | $27^{\circ} 39^{\prime} 15^{\prime \prime}$ N., $115^{\circ} 16^{\prime}$ W. | 874 |  | 1 (66) |
|  | 12816 | $27^{\circ} 38^{\prime} 45^{\prime \prime} \mathrm{N}, 115^{\circ} 1 \bar{z}^{\prime} 40^{\prime \prime} \mathrm{W}$. | 956 |  | 1 (71) |
|  | 12817 | $33^{\circ} 13.5^{\prime}$ N., $120^{\circ} 04.5^{\prime} \mathrm{W}$. | 921 |  | 1 (76) |
|  | 12819 | $25^{\circ} 23^{\prime} 45^{\prime \prime}$ N., $113^{\circ} 16^{\prime} \mathrm{W}$. | 1338 |  | 1 (74) |
|  | 12820 | $31^{\circ} 08.2^{\prime}$ N., $118^{\circ} 29.5^{\prime} \mathrm{W}$. | 1462 |  | 1 (66) |
| - | 12912 | $33^{\circ} 33^{\prime} \mathrm{N} ., 120^{\circ} 17.5^{\prime} \mathrm{W}$. | 961 |  | 1 (65) |
| BOC | 2700 | $24^{\circ} 07^{\prime}$ N., $108^{\circ} 40^{\prime} \mathrm{W}$. |  |  | 10(41-55) |
|  | 2701 | $20^{\circ} 48^{\prime} 15^{\prime \prime} \mathrm{N} ., 106^{\circ} 11^{\prime} 50^{\prime \prime}$ | 972 w |  | 2(53-58) |
| NYZS | 24798 | $22^{\circ} 44^{\prime}$ N., $110^{\circ} 08^{\prime} \mathrm{W}$. | 1000 | D | 1 (28) |
| $-$ | 25454 | $23^{\circ} 25^{\prime}$ N., $108^{\circ} 31^{\prime} \mathrm{W}$. | 732 | D | 3(16-1 |
|  | 25455 | $23^{\circ} 25^{\prime} \mathrm{N} ., 108^{\circ} 31^{\prime} \mathrm{W}$. | 914 |  | 4(14-18) |
| - | 25460 | $23^{\circ} 27^{\prime}$ N., 108 $8^{\circ} 49^{\prime} \mathrm{W}$. | 914 | D | 2(36) |
|  | 25476 | $23^{\circ} 27^{\prime}$ N., $108^{\circ} 49^{\prime} \mathrm{W}$. | 732 |  | 1 (50) |
| SIO | 50-269 | $32^{\circ} 30.5^{\prime} \mathrm{N} .1117^{\circ} 27.5^{\prime} \mathrm{W}$ | 750 | D | 4 (53-69) |
| - | 51-75 | $29^{\circ} 02^{\prime}$ N., $118^{\circ} 08^{\prime} \mathrm{W}$. | 360 | N | 2(72) |
| - | 51-90 | $25^{\circ} 52^{\prime} \mathrm{N}, 117^{\circ} 40^{\prime} \mathrm{W}$. | 2213 | ND | 1 (80) |
| - | 51-167 | $32^{\circ} 57^{\prime}$ N., $117^{\circ} 54^{\prime} \mathrm{W}$. | 550 | N | 7(46-76) |
| - | 51-18 | $32^{\circ} 45^{\prime} \mathrm{N} ., 117^{\circ} 37^{\prime} \mathrm{W}$. | 550 | N | 3 (24-66) |
| - | 51-399 | Calif.: off San Diego | 720 | N | 1 (63) |
| - | 52-39 | $33^{\circ} 10.4 \mathrm{~N},{ }^{11} 8^{\circ} 31.5^{\prime} \mathrm{W}$ | 850 | N | 1 (91) |
| - | 53-223 | $32^{\circ} 39^{\prime}$ N., $117^{\circ} 37^{\prime} \mathrm{W}$. | 1125 | N | 2(54-72) |
| - | 53-225 | $32^{\circ} 39^{\prime}$ N., $117^{\circ} 37^{\prime} \mathrm{W}$. | 954 | ND | 1 (71) |
| - | $54-82 \mathrm{~A}$ | $32^{\circ} 47.5^{\prime} \mathrm{N} .117^{\circ} 28.5^{\prime} \mathrm{w}$. |  | N | 1 (55) |
| - | 54-96 | $24^{\circ} 35.5^{\prime} \mathrm{N} ., 121^{\circ} 07^{\prime} \mathrm{W}$. | 185 |  | 55(17-35) |
| - | 54-98 | $26^{\circ} 23.5^{\prime} \mathrm{N}, 123^{\circ} 14^{\prime} \mathrm{W}$. | 2880 | N | 3(46-84) |
| - | 57-41 | $28^{\circ} 58.5^{\prime} \mathrm{N}, 118^{\circ} 21^{\prime} \mathrm{W}$. | 510 |  | 25 (44-79) |
| - | 59-201 | $25^{\circ} 15^{\prime} \mathrm{N} ., 110^{\circ} 36^{\prime} \mathrm{W}$. | 1670 | D | 1 (26) |
| - | 60-206 | $24^{\circ} 13^{\prime}$ N., $121^{\circ} 35^{\prime} \mathrm{W}$. | 2000 | D | 2(43-46) |
| - | 60-207 | $21^{\circ} 33^{\prime}$ N., $123^{\circ} 02^{\prime} \mathrm{W}$. | 1500 | DN | 3(17-30) |
| - | 60-276 | $24^{\circ} 29^{\prime}$ N., 147055.5' W | 3000 | N | 1 (15) |
| - | 60-282 | $27^{\circ} 05^{\prime}$ N., $138^{\circ} 25^{\prime} \mathrm{w}$. | 3000 | D | 2(23-25) |
|  | 60-285 | $29^{\circ} 58^{\prime}$ N., $128^{\circ} 48^{\prime} \mathrm{W}$. | 3214 | DN | 1 (54) |
| - | 60-280 | $30^{\circ} 47.6^{\prime}$ N., $125^{\circ} 25^{\prime} \mathrm{W}$. | 2868 | N | 3(60-68) |
| - | 60-287 | $31^{\circ} 33^{\prime}$ N., $121^{\circ} 57^{\prime} \mathrm{W}$. | 2500 | N | 2(33-37) |
| - | 61-21 | $27^{\circ} \mathrm{N} ., 112^{\circ} \mathrm{W}$. | 2220 | N | 1 (37) |
|  | LL-3-8.5 | $28^{\circ} \mathrm{N} ., 118^{\circ} \mathrm{W}$. |  | N | 1 (27) |
|  | LL-2-19.5 | $28^{\circ} \mathrm{N} ., 118^{\circ} \mathrm{W}$. |  | N | 1 (42) |
| USNM | 87567 | $33^{\circ} 33^{\prime}$ N., $120^{\circ} 17.5^{\prime} \mathrm{W}$. | 940 |  | 1 (64) |
| UW | 14536 | $33^{\circ} 27^{\prime}$ N., $126^{\circ} 41.1^{\prime} \mathrm{W}$. | 1000 w | N | 1 (42) |
| - | 14539 | $32^{\circ} 05.5^{\prime} \mathrm{N} ., 128^{\circ} 50.8^{\prime} \mathrm{W}$. | 1400 w | N | 1 (64) |
| - | 14540 | $35^{\circ} 16.7^{\prime} \mathrm{N} ., 130^{\circ} 14.5^{\prime} \mathrm{W}$. | 1400w | N | 1 (25) |
|  | (BB254) | $37^{\circ}+45^{\prime} \mathbf{N}, 129^{\circ} 19^{\prime} \mathbf{W} .$ | $400$ | N | $2(84-9$ |



Equatorial North Pacific, between $0^{\circ}$ and $20^{\circ} \mathrm{N}$ and between $11^{\circ}$ and $180^{\circ} \mathrm{W}$ (Area F of Table V ):

| BOC | 2702 | $16^{\circ} 14^{\prime}$ N., $99^{\circ} 30.5^{\prime} \mathrm{W}$. | 3240 | . . large ‥ties (39 in) |
| :---: | :---: | :---: | :---: | :---: |
| - | 2703 | $14^{\circ} 30.5^{\prime} \mathrm{N} ., 96^{\circ} 14^{\prime} \mathrm{W}$. | 1125 w |  |
| POFI | 1806 | ca. $7^{\circ}$ N., $155^{\circ} \mathrm{W}$. |  | 3(24 in) |
| - | 1808 | ca. $9^{\circ} \quad$ N., $140^{\circ} \mathrm{W}$. |  | 1 (61) |
| - | 1809 | ca. $8^{\circ}$ N., $155^{\circ} \mathrm{W}$. |  | $4(39$ isi |
| - | 1813 | ca. $9^{\circ}$ N., $150^{\circ} \mathrm{W}$. |  | 2(12 min |
| - | 1822 | $12^{\circ} 20^{\prime}$ N., $112^{\circ} 30^{\prime} \mathrm{W}$. | 322 | N 2(3n is |
| SIO | 52-89 | $12^{\circ} 48.2^{\prime}$ N., $134^{\circ} 25.8^{\prime} \mathrm{W}$. | 1320 | D) 1178 |
| - | 52-309 | $17^{\circ} 48^{\prime}$ N., $124^{\circ} 07^{\prime} \mathrm{W}$. | 1160 | D 5 (32 - |
| - | 52-338 | $0^{\circ} 17.7^{\prime}$ N., $110^{\circ} 26^{\prime} \mathrm{W}$. | 1260 | D) $2(53)!2$ |
| - | 52-355 | $4^{\circ} 06^{\prime}$ N., $97^{\circ} 09.8^{\prime} \mathrm{W}$. | 1370 | D $5(4) \quad 73$ |
| - | 54-92 | $19^{\circ} 52^{\prime} \mathrm{N} ., 113^{\circ} 20.5^{\prime} \mathrm{W}$. | 180 | DN 94 (16im) |
| - | 60-209 | $18^{\circ} 44^{\prime}$ N., $124^{\circ} 24^{\prime} \mathrm{W}$. | 2324 | DN $7(3): 1$ |
| - | 60-212 | $16^{\circ} 03^{\prime}$ N., $125^{\circ} 51^{\prime} \mathrm{W}$. | 2325 | $8(23)$ |
| - | 60-215 | $13^{\circ} 13^{\prime}$ N., $127^{\circ} 06^{\prime} \mathrm{W}$. | 2325 | 1) 12 (17 - |
| - | 60-216 | $10^{\circ} 26^{\prime}$ N., $128^{\circ} 22^{\prime} \mathrm{W}$. | 2817 | D 5 (35-44) |
| - | 60-218 | $7^{\circ} 47^{\prime} \mathrm{N} ., 129^{\circ} 37^{\prime} \mathrm{W}$. | 3155 | N 3(1.4-8) |
| $\cdots$ | 60-219 | $4^{\circ} 51^{\prime}$ N., $130^{\circ} 43^{\prime} \mathrm{W}$. | 2160 | DN 7 (3) ib |
| - | 60-229 | $1^{\circ} 34^{\prime} \mathrm{S} ., 133^{\circ} 27.5^{\prime} \mathrm{W}$. | 2326 | D 1 (39 |
| - | 60-232 | $5^{\circ} 02^{\prime} \mathrm{S} ., 135^{\circ} 03^{\prime} \mathrm{W}$. | 2750 | D $3(23$ |
| - | 60-234 | $2^{\circ} 31^{\prime} \mathrm{S} .,{ }^{137}{ }^{\circ} 04^{\prime} \mathrm{W}$. | 2500 | DN $2(25$ |
| - | 60-236 | $2^{\circ} 05^{\prime}$ N., $140^{\circ} 39^{\prime} \mathrm{W}$. | 2100 | DN 1 157 |
| - | 60-239 | $4^{\circ} 56^{\prime}$ N., $142^{\circ} 54^{\prime} \mathrm{W}$. | 2500 | D 2(43 - |
| - | 60-243 | $10^{\circ} 09^{\prime}$ N., $147^{\circ} 08^{\prime} \mathrm{W}$. | 2100 | N $8(18-: 1)$ |
| V | 3791 | $11^{\circ} 02^{\prime}$ N., $173^{\circ} 45^{\prime}$ | 1000 | $8(22$ |

Eastern tropical North Pacific, between $2^{\circ}$ and $20^{\circ} \mathrm{N}$ and $78^{\circ}$
and $90^{\circ} \mathrm{W}$ (Area G of Table V) :
BMNH 1931.12.18.1 Off west coast

|  |  | of Central America |  |  | 1 (61) |
| :---: | :---: | :---: | :---: | :---: | :---: |
| BOC | 2704 | $11^{\circ} 05^{\prime}$ N., $89^{\circ} 21^{\prime} \mathrm{W}$. | 540 |  | 2 (33-1.! |
| D | 1203(1) | $7^{\circ} 30^{\prime} \mathrm{N} ., 79^{\circ} 19^{\prime} \mathrm{W}$. | 1000 w | N | 1 (36) |
| - | (12) | $7^{\circ} 30^{\prime}$ N., $79^{\circ} 19^{\prime} \mathrm{W}$. | 2500w | D | 1 PL ( |
| - | (17) | $7^{\circ} 30^{\prime}$ N., $79^{\circ} 19^{\prime} \mathrm{W}$. | 1000 w | N | 3 PI $(12-3)$ |
| - | 1205(2) | $6^{\circ} 49^{\prime}$ N., $80^{\circ} 25^{\prime} \mathrm{W}$. | 1000 w | N | 1 (19) |
| - | 1206(1) | $6^{\circ} 40^{\prime}$ N., $80^{\circ} 47^{\prime} \mathrm{W}$. | 4500 w | N | 4 (44-1.1) |
| - | (3) | $6^{\circ} 40^{\prime}$ N., $80^{\circ} 47^{\prime} \mathrm{W}$. | 3500 w | N | 1 (19) |
| - | (7) | $6^{\circ} 40^{\prime} \mathrm{N} ., 80^{\circ} 47^{\prime} \mathrm{W}$. | 1200 w | N | 2(32-il) |
| - | (8) | $6^{\circ} 40^{\prime} \mathrm{N} ., 80^{\circ} 47^{\prime} \mathrm{W}$. | 800 w | N | 2 (21-1) |
| - | 1208(1) | $6^{\circ} 48^{\prime}$ N., $80^{\circ} 33^{\prime}$ W. | 1000 w | N | $\begin{aligned} & 3 \text { PL }-1 \\ & (17-2) \end{aligned}$ |
| - | (2) | $6^{\circ} 48^{\prime} \mathrm{N} ., 80^{\circ} 33^{\prime} \mathrm{W}$. | 600w | N | 3 (11-\%) |
| - | (4) | $6^{\circ} 48^{\prime}$ N., $80^{\circ} 33^{\prime} \mathrm{W}$. | 3500w | D | 5 (20-*) |
| - | (5) | $6^{\circ} 48^{\prime}$ N., $80^{\circ} 33^{\prime}$ W. | 3000 w | D | $\begin{gathered} 3 \text { PL- } 14 \\ (11-! \end{gathered}$ |
| - | (6) | $6^{\circ} 48^{\prime}$ N., $80^{\circ} 33^{\prime} \mathrm{W}$. | 2500 w | N | $4 \mathrm{PL}-\mathrm{I}_{-}$ $(8-2)$ |
| - | (8) | $6^{\circ} 48^{\prime} \mathrm{N} ., 80^{\circ} 33^{\prime} \mathrm{W}$. | 1500w | N | 2(18-1: |
| - | (13) | $6^{\circ} 48^{\prime}$ N., $80^{\circ} 33^{\prime}$ W. | 3600 w | D | 6 (22-新 |
| - | 1209 (2) | $7^{\circ} 15^{\prime}$ N., $78^{\circ} 54^{\prime} \mathrm{W}$. | 3000 w | N | 1 (43) |
| - | (3) | $7^{\circ} 15^{\prime} \mathrm{N} ., 78^{\circ} 54^{\prime} \mathrm{W}$. | 2500 w | N | $2(20-3)^{+1}$ |
| - | 1217(1) | $18^{\circ} 50^{\prime}$ N., $79^{\circ} 07^{\prime} \mathrm{W}$ | 4000 w | D | 2(41-5, |
| - | 3548 (2) | $7^{\circ} 06^{\prime} \mathrm{N} ., 79^{\circ} 55^{\prime} \mathrm{W}$. | 3000 w | D | 1 (28) |
| - | (3) | $7^{\circ} 06^{\prime}$ N., $79^{\circ} 55^{\prime} \mathrm{W}$. | 2000 w | D | 15(23-1:3 |
| - | (6) | $7{ }^{\circ} 06^{\prime}$ N., $79^{\circ} 55^{\prime} \mathrm{W}$. | 300 w | N | 9 PL (3-1i |
| - | 3549 (4) | $7^{\circ} 16^{\prime}$ N., $78^{\circ} 30^{\prime} \mathrm{W}$. | 4000 w | П | 2 (25-3-1 |



| In-stitution | Cat- <br> alog <br> no. | Locality | Depth | Time | Spec. imens |  | Catalog no. | Locality | Depth | Time |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GNM | 8401 | $46^{\circ} 30^{\prime}$ N., $6^{\circ} 42^{\prime} \mathrm{W}$. |  |  | 1 (114) | D | 4005 (7) | $13^{\circ} 31^{\prime} \mathrm{N} ., 18^{\circ} 03^{\prime} \mathrm{W}$. | 1000 w | DN | $4(1)+1)$ |
| MCZ | 27802 | $40^{\circ} 29^{\prime}$ N., $66^{\circ} 04^{\prime} \mathrm{W}$. | 3220 | . | 1 (101) | - | 4006 (1) | $15^{\circ} 31^{\prime} \mathrm{N} ., 18^{\circ} 05^{\prime} \mathrm{W}$. | 1000 w |  | $18 \mathrm{Pl}-\mathrm{Hg}$ |
| - | 31654 | $40^{\circ} 56^{\prime} \mathrm{N} ., 39^{\circ} 54^{\prime} \mathrm{W}$. |  |  | 1 (103) |  |  |  |  |  | (1-39) |
| - | 31655 | $40^{\circ} 05^{\prime}$ N., $35^{\circ} 10^{\prime} \mathrm{W}$. | 1638 |  | $4(96-101)$ | - | (3) | $15^{\circ} 31^{\prime} \mathrm{N} ., 18^{\circ} 05^{\prime} \mathrm{W}$. | 300 w | DN | 3 Pl . |
| - | 31656 | $41^{\circ} 28^{\prime}$ N., $43^{\circ} 29^{\prime}$ W. | 1456 |  | $2(80-102)$ |  |  |  |  |  | $\left(\begin{array}{ll}9 & 12\end{array}\right)$ |
| - | 31657 | $47^{\circ} 40^{\prime} \mathrm{N} ., 37^{\circ} 20^{\prime} \mathrm{W}$. | 1097 |  | 2(33-39) | - | 4007 (1) | $18^{\circ} 22^{\prime} \mathrm{N} ., 18^{\circ} 14^{\prime} \mathrm{W}$ | 1000 w |  | $35(16.52)$ |
| - | 31660 | $50^{\circ} 40^{\prime} \mathrm{N} ., 27^{\circ} 16^{\prime} \mathrm{W}$. |  |  | 1 (29) | - |  | $18^{\circ} 22^{\prime} \mathrm{N} ., 18^{\circ} 14^{\prime} \mathrm{W}$ | 300 w |  | 15 P |
| - | 31661 | $41^{\circ} 30^{\prime}$ N., $45^{\circ} 57^{\prime} \mathrm{W}$. |  |  | 3 (23-33) | - |  | $18^{\circ} 22^{\prime}$ N., $18^{\circ} 14^{\prime} \mathrm{W}$ | 4000 w | D | 9 (3) 44) |
| - | 31662 | $40^{\circ} 56^{\prime}$ N., $39^{\circ} 54^{\prime} \mathrm{W}$. |  |  | 1 (13) | - |  | $18^{\circ} 22^{\prime} \mathrm{N} ., 18^{\circ} 14^{\prime} \mathrm{W}$ | 3000 w | D | $3(42-85)$ |
| - | 34963 | $40^{\circ} 56^{\prime}$ N., $39^{\circ} 54^{\prime} \mathrm{W}$. | 1600 w |  | $\begin{gathered} 3(102 \\ -107) \end{gathered}$ | - |  | $18^{\circ} 22^{\prime}$ N., $18^{\circ} 14^{\prime} \mathrm{W}$. | 2500 w | D | $\begin{array}{r} 15 \mathrm{Pl}-\mathrm{dd} \\ (\mathrm{y} \end{array}$ |
| - | 34969 | $40^{\circ} 56^{\prime}$ N., $39^{\circ} 54^{\prime} \mathrm{W}$. | 1600 w |  | 1 (102) | - | (10) | $18^{\circ} 22^{\prime} \mathrm{N} ., 18^{\circ} 14^{\prime} \mathrm{W}$. | 2000 w |  | 21 Pl - 1 d |
| - | 34971 | $40^{\circ} 56^{\prime}$ N., $39^{\circ} 54^{\prime}$ W. | 1600 w |  | 1 (107) |  |  |  |  |  | ( $\times 19$ |
| - | 34973 | $40^{\circ} 56^{\prime}$ N., $39^{\circ} 54^{\prime}$ W. | 200 |  | $2(34-104)$ | - |  | $18^{\circ} 22^{\prime} \mathrm{N} ., 18^{\circ} 14^{\prime} \mathrm{W}$ | 1000 w | D | 2 Pl (6-8) |
| - | 34980 | $40^{\circ} \mathrm{5} 6^{\prime}$ N., $39^{\circ} 54^{\prime} \mathrm{W}$. | 1600 w |  | 1 (86) | - | 4008(1) | $21^{\circ} 40^{\prime}$ N., $18^{\circ} 00^{\prime} \mathrm{W}$ | 1000 w | N | $8(21-65)$ |
| - | 37533 | $39^{\circ} 55^{\prime}$ N., $69^{\prime} 12^{\prime} \mathrm{W}$. | 819 |  | 1 (?) | - | 4009 (6) | $24^{\circ} 36.5^{\prime}$ N., $19^{\circ} 27^{\prime} \mathrm{W}$. | 4000 w | D | $2(3:-34)$ |
| - | 37540 | $39^{\circ} 55^{\prime}$ N., $69^{\circ} 09^{\prime} \mathrm{W}$. | 892 |  | 1 (?) | - |  | $24^{\circ} 36.5^{\prime}$ N., $19^{\circ} 27^{\prime} \mathrm{W}$. | 3500 w | D | 3 (31; 34) |
| - | 37880 | $42^{\circ} 35^{\prime}$ N., $64^{\circ} 03^{\prime} \mathrm{W}$. | 1092 |  | 6 (98-111) | - | 4014(1) | $28^{\circ} 09^{\prime}$ N., $15^{\circ} 19^{\prime} \mathrm{W}$. | 1500 w | $N$ | 1 (H1): |
| - | 37934 | $42^{\circ} 39^{\prime}$ N., $63^{\circ} 41^{\prime} \mathrm{W}$. | 673 |  | $2(?)$ | IFAN | 59-210 | $15^{\circ} 57^{\prime} \mathrm{N} ., 20^{\circ} 39^{\prime} \mathrm{W}$. | 1000 |  | 1(4:) |
| - | 40604 | $38^{\circ} 46^{\prime}$ N., $72^{\circ} 54^{\prime} \mathrm{W}$. | 1147 |  | 2(?) | - | 59-215 | SW. Cape Manuel, |  |  |  |
| - | 40605 | $38^{\circ} 43^{\prime}$ N., $72^{\circ} 56^{\prime} \mathrm{W}$. | 1229 |  | 2 (?) |  |  | Sénégal. | 800 |  | 1 (3) |
| - | 40607 | $40^{\circ} 10^{\prime}$ N., $68^{\circ} 16^{\prime} \mathrm{W}$. | 892 |  | 1 (?) | - | 59-223 | $15^{\circ} 57^{\prime} \mathrm{N} ., 20^{\circ} 39^{\prime} \mathrm{W}$. | 1000 |  | 1 (1ini) |
| - | 40608 | $42^{\circ} 35^{\prime}$ N., $64^{\circ} 03^{\prime} \mathrm{W}$. | 1092 |  | $3(?)$ | - 5 | 59-(226-8) | $15^{\circ} 25^{\prime} \mathrm{N} ., 18^{\circ} 40^{\prime} \mathrm{W}$ | 1000 |  | $3(4 ;-76)$ |
| SU | 168 | Cape May, New Jersey |  |  | 1 (92) |  | 59-(231-3) | Off Sénégal. | 800 | . | 3 (6:-79) |
| USNM | 35412 | $39^{\circ} 30^{\prime}$ N., $71^{\circ} 44^{\prime} \mathrm{W}$. | 1567 |  | 1 (103) |  | 59-234 | SW. Cape Manuel, |  |  |  |
| - | 35522 | $39^{\circ} 45^{\prime} N$. | 1051 |  | 1 (96) |  |  | Sénégal. | 800 |  | 1 (5) |
| - | 39245 | $37^{\circ} 35^{\prime} \mathrm{N} ., 73^{\circ} 58^{\prime} \mathrm{W}$. | 1476 |  | 1 (87) |  | 59-235 | $16^{\circ} 16^{\prime}$ N., $22^{\circ} 16^{\prime} \mathrm{W}$. | 1000 | . | 1 (4: |
| - | 44459 | $42^{\circ} 48^{\prime}$ N., $50^{\circ} 56^{\prime} \mathrm{W}$. | 1503 |  | 1 (59) |  |  |  |  |  |  |
| - | 44613 | $40^{\circ} 10^{\prime}$ N., $67^{\circ} 09^{\prime} \mathrm{W}$. | 2468 |  | 1 (110) |  |  |  |  |  |  |
| - | 83885 | $36^{\circ} 42^{\prime}$ N., $74^{\circ} 30^{\prime} \mathrm{W}$. | 1323 |  | 1 (109) | Circumglobal, south of $30^{\circ} \mathrm{S}$ (Area L of Table 5) : |  |  |  |  |  |
| - | 83886 | $38^{\circ} 30^{\prime}$ N., 7055 ${ }^{\prime} \mathrm{W}$. | 3191 |  | 1 (105) | BMNH | 1930.1.12. |  |  |  |  |
| WHOI | 462 | $41^{\circ} 53^{\prime}$ N., $6427^{\prime} \mathrm{W}$. | 7016 | DN | 16(51-113) |  | 1015-16 | $33^{\circ} 54^{\prime}$ S., $9^{\circ} 27^{\prime}$ E. | 1000 |  | $\begin{gathered} 2(14: 3 \\ -1: 7) \end{gathered}$ |
| Eastern Atlantic, between $30^{\circ} \mathrm{N}$ and $25^{\circ} \mathrm{S}$ (Area K of Table V):BMNH 1930.1.12. |  |  |  |  |  | - | 1930.1.12. |  |  |  |  |
|  |  |  |  |  |  |  | $1017$ | $33^{\circ} 20-46^{\prime} \mathrm{S} ., 1^{\circ} 18-08^{\prime} \mathrm{E} .$ | 1000 | -• | 1 (1:3) |
| - | 1930.1.12. |  |  |  |  |  | 1020-21 | $33^{\circ} 25^{\prime}$ S., $6^{\circ} 31^{\prime}$ E. | 1000 |  | $2(3-54)$ |
| - | 1023-24 | $15^{\circ} 55^{\prime}$ S., $10^{\circ} 35^{\prime}$ E. | 700 |  | $2(65-67)$ | - | 1930.1.12. |  |  |  |  |
|  | 1930.1.12. |  |  |  |  |  | 1022 | $35^{\circ} 18^{\prime}$ S., $19^{\circ} 01^{\prime} \mathrm{W}$. | 1000 |  | 1 (6) |
|  | 1049-50 | $13^{\circ} 25^{\prime}$ N., $18^{\circ} 22^{\prime} \mathrm{W}$. | 900 |  | 2 (38-53) | D | 3627 (3) | $30^{\circ} 08^{\prime} \mathrm{S} ., 176^{\circ} 50^{\prime} \mathrm{W}$. | 3000 w | D | 1 (2: |
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# THE CARLSBERG FOUNDATION'S <br> OCEANOGRAPHICAL EXPEDITION ROUND THE WORLD 1928-30 AND PREVIOUS "DANA"-EXPEDITIONS 

## DANA-REPORT No. 61 .

## THE EYES OF SOME CERATIOID FISHES

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## WITH 3 FigURES IN THE TEXT AND 1 PLATE

APPENDIX: THE REFRACTION OF LIGHT IN A SPHERICAL LENS
BY
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$\qquad$

PUblished by the Carlsberg foundation
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## INTRODUCTION

The ceratioid fishes-The deep-sea angler-fishes-constitute a suborder of the Pediculati. The adult specimens are bathypelagic; it has been suggested that Galatheathauma might be benthic (abyssal; cf. Buble 1953: 177 and Wolff 1961: 137). The larvae are found in the epipelagic zone, but during metamorphosis $\therefore$ rapid descent takes place and the metamorphosed males are mostly found at about 2000 m where the hance of meeting a mature female is probably greatest (Bertelsen 1951). Parasitic males are known in - everal families.

The ceratioid fishes show sexual dimorphism. Most adult females have a light organ at the end of the illicium; in the Ceratidae 2 (Ceratias) or 3 (Cryptopsaras) of the foremost dorsal rays also have light organs (caruncles). None of the males have light organs. In the larvae the eyes are well-developed and look alike in both sexes. Their relative size lecrease during the larval development. The eyes of the females show only a slight increase in growth after metamorphosis and "in the largest known specimens they are so small and legenerate as to be functionless" (Bertelsen 19ã: 24). In the adult males the eyes differ considerably from one family to another; thus for example they are very small in the Gigantactinidae, tolerably large in Melanocetidae, tubular in Linophrynidae (Fig. 1 C ), and very large, with big crescent-shaped aphakic spaces in the Ceratiidae (Fig. 1 A and B). In the parasitic males the eyes are more or less degenerated. The olfactory organs are small in larvac of both sexes and remain small in the adult females, but in the males their size increase greatly during metamorphosis except in the Ceratiidae. In the parasitic males the olfactory organs are as a rule degenerated, in the Ceratiidae they disappear completely.

As stated by Bertelsex (1951: 249) the visual and olfactory sense organs of the adult free-living males, "their-in contrast to the females-considerable and often enormous development of either eyes or olfactory organs or both nust undoubtedly be regarded as an adaptation to the difficult task of the male-to find the female."

The present paper deals with the eyes of larval and adult male and female ceratiid fishes (Ceratias and Cryptopsaras), the eyes of a metamorphosed male of Linophryne arborifera, and the eye of an adult female of Galatheathauma axeli. Ceratias and Cryptopsaras have parasitic males; unfortunately it proved impossible to obtain eyes of parasitic males. The male of Linophryne arborifera is probably also parasitic (Bertelsen 1951: 183). In the Ceratidae the'sex can be determined with certainty even in the youngest larvae from the caruncles which are missing in the males.

Mr. Steenberg B. Sc., has been so kind as to add an appendix on the refraction of light in spherical lenses.

## MATERIAL AND METHODS

Cryptopsaras couesi Gile, 1883. Larval males, 4 and 9 mm long (total length, fractions of mm omitted), adult males, 11,13 , and 14 mm long, larval females, $4,6,8$, and 15 mm long, were embedded in paraffin or celloidin and cut into transverse or horizontal serial sections, paraffin sections at $8 \mu$, celloidin sections at 25 or $30 \mu$. Both eyes of a 92 mm long adult female were embedded in paraffin and cut into $8 \mu$ serial sections, one into horizontal sections, the other into vertical sections. The left eye of a 90 mm long (standard length) adult female and the right eye of a 127 mm long (standard length) adult female were embedded in paraffin and cut into $8 \mu$ serial vertical sections.

Ceratias holboelli Kröyer, 1844. Larval males, 4 and 6 mm long, adult free-living males, 12, 13 , anil 15 mm long, larval females, 9,12 , and 13 mm long, were embedded in paraffin or celloidin and cut $\mathrm{i}_{\mathrm{H}_{\mathrm{i}}, \text {, }}$ serial transverse or horizontal sections. The paraffin sections were cut at $8 \mu$, the celloidin sections at 30 : One adult female, 36 mm long, were embedded in celloidin and cut into $50 \mu$ serial transverse section. The right eye of a 110 mm long adult female was embedded in paraffin and cut into $8 \mu$ serial horizont: sections.

Linophryne arborifera Regan, 1925. The anterior part of the body of a 21 mm long metamorphosed ma! was embedded in celloidin and cut into $30 \mu$ serial horizontal sections.

Galatheathauma axeli Brics, 1953. The right eye of a 47 cm long adult female was embedded in cel. loidin and cut into $20 \mu$ serial horizontal sections.

The 92 mm adult female of Cryptopsaras was fixed in Boun's fluid, all other specimens in formalin. The celloidin sections were stained with Mallory's phosphotungstic acid hematoxylin or a modification of Heidenilais's azocarmine-aniline blue stain. The paraffin sections were stained with Ehrliciss hema. toxylin and eosin, hematoxylin-orange G, Heidenhaix's azocarmine-aniline blue stain, PAS, AB (Alcian blue), AB-PAS, Rinehart-Abll-Had stain for acid mucopolysaccharides (AMP), according to the MüllerMowry method for AMP (McManes \& Mowny 1960: 135), luxol fast blue-cresylecht violet, gallocyaniu stain for Nissl substance, Wilder's reticulum stain, according to Bodiay's protargol method, and in some cases with a combination of Bodian, Rinehart-Abcl-Haj and PAS stains.

## OCULAR ANATOMY

## 1. Cryptopsaras cousei.

In the smallest larvae the diameter of the retinal cup (pars optica + pars coeca retinae) is appr. 20 per cent of the standard length, in $9-10 \mathrm{~mm}$ specimens 12 per cent. In the females the diameter is 7 per cent of the standard length in the metamorphosis stage (about 15 mm total length), 2.5 per cent in appr. 100 mm adult females, and in the two largest known specimens ( 300 and 440 mm ) only 1 per cent (Blehtielsex 1951 : 141). The form of the eye is not altered in the females during growth, cf. Bertelsen 1951, Fig. 93: 140.

The metamorphosis of the males starts at $9-10 \mathrm{~mm}$ total length. In $10-12 \mathrm{~mm}$ males the horizontal diameter of the eye is slightly greater than the vertical diameter and a narrow aphakic space has developed rostrally of the lens (ibid., Fig. $93 \mathrm{~J}: 140$ ). In the largest free-living male ( 14.3 mm total length) the retina is bowl-shaped and the crescent-shaped aphakic space has grown considerably (Fig. 1 B ).

Males. In horizontal sections of adult free-living males the eyes show a pronounced rostral asymmetry, esp. the retina which is formed as a big flat bowl (Fig. 2 B ). The curvature of the rostral part of the retina (i. e. that part of the retina which is situated in front of the papilla of the optic nerve) is lesser than that of the temporal part; thus the rostral part of the ora terminalis retinae is much closer to the median plane of the animal than the temporal part. The iris is short. The diameter of the spherical lens is considerably smaller than that of the pupillary aperture. An aphakic space separates the lens from the pupillary margin in the rostral part of the eye.

The eyes are separated from the skin of the head by the so-called gelatinous tissue (Byrtelsex 195l: 12) which in fact is a very loose connective tissue, in the eve region represented only by a very few connective tissue fibres. This layer is identical with the so-called intermidiary cornea (Rochon-Duvig.ieatd 1943: 260) found in certain other teleosts, e. g. Anguilla. As the epidermis of the head skin is missing, it is unknown whether the skin which covers the eyeball-the dermal cornea-is different from the adjacent head skin. There are no palpebral folds. Rostrally of each eve a shallow horizontal groove (sighting groove) is found.

The sclera shows a normal structure with a cartilaginous ring corresponding to the equatorial region of the eyeball. There are no scleral bones. The form of the sclera is asymetric.

The scleral cornea (Rochod-Devigniate 1943: 261) is very thin. The inside is covered with an endothelium.

The iris has a very thin stroma. The front of the iris is covered with the endothelium iridis, which is continuous with the endothelium on the inside of the seleral cornea.

The choroid is represented exclusively by the lamina choriocapillaris. There is no pigment in the choroid. The argentea is missing both in the iris and in the choroid. The space between the lamina choriocapillaris and the inside of the sclera is optically empty. The $m$. tensor chorioideae is missing.

The retina. The maximal thickness, appr. $95 \mu$, is found in the temporal part of the retina. Rostrally of the papilla of the optic nerve the thickness is appr. $55 \mu$. The pigment is in dark-position and the pigment epithelium has apparently no processes.

The retina proper contains only rods, the ellipsoids of which are short and cylindrical, in the rostral part of the retina the length of the rods, i. e. the distance between the external limiting membrane and the inside of the pigment epithelium, is appr. half of the thickness of the retina, in the temporal part probably slightly greater. The outer nuclear layer contains $3-4$ layers of nuclei in the temporal part of the retina, rostrally only $2-3$ layers. In the inner nuclear layer 2 rows of nuclei are found temporally. rostrally only 1

A


B


Fig. 1. Metamorphosed free-living Ceratioid males. Re-drawn from Bertelsen 1951
A: Ceratias holboelli (total length 15.6 mm )
B: Cryptopsaras couesi (total length 14.3 mm )
C: Linophryne arborifera (total length 21 mm )
laver. The ganglion cell layer is constituted by a single layer of nuclei. A clearly defined layer of optic nerve fibres is not found (cf. that the thickness of the optic nerve is only appr. $36 \mu$ ).

There are no hyaloid vessels on the inside of the retina. The optic nerve is accompanied by an artery (a. centralis retinae) which passes from the papilla of the optic nerve along the ventral part of the retina to a small hole in the iris situated very close to the ora terminalis retinae in the medio-ventral part of the eye. The choroid fissure is obliterated, and hence there is no falciform process. The said hole in the iris may represent part of the choroid fissure.

In the medio-ventral part of the eye a small $m$. retractor lentis is found on the inside of the iris. This muscle is probably vascularized from the a. centralis retinae. No accomodatory nerve was found in the sections.


Fig. 2. Diagrams of horizontal sections of lest eyes of Ceratioid fishes. Rostral part of eyes upward. A-F appr. $55 \times$, G appr. $22 \times$.
A: Ceratias holboelli. Adult free-living male. Total length 15 mm
B: Cryptopsaras couresi. Adult free-living male. Total length 14 mm
C: Linophryne arborifera. Metamorphosed male. Total length 21 mm
D: Cryptopsaras couesi. Larval male. Total length 4 mm
E: C. couesi. Larval male. Total length 9 mm
F: C. couesi. Larval female. Total length 8 mm
G: C. couesi. Adult female. Total length 92 mm
Lettering:
c: scleral cornea
ch: choroid
co: corium of head skin
L: lens
on: optic nerve
r: retina
sc : scleral cartilage
sf: flbrous part of sclera

The rostral asymetry of the male eye can be traced in horizontal sections, even at the 4 mm larval stage (Fig. 2 D) where the rostral part of the iris is slightly shorter than the temporal part, and the temporal part of the retina slightly thicker than the rostral part. If the retina of the 14 mm adult male is compared with that of the 4 mm larval male it is found that the temporal part of the retina shows a slight increase in thickness during growth (from appr. $80 \mu$ to appr. $95 \mu$ ), whereas the rostral part of the retina is thinner in the adult specimen than in the larva; in the temporal part of the retina the length of the rods increases from appr. $15 \mu$ to appr. $55 \mu$. Furthermore, there is a substantial increase in the retinal summation during growth. Thus in the 4 mm larva there is 1 layer of nuclei in the outer nuclear layer, 6-10 layers in the inner nuclear, and $3-4$ in the ganglion cell layer; in the temporal part of the retina of the 14 mm adult male there are $3-4$ layers of nuclei in the outer nuclear layer, $1-2$ in the inner, and 1 in the ganglion cell layer. There are strik-
ingly few horizontal cells in the retina of the adult male. In the larval males the pigment of the retina is in light-position. The choroid is unpigmented as in the adult animals.

Females. In the adult female the eyes are situated beneath a small oval transparent skin area, the dermal cornea (Fig. 2 G ). The dermal cornea differs from the adjacent skin by 1) being transparent (the pigment which is apparently found only in the basal cell layer of the epidermis is missing in the scleral cornea), 2) by having a thin corium in which no vessels are found, and 3) by lacking the spines found elsewhere in the skin. The eyes are connected with the dermal cornea by means of a few connective tissue fibres ("the intermediary cornea"). Bratir gives a picture of the eye of an adult female Cryptopsaras (Brauer 1908, Plate 34, Fig. 17) and a few notes on the retina (ibid.: 185).

The scleral cornea is thin. The inside is covered with an endothelium which is continuous with the endothelium iridis. Corresponding to the iris the scleral cornea is thickened ("autochthonous cornea", ef. Fig. 2 G).

The selera has the same structure as in the adult free-living male.
The iris is not reduced as in the males. It is slightly shorter rostrally than temporally. There is no aphakic space. The stroma is heavily pigmented. A characteristic difference in size between the pigment granules of the choroid, the retinal pigment epithelium, and the stroma iridis was observed. The pigment granules of the choroid are very small, definitely smaller than the granules of the retinal pigment epithelium and the pars iridica retinae. The pigment granules found in the stroma iridis are very big, blunt and rodlike, $2-2.3 \mu$ long. A small number of choroid granules may also be found in the stroma.

As the retinal cup is somewhat smaller than the sclera (the horizontal and vertical diameters are appr. ${ }^{2} / 3$ of the horizontal and vertical diameters of the sclera in a 92 mm specimen), the angulus iridocornealis is not situated in the limbus region as is normally the case, but close to the pole of the scleral cornea. The socalled ligamentum annulare is represented by a small aggregation of mesodermal cells, some of which are vacuolized.

The choroid differs from that of the adult free-living males by containing melanocytes in the lamina choriocapillaris. The argentea is missing both in the choroid and in the iris. The m. tensor chorioideae is missing.

The retina has a normal curvature. The pigment is in dark-position and the pigment epithelium has apparently lost its processes (Plate I, Fig. $\mathbf{5}$ ). The thickness of the retina appears quite uniform in its whole extent, viz. appr. $110 \mu$ ( 92 mm specimen). The retina contains only rods the length of which is appr. $43 \mu$ ( 92 mm specimen), the same as in Lophius (Verfier 1928: 93). The ellipsoid is short and cylindrical. In the outer nuclear laver 2 rows of nuclei are found. In the 92 mm specimen the nuclei inside the rod nuclei are often seen to be arranged into 2 separate layers corresponding to the inner nuclear and ganglion cell layer of the normal vertebrate retina. These nuclei, however, hardly form continuous rows, esp. not in the innermost part of the retina where nuclei are often lacking in some areas. Locally these inner nuclei appear to be situated completely at random, forming no distinct layers. The nuclei of the Müller fibres are generally situated just between the inner limiting membrane and the rod nuclei, but in some cases the outer half of the nucleus was in fact situated in the outer nuclear layer. Some sections of the eye of a formalin fixed adult female were stained for Nissl substance (cresylecht violet, gallocyanin), but this proved to be of little help for the identification of the glia cells as no Xissl substance at all was seen in the retina. In the 127 mm specimen the nuclei inside the inner nuclear layer are not arranged in definite layers (Plate I, Fig. 6). In the 90 mm specimen optic nerve fibres were demonstrated in the retina by means of the Bodian method.

As in the male there are no hyaloid vessels on the inside of the retina. In the adult female the m . retractor lentis is situated in the ventro-rostral part of the eye. The a. centralis retinae has the same general course as in the male and leaves the interior of the eye through a hole in the iris close to the retractor muscle. No accomodatory nerve was seen. The choroid fissure is obliterated (with the probable exception of the abovementioned hole in the iris).

In an 8 mm larval female (Fig. 2 F ) the iris was found to be shorter rostrally than temporally. The stroma iridis is thin and covered with the endothelium iridis. No aphakic space exists. The retina has a uniform thickness in its whole extent. The length of the rods is appr. $24 \mu$. In the outer nuclear layer 1-2 layers
of nuclei are found, in the inner nuclear layer appr. 10 layers, in the ganglion cell layer $3-4$. The inner nudear layer and the ganglion cell layer are slightly thickened at the ora terminalis. There are no hyaloid vessels on the inside of the retina. The pigment is in light-position. The choroid is unpigmented.

The eyes of this 8 mm specimen show a close resemblance with those of a 9 mm larval male (Fig. 2 E ). in the 9 mm male the temporal part of the retina was found to be slightly thicker than the rostral part.

It should be noted that in horizontal sections the retina of both male and female larvae has an open bowlhaped form. In the males this form is also found in adult free-living specimens, whereas in the adult females the retina shows a fairly normal curvature. The adult female eve, however, also shows a rostral asymmetry: the iris is slightly shorter rostrally than temporally, and the centre of the lens is situated a little ostrally of the antero-posterior diameter of the retinal cup.

## 2. Ceratias holboelli.

The eyes of the larvae in this genus are somewhat smaller (the diameter of the retinal cup is 15 per cent of the standard length, in the smallest specimens) than in Cryptopsaras. The development of the eyes during rowth, however, and their major structural features in both larval and adult specimens correspond largely with Cryptopsaras. During growth the relative size of the eye decreases to less than 1 per cent of the standard length in the adult females. In the oldest adult free-living males the horizontal diameter of the eye is appr. 11 per cent of the standard length, and a very big aphakic space has developed; the retina is more flat and the iris more reduced than in Cryptopsaras.

Males. Horizontal sections of the greatest adult free-living male show an eye in which the rostral asymmetry has developed further than in Cryptopsaras (Fig. 2 A ): rostrally the iris has completely disappeared, and the rostral part of the retina is parallel with the median plane of the animal. The very short iris found temporally has apparently lost the stroma. A similar simple iris was found by Rochon-Duvigneate in a pecimen of Lepidosiren (Rochon-Duvigneatd 1943: 317). In a 13 mm adult male a short iris was found rostrally.

The eyes are situated beneath the skin as in Cryptopsaras and in front of each eye is a shallow horizontal sighting groove. The temporal part of the retina (Plate I, Fig. 2) has a thickness of appr. $86 \mu$, whereas the rostral part (Plate I, Fig. 1) is only $42 \mu$ thick. Structurally the retina shows no striking differences from that of Cryptopsaras. The length of the rods is more than half of the retinal thickness. In the temporal part of the retina the outer nuclear layer contains $1-2$ layers of nuclei, the inner nuclear and the ganglion cell layer only 1 layer each. In the rostral part of the retina there is one layer of rod nuclei, but the typical stratification of the inner part of the retina has been lost; the nuclei situated inside the rod nuclei form no distinct layers.

There are no hyaloid vessels on the inside of the retina. The m. retractor lentis (Plate I, Fig. 4) is situated in the medio-ventral part of the eyc. The a. centralis retinae has the same course as in the adult males of Cryptopsaras. The $n$. accomodatorius was not seen in the sections. The optic nerve is thin ( $15-18 \mu$ ).

The larval eye corresponds largely with that of Cryptopsaras. Adequate horizontal sections of larval males of Ceratias were not obtained.

Females. The cyes of larval and adult females correspond closely to those of Cryptopsaras. In a 110 mint long adult female the thickness of the retina was found to be $64 \mu$. The length of the rods is appr. half of the retinal thickness. The outer nuclear layer contains $1-2$ layers of nuclei. The nuclei situated inside the rod nuclei do not form distinct nuclear layers, but seem to be scattered at random.

The vascularization of the interior of the eye of Ceratias and Cryptopsaras corresponds closely with that of Lophius. Thus Hanye found a single vessel (a. centralis retinae) running from the papilla of the optic nerve to the m. retractor lentis in L. americanus Valenciennes (Hanyu 1962, fig. 10: 98); the choroid fissure was found to be completely obliterated.

The so-called interstitial s. intercellular matrix (Sidman 1958, Zimmermax 1958) was found in the layer of rods in adult males and females of Ceratias and Cryptopsaras. The interstitial matrix is a mucoid material which is situated between the visual cells and the processes of the pigment epithelium. It is seen in sections
stained for acid mucopolysaccharides and was found by Sidman (1958) in the retina of adult albin, mouse, pigeon, and monkey, and by Zimmerman (1958) in the human retina. In sections stained with Alcia:a blue and the Rinfhart-Able-Haj stain the present author has found this intercellular substance in f:" retinae of various deep-sea fishes (Argyropelecus hemigymnus Cocco, Sternoptyx diaphana Hivmann, Stomís boa ferox Reinhandt, Chauliodus sloanei Scineider, Ipnops murrayi Güvther, Lampanyctus crocodilns Risso), and in the pike (Esox lucius L.), the sea-snail (Liparis liparis (L)), and the swordtail (Xiphophoris helleri Heckis.). Thus the interstitial matrix is probably also a normal constituent of the teleostean retine: The fact that the interstitial matrix of deep-sea fishes shows the same localization as in other teleosts migh: indicate the presence of unpigmented processes from the pigment epithelium between the rods; the final solution of this question will depend on electron microscopic studies.

## 3. Linophryne arborifera.

Each of the rostro-ventrally directed tubular eyes of this 21 mm long metamorphosed male was situated beneath an oval transparent skin area (the dermal cornea). The sclera has the same form and structur: as in the adult free-living ceratiid males (Fig. 2 C). The choroid is unpigmented. The lens was found $t$. be somewhat llattened in both eyes, probably artificially. The m. retractor lentis is situated rostro-ventrally. The choroid fissure is obliterated.

The retina and the iris from together a short rostro-ventrally directed tube, which is completely closed rostrally by the big lens. The iris is broader laterally than medially. The stroma iridis is very thin; close $t_{1}$ the pupillary margin the mesodermal component of the iris is apparently represented exclusively by the endothelium iridis, which is continuous with the endothelium on the inside of the seleral cornea.

The greatest thickness of the retina--appr. $130 \mu$-is found in the temporal part of the eye (Plate I, Fig. 3). The retina shows the typical stratification in its whole extent. There are probably only rods. The pigment is in dark-position, and the pigment epithelium has apparently lost its processes. There are hyaloid vessels oni the inside of the retina.

## 4. Galatheathauma axeli.

This unique specimen has recently been described by Brotw (1953). Unfortunately the eye was found to be in a rather bad condition. The retinal cup measured $2.6 \times 1.9 \times 1.4 \mathrm{~mm}$ (horizontal $\times$ vertical $\times$ anteroposterior diameter), the selera $4.5,2.9 \mathrm{~mm}$ (horizontal $\times$ vertical diameter). The pupil was found to be oval. and rostrally of the lens an aphakic space was seen. The retina proper was completely detached from the pigment epithelium and was lying close to the lens, the diameter of which was appr. 1.3 mm . With the exception of the aphakic space this eye corresponds largely with those of the ceratiid females examined.

The cartilaginous ring of the sclera is considerably broader and thicker than in the ceratiid females. The scleral cornea is slightly thickened corresponding to the iris. The lens is flattened, probably artificially. The iris is short and has a thin stroma covered with the endothelium iridis, which is continuous with the endothelium on the inside of the scleral cornea. The choroid probably has the same structure as in the ceratiid females.

The thickness of the retina is appr. $90 \mu$. The pigment is in dark-position, and the processes of the pigment epithelium have apparently been lost. There are probably only rods in the retina. Their length is appr. ${ }^{2} / 5$ of the retinal thickness. The outer nuclear layer contains 1 layer of nuclei. The nuclei situated inside the rod nuclei do not form definite layers. Thus the retinal structure corresponds closely with that of the female Ceralias. There are probably no hyaloid vessels on the inside of the retina. The choroid fissure is obliterated. The m . retractor lentis is situated below the rostral part of the lens.

## DISCUSSION

As in other deep-sea fishes the retina of the adult ceratioid fishes is characterized by the lack of cones, the dark-position of the retinal pigment, and a considerable retinal summation. The larvae are found in the epipelagic zone. In Ceratias and Cryptopsaras the deseent which takes place during metamorphosis is accompanied by a very marked structural alteration of the retina which leads to a considerable increase "f the retinal summation; this may undoubtedly be regarded as an adaptation to the bathypelagic life.

The eyes of the adult free-living males of Ceratias and Cryptopsaras are characterized by having a very wide rostral linocular field of vision due to the large aphakic spaces, the slightly curved rostral part of the retina, and the sighting grooves. The temporal part of the retina on which the image of objects situated in the rostral binocular field of vision is produced is definitely thicker and has longer rods than the rostral part of the retina.

It might be argued that the reason why the pupil is enlarged is that it allows more light to enter into the eye (ef. Walls 1942: 211 and Mashall 1958: 218). This view, however, does not give a satisfactory explanation of the fact that aphakie spaces are lacking in the eyes of the female. According to the author's opinion the presence of the sighting grooves and the peculiar form of the retina in the males show that the primary function of the aphakic spaces is to increase the rostral binocular field of vision. The rostral aphakic spaces found in the eyes of many teleosts and some other vertebrates are generally regarded as devices for increasing the rostral binocular field of vision.

In the ceratiid larvae of both sexes part of the outer segments of the rods is covered with the pigmented processes of the pigment epithelium, whereas in the bathypelagic adult animals the processes have apparently been lost. It is unknown whether the pigment is stationary or migratory in larval fishes.

The metamorphosed male of Linophryne arborifera examined has tubular forwardly directed eyes. As in the ceratid adult males the retina attains its maximum thickness temporally. From a morphological point of view the Linophryne-eye may easily be derived from the male ceratid-eye. Brater (1908: 184-185) gives a short description and a picture of the eve of a male Linophryne ("Aceratias") macrorhinus which according to him does not have tubular eyes.

The eyes of adult free-living inales of Ceratias and Cryptopsaras show some of the morphological features which according to 13 mater (ibid.: 237-238) may be regarded as an intermediary phase in the development of tubular eyes. Brater (ihid.: 242) regards the tubular eyes of deep-sea fishes as an adaptation to life in darkness. The distance from the centre of the lens to the main retina allows objects to be focused on the latter, but on the accessory retina which is situated very close to the lens no clear image can be produced (ibid.: 244-245, Frasz 1905: 825, Frasz 1907: 347 and 349, Frivz 1934: 1049, and Cowtino 1939: 418). The retinal summation is smaller in the main retina than in the accessory relina. Walls (1942: 257) states that the tubular eyes of deep-sea fishes are bifocal, i. e. distant objects are focused on the accessory retina while nearby objects are focused on the main retina. This view has been adopted by most later authors (e.g. Marsinale 1958: 230 and Deke-Eider 1958: 643). It can be denionstrated, however, that the tubular eyes of deep-sea fishes are not bifocal. The formula $1 / \mathrm{a}+1 / \mathrm{f}=1 / \mathrm{p}$ for a biconvex lens (where $\mathbf{a}$ is the distance of the object from the optical centre of the lens, $f$ the distance of its image, and $p$ the principal focal distance of the lens) is also valid for spherical lenses, ef. appendix. Furthermore, Covtro (1939) has measured the refraction in the eyes of Argyropelecus hemigymmus and actually demonstrated that objects can be focused on the main retina. It is apparent from the values of $f$ calculated by Stereberg (cf. appendix) that the image of an object is shifted only appr. $630 \mu$ when the distance of the object from the lens is altered
from 20 mm to $\infty$. Consequently no clear image can be produced on the accessory retina because it is situate: too close to the lens. In the tubular eyes of some deep-sea fishes objects may possibly be focused on th: part of the accessory retina which is situated very close to the main retina. It should be borne in mind, how ever, that according to Bracer (1908) the most highly developed part of the accessory retina is always foun : close to the pupil, while the remaining part of the accessory retina which from a purely optical point of viev: has a more favourable position is more or less degenerated in some species.

A wide binocular field of vision, however, may offer certain advantages for the animal, viz. a greatei: sensitivity to light, a better judgement of distances, and maybe stereopsis. Weale (1955) has suggested that the increase in sensitivity to light may be an important factor in the development of binocular vision in deepsea fishes. In man the binocular sensitivity to light is appr. 10 per cent greater than the uniocular (Pirexni: 1943). The possibility of stereopsis in non-mammalia which have a total decussation of the optic nerve fibres in the chiasma is often denied, esp. in the older literature (e. g. Rochon-Duvigneate 1943: 686 ff.). A valuable discussion can be found in Walls (1942:329-330) and Deke-Elder (1958: 697 ff.). Which of thess factors is the most important to the adult free-living ceratiid males is unknown, but they are probably all of some significance since these fishes apparently have to rely entirely on their visual organs in their search for and identification of the female. The extra light organs found in the ceratiid females may be important in this connection (Bertelsen 1951: 249). In the Linophryne male both the eyes and the olfactory organs are well-developed.

It is often stated that the eyes of the adult females of the deep-sea angler-fishes are probably functionless because of their small size (e.g. Waterman 1948: 128). In the specimens examined there is no evidence of ocular degeneration. In females of Certaias and Cryptopsaras the retinal summation is increased during growth which is apparent from the decrease in the number of nuclei situated inside the outer nuclear layer. Gradually the typical stratification is lost in the inner part of the retina. Exactly the same development is established in the males, esp. in the rostral part of the retina in Ceratias. The obvious purpose is an increase in the sensitivity to light. The retina of Galatheathauma corresponds closely with that of the ceratid females. A retina with a similar structure and a high degree of summation is found in other deep-sea fishes, e.g. Argyropelecus hemigymnus (the accessory retina, cf. Contivo 1939, Fig. 21: 412) and Ipnops murrayi (Мıкк 1959, Plate 2).

Finally it should be noted that the eyes of the ceratiid females examined differ from most other teleostean eyes by the fact that the whole of the lens is situated behind the iris. As the eyes are situated beneath the skin, the visual field of each eye must be rather restricted because the refractive index of the cornea in telcosts is known to be practically identical with that of water (Matthessen 1880, Contino 1939). In the adult female angler-fishes examined the lens is situated rather close to the retina. Because of this, and because of the restricted visual field, it seems reasonable to suppose that the eyes of the female angler-fishes examined function as mere light-detectors.

## SUMMARY

The paper deals with the eyes of both larval and adult specimens of males and females of Ceratias holboelli and Cryptopsaras couesi; eyes of parasitic males of these two genera are not included in the material. Furthermore, the eyes of a metamorphosed male of Linophryne arborifera and one eve of a female Galatheathauma axeli have been examined. The eyes of adult free-living males of Ceratias and Cryptopsaras have a very wide rostral binocular field of vision due to the large aphakic spaces, the peculiar form of the retina, and the horizontal sighting groove found rostrally of each eye. The metamorphosed male of Linophryne arborifera has tubular eyes which from a morphological point of view may easily be derived from the male ceratiid eye. It is pointed out that the tubular eyes of deep-sea fishes are not bifocal as generally stated in the literature on the subject. A wide binocular field of vision, however, possibly means a greater sensitivity to light, a better judgement of distances, and maybe stereopsis. The adult Ceratias and Cryptopsaras males apparently have to rely entirely in their visual organs in their search for and identification of the female, whereas the Linophryne male also has well-developed olfactory organs.

In the ceratiid females the form of the eye remains practically unaltered during growth. In adult specimens the retinal cup is somewhat smaller than the sclera, and the lens is situated behind the iris. As in the males the retinal summation is increased during growth. The visual field is rather restricted because of the position of the lens, and because the eyes are situated beneath the skin. Furthermore, the lens is placed rather close to the retina, and it is suggested that the eyes function as mere light-detectors in the adult females. With the exception of the rostral aphakic space the eye of Galatheathauma corresponds largely with that of the ceratiid female. There is no evidence of ocular degeneration in the female angler-fishes examined. The interstitial matrix was demonstrated in the layer of rods in the retinae of adult males and females of Ceratias and Cryptopsaras.

## APPENDIX

## The Refraction of Light in a Spherical Lens

By

## K. Steenberg

Each line which passes through the centre 0 of a spherical lens can be chosen as optical axis. The two angles $b$ between the refracted ray inside the lens and the two normals $n$ are equal. Hence the two angles i between the incident and the refracted ray and the two normals are also equal. The two principal planes pp coincide and are situated at right angles to the optical axis through the centre of the lens.


$$
\begin{aligned}
\alpha+\beta+2 \mathrm{~b}+360^{\circ}-2 \mathrm{i} & =360^{\circ} \\
\alpha+\beta & =2(\mathrm{i}-\mathrm{b}) \\
\sin \mathrm{i} & =\mathrm{n} \sin \mathrm{~b} ; \quad \frac{\sin \mathrm{i}}{\mathrm{a}}=\frac{\sin \alpha}{\mathrm{r}} ; \quad \frac{\sin \mathrm{i}}{\mathbf{f}}=\frac{\sin \beta}{\mathrm{r}} ;
\end{aligned}
$$

For small angles $v$ is substituted for $\sin v$.

$$
\begin{aligned}
\frac{i}{a}+\frac{i}{f} & =\frac{x+p^{2}}{r}=\frac{2(i-b)}{r} \\
\frac{1}{a}+\frac{1}{f} & =\frac{2(n-1)}{n r}=\frac{1}{p} \\
p & =\frac{n}{2(n-1)} r \text {, where } p \text { is the principal focal distance of the lens }
\end{aligned}
$$

If the refractive index $n_{1}$ of the medium which surrounds the lens is equal to 1.34 and that of the lens $n_{2}=1.7$ (Contino 1939) it follows that

$$
\mathrm{n}=\mathrm{n}_{2} / \mathrm{n}_{1}=1.7 / 1.34=1.25, \text { and } \mathrm{p}=2,5 \mathrm{r}
$$

If the radius $r$ of the lens is equal to 1.3 mm (average of the specimens of Argyropelecus hemigymints examined by Contivo 1939) it follows that $p=3.25 \mathrm{~mm}$, and f can be calculated at different values of a :

| a | $f$ |
| :--- | :---: |
| 20 mm | 3.88 mm |
| $40-$ | $3.54-$ |
| $80-$ | $3.39-$ |
| $\infty$ | $3.25-$ |

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Fig. 1. Rostral part of retina of 15 mm male of Ceratias holboelli. $8 \mu$ section. Heidenhain's azocarmine-aniline blue stain. NA: 1.30 . Fig. 2. Temporal part of retina of 15 mm male of Ceratias holboelli. $8 \mu$ section. Heidenharn's azocarmine-aniline blue stain. NA: 1.30 . Fig. 3. Temporal part of retina of 21 mm male of Linophryne arborifera. $30 \mu$ section. Mallory's phosphotungstic acid hematoxylin. NA: 0.65 .
Fig. 4. Vertical section through ventral part of eye of 12 mm adult male of Ceratias holboelli. $8 \mu$ section. H-E. NA: 0.7 .
Fig. 5. Retina of 92 mm adult female of Cryptopsaras couesi. $8 \mu$ section. Heidenhain's azocarmine-aniline blue stain. NA: 1.0 .
Fig. 6. Retina of 127 mm adult female of Cryptopsaras couesi. $8 \mu$ section. Heidenhain's azocarmine-aniline blue stain. NA: 1.0 .

1: pigment epithelium
2: layer of rods.
3: external limiting membrane.
4: outer nuclear layer.
5: outer plexiform layer.
6: inner nuclear layer.
7: inner plexiform layer.
8: ganglion cell layer.
9: optic nerve fibre layer.
i. 10: internal limiting -membrane.

A: angulus iridocornealis.
C: scleral cornea.
CH: choroid.
M: musculus retractor lentis.
P: pupillary margin of iris.
R : retina.
S: corneal rim of scleral cartilage.
V: vitreous.

## DANA-REPORT No. 62.

# RECTAL LIGHT ORGANS IN THE ARGENTINOID FISHES opisthoproctus and winteria 

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## INTRODUCTION

Among the various types of luminous organs known in deep-sea fishes only a few can be definitely regarded as derivatives of the mucous membrane of the alimentary canal (Hamms 1928, Kıто 1947, Haneda $1950 \& 1955$ ). A preliminary report on the rectal bulb and the reflector organ of Opisthoproctus has been published by one of us (BERTELSEX 1958). The present paper describes the histology of the rectal hulbs of the argentinoid fishes of the genera Opisthoproctus Vallant ${ }^{1}$ ) and Winteria Brater. The rectal bulbs of these two genera are luminous organs derived from the mucous membrane of the rectum. In both genera a reflector organ is situated in the ventral body wall, from which the light is emitted.

Representatives of related genera have been examined but in none of these similar organs were observed ${ }^{2}$ ).
The study is based on material from the Dana Oceanographical Collections. For the loan of specimens of Rhynchohyalus natalensis (Gilchrist and von Bonde) and of Macropinna microstoma Ciapman we express our gratitude to the Chicago Natural History Museum and the Smithsonian Institution, U.S. National Museum respectively.

## MATERIAL AND METHODS

1. Opisthoproctus soleatus Valleant. A 12 mm long larva (standard length) from Dana st. 4006 II was enubedded in paraffin, cut into $8 \mu$ serial transverse sections, and stained with hematoxylin and orange G. One adult specimen, 42 mm long (standard length), from Dana st. 1181 IV was embedded in celloidin, cut into $50 \mu$ serial transverse sections, and stained with Mallory's phosphotungstic acid hematoxylin. Enstained celloidin sections of the rectal bulb of one adult specimen were made; the plane of sectioning was parallel to the median plane of the animal. Furthermore, the rectal bulb and the reflector organ of several larval and adult specimens were dissected.
2. Opisthoproctus grimaldii Zygmayer. Two larvae, 10 and 14.5 mm long, from Dana st. 4010 II and 4019 VII resp., were embedded in paraffin, cut into $8 \mu$ serial transverse sections, and stained with Ehrlich's hematoxylin and eosin, hematoxylin and orange $G$, Heidenhan's azocarmine-aniline blue stain, PAS, Alcian blue (AB), AB-PAS, according to the MÜLLER-Mowry method for acid mucopolysaceharides (McManus \& Mowry 1960: 135), Wilder's reticulum stain, and Gabe's stain for elastic fibres.
3. Winteria telescopa Brauer. A specimen, 99 mm long (standard length), from Dana st. 3847 lII was dissected; the posterior part of the intestine, the rectum, the rectal bulb, and part of the ventral body wall including the anus were removed as a whole, embedded in paraffin, cut into $8 \mu$ serial sections, and stained with Eirlicu's hematoxylin and eosin, Heidenhain's iron hematoxylin, Heidenhain's azocarmine-aniline blue stain, Foot's modification of Masson's trichrome stain (Foot 1933), PAS, AB, AB-PAS, the Rine-hart-Abul-Haj stain for acid mucopolysaccharides, Gram's stain for bacteria in sections (Lillie 1954: 371 ), and according to Boman's protargol method. The plane of sectioning was at right angles to the median plane of the animal and transversal to the pear-shaped rectal bulb.

All specimens were fixed in formalin.

[^10]
## ANATOMY OF LIGHT AND REFLECTOR ORGANS

## A. Opisthoproctus soleatus and grimaldii.

The position and relative size of the light and reflector organs in an adult Opisthoproctus soleatus is shown diagrammatically in Fig. 1.

As no principal differences were found between Opisthoproctus soleatus and O. grimaldii in the structure of these organs, the following description covers both species.


Fig. 1. Position of light organ and reflector in Opisthoproctus soleatus.
Above: Diagram based on dissections and serial sections of adult specimen 42 mm in standard length. I-III transversal section of reflector.
IV median section of rectal hulb and posterior part of reflector.
Below: Ventral view of adult showing sole and position of anus (an).

## 1. The rectal bulb. (Figs. 2-4 and Plate I).

The highly vascularized rectal bulb of the adult specimens shows a heavy pigmentation except in the ventral region of contact with the reflector organ where the wall is unpigmented and functions as a window between the lens and the hyaloid body ( $w$ in Figs. 3, 4 and Plate I 2). The bulb is completely filled with longitudinal folds formed by the mucous membrane of the rectum leaving only a narrow ventral passage for the faeces. The ventral part of the wall shows only a few low folds, whereas the dorsal and lateral parts possess high, narrow, tightly packed folds. Two specialized cell types are found in these folds, viz. luminous epithelium and lens cells (Fig. 4 and Plate I).

The folds originating from the lowermost parts of the lateral walls only show lens cells. On the folds originating from the upper parts of the lateral walls luminous epithelium is seen in the proximal parts of


Fig. 2. Rectal bulb and posterior part of reflector in Opisthoproctus soleafus. Based on dissection of adult specimen.
Lettering Figs. to 2 and 3: an : anus; ar: rudimental anal fin rays; h: hyaloid body; hl: lateral part of hyaloid body ; hm: median part of hyaloid body; i: intestine; l: lens; ll: distal part of folds with low epithelial cells; lu: proximal part of folds with luminous epihelial cells; ml : dorsal striated muscle of reflector organ; m2: posterior striated muscle of reflector organ; pc: pigmented connective tissue; pt: pterygiophor of anal fin rays; rb: rectal bulb; s: median septum of hyaloid body; u: urogenital duct; v; blood vessel; w: window.
the folds, lens cells in the distal parts. The major part of the folds originating from the dorsal wall do not carry lens cells and show luminous epithelium proximally, whereas the ridges of the folds are covered with low epithelial cells. The same type of low cells is found intercalated between the lens cells and the luminous epithelial cells on folds carrying both of these cell types. The lens cells on the tightly packed folds form together a lentiform body in the ventral part of the bulb (Fig. 3 and Plate I). The spaces between the folds of the rectal bulb contain a granular material which at high magnification is seen to consist of a great number of spheroid elements of uniform size, measuring appr. $2 \mu$ (g in Fig. 4 and Plate I). Each element contains several darkstained granules which are generally situated peripherally. These elements might very well be bacteria in which the nuclear material has been stained by the phosphotungstic acid hematoxylin. We have not in any of the specimens examined observed secretion in the lumen between the folds of the rectal bulb.

The luminous epithelium consists of cuboidal-columnar cells showing a heavy yellow colour which completely masks the nuclei; this colour was also seen in unstained longitudinal sections of the rectal bulb in adult specimens of both species. In some places blood vessels were seen in the connective tissue in the proximal parts of the folds corresponding to the luminous epithelium. The lens cells are high columnar cells with a hyaline cytoplasm. We have not been able to recognize any nuclei in the lens cells of adult specimens, but since the sections are very thick and the cytoplasm is often heavily stained, this does not necessarily mean that nuclei are absent.

The distal part of the rectum behind the rectal bulb possesses a heavily pigmented wall. Furthermore the wall is thickened owing to the presence of abundant loose connective tissue.

The rectal bulb of the larvae shows principally the same structure as in the adult specimens; the number of folds is smaller and the columnar lens cells possess a prox-


Fig. 3. Median section of rectal bulb and posterior part of reflector in Opisthoproclus solealus. Based on dissections of adult specimen. Letters as in Fig. 2.


Fig. 4. Horizontal section of rectal bulb and posterior part of reflector in Opisthoproctus soleatus. Diagram reconstructed from serial sections of postlarval specimen: ca: capsule of rectal bulb; f : connective tissue of fold; g : granular material; x: lumen of rectum. Other letters as in Figs. 2-3.
imal nucleus. The cells of the luminous epithelium are heavily vacuolized. In the spaces between the folds a granular material consisting of spheroid elements of uniform size is found.

In all the larvae examined the wall of the posterior part of the intestine was found to be pigmented. This pigmentation is missing in the adult specimen sectioned, where only the rectal bulb and the distal part of the rectum behind the bulb are pigmented.

The specially stained sections of the 14.5 mm O . grimaldii larva show the following features: The hyaline cytoplasm of the nucleated lens cells is rather faintly stained with PAS. The cells of the luminous epithelium are heavily vacuolized. The free surfaces of the cells as well as the cytoplasmic strands in the cells stain faintly PAS-positive. In sections stained for acid mucopolysaccharides (AMP) the free surface and the cytoplasmic strands of the cells show a definite AMP-positive staining (Alcianblue, Alcian blue-PAS, the Müllef-Mowry method for AMP). The vacuoles remain unstained. The cytoplasm of the low epithelial cells found distally on the folds is PAS-positive and AMP-positive.

It should be noted that the cells in the luminous epithelium of the specimens examined show a certain resemblance to mucous cells which in ordinarily fixed and stained sections contain an artificial cytoplasmic network with precipitated mucigen. Secretory granules and basophilic substance were not seen in the cells of the luminous epithelium.

We have not found any definite morphological features by means of which the rectum (hind-gut) may be clearly distinguished from the intestine (mid-gut) in Opisthoproctus.

## 2. The reflector organ. (Figs. 1, 2, 5 and Plate I).

The reflector organ is situated in the ventral body wall in the so-called sole, which reaches from under the head to the anus. (Fig. 1). The rostral part of the sole is supported by the cleithra to which the reflector organ is attached. Caudally the sole is relatively narrow and the reflector organ is seen as a trapeziform structure in transverse sections (Fig. 5 and PI. I 1). More anteriorly the sole is wider, and the height of the reflector organ is gradually diminished, so that the organ appears roughly triangular in transverse sections.

The bulk of the reflector organ is constituted by the hyaloid body which consists of very loose connective tissue enclosed between smooth muscles, the dorsal and the ventral smooth muscle of the sole. The ventral smooth muscle is a horizontal muscle situated in the ventral part of the sole. The dorsal smooth muscle has the shape of a bent plate which is concave towards the ventral smooth muscle. In both muscles the spindleshaped cells are orientated transversally in proportion to the median plane of the animal and both muscles reach the edges of the sole, but they do not fuse with each other. The dorsal smooth muscle is missing in the anteriormost part of the sole.

In the median part of the reflector organ, between the ventral and the dorsal smooth muscle, a tube-like structure, the major part of which is constituted by transversally orientated smooth muscle cells, is situated. The smooth muscle cells form an incomplete circular muscle, dorsally completed by a thin connective tissue membrane. Ventrally the muscle is partly continuous with the ventral smooth muscle.


The hyaloid body is thus subdivided into a median and two lateral parts by the incomplete circular smooth muscle of the sole. The connective tissue in the two lateral parts of the hyaloid body is definitely fibrillar, esp. laterally, whereas the connective tissue in the median part of the hyaloid body is more mesenchyme-like.

In the median part of the hyaloid body of the 0 . soleatus an incomplete longitudinal septum, originating from the incomplete circular smooth muscle and constituted by vertically orientated smooth muscle cells, is seen (s); this septum was found to be attached dorsally only in the anterior part of the reflector organ, but the very fact that it is constituted my muscle cells strongly suggests that it is artificially detached. Both the septum and the incomplete circular smooth muscle are missing in the anteriormost part of the reflector organ; thus the median and the two lateral parts of the hyaloid body communicate freely in the anteriormost region of the sole.

The median septum is present in larval specimens of $O$. soleatus as well, but is not found in the serial sectioned larval O. grimaldii nor could it be observed in dissection of an adult specimen of this species.

The reflector proper is situated on the dorsal surface of the dorsal smooth muscle and reaches the edges of the sole. It is constituted by spindle-shaped cells with spindle-shaped nuclei and shows a silky brilliance in dissections. It is delimited from the coelom by the heavily pigmented peritoneum. The peritoneum does not reach the edges of the sole, and the pigment, which covers the lateral parts of the reflector layer is situated in the adjoining connective tissue.

Subjacent to the ventral smooth muscle of the sole a dense layer of collageneous fibres is seen (cf in Fig. 5 and PI. I). This layer is situated beneath the skin and the scales of the sole and seems to be continuous with a similar dense layer of collageneous fibres situated beneath the skin on the flanks of the animal; the layer on the flanks is thinner dorsally than ventrally, and the adjoining loose connective tissue covering the inside and the outside of the layer shows a heavy pigmentation, esp. ventrally. In the sole this layer of dense collageneous fibres is not associated with pigment.

Caudally the reflector organ is situated in close contact with the window of the rectal bulb. In this region the dorsal smooth muscle and the reflector layer are both missing and replaced by a very thin connective tissue membrane which is fused with the peritoneum. Corresponding to the area of fusion the peritoneum is unpigmented (Fig. 3 and Plate I 2).

In the posterior part of the reflector organ corresponding to the window both the ventral and the dorsal smooth muscle of the sole are practically missing. Of the incomplete circular smooth muscle only the ventral part is left (PI. I 3); it turns dorsally and fuses with the con-

Fig. 5. Transverse sections of the sole of an adult Opisthoproctus soleatus (cf. Fig. 1). cf: layer of dense collageneous fibres; cl: cleithrum; li: liver; mc: incomplete circular smooth muscle of sole; md: dorsal smooth muscle of sole; mv: ventral smooth muscle of sole; mra: musculus rectus abdominis; r: reflector layer. Other letters as in Figs. 2-3.
nective tissue membrane corresponding to the window. In this posterior region the loose connective tissue in the median part of the hyaloid body is definitely fibrillar and apparently not effectively separated from that of the two lateral parts. The two lateral parts of the hyaloid body continue a little further caudally, one on each side of the ventral part of the rectal bulb (Pl. I 3).

Three pairs of striated muscles insert into the reflector organ:

1. The two portions of a paired muscle-the anterior striated muscle of the reflector organ (mra in Fig. 5)originate from the rostro-ventral parts of the cleithra, pierce the reflector layer in the anterior part of the sole, and run ventro-caudally, one on each side of the median septum, to the ventral part of the circular muscle into which they are embedded. From here they can be followed as two separate muscles situated close to the median plane through the anterior $\frac{2}{2}$ of the reflector organ. They apparently insert into the ventral part of the circular smooth muscle. Since the two portions of this muscle show typical inscriptiones tendineae, and since they originate from the cleithra and are situated in the ventral body wall, it seems reasonable to suppose that the muscle is the anterior part of the nı. rectus abdominis.
2. A paired striated muscle-the posterior striated muscle of the reflector organ ( $\mathrm{m}_{2}$ in Fig. 2 and Pl. I 5)originates from the distal part of the curved rod which supports the small anal rays. The two portions run rostrally, one on each side of the rectum, and insert ventrally into the posterior part of the circular smooth muscle of the reflector organ.
3. A paired muscle-the dorsal striated muscle of the reflector organ ( $m_{1}$ in Fig. 2 and Pl. I 2-3)-originates in the dorsal wall of the rectal bulb, runs rostro-ventrally, and inserts laterally into each side of the reflector organ, on the outside of the reflector layer corresponding to the window.

Even in the smallest of the larval specimens examined the posterior part of the reflector organ is clearly differentiated, and the silky reflector can be observed through the transparent skin. In the adults the skin of the sole is pigmented, but transparent. The pigmentation is strongest posteriorly. On each of the large scales the greatest density of pigment is found distally.

In the 10 mm larva ( Pl .16 ) (O. grimaldii) only that part of the ventral body wall which is situated immediately rostrally of the rectal bulb shows the typically flat sole-shape. In this region the circular muscle is clearly differentiated, and the loose connective tissue found in the ventral body wall has been separated into a median and two lateral parts. As in the adult specimen the smooth muscle cells form an incomplete circular muscle, dorsally completed by means of a thin connective tissue membrane.

No trace of the dorsal and the ventral smooth muscles found in the adult specimen was seen in the sections. The median septum is missing too. The anteriormost part of the circular muscle, which is seen as a $v$-shaped figure in the sections, is situated appr. halfway between the anus and the skull. The ventral part of the peritoneum shows a rather heavy pigmentation in this posterior region of the body wall. This pigmented zone stops abruptly corresponding to the anteriormost part of the developing circular muscle and the rostral part of the peritoneum covering the ventral body wall is practically unpiginented.

Subjacent to the pigmented ventral part of the peritoneum a layer of spindle-shaped cells with spindleshaped nuclei is found, probably the reflector or its progenitor. The dense layer of collageneous fibres is well-developed, especially in the posterior part of the body wall. In the region immediately rostral of the rectal bulb this layer of collageneous fibres is clearly seen to be situated beneath the skin, because it is separated from the scales by a thin layer of connective tissue. Whether this is also the case on the flanks of the animal is unknown, because the epidermis in all the larvae examined is missing. This peculiar layer of dense collageneous fibres is thus probably not identical with the corium of the skin, neither in the larva nor in the adult, at least not ventrally corresponding to the sole.

In the rostral region of the ventral body wall, i. e. the region situated between the anteriormost part of the developing circular muscle and the cleithra, the only constituents of the adult reflector organ found are the dense layer of collageneous fibres and the anterior striated muscle ( m . rectus abdominis). This muscle is embedded in dense connective tissue and can be followed to its origin on the cleithra.

In the 12 mm larva ( $O$. soleatus) the reflector organ reaches further rostrally; thus the anteriormost part of the circular smooth muscle is situated slightly behind the skull. The median septum is seen; it is not attached dorsally and seems yet to be constituted solely by connective tissue cells. The entire ventral part of
the peritoneum shows a heavy pigmentation. Probably the major part of the ventral body wall has possessed the typical sole-shape of the adult. Below the reflector proper the dorsal smooth muscle is clearly differentiated in the median part of the reflector organ, corresponding to the incomplete circular smooth muscle. The $m$. rectus abdominis is embedded in the ventral part of the circular smooth muscle as in the adult.

The two pairs of striated muscles, which were scen to insert into the posterior part of the reflector organ in the adult specimen, were also found in the larvae.

The entire ventral body wall is sole-shaped in the 14.5 mm larva ( $O$. grimaldii). The incomplete circular muscle is fully differentiated, but as mentioned above no trace of the median septum was seen. The reflector organ differs from that of $O$. soleatus by lacking the dorsal smooth muscle; a ventral smooth muscle exists, but it is situated immediately below the dense layer of collageneous fibres of the sole (Pl. I 8). This muscle reaches from one edge of the sole to the other and is attached to the layer of dense collageneous fibres corresponding to the lateral parts of the sole.

## B. Winteria telescopa.

## 1. The rectal bulb.

The skin of the ventral side of the examined specimen of Winteria telescopa (Fig. 6) had been rubbed off in the net and a distinct pigmented rectal bulb could be observed.

As described by Bracer (1906) and shown in Figs. 6 and 7 a pair of tapering appendages are situated just in front of the anus.


Fig. 6. Ventral view of adult Winteria telescopa 99 mm in standard length. The skin of the ventral side has been lost except on the rectal bulb.

Dissection and serial sections showed that the bulb is also a light organ evolved from the mucous membrane of the rectum, but whereas the rectal bulb of Opisthoproctus is in fact a widened section of the rectum possessing very high and narrow folds, the rectal bulb of Winteria is an outgrowth of the caudal part of the wall of the rectum, close to the anus. The bulb is provided with a relatively thick connective tissue capsule in which striated muscle fibres are found, and it is situated in close contact with the caudal wall of the descending part of the rectum. Ventrally the bulb shows a heavy pignentation, but on the greater dorsal part only pigment lumps are seen (Fig. 7). The wall of the rectum is pigmented only below the bulb.

Communication with the lumen of the rectum is found only in the lowermost part of the bulb (Fig. 8 and Pl. II 1-2). In this region the wall of the rectum is seen to be very thick owing to the presence of a very thick layer of connective tissue (lamina propria + tela submucosa), esp. in the caudal part of the wall, where deep, branched, longitudinal infoldings of the single-layered epithelium are seen. This thickened caudal part of the rectal wall actually represents the lowermost part of the rectal bulb. It should be noted that the term 'infolding' is used solely for descriptive reasons with no developmental implications; these infoldings might very well have originated from primarily solid epithelial ridges.

In the region of communication secretion-filled lumina are seen in the caudal parts of the longitudinal infoldings (se in Pl. II 2). The lumina communicates with the lumen of the rectum by means of winding tubules made by low epithelial cells (wt). The tubules may have been formed by a partial fusion of the epithelial cells covering the two opposite walls of each infolding.


Fig. 7. Lateral view of rectal bulb and posterior part of reflector organ of Winteria telescopa. r: reflector. Other letters as in Figs. 2-3.


Fig. 8. Median section of rectal bulb and posterior part of reflector organ of Winteria telescopa. Based on dissection. ce: central part of bulb with cleft-like secretion-filled lumina separated by loose connective tissue with pigment lumps. gl: glandular cells, z: zone of communication between rectum and lumina of rectal bulb. Other letters as in Figs. 2-3.

These longitudinal infoldings of the single-layered epithelium can be recognized throughout the rectal bulb. In the central part of the bulb cleftlike secretion-filled spaces (se) separated by loose connective tissue containing big pigment lumps (pi) are seen (PI. II 3-4 and 9). These spaces are continuous with the secretion-filled lumina seen in the region of communication with the rectum. The walls of the spaces are constituted by cuboidal secretory epithelial cells. In the peripheral parts of the bulb the infoldings are tightly packed, separated only by thin sheets of vascularized connective tissue and constituted by columnar epithelial cells differentiated into glandular cells (gl) and lens cells ( 1 ), the lens cells being invariably situated immediately beneath the connective tissue capsule of the bulb (PI. II 4-6). The peripherally situated parts of the infoldings in the rostral and caudal parts of the bulb communicate directly or via winding tubules (wt in Pl. II 6) with the secretion-filled spaces in the central part of the bulb; they do not show simple cleft-like lumina, but the lumina are shaped like winding tubules which may have been formed by partial fusion of single-layered epithelia covering opposite walls of simple sackshaped infoldings. These closely packed infoldings may have originated by further branching of the relatively few primary epithelial infoldings represented by the cleft-like secretion-filled spaces situated in the central part of the bulb.

Part of the glandular epithelium situated in the two lateral parts of the bulb, i. e. laterally of the secretion- filled spaces, shows a true tubular structure (gl in Pl. II 7), as seen in compound tubular glands with coiled branching tubules. The lumina do not communicate with the central secretion-filled spaces. This glandular epithelium originates from the two most lateral infoldings-one on each side of the median plane-in the region of communication with the rectum.

Corresponding to the lens cells the connective tissue capsule of the bulb only possesses pigment lumps; thus the localization of the lens cells is indicated on the outside of the bulb (Figs. 7 and 8). The lens cells form together a concavo-convex lens (concave towards the central part of the bulb).

In the following the three different cell types found in the epithelial infoldings in the rectal bulb will be dealt with.

1. In the secretion-filled parts of the infoldings the walls consist of cuboidal or slightly lower, heavily vacuolized secretory epithelial cells (Pl. II 9, 10 and 11), some of which are provided with stereocilia (st). The free surface of the cells which is often convex (shrinking-artefact) is provided with terminal bars. The oval nucleus is as a rule situated in the central part of the cell. Some of the cells, however, are apparently distended by accumulated secretion. In these cells only a narrow brim of vacuolized cytoplasm is seen along the walls of the cell, and the displaced nucleus is situated basally or on one of the lateral walls. This accumulated secretion is PAS-negative and AMP-negative; it shows a heavy staining with azocarmine (Heidenhain's azan) and a few similarly stained lumps of material are seen in the secretion-filled lumina. In some places the entire secretion in the cleft-like spaces is heavily stained with azocarmine.

The cytoplasmic strands and the free surface of these vacuolized epithelial cells are PAS-positive and AMP-positive. These cells thus show a certain resemblance to mucous cells. Their mode of secretion is unknown, but since we have not observed degenerated nuclei, holocrine secretion seems out of question. The secretion found in the lumina is PAS-negative and AMP-negative.

In the secretion of the cleft-like lumina a granular material of similar appearance as that found in Opisthoproctus was seen (Pl. II 10). It consists of small, often spheroid elements measuring appr. $1.4 \mu$. They are seen particulaily well in Bodian-stained sections, where in some places short chains formed by several elements were recognized. Very often the spheroid elements are lying two and two together. Short rod-shaped elements were also seen and some of these showed a constriction in the middle. A few peripherally situated granules were seen in most of the elements. The elements are PAS-positive and AMP-positive, but Gram-negative.
2. Glandular cells which show a rather close resemblance to the luminous epithelium of Opisthoproctus, are found peripherally in the lateral, caudal, and rostral parts of the bulb. As mentioned above the lumina of the peripherally situated parts of the infoldings in the rostral and caudal portions of the bulb communicate with the central cleft-like secretion-filled spaces, but part of the infoldings in the rostral portion of the bulb furthermore communicates with the lumen of the rectum by means of winding tubules. In the ventral portion of the bulb both glandular cells and lens cells are seen in the infoldings, the lens cells being invariably situated immediately beneath the capsule; in the dorsal portion of the bulb the lens cells predominate, in the dorsalmost portion only lens cells are found.

The glandular cells are cuboidal, columnar, or pyramidal, with a heavily vacuolized cytoplasm, and an oval often irregularly contoured nucleus situated near the base of the cells. The free surfaces of the cells are provided with terminal bars. The lumen is comparatively wide. The cytoplasmic strands (artificial cytoplasmic network) are PAS-positive and AMP-positive. Locally a PAS-positive material, probably secretion, is seen in the lumina or precipitated on the free surface of the glandular cells. Granular material was not seen in the lumina. Secretory granules and besophilic substance were not found in either of the two types of glandular cells.

In some places part of the glandular epithelium is distended by a homogeneous secretion-like mass, in which strands of vacuolized cytoplasm are seen (PI. II 8). Since this secretion-like mass is apparently not situated in the lumina, it is probably an artefact or an abnormal feature, which stems from necrosed glandular cells. The mass is PAS-negative and AMP-negative and contrary to the secretion in the cleft-like spaces in the central part of the bulb it is not stained with azocarmine.
3. The lens cells (Pl. II 4,5 and 13) have the same shape as the glandular cells. The major part of the cell is constituted by a homogeneous hyaline mass, and only a narrow AMP-positive brim of vacuolized cytoplasm is seen along the walls. Typically the flat nucleus is situated on one of the lateral walls. Some of the lens cells show a quite uniform staining with eosin, and with azocarmine all lens cells show a heavy staining, which completely conceals the narrow brim of cytoplasm and the nucleus. The homogeneous central mass in the lens cells is PAS-negative and AMP-negative. Lumina are apparently missing in those parts of the infoldings in which the lens cells are found.

Cells possessing various amounts of a centrally located homogeneous material (Pl. II 12) are seen among the glandular cells in the peripheral parts of the bulb; the intracellular material shows a heavy stain-
ing with azocarmine. It seems highly probable that these cells represent early stages in the differentiation of lens cells.

In Winteria it seems possible to distinguish the hind-gut from the mid-gut on the basis of the histologis criteria given by Al-Hussaini (1949:133 and 134), viz. the height and thickness of the folds of the mucous membrane and the relative number of goblet cells. The rectum (hind-gut) of Winteria is characterized by: possessing low broad folds, whereas the intestine (mid-gut) shows very high thin folds; the zone of transition is situated slightly rostrally of the descending portion of the gut. The proximal part of the rectum shows at definitely increased number of goblet cells as compared with the mid-gut, but in its distal part, i. e. closer to the anus, there is no extraordinary concentration of these cells in the epithelium. Furthermore, the epithelium in the descending part of the rectum differs from that of the intestine by being ciliated (PI. II 14). It is unknown at present whether ciliated epithelium is found elsewhere in the alimentary canal of Winteria. The presence of ciliated epithelium in the alimentary canal has only been recognized in very few teleosts (cf. Isimda 1935, also for references), and as far as we know never in the rectum. The functional significance of the ciliated epithelium of the rectum of Winteria remains unknown.

## 2. The reflector organ.

On the ventral side of Winteria a transparent median area appears between the lateral body muscles. This lancet shaped area reaches from the isthmus to the base of the anal fin (Fig. 6). Under this transparent area a hyaloid body is situated (Fig. 9). It consists of very loose connective tissue with comparatively few star-shaped cells with flat oval nuclei. The hyaloid body is enclosed laterally by the body muscles and dor-


Fig. 9. Diagrammatic transversal section through body of Winteria. h: hyaloid body; mra: musculus rectus abdominis; $r$ : reflector layer. sally by the peritoneum, which is silvery and highly reflective. The reflector layer consists of long thread-shaped elements with long spindle-shaped nuclei. It should be noted, however, that only comparatively few nuclei are seen in this layer. The reflector layer shows a moderate PAS-positive and a definite AMPpositive staining.

In the ventral part of the hyaloid body a paired longitudinal striated muscle which shows inscriptiones tendineae is seen (Figs. 6 and 9). This pair of muscles, which probably represent the musculus rectus abdominis (mra in Fig. 9), is caudally continued in two lateral tendons, one on each side of the rectal bulb. Caudally of the rectal bulb the tendons are continuous with the two portions of a paired striated longitudinal muscle ( $\mathrm{m}_{2}$ in Fig. 7) which do not show inscriptiones tendineae, at least not in the part of the muscle seen in our sections. This longitudinal muscle may correspond to the posterior striated muscles of the reflector organ of Opisthoproctus, but its origin is unknown at present. As in Opisthoproctus a paired striated muscle connects the dorsal part of the bulb with the reflector ( $\mathrm{m}_{1}$ in Fig. 7).

## C. Related argentinoids.

Opisthoproctus and Winteria belong to a group of highly specialized bathypelagic genera of argentinoids. According to Hubbs (1953) external characters seem to link the following genera into a rather tight chain Dolichoptery $x$ Rhynchohyalus $\rightarrow$ Macropinna $\rightarrow$ Monacoa (Opisthoproctus grimaldii) $\rightarrow$ Opisthoproctus ( $O$. soleatus), and he presumes that Winteria should be included in this group which might be regarded as a family.


Fig. 10. Ventral view of Rhynchohyalus natalensis ( 94 mm in standard length).

Representatives of the genera Dolichopteryx - Rhynchohyalus and Macropinna have been examined for presence of rectal light organs. An area of the ventral body wall of Dolichopteryx is not covered by muscles and appears similar to that of Winteria, but no reflector could be observed in the examined specimens. The rectum is slightly bulb shaped, but dissection showed none of the modifications found in Opisthoproctus and Winteria. In the examined specimen of Macropinna microstoma ( 27.5 mm in standard length) no morphological features which resemble light organs and reflectors could be observed by dissection ${ }^{1}$ ).

In the specimen examined of Rhynchohyalus natalensis ${ }^{1}$ ) ( 94 mm in standard length) a lancet shaped area resembling that of Winteria is present in the ventral body wall (Fig. 10). A heavily pigmented anal bulb is situated approximately centrally in this area between the bases of the ventral fins. Dissection of this region showed, however, that the bulb is constituted by a pair of short thick muscles, between which part of the rectum is sandwiched (Fig. 11). The muscles originate from the pelvis and run caudo-ventrally and insert into the ventral body wall slightly caudally of the anus. The


Fig. 11. Dissection of anal bulb of Rhynchohyalus natalensis (arrow pointing rostral). Left bulb muscle cut. an: anus; i: intestine; m: muscles; u: urogenital duct. muscles are coated by heavily pigmented membranes.

The posterior part of the intestine forms a sling in such a way that the rectal part is turned rostro-ventrally. No rectal bulb is present. The part of the rectum which is situated between the two bulky muscles has a very thin wall and no distinct folds. In the anal part of the rectum the mucous membrane is provided with longitudinal lamellar foldings.

The peritoneum covering the posterior sling of the intestine is black except ventrally immediately behind the anal bulb, where it is in contact with the urogenital duct. No reflector or hyaloid body could be observed within the lancet shaped area of the ventral body wall.

## DISCUSSION

The light organs of Opisthoproctus and Winteria are of the so-called open type (Harvey 1952: 512) and of the "indirect or reflecting type of luminous organ functioning by reflected light" (Haneda 1950: 220). Granular inaterial found in the rectal bulb of Opisthoproctus and Winteria shows a definite morphological resemblance to bacteria; whether they are luminous bacteria can be definitely proved only by means of bacteriological techniques applied on fresh material.

The light organs of Opisthoproctus and Winteria are remarkable for the fact that they are clearly evolved from the mucous membrane of the rectum. The rectal bulb of Opisthoproctus is simply a widened section of the rectum possessing very high and narrow folds, the epithelium of which is differentiated into luminous epithelium and lens epithelium. The rectal bulb of Winteria is an outgrowth of the caudal part of the wall of the rectum with a rather complicated system of epithelial infoldings originating from the mucous membrane of the rectum. In these infoldings lens cells and two morphologically different types of secretory epithelial cells are found. The lens cells of the rectal bulb of Winteria show a certain resemblance to those of

[^11]the rectal bulb of Opisthoproctus, especially $O$. grimaldii. The cytoplasm of the lens cells of $O$. grimaldii, however, shows a uniform staining, and we have not seen a narrow brim of vacuolized cytoplasm along the walls of the cells as is found in at least some of the lens cells of Winteria.

The lens cells of the rectal bulb of Opisthoproctus form together a lentiform body lying close to the window of the bulb. The light produced in the rectal bulb is thus probably concentrated by refraction in the lentiform body before it is transmitted to the crystal-clear hyaloid body of the reflector organ through the window. In this organ the light is reflected downwards by the reflector proper and dispersed over the whole sole.

By elongation of the sole part of the transparent basal portion of the thin scales of the sole is exposed, thereby increasing the quantity of light emitted. Contrarily a relaxation of the smooth muscles of the sole causes a shortening of the sole and thus a screening of the light.

By simultaneous contraction of the smooth muscles of the reflector organ the sole is probably elongated, and at the same time the width of the sole is probably slightly diminished. This is apparent from the structure of the reflector organ; contraction of the smooth muscles must have a squeezing effect on the hyaloid body, which is in principle a closed horizontal cylinder with a non-compressible watery content. The incomplet circular smooth muscle of the sole is probably the most effective squeezer.

It is more difficult to give a functional interpretation of the three pairs of striated muscles, which insert into the reflector organ. The purpose of the dorsal striated muscle which connects the posteriormost part of the reflector organ with the rectal bulb, might be to keep the rectal bulb in contact with the window during elongation and shortening of the sole.

In Winteria the lens cells are situated in the peripheral part of the rectal bulb, and the lens cells form together a concavo-convex lens. It seems reasonable to suppose that the light produced in the rectal bulb is refracted in such a way that it is transmitted into the hyaloid body in the ventral body wall; the refraction probably also results in concentration of the light. As in Opisthoproctus the light is reflected by the reflector layer situated beneath the peritoneum. We do not know whether Winteria possesses a screening-mechanism.

It is at present unknown whether any of the related argentinoid fishes are luminous ${ }^{1}$ ). The modified ventral body wall found in Dolichopteryx and Rhynchohyalus shows a certain resemblance to that of Winteria which might indicate a similar function as light transmitters. Considering the evidence for presence of luminous bacteria in the rectal bulbs of Opisthoproctus and Winteria the possibility that such bacteria should be found in the intestine of these related species cannot be excluded.

The function of the anal bulb of Rhynchohyalus is not evident ${ }^{1}$ ). The strong bulb muscles seem to form a mechanism by which the rectum can be very effectively closed, or by which the content of the rectum can be ejected.

Luminous organs of the indirect type emitting reflected light through parts of the body have been found in some percomorphi (Harms 1928, Haneda $1950 \& 1955$, Iwai 1958, Kato 1947, Yasaki \& Haneda 1936), Gadidae, and Macrouridae (Hickling 1925, $1926 \& 1931$, Haneda 1951, Kishitani 1930). In the major part of these fishes the luminous gland is of the open type and situated in the ventral body wall, while the external opening of the duct of the gland is found in the distal part of the rectum or near the anus; the luminous gland in the apogonid fish described by Iwai (1958) has apparently no lumen, nor any duct. The lens, reflector, and screening mechanism of the light organs of Opisthoproctus and Winteria seem to have reached a higher specialization than in any of those mentioned above.

Only some of the open luminous organs of the indirect type described in literature can be definitely regarded as derived from the mucous membrane of the alimentary canal; in Apogon marginatus (Кato 1947) the luminous epithelium is situated in diverticula of the intestine, and some leiognathid fishes posses a ringshaped luminous gland which encircles the oesophagus (Harms 1928, Haneda $1950 \& 1955$ ).

With the exception of the histological descriptions found in the papers of Harms (1928) and Hichling ( $1925,1926 \& 1931$ ) detailed information on the finer structure of the open luminous organs is scarce. According to Harms (1928) the luminous gland of the Leiognathus sp. examined by him has a tubular structure. The cells found in the terminal portion of each tubule has a basal nucleus, whereas the whole distal part is occupied by one large vacuole (cf. Harms 1928, Fig. 2: 162). These cells show a certain resemblance to
${ }^{1}$ ) Cf. foot-note p. 13.
the lens cells found in the rectal bulb of Opisthoproctus and Winteria. Hickling has described secretory epithelial cells distended by secretion in the luminous gland of Malacocephalus laevis (Hickling 1926, Fig. I: 496); these cells resemble the cuboidal epithelial cells distended by accumulated secretion which we have seen in the rectal bulb of Winteria.

It may also be mentioned that the cells in the luminous organs of Apogon marginatus, which are simple diverticula from the intestine, are filled with an esosinophilic secretion (Karo 1947, Fig. 4: 197).

As regards the biological significance of the luminous organs of Opisthoproctus and Winteria we have no actual knowledge. Owing to the shape of the reflector proper the major part of the light transmitted through the hyaloid body is cast downwards. Clarke (1963) has recently suggested that the ventrally situated luminous organs of mesopelagic animals might function partly as a countershading mechanism. This hypothesis is based on the fact that the quality of the light emitted from the luminous organs of deep-sea animals examined shows a close correspondance with that of the residual daylight (for references see Clarke 1963). Since both the daylight and the light produced by the luminous organs of deep-sea animals are directed downwards, the light from the latter may serve to dissolve the contour of the animals when seen from below. This hypothesis presupposes that light is emitted continuously from the luminous organs which may very well be the case in such species as Opisthoproctus and Winteria. The screening mechanism of Opisthoproctus furthermore allows a gradation of the intensity of the light emitted.

It seems reasonable to suppose, however, that the light from the sole of Opisthoproctus might also serve as a recognition sign; the dorsally directed tubular eyes seem to be particularly well adapted for the detection of the faint downwardly directed light emitted from the sole which might thus facilitate recognition by specimens of its own kind (see Walls 1942: 402). The use of the light as a recognition sign presupposes a light intensity which makes at least part of the sole conspicuous against the background when seen from below. Owing to the direction of the light from the sole, this comparatively bright light is probably difficult to detect for a predator which is not situated straight below and fairly close to the fish.

In a larger sexually mature specimen of $O$. grimaldii Cohen (1960) found four dark patches on the posterior part of the sole. He suggests that they might be of significance for species recognition. Cohen found no patches on the sole of large specimens of $O$. soleatus.

## SUMMARY

The histology of the reflector organs and the rectal bulbs of Opisthoproctus and Winteria is described. The rectal bulb is a luminous organ derived from the mucous membrane of the rectum. The rectal bulb of Opisthoproctus is simply a widened section of the rectum possessing very high and narrow folds, whereas the rectal bulb of Winteria is an outgrowth from the caudal wall of the rectum with a rather complicated system of epithelial infoldings. There is some morphological evidence of the presence of bacteria in the lumina of the rectal bulbs in both genera. Both in Opisthoproctus and Winteria the epithelium of the rectal bulb possesses 2 specialized cell types, viz. glandular cells and lens cells. The lens cells form together a lentiform body in Opisthoproctus and a concavo-convex lens in Winteria. In both genera the light produced in the rectal bulb is transmitted through the lens to the crystal-clear hyaloid body of the reflector organ situated in the ventral body wall; here the light is reflected downwards by the reflector proper. Opisthoproctus possesses a screening mechanism, by means of which the intensity of the light emitted can be regulated. The possible biological significance of the luminous organ is discussed. Specimens representing the related genera Dolichopteryx, Macropinna, and Rhynchohyalus were examined. In a young specimen of the last mentioned genus a rectal light organ was observed (foot-note p. 13.), while in the representatives of the two other genera no light organs of the same type as in Opisthoproctus and Winteria and no conclusive evidence of luminescence were found.

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## Plate I.

## Adult Opisthoproctus soleatus

Fig. 1. Transverse section through posterior part of reflector organ. $50 \mu$ section. Mallory's phosphotungstic acid hematoxylin. NA: 0.10. Reduced from $42 \times$.
Fig. 2. Transverse section through window of rectal bulb. $50 \mu$ section. Mallory's phosphotungstic acid hematoxylin. NA: 0.10 . Reduced from $42 \times$.
Fig. 3. Transverse section through rectal bulb and posteriormost part of reflector organ. $50 \mu$ section. Mallory's phosphotungstic acid hematoxylin. NA: 0.10. Reduced from $42 \times$.
Fig. 4. Transverse section through middle of rectal bulb. $50 \mu$ section. Mallory's phosphotungstic acid hematoxylin. NA: 0.10 . Reduced from $42 \times$.
Fig. 5. Transverse section through posterior part of rectal bulb. $50 \mu$ section. Mallory's phosphotungstic acid hematoxylin. NA: 0.10 . Reduced from $42 \times$.

## Larval Opisthoproctus grimaldii

Fig. 6. Transverse section through reflector organ of 10 mm larva. $8 \mu$ section. Hematoxylin-orange G. NA: 0.45. Reduced from $141 \times$.
Fig. 7. Transverse section through rectal bulb of 10 mm larva. $8 \mu$ section. Hematoxylin-orange G. NA: 0.45 . Reduced from $141 \times$.
Fig. 8. Transverse section through reflector organ of 14.5 mm larva. $8 \mu$ section. Heidenhain's azocarmine-aniline blue stain. NA: 0.45 . Reduced from $141 \times$.
Fig. 9. Ridges of folds from dorsal part of rectal bulb of 14.5 mm larva. $8 \mu$ section. Heidenhain's azocarmine-aniline blue stain. NA: 0.65 . Reduced from $564 \times$.

Fig. 10. Luminous epithelium from rectal bulb of 14.5 mm larva. $8 \mu$ section. Alcian blue-Kernechtrot. NA: 1.30 . Reduced from $1410 \times$.
Fig. 11. Lens epithelium from rectal bulb of 14.5 mm larva. $8 \mu$ section. H-E. NA: 1.30 . Reduced from $1410 \times$.
Fig. 12. Luminous epithelium from rectal bulb of 14.5 mm larva. $8 \mu$ section. Heidenhain's azocarmine-aniline blue stain. NA: 1.30 . Reduced from $1410 \times$
Fig. 13. Lens epithelium from rectal bulb of 10 mm larva. $8 \mu$ section. Hematoxylin-orange G. NA: 1.30 . Reduced from $1410 \times$.

## Lettering to Figures on Plate I.

| a: artificial fissue or hole | $\mathbf{m 2}:$ posterior striated muscle of reflector organ |
| :--- | :--- |
| c: coelom | mc : incomplete circular smooth muscle of sole. |
| cf: layer of dense collageneous fibres. | $\mathrm{md}:$ dorsal smooth muscle of sole |
| ct: connective tissue in wall of rectum | mv : ventral smooth muscle of sole |
| g: granular material | $\mathrm{p}:$ peritoneum |
| hl: hyaloid body - lateral part | $\mathrm{pf}:$ pelvic fin |
| hm: hyaloid body - median part | r: reflector layer |
| i: intestine | rb: rectal bulb |
| le: lens epithelium | s: median septum of hyaloid body |
| lu: luminous epithelium | w: window (between arrows) |
| m1: dorsal striated muscle of reflector organ | x: lumen of rectum |



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[^0]:    ${ }^{1}$ Fork length is defined as the distance from tip of snout to tip of middle ray of caudal fin.

[^1]:    ${ }^{2}$ Based on length-weight relation, $\log$ weight $=-7.1167+2.9304 \log$ fork length, calculated for P. sibi from Hawaiian waters by the Bureau of Commercial Fisheries Biological Laboratory, Honolulu.
    ${ }^{3}$ Tuna Fishing, Nos. 11, 13, 19, 45, 55.

[^2]:    - Tuna Fishing, Nos. 16-18, 39, 48.
    s Tuna Fishing, Nos. 17 and 18.

[^3]:    $3 \quad 4 \quad 5$
    1-5' 2-4, 2-3.
    ${ }^{8}$ Tuna Fishing, Nos. 1, 12, 13, 23, 24, 34, 35, 36.

[^4]:    7 Oceanographic research vessel of the C.S. Fish and Wildife Service formerly used in the Philíppine Físheríes Program.

[^5]:    ${ }^{1}$ Ebeling's revision of the genus Melamphaes (Melamphaidae I. Systematics and zoogeography of the species in the bathypelagic fish genus Melamphaes Gënther) was submitted for publication simultaneously with the present contribution and will for editorial reasons appear as Dana-Report no. 58. (Editor's note).

[^6]:    Fig. 2. Distribution of Sio nordenskjoldii. Expeditions providing specimens for the present study are designated by the following s $\leq$ mbols: Academy of Sciences of the L.S.S.R.. Institute of Oceanology, R V"Vitiaz"; Carlsberg Foundation, Denmark, R V "Dana": , Discovery Committee, Great Britain Colonial Office, R, V'Discovery"; e, Galathea Committee, Denmark. R v"Galathea": 1 . Iniversity of California, Scripps Institution of Oceanography "Monsoon" Expedition. The locality of capture of the holotype is designated ' $X$ '. Each plotted symbol represents a net tow in which one or more specimens of $S$. nordenskjödii were taken. The stippled bands indicate water-mass boundaries, the positioning of which was adapted from Sverdrup et al. (1942).

[^7]:    ${ }^{1}$ The lateralis branch of the vagus nerve, however, is well developed and extends midlaterally along the length of the body

[^8]:    ${ }^{1}$ While this paper was in press, however, additional synonymies were established with some degree of certainty. Scopelogadus cocli: is a synonym of $S$. mizolepis, which comprises 2 subspecies, S. m. mizolepis in the Atlantic and Indo-Pacific, S.m. bispinosus in the eastern Pacific. Poromilra cristiceps, P. frontosa, P. nigrofulva, P. nigriceps, P. atlantica and P. rugosa, all are probably synonyms of P. crassiceps. Scopeloberyx nigrescens and S. opercularis are synonyms of S. robuslus.

[^9]:    * Counts based on especially large numbers of specimens.
    ** For an adult 75 mm . in standard length, BOC 2630 , from the western North Atlantic the count was $4+11+8+3$.
    *** For an adult 112 mm . in standard length, G 654, from the Tasman Sea the full count, in order, was $108+90+59+90$.

[^10]:    ${ }^{1}$ ) In accordance with Cohen 1960 Monacoa Whitley is regarded as synonymous with Ophisthoprocius Vaillant.
    ${ }^{2}$ ) Cf. foot-note p. 13.

[^11]:    ${ }^{1}$ ) After the manuscript of this paper had been completed an adult specimen ( 122 mm in standard length) of Macropinna microstoma and a postlarval specimen ( 23 mm in standard length) of Rhynchohyalus natalensis were obtained for examination. Serial sections of the anal region of the Macropinna specimen confirmed that no rectal light organ is present in this species.

    Serial $8 \mu$ sections of the 23 mm Rhynchohyalus nalalensis revealed that the mucous membrane of the anal part of the rectum is provided with tightly packed folds with luminous cpithelium showing a very close resemblance to that of opishoproctus. Abundant granular material (bacteria) is situated between the folds. No lens epithelium is present. A description of this specimen is under preparation.

