

**“STUDIES ON BIOLOGICAL ASPECTS OF THE MOON FISH,
MENE MACULATA (BLOCH AND SCHNEIDER, 1801) OFF
MANGALORE COAST”**

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Thesis submitted to the
Karnataka Veterinary, Animal and Fisheries Sciences University,
College of Fisheries, Mangalore, in partial fulfillment of the requirements for the award of
the degree of

MASTER OF FISHERIES SCIENCE

IN

FISHERIES RESOURCES AND MANAGEMENT

BY

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**DEPARTMENT OF
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COLLEGE OF FISHERIES, MANGALORE**

**KARNATAKA VETERINARY, ANIMAL AND FISHERIES SCIENCES
UNIVERSITY, BIDAR, KARNATAKA**

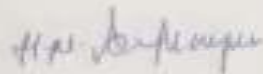
June, 2019

Karnataka Veterinary, Animal and Fisheries Sciences University, Bidar
 Department of Fisheries Resources and Management
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Certificate

This is to certify that the thesis entitled "STUDIES ON BIOLOGICAL ASPECTS OF THE MOON FISH, *MENE MACULATA* (BLOCH AND SCHNEIDER, 1801) OFF MANGALORE COAST" submitted by Mrs. Sueha Darshan, C.I.D. No. MFK 1528 in partial fulfillment of the requirements for the award of Master of Fisheries Science in Fisheries Resources and Management of the Karnataka Veterinary, Animal and Fisheries Sciences University, Bidar is a record of bonafide research work carried out by her during the period of her study in this University under my supervision and the thesis has not previously formed the basis for the award of any degree, diploma, association ship, fellowship or other similar titles.

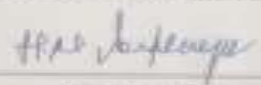
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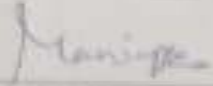
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DEDICATED

to my

Beloved Parents

For their endless love and encouragement

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June, 2019


(Sucha Darshan C)

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LIST OF ABBREVIATIONS AND THEIR SYMBOLS

%	:	Per cent
@	:	At the rate
cm	:	Centimeter
<i>et al.</i>	:	Co-authors
Fig.	:	Figure
i.e.	:	id est; that is
kg	:	Kilogram
m	:	Meter
mm	:	Milimeter
mt	:	Million tonne
No.	:	Number
<i>viz.</i>	:	Namely
wt.	:	Weight
Fig.	:	Figure
Jan.	:	January
Feb.	:	February
Mar.	:	March
Apr.	:	April
Sep.	:	September
Oct.	:	October
Nov.	:	November
Dec.	:	December

1. Introduction:

The moonfish, *Mene maculata* is belonging to genus *Mene*, family Menidae, Order Perciformes are popularly called as Moonfish. It was considered as a single most species in the family Menidae but in the year 2005, Friedman and Johnson (2005) identified and described a new species in the same family i.e *Mene purdyi* from northwestern Peru. *Mene maculata* was morphologically identified by deeply forked caudal fin, body is highly compressed laterally and very deep vertically. The ventral profile is steep, with a sharp ventral edge. The mouth small and protrusible, body is silvery below and blue-green on the back, with three to four rows of dark gray spots on the upper side. The first two rays of the pelvic fin are greatly elongated, forming a prominent backward-pointing process on the underside of the fish. They occur at depths from 50 to 200m. Also, it is reported that this species can reach a length of 30 cm TL. It inhabits deeper coastal waters especially around coral reefs (Carpenter *et al.*, 1997) *Mene maculata* is known to school (Lee *et al.*, 1988) near the bottom on both the continental shelves and around major Island groups; sometimes in estuaries. Distributed in the Indo-Pacific region tropical waters from East Africa to southern Japan and northeastern Australia, South China Sea and Arafura Sea (Friedman and Johnson, 2005). It is an important species in the mouth of Beibu Gulf, South China sea and Western Taiwan waters (Shi-Qiang *et al.*, 2012; Hwang *et al.*, 2002). *Mene maculata* is distributed in several Asian countries including India.

The economics of low value bycatch marketing was studied by Aswathi *et al.*, (2011), observed that, there is an urgent need for comprehensive estimation of bycatch and discards from trawlers from all coastal states of the country for developing policies to reduce bycatch and discards. The issue of discards is of great concern worldwide and

extensive studies were carried out to understand its impact on the structure of marine communities or ecosystems.

Over recent years, there has been an increased need to estimate the reproductive population variables of marine fishes in order to obtain accurate estimates of the effect of fishing on the reproductive potential of the stock (Murawski *et al.*, 2001). To understand the biology of Menidae is essential to determine the parameters to be used in stock assessment, conservation and management measures. Moreover, knowledge of spawning season, breeding area and fishing location are instrumental in establishing time and area closures to protect essential fish habitats along with modification of fishing gear to enhance the survival of heavily exploited species (Rosenberg *et al.*, 2000). Study conducted by Shi-qiang (2012), Gonado-Somatic index (GSI) of *Mene maculata* fish indicated reproduction and annuli formation were the same time mainly from August to October. Hwang *et al.* (1981, 1984, 2002) described the fishery, reproduction, age and growth of moon fish before and after heavy exploitation in Taiwan waters. Chung (1981) and Luo (1982) examined stomach content to study the food and feeding habits.

In addition, food and nutrition security problem of world can be overcome from fisheries, because of low cost and high nutritional value. But, major economic value species are declining and it is necessary to find an alternative species and manage the resources by studying its biology. Hence, at present best alternative is moon fish and it already proved by increasing its market and price. Therefore, it is necessary to study the nutrient contents in the fish to get the knowledge and correlate with biological aspects. Based on available literature, Palanivel *et al.*, (2014) and Bijukumar *et al.* (2013) studied the proximate composition of moon fish but, data was not sufficient to correlate with the biology and sample collected from different coast. However the moon fish *M. maculata*, it

has commercial value. Therefore, comprehensive information on *M. maculata* catches from Karnataka state and no serious attempts have been made so far to investigate on the biology and population characters of the species.

As there is paucity of information on biological aspects (biology, reproductive biology, food and feeding habits) of *M. maculata* off Mangalore coast, hence, the present study is undertaken with following objectives.

Objectives of the study:

1. To understand the length weight relationship and relative condition factor of *Mene maculata*.
2. To understand the food and feeding habits and reproductive biology of *Mene maculata*.
3. To assess the proximate composition of *Mene maculata*

2. REVIEW OF LITERATURE

2.1. Taxonomic Studies:

The Moonfish, *Mene maculata* (Bloch and Schneider, 1801) belongs to the single genus *Mene*, and family Menidae and comes under order Perciformes. Unique morphological character of moon fish is described as follows-Body deep, almost triangular, and extremely compressed; breast sharp-edged. Mouth small, almost vertical, protrusible; teeth limited to villi form bands in jaws. Dorsal fin single, long-based, and low, except for a short peak anteriorly, spines thin and flexible and difficult to distinguish from the 34th to 36th soft rays. Anal fin long, commencing at point of insertion of pelvic fin, caudal fin deeply forked. Pectoral fins shorter than head length. Pelvic fins inserted slightly in front of pectoral fins, with 1 short spine followed by 5 soft rays, the first 2 soft rays fused and greatly elongated. Lateral line tracking upwards towards base of last ray of dorsal fin and often terminating well above midline of caudal peduncle but sometimes continuing onto base of upper lobe of caudal fin. Body covered with minute scales invisible to the naked eye, easily brushed off. Colour of the species is a deep metallic blue upper side of the body, remainder silvery, with a row of round to ovoid, dark slaty-blue spots above and below lateral line, sometimes a few additional spots above and below these rows; pelvic fin with a trace of blue, other fins hyaline or slightly dusky.

2.2. Geographical distribution

Mene maculata is broadly distributed from East Africa, as far south as Durban, to the western Pacific; in Australia, stragglers as far south as Shark Bay (Western Australia) and Noosa R. on the eastern Australian coast; northern limits of southern Japan (Bloch and Schneider, 1801). Similar, observations were made in the year 1935 and 1984 by other

scientists (Montilla, 1935; Masuda *et al.*, 1984). Recently, Shi-Qiang (2012) stated that, the moon fish is distributed in the Indo-Pacific tropical waters from East Africa to southern Japan and northeastern Australia, recorded from the South China Sea and the Arafura Sea. Also, it is an important species in the mouth of Beibu Gulf and its catch increased yearly according to resources survey in the south China sea from 2008 to 2010. According to fish database moon fish is distributed in Indo-West Pacific, East Africa, as far south as Durban in South Africa, to southern Japan and northeastern Australia, east to New Caledonia. From FAO reported that, species is native to Indian Ocean - Western and eastern, Pacific- Northwest, Western Central and Southwest.

2.3 Length-Weight relationship and relative condition factor:

Study conducted by Hwang *et al.* (2002) on moon fish in Southwestern Taiwan waters reported that the length ranged from 102.0 to 209.8 mm and 107.0 to 208.3 mm for the year 1981-1984 and 1995-1997 respectively. Also, length-weight relationship data sets were estimated as $W = 3.961 \times 10^{-5} L^{2.939}$ ($r^2 = 0.95$, $n = 150$, $P < 0.05$) for the year 1981-1984 and $W = 1.568 \times 10^{-5} L^{3.147}$ ($r^2 = 0.99$, $n = 154$, $P < 0.05$) for 1995-1997. They inferred that, there was no significance difference in mean length and growth of moon fish. Recently, Shi-qiang (2012) studied fishery biology of Moonfish *Mene maculata* and resources exploitation status in the Mouth of Beibu Gulf. He reported that, the body weight and fork length data fitted to the function $W = 6 \times 10^{-5} L^{2.8415}$ and Fork length and age data were fitted to the von Bertalanffy growth function $L_t = 334.85 [1 - e^{-0.17(t+0.92)}]$ concluded that, growth of moonfish is fast till age three, and then gradually slows down.

Manojkumar (2007) studied on length-weight relationship of *Nemipterus mesoprion* from Malabar coast showed no significant difference between the regression coefficients of

both the sexes, hence a common equation was fitted as $\text{Log } W = - 3.9620 + 2.8298 \text{ Log } L$. Similarly, length-weight relationship of *N. japonicas* from Varaval waters was derived to be $\text{Log } W = -4.7338 + 2.9902 \text{ Log } L$ ($r=0.9786$) by Manojkumar (2004). Zacharia and Nataraj (2003) estimated the length – weight relationship for male and female of *N. mesoprion* separately. The relationship for male was $\text{Log } W = -4.64163 + 2.89452 \text{ Log } L$ and that for female was $\text{Log } W = -4.7832 + 2.9628 \text{ Log } L$. Joshi (2005) assessed the length-weight relationship to be $\text{Log } W = - 4.700 + 2.926 \text{ Log } L$ for *N. mesoprion* off Cochin waters. Manojkumar (2007) studied the length-weight relationship of *N. mesoprion* off Malabar Coast and found that there is no significant difference between the sexes and hence a common equation was fitted as $\text{Log } W = - 3.9620 + 2.8298 \text{ Log } L$. Afshari *et al.* (2013) studied the length-weight relationship of *N. japonicas* and found combined equation for both the sexes $BW = 0.0001 \times FL^{2.83}$ ($r^2 = 0.9425$, $n = 212$).

Mohanraj (2008) assessed length- weight relationship of *Upeneus sundaicus* and *Upeneus tragula* from Tuticorin coast of Gulf of Mannar. Found the results of the two species of *U. sundaicus* (male) $\log \text{ wt} = -5.1327 + 3.1032 \log \text{ Lt}$ ($r=0.9096$) *U. sundaicus* (female) $\log \text{ wt} = -4.5318 + 2.8313 \log \text{ Lt}$ ($r=0.9231$) *U. tragula* (male) $\log \text{ wt} = -5.0014 + 3.0354 \log \text{ Lt}$ ($r=0.9529$) *U. tragula* (female) $\log \text{ wt} = -4.8868 + 2.9848 \log \text{ Lt}$ ($r=0.9504$). F values indicated that the comparison of slopes is significant at $>5\%$ level for *U. sundaicus* and it is not significant for *U. tragula*.

Ghosh *et al.* (2010) studied on fishery and population dynamics of *Protonibea dicanthus* (Lacepede) and *Otolithoides biauritus* (Cantor) from Diu, west coast of India. It showed that, length –weight relationship for *Protonibea dicanthus* and *Otolithoides biauritus* was $\text{Log } W = -1.783 + 2.857 \log L$ and $\text{Log } W = -1.427 + 2.539 \log L$ respectively. However,

Kizhakudan *et al.* (2012) studied the length-weight relationships of silverbellies (*Photopectoralis bindus*, *Secutor insidiator* and *Gazza minuta*) from Tamil Nadu coast showed, length-weight equations for each species *P. bindus* $W = 0.000011989 L^{3.0515}$ ($r = 0.9788$) *S. insidiator* $W = 0.00002369 L^{2.905}$ ($r = 0.9896$) *G. minuta* $W = 0.00002088 L^{2.9228}$ ($r = 0.9894$) and estimated b values for these three species do not deviate significantly from the isometric value of '3' at 5% level. Similarly for *U. pori* expressed $W = 0.01073 \times L^{2.994}$, with $r^2 = 0.980$ for male and $W = 0.01055 \times L^{3.001}$ with $r^2 = 0.986$ for female indicated its isometric growth (El-Drawany, 2013). And, for ponyfish *Secutor insidiator* (Bloch, 1787) from Visakhapatnam coastal waters showed length-weight relationship $W = 0.0000170 L^{2.9143}$ in females $W = 0.00000369 L^{2.7976}$ in males $W = 0.00000352 L^{2.8920}$ in pooled regression. The regression coefficient (b) was found to be 2.9143 which differ significantly from hypothetical value (3) indicating negative allometric growth (Muddula *et al.* 2015).

Length-weight relationship gives information on the condition and growth patterns of fish. Usually, growth coefficient 'b' of length-weight relationship generally between 2.0 to 4.0 and the relation is said to be absolute isometric growth when 'b' value is 3 (Carlander, 1977; Le Cren, 1951). Study conducted on *N. japonicas* from Veraval waters 'b' value found 2.9807, indicates the allometric growth (Swatipriyanka *et al.* 2014). However, occurrence of absolute isometric growth (b=3) in nature is occasional (Pauly, 1984). Study conducted on cultured species showed 'b' value about 3.136.

2.4 Food and feeding habit:

Feeding is one of the basic and vital functions of an organism since all its activities starts from food energy consumed by it (Nikolsky, 1976). Study of food and feeding habits of

any fish forms one of the main aspects in the study of its biology (Qasim, 1972). In regard, study of food and feeding habits of fishes first attracted the attention of fishery biologist in the later half of the 18th century. The pioneering work in this field was that of Day (1889) on two groups of marine fishes. Subsequently a number of studies on food and feeding habits all over the world carried out and valuable information is available regarding the food and feeding habits of fishes. In our country the investigation in this direction was initiated comparatively late and it has attained tremendous momentum in the recent past. The important work were of Devanasan (1932); Job (1940); Chacko *et al.* (1949); Pillai (1953); Sarojini (1954); Venkataraman (1960); Thomas (1969); Pillai *et al.* (1985); Jayabalan (1991); Mohanraj (2000); Durgaprasad (2002); Appala Naidu (2003); Ramana (2007); Shanti Prabha *et al.* (2008) etc. An important aspect in fishery biology investigation is the study of food and feeding habits which include a Quantitative and Qualitative study of different kinds of food consumed and the way in which food habits are influenced by habitual; preference; season etc. These studies helped to determine population level, rate of growth and condition; ecological links, habitual niches; energy flow, abundance and migration etc.

Chung, K. J. (1981) studied on the stomach content of fish *M. maculata* and published papers in Chinese language. Hence, could not able to get the information. Studies on food and feeding habits of *N. japonicus* reported that, no seasonal variation was observed in the feeding habits of fish whereas, depth wise analysis indicated remarkable changes in the composition of diet. Fishes occurring at 10-20m depth were fed mainly on *Metapenaeus dobsoni* and *Parapenaeopsis stylifera* along with some other crustaceans, tube dwelling polychaetes, mud with shell pieces, foraminiferans, partly digested fish remains, diatoms and

algae. Diet of fishes caught in 20-30m depth included teleosts besides crustaceans. In 40-50 M depth the fish was found to be cannibalistic (Kuthalingam, 1965).

Food and feeding habits of *Nemipterus* viz. *N. bathybus*, *N. japonicus*, and *N. virgatus* in Hong Kong waters showed that they are active predators (Eggleston, 1972). He noticed that adult fishes feed mainly on crustaceans, fishes and cephalopods. He opined that feeding is by day and hunting is by sight. Young fish (particularly *N. bathybus*) consume considerable quantities of copepods, ostracods and amphipods. His study showed that the cephalopods form bulk in *N. virgatus* diet, small crustaceans were noticed in *N. bathybus* and more polychaetes and lamellibranchs were present in *N. japonicus*. Manojkumar *et al.* (2015) studied on *N. japonicus* (Bloch) from Malabar Coast, Kerala. He reported that, diet consisted of fishes, crustaceans, molluscs, polychaetes and miscellaneous food items. The trophic spectrum of *N. japonicus* is composed of 34 food items. All size groups of fishes preferred crustaceans such as Penaeid shrimps, *Acetes* spp. and deep sea shrimps were the dominant crustacean components.

Somashekara (2009) studied on food and feeding habits of *N. mesoprion* indicated that the species mainly fed on crustaceans (51.35%) followed by fishes (29.24%). Molluscs (4.95%), polychaetes (1.00%), unidentified matter (7.37%) and semi – digested matter (5.97%) and is considered as carnivorous and predacious at bottom. And other earlier works (Anonymous, 1960; Rao, 1967; George *et al.*, 1968; Krishnamoorthi, 1971; Eggleston, 1972; Qasim and Jacob, 1972; Muthiah and Pillai, 1979; Daud and Taha, 1986; Rao, 1989; Rao and Rao, 1989; Zacharia and Nataraj, 2003 and Manojkumar, 2004) also indicate that threadfin breams are bottom feeders and mainly feed on crustaceans and teleosts.

Rao (1967) made observation on food and feeding habits of *Otolithes cuvieri*, mainly prawns (viz., *Acetes spp*, *Solenocera spp*, and *Hippolysmata spp*) and teleosts were recorded in the stomach. The food and feeding habit of *Upeneus vittatus* from Mangalore coast was studied by Jayaramaiah *et al.* (1996). For *U. moluccensis* along North West coast and Madras coast of India was studied by Bhargava and Somvanshi (1998) and Mohanraj (2000) respectively. *U. vittatus* and *U. moluccensis* from the Coastal waters of Visakhapatnam. The study revealed that, the species are carnivorous feeding mainly on crustaceans and teleosts fishes and occasionally on molluscs.

Blay (2006) reported on preliminary study of the juveniles of *B. auritus* and *Pseudotolithus senegalensis* from Ghanaian coastal waters revealed that, the species were stenophagous carnivores with high preference for juveniles of shrimps and other fishes. Similarly, Xue *et al.* (2005) reported diversity of prey species in the stomach of the yellow croaker, *Pseudosciaena polyactis* from Central Yellow Sea. And, study conducted by Nunoo *et al.*(2013) on *P. senegalensis* and *P. typus* from Benin near shore waters showed major dietary components were shrimps such as *P. senegalensis* and *P. typus* but did not show any variation with season. In *Leiognathus berbis* (Valenciennes) from Turicorin, Southeast coast of India, major food items of are Phytoplankton, Zooplanktons and micro invertebrates but it also showed no remarkable variation in size related selection of food items. And also, no sexual variation in selection and preference of food was observed (Nagarajan, 2014). For another silverbelly *Leiognathus dussumieri* (Valenciennes) from Thoothukudi had showed zooplanktons as a major constituent and no remarkable variation in size related selection of food items. And other minor constituents of the diet were fish scale, amphipods, crustacean remains, bivalves, foraminiferans, diatom, polychaetes, nematodes and gastropods. It also

showed no sexual variation in selection and preference of food was observed in the study (Nagarajan, 2014). Sebastian *et al.* (2011) Silverbelly, *Leiognathus brevis* (valenciennes, 1935) from Kerala coast fed mainly on Planktonic crustaceans, diatom, nematodes, polychaetes and foraminiferans. Ayyappan *et al.* (2011) for *Leiognathus* stated that, no significant variations in the food of the fish from different place in different seasons. All size groups ranges from 6.1 –12.5 cm, fish species showed food items comprised of zooplankton, mollusca, phytoplankton and crustacean remains, nematodes, sand grains, semi-digested matter, fish scales were found in different proportions.

2.5 Reproduction:

It is an important aspect of fishery biology it includes length at first maturity, maturation cycle, fecundity, sex-ratio and spawning season. By knowing all the above aspects will exploit the fish without affecting their population. Identification of the breeding activity of an exploited fish species provides management options for the protection of its spawning stocks (McPherson, 1993). Information on the length at first maturity is constitutive to ensure a sustained yield by regulating the mesh size of the net, to make sure that the smaller fish also gets an opportunity to spawn at least once in their life span. In addition, knowledge on maturation process and spawning frequency is reported to be useful for understanding the life history, stock structure, recruitment and fishery dynamics (Schaefer, 1957). Sex-ratio study is important because males and females are of different sizes in majority of fishes, a displacement of the average size of fish in the commercial catches in either direction will also alter sex composition of the stock. Ceratin internal factors (hormones) and external factors (water temperature and salinity) reported to act as stimuli for inducing spawning in fishes (Qasim, 1973). But, scanty information is available on the reproductive aspects of *M.*

maculata and no contemplation was so far paid to *M. maculata* distributed along the Indian waters. Previous work on the reproductive biology of the *M. maculata* from abroad included Hwang *et al.* (1984) study on maturity and fecundity of moon fish, *M. maculata* in adjacent waters of Taiwan and it was published in Chinese language.

Manojkumar (2004) studied on the biology of *Nemipterus japonicas* (Bloch) from Veraval in Gujarat, size at first maturity was estimated at 183 mm and spawning occurs mainly from November to December and in February. The females marginally dominated the fishery and the sex ratio between males and females was 1:1.01. The fecundity ranged from 14212 to 46387. Where as in Northern Persian Gulf (Kerdgari *et al.*, 2009) showed sex-ratio between male and female reported to be was 1: 2.6 and length at 50% maturity was estimated to be 19.1 cm for female and 19.6 cm for male. They also revealed that the maximum GSI value was recorded in the month of April (2.7%) and September (0.45%) for female and male respectively while the spawning occurred in spring and autumn season. Kuthalingam (1965) opined that the fishes move towards the deeper regions became sexually mature. On the basis of observation of *N. japonicas* catch off Mangalore coast, he suggested that the spawning ground may be somewhere beyond 50 m depth and it is possible that the breeding takes place during January or February. Dan (1997) studied the fecundity and maturity of *N. japonicas* from Visakhapatnam defined ova in to 6 stages and ovary into 7 stages with fecundity from 10.5 to 80.8 thousand in fish ranging in size from 13 to 20.9 cm and increased fecundity with size. He also reported that fish bred twice a year viz. December, February and June-July, with short spawning period. Similarly, on *N. delagoae* from Bombay waters was studied on Sex-ratio, maturity condition, ova diameter, spawning season and spawning period (Muthiah and Pillai, 1979). At Saurashtra coast (Gujarat), *Nemipterus japonicus* (Bloch, 1791) and *N.*

mesoprion (Bleeker, 1853) showed females dominated the catches and size at first maturity was estimated to be 141 mm for *N. japonicus* and 135 mm for *N. mesoprion*. The spawning peak in *N. japonicus* was found to occur during September-December, with a secondary peak in May. *N. mesoprion* had a prolonged spawning period extending from October to March (Shoba *et al.*, 2008). However, at Cochin coast, *N. mesoprion* showed estimated length at first maturity was 106 mm and spawning season extends from May to November (Joshi, 2005).

Rao (1967) studied the spawning season of *L. splendens* along the Madras coast and inferred that the species was a prolonged one, with two peaks, during January, February and June. Jayabalan (1986) reported *L. splendens* spawn throughout the year with peaks in April-May and October- January along the Port Novo coast and high gonado-somatic indices correspond well with the peak spawning months, also females always have higher values. The Relative condition factor does not indicate any relation with the reproductive cycle. Females mature between 76 mm and 111 mm total length whereas, male mature between 81 mm and 111 mm. Sex-ratio shows general preponderance of males. Fecundity, varying between 7099 and 21,507, appears to increase with length of fish. Abraham *et al.*(2011) reported *L. splendens* showed a prolonged spawning period, extending almost throughout the year and length at first maturity was 75 mm. The estimated fecundity ranges from 5715 (88 mm TL) to 37160 (106 mm TL). And, Arora (1952) reported *L. splendens* from Rameshwaram fish matures first at an average length of 60 mm and spawns more than once in a season, based on the presence of both maturing and mature eggs in the ripe ovary. The spawning season extends from March – August with peak in April and August and Fecundity of 10588 ova for a fish of 74 mm length was recorded. Similarly, for *L. bindus* from Calicut coast found length at first maturity at 87 mm and fecundity ranged between 4950 to 7735 (Balan, 1963). Also, Murthy

(1983) reported the length at first maturity as 80 mm for *L. bindus* from Kakinada and spawns almost throughout the year. Thus the Indian silver bellies spawn round- the- year with one or two peaks.

Borah *et al.*(2016)reported *Photopectoralis bindus* from Ratnagiri coast showed length at first maturity at 93.5mm and fractional spawner. It appears to release the ova in at least two spawning acts during the peak spawning season extending from October to December. High gonado-somatic indices corresponded well with the peak spawning seasons and female always indicated higher values. The estimated fecundity ranged from 4377 to 10449. For the same species collected from Visakhapatnam coast showed six maturity stages and sex-ratio was significantly different ($p < 0.05$) between the sexes in their occurrence. The mean length at first maturity was found to be 85mm in female and peak spawning season was noticed during the month of September to December. GSI was found to be high during September to December in female. Fecundity varied from 6009 to 18786 ova (Rao *et al.*, 2015).

Studies on reproductive biology of *Secutor insidiator* from Kakinada coast, reported, the species exhibited protracted spawner, running almost throughout the year, with a peak during January to March and length at first maturity was found at 90 mm (Murty, 1990). James and Badrudeen (1975) reported the length at first maturity of *L. brevirostris* to be 63mm and 68mm for female and male respectively along the Palk Bay and Gulf of Mannar. Fecundity ranged between 3646 to 16243 mature eggs with a size range of 106-132mm TL. Whereas, *Leiognathus dussumeiri* size at maturity of female fish was at 83 mm TL and spawn throughout the year with two peaks from April – May and November – December from Indian waters, fecundity ranged from 805 to 41683 (James and Badrudeen, 1981).

2.6 Proximate composition of the fish:

Fish is known to be highly nutritious and an important component of the diet of the human beings. It is an excellent source of protein and other essential nutrients for human diets (Fawole *et al.*, 2007) Fish is basically composed of water, lipid, and protein, which create the nutritional value, functional aspects, and sensory characteristics of the flesh. It also contains vitamins and minerals which plays an important role in post-mortem biochemical changes (Gokoglu and Yerlikaya, 2015). The knowledge of proximate composition of fish species is essential in estimating the quality of the raw material and for its maximum utilization which has fundamental importance in the application of different technological processes in fish preservation, processing and product development (Mridha *et al.*, 2005).

Studies on nutritional evaluation of the moonfish, *Mene maculata* (Bloch & Schneider, 1801) from Parangipettai, southeast coast of India showed high percentage of protein in the tissue (23.16%), followed by the lipid (2.62%) and carbohydrate (1.3%). Total 20 essential and non-essential amino acids were present at the rate of 46.72% and 43.91% respectively. Vitamins were noticed in *M. maculata* found in higher levels (124.5 mg/g) and 5 macro minerals and 2 trace minerals were recorded, macro mineral calcium (156.7 mg/g) was found at the highest level. Palanivel *et al.*, (2014) studied the nutritional value of *M. maculata* and reported that, tissue is a valuable food recipe for human consumption, due to its high quality protein and well-balanced amino acids. Similarly, Bijukumar *et al.* (2013) recorded Moisture 71.1 %, Protein 19.01 %, Lipid 0.75 %, Ash 8.00 %, Carbohydrate 0.28 %. Lipid content was lowest in (0.75 %) and Ash content (8.00 %) was recorded higher values in Menidae when compared with other species. However, Abdullah *et al.* (2011) studied on the nutrient content in gold band goatfish they found that 4.35 %, 79.41% and 1.1% lipid,

moisture and ash content respectively. In striped red mullet found to be 10.38 %, 73.14%, 1.6 %, lipid, moisture and ash content respectively. The ash content shows the richness of the fish in minerals. It show that, the lipid content of the fish were found to be suitable for a healthy diet.

Abimbola *et al.*(2016) reported the proximate composition for the *P. senegalensis*, the protein, fat, ash, fiber, carbohydrate and moisture contents were found to be 21.21%, 0.86%, 2.01%, 1.19%, 5.05% and 69.70% respectively while in *P. typus* the composition was found to be 20.28%, 1.05%, 1.85%, 1.81%, 8.66% and 66.35%, respectively. *P. senegalensis* and *P. typus* belonging to high- protein lean fish category and are a good source of minerals.

Palanikumar *et al.* (2014) studied on the proximate and major mineral composition of 23 marine fin fishes from Thoothukudi coast of India. They revealed that average moisture content ranged from 67.23 % to 80.48%. Coral reef fishes of the genera, *Lutjanus*, *Nemipterus* and *Scolopsis* had high protein content (>21%).The fat content varied widely from 0.24 % to 14.72 %, *Leiognathus dussumieri* being the most fatty fish (14.72 %). The average ash contents of most of 87% of fishes were < 2% and two species, *Nemipterus japonicas* and *Epinephelus areolatus* had high values of 3.92% and 3.79 % respectively. The total high energy value was noticed in *Leiognathus dussumieri* (174 kcal), mainly due to their fat content. Sankar *et al.* (2013) reported that *N. japonicas* constitutes moisture content 75.72 %, protein 13.24 %, Carbohydrate 0.26 % and Ash content 3.97 %. And, for *Epinephelus areolatus*, moisture 79.99 %, protein 13.84 %, carbohydrates 0.06 %, fat 0.95 % and ash 3.89 % respectively. Similarly for *Lutjanus quinquelineatus* moisture content 76.75 %, protein 22.46 %, carbohydrate 0.05 %, fat 43 % and ash 1.91 % were noticed.

3. MATERIALS AND METHODS

3.1 Material

The present study was based on the observation of a total of 452 *M. maculata* individuals ranging in size from 11.0 to 27.0 cm in total length (TL) comprising 227 male and 225 female (Plate 1). Monthly fish samples were collected from Mangaluru fishing harbour (Lat.12°50'54"N; Long. 74°50'11"E) (Plate 2 and 3). The data collected for the present study from the multiday trawlers, gill nets and purse seiners operating from Mangaluru fishing harbour during the period from October 2016 to May 2017.

3.2 Laboratory observations

Samples of *M. maculata* collected from fish landing center were brought to the laboratory for recording morphometric measurements, to study the food and feeding habits, reproduction and other related aspects (Plate 4). The total length from the tip of the snout to the tip of the caudal fin was measured to the nearest one cm. using graduated measuring board. The fish was then cut open to record sex and stage of maturity. Gonad was then weighed using an electronic balance to the nearest of 0.01g. Stomach and ovaries were preserved in 5% formalin for further analysis.

3.2.1 Length-weight relationship

The parabolic equation $W = aL^b$ (Le Cren, 1951) was linearized to the form $Y = A + BX$ where, $Y = \log W$, $A = \log a$, $B = b$ and $X = \log L$. Based on the equation, constants A and B were estimated for each month using least squares method. The data for the sexes were treated separately in order to examine differences between sexes. Analysis of co - variance (Snedecor and Cochran, 1967) was used to test the significant difference in the estimates of “b” between sexes.

3.2.2 Relative condition factor

The relative condition factor K_n (Le Cren, 1951) for individual fish was calculated using the formula $K_n = W_o/W_c$, where W_o = observed weight; W_c = calculated weight. Monthly mean values of K_n were calculated for both the sexes separately to find out the relation, between spawning season and relative condition factor. To study the fluctuations in the relative condition factor with the length of fish of either sex, mean K_n values were calculated for each size group in order to ascertain the breeding season and feeding pattern.

3.3. Food and feeding habits

Both qualitative and quantitative analyses were carried out to study the food and feeding habits of *M. maculata*.

3.3.1. Qualitative analysis

Qualitative analysis consisted of identification of all organisms encountered in the stomach. The identification was done using compound microscope and were made group wise, most of the time stomach contents were in advanced stage of digestion hence specific identification was not always possible. Food items in the advanced stage of digestion were treated as semi-digested matter.

3.3.2. Quantitative analysis

The stomach contents were washed into a Petri dish and analyzed by Points Volumetric methods (Hynes, 1950; Pillay, 1952) taking into consideration the extent of fullness of the stomach. Points were allotted for each food item based on its relative volume. From the values obtained for individual fish, monthly average and percentage were worked out. The volume index, which is the percentage of each food item, was calculated from the total points of all the items over the study period.

3.3.3. Feeding intensity

The feeding intensities in various months were studied by the degree of fullness of the stomach in relation to the size of the fish. The fullness of the stomach was classified as, (i) full (ii) $\frac{3}{4}$ full; (iii) $\frac{1}{2}$ full; (iv) $\frac{1}{4}$ full; (v) little (containing traces of food) and (vi) empty (when the stomach did not contain any food). Fishes having full stomach were considered for feeding actively whereas those fishes with $\frac{3}{4}$ full and $\frac{1}{2}$ full stomachs were denoted as moderate feeding. Similarly, stomachs with $\frac{1}{4}$ full and little were considered to indicate poor feeding activity. The percentage occurrence of stomach in different conditions of feeding over the whole period was also calculated. Food preference in relation to size of the fish was known by tabulating percentage occurrence of each food item against the size of the fish.

3.4 Reproduction

3.4.1 Gross examination of gonads

The length, weight, sex and stage of maturity of individual fish in each sample were noted. The ovaries were removed and preserved in 5 % formalin for further studies.

3.4.2 Maturity stages

Maturation refers to the cyclic morphological changes that the male and female gonads undergo to attain full growth and ripeness (Qasim, 1973) to understand those changes. It is also necessary to follow the regular and cyclic changes undergone by the gonad. This can be best done by recognizing the different phases in the cycle by assigning set of unique stages that identify the state of maturity of the gonads, as they pass through the different stages of development and spawn. Thus, different maturity stages are assigned to the gonads, based on the well-defined criteria (Crossland, 1977).

Maturity stages of female were classified based on macroscopic appearance of the ovary and microscopic characteristics of ova. In the male, maturity stages were classified based on the macroscopic appearance of testis. The macroscopic observations were based on fresh material, whereas, the microscopic observations were on 5% formalin preserved material.

3.4.3 Growth of ova

For ova diameter studies of intra-ovarian eggs, small pieces of ovaries from the anterior, middle and posterior region were cut and then ova were squeezed out on to a glass slide. The progress of growth of ova from one stage of maturity to another was studied by using compound microscope fitted with ocular micrometer where ocular division had magnification 0.01 mm. For ova diameter study a total of 300 - 400 ova were measured from each individual fish. These were grouped into four ocular micrometer divisions and frequency polygons were drawn for all stages of maturity.

To avoid measuring each ovum more than once, the ova were arranged in rows on slide and the diameter of ova in each row was measured by moving the slide along one direction. In the immature ovaries, the ova were minute and it was not possible to arrange them in rows; they were spread evenly on the slide and the diameter of the ova lying parallel to two horizontal guidelines on the slide was measured. In mature ovaries, samples for ova diameter measurements were taken after noting the total weight of the ovary and the sample weight. All the ova in each sample spread on the slide were measured.

3.4.4 Spawning frequency

Based on the pattern of ova diameter distributions in advanced stages of ovaries, the frequency of spawning was estimated using the methods of Hickling and Rutenberg (1936) and DeJong (1940).

3.4.5 Spawning season

Spawning season was determined on the basis of availability of mature gonads in the commercial catches. The Gonado - Somatic Index (GSI) and relative condition factor (K_n) were also considered for assessing the spawning season.

3.4.6 Size at first maturity

The size at first maturity was determined using (a) mean relative condition factor with respect to size of fish (Hart, 1946); (b) length - weight relationship for male and female (Natarajan and Jhingran, 1963); (c) plotting cumulative percentage of mature fish - III, IV, V, VI and VII stages in case of male and female against size (James and Badrudeen, 1981); (d) by the method of Jayabalan (1986).

3.4.7 Gonado-Somatic Index

For calculating the Gonado - Somatic Index, the weight of the individual fish was noted and the gonads were removed carefully and weighed in an electronic balance after removing the excess moisture using a blotting paper. The Gonado-somatic Index (GSI) was calculated using the formula suggested by James (1967) and Baragi (1977). The average GSI values were plotted against months.

$$\text{GSI} = \frac{\text{Weight of the gonad} \times 100}{\text{Weight of the fish}}$$

3.4.8 Fecundity:

Fecundity was estimated gravimetrically using formalin preserved ovaries. The excess moisture was drained out and the ovaries were weighed to the nearest milligram. Ovaries of the IV, V and VI stages were used for fecundity estimation. A small sample from each ovary was removed and weighed. The number of mature ova in the weighed sample was counted. Fecundity was calculated from the number of mature ova for each individual.

Absolute fecundity = Number of mature ova in the sample × Total weight of ovary (g)

Weight of the sample (g)

3.4.9 Fecundity: length/weight/gonad weight-relationships:

The relationships between fecundity and length of fish/weight of fish/ovary weight were calculated using appropriate statistical methods.

3.4.10 Sex - ratio:

Sex - ratio was studied with respect to months and size groups of fish. Data on sex-ratio were analyzed by Chi-square test to find out whether there was any dominance of either sex.

$$\chi^2 = \frac{(OM - E)^2}{E} + \frac{(OF - E)^2}{E}$$

Where, OM and OF = Observed number of male and female in the month respectively.

E = expected number of male or female in a month.

E = n/2

3.5 Proximate composition

Moisture, protein, fat, and ash, were determined by the methods of AOAC (1990). Moisture content was estimated by heating sample in a thermostatically hot air oven controlled

at 100⁰C for 6 hours. The Petri dish is cooled in a desiccator and weighed, the process of heating, cooling and weighing are repeated until successive weighing differences of not more than 1 mg. Ash was determined by igniting the moisture free sample in muffle furnace at 550±20⁰C until white ash is obtained (for 6 hours). Fat content was analysed by Soxhlet extractor and protein content was determined by Micro kjeldahl method.

4. RESULTS

4.1 Length - weight relationship

The length-weight relationship data were computed from the monthly samples of *M. maculata* in Table 1. The relationships obtained were as follows:

$$\text{For male, } \log W = -1.6031 + 2.8519 \log L \quad \text{or} \quad W = 0.0266 L^{2.8519}$$

$$\text{For female, } \log W = -1.5978 + 2.8756 \log L \quad \text{or} \quad W = 0.0287 L^{2.8756}$$

Table 2 showed that the results of analysis of Co-variance of length - weight relationship of male and female of *M. maculata*. From F- ratio it is evident that there is no significant difference among the regression coefficient between male and female. Hence, the pooled regression equation for male and female could be drawn as follows

$$\log W = 0.0276 + 2.8567 \log L$$

The corresponding non-linear equation is represented by

$$W = 0.0276 L^{2.8567}$$

The Parabolic and linear relationship of for male and female were plotted and curve was drawn Fig. 1a and 1b. Further t-test was employed to know the growth pattern of *M. maculata*, observed that the calculated 'b' value differ significantly from the theoretical value of '3' at 5% level of significance. Hence, it indicates the allometric growth in the fish.

4.2 Relative condition factor

The relative condition factor $K_n = W_o / W_c$ was calculated for both male and female using respective length - weight relationship.

4.2.1 Seasonal variation in relative condition factor

To study the variation in the condition factor of the fish in different months, relative condition factor of monthly mean values were used (Table 3 and Fig. 2).

In case of male, the K_n values were lower than the weighted average (1.0900) during October, November, December and May. The lowest K_n value was noticed during October (0.9616) and the highest during February (1.2430).

In case of female, the K_n values were lower than weighed average (1.1774) during October, November and December. The highest K_n value was found during February (1.3886), whereas the lowest K_n value was recorded during October (0.9886).

4.2.2 Size dependent fluctuations in relative condition factor:

The data on the mean K_n values of each size group of male and female are presented separately in Table 4 and Fig. 3.

The K_n values for male showed that the condition remained low in the size range 11-13 cm (0.9555) followed by a sudden recovery in the next successive size groups till 19 - 21 cm. A sudden decline in the K_n value from size group, 21 - 23 cm (1.0483) was noticed. In case of female, K_n value remained lowest (0.9879) in the size range 11-13cm. Thereafter gradual rise was observed up to size range 19-21cm (1.1755). But again, a sudden decrease in the size group 21-23cm (1.0196), again increase in K_n value was noticed in the size group 25-27cm.

4.3 Food and feeding habits

4.3.1 Qualitative and quantitative analysis

The details of qualitative and quantitative analysis of gut contents of *M. maculata* are presented in Tables 5,6,7,8 and Fig.4,5,6,7 respectively. The data revealed that the gut contents of *M. maculata* mainly composed of crustaceans, fish, mollusks, debris and miscellaneous items. Crustaceans represented mainly by shrimps besides some prawns and crabs. Some of the food items were identified based on their availability of body parts like scales, eyes, bones and vertebrate, but most of the food items remains unidentified, since they

were found in advanced stages of digestion with only skeletal remains. Molluscs were identified as bivalve, debris as sand and mud and miscellaneous items as algal filaments, polychaetes.

4.3.2 Food items in relation to months

Monthly diet composition of *M. maculata* is presented in Table 5 and Fig. 4. The analysis revealed that, overall diet composition of *M. maculata* is dominated by crustaceans (30.39 %) followed by fish (28.19 %), molluscs (16.97 %), debris (12.69 %) and miscellaneous items (11.76 %). Whereas, crustaceans percentage was high in the month of January (35.04%) followed by December (31.85 %), April (30.71 %), November (30.05 %) and lowest in the month of October (28.13 %) followed by March (28.71 %), May (29.21 %) and February (29.39 %). Fish formed an important food item next to crustaceans the analysis revealed that the highest value was recorded in the month of October (31.50 %), January (28.59 %), February (28.23 %), April (28.08 %) and lowest in the month of March (26.41 %), December (27.13 %), May (27.57 %), November (28.00 %). After fish, molluscs formed the most important food item, considerable quantities were found recorded highest and lowest in the month of March (20.71 %) and December (12.98 %) respectively. Also, highest debris and miscellaneous items was recorded in the months of March (15.00 %) and December (13.93 %) respectively.

4.3.3 Food items in relation to size

The details of percentage occurrence of various food items in the stomach contents of *M. maculata* belonging to various size groups are given in Table 6 and Fig 5. In the table it is evident that the crustaceans (30.76 %) were most abundant in all the size groups followed by fish (27.62 %), molluscs (18.13 %), debris (12.07 %) and miscellaneous item (11.42 %). The

analysis revealed that the crustaceans were most abundant in different size groups occurred in different proportions, the highest percentage was noticed in the size groups of 23-25cm (32.90%), followed by 11-13 cm (31.36%) and lowest was found in the size range of 25-27cm (29.50%). Fish remains formed the second important item of food and were recorded in the different proportions in different size groups. Highest percentage was recorded in the size group of 23-25 cm(30.20%) followed by 11-13 cm (28.55%) and lowest quantity was observed in the size group of 25-27cm (22.83%).Third predominant category of food was molluscan remains, the occurrence was highest in the size range of 25-27 cm (25.83 %) followed by 11-13cm(19.82 %) and lowest in the size group of 23-25 cm (15.50 %).Highest quantity of sand and debris remains were in the size group of 15-17 cm (13.49 %) and lowest in 11-13 cm (9.36 %).Miscellaneous items constituted highest in the size group of 21-23cm (13.07 %) and lowest 13-15 cm (9.45 %).

4.3.4 Feeding intensity in relation to months

The details of percentage occurrence of feeding intensity in different months of *M. maculata* are presented in Table 7 and Fig 6. Fishes which fed actively was highest in the month of November (54.39%) followed by December (33.33 %), January (30 %), October (21.88 %) and lowest in the month of April (9.52%) followed by February (11.11 %), May (14.04 %), March (20 %). Whereas, fishes fed moderately, those with 3/4 stomach content was highest in the month of November (24.56%) followed by May (22.81 %), October (18.75 %), April (17.46 %) and lowest recorded in the month of December and January (11.67%) followed by February (12.79 %), March (13.33 %). Stomach with half-full was high in the month of May (29.82 %) followed by October (25 %), April (22.22 %), February (19.05 %) and lowest in November (10.53%) followed by March (11.67 %), December (15 %), January

(16.67 %). Fishes having poor feeding intensity was highest recorded in the month of April (26.98%) and lowest in November (5.26%). Stomach containing traces of food was observed highest in the month of February (33.33%) and lowest in November (3.51%).

4.3.5 Feeding intensity in relation to size

The details of percentage occurrence of stomach in various degrees of fullness in different size groups of *M. maculata* are given in the Table 8 and Fig.7. From the table it is evident that the highest percentage of full stomach was observed in the size group of 15-17cm (28.57%) and lowest in the size range of 21-23cm (11.25%). 3/4th full stomach was recorded highest in the size range of 11-13cm (27.27%) and lowest 15-17cm and 21-23cm size groups (12.50%). In case of 1/2 full stomach, percentage was high in the size group of 25-27cm (33.33%) lowest 17-19cm (13.95%). Fish with 1/4th full stomach was found to be highest in the size of 11-13 cm (27.27%) and lowest 23-25 cm (6.45%). In case of stomach with little food was recorded highest at 23-25cm (35.48%) and lowest at 13-15cm (16.00%). In addition, empty stomach was observed highest at 13-15 cm (10.00%) and lowest at the size group of 21-23 cm (5.00%), 11-13 and 23-27 cm (0%).

4.4 Reproduction

The results of the studies on maturity, spawning, size at first maturity, fecundity and sex-ratio are presented below:

4.4.1 Maturity stages of gonads

4.4.1.1 Classification of maturity stages - male

Stage I - Immature

Testes occupy less than half of the length of the body cavity. Testes are very thin, thread like structure with whitish in colour.

Stage II - Maturing

Testes occupying slightly more than half of the body cavity. Testes were whitish in appearance, more or less symmetrical.

Stage III – Early Mature

Testes extend to about $2/3^{\text{rd}}$ of the length of the body cavity, ribbon like, opaque with whitish in colour.

Stage IV -Late Mature

Testes were whitish to creamy in appearance, occupying about $3/4$ of the body cavity

Stage V - Ripe

Testes extend over the entire length of the body cavity, in this condition ooze freely with slight pressure on abdomen.

Stage VI - Spent

Testes appeared empty, translucent and shrunken.

4.4.1.2 Classification of maturity stages - female

The details of classification of maturity stages in female are given in the Table-9.

Stage I - Immature

The ovaries appear thin cylindrical opaque and light pink colour. They extend up to $1/3$ of the body cavity. Ova invisible to the naked eye, irregular in shape, yolkless and transparent. The size range of ova in this stage was 0.04 mm to 0.08 mm.

Stage II - Maturing:

Ovary slightly more than half the length of the body cavity, pinkish in colour. Ova visible to the naked eye, ovary slightly granular in appearance. Small opaque ova, white in appearance.

The ova ranged in size between 0.07 mm and 0.11 mm.

Stage III –Early Mature

Ovary extending to about $\frac{2}{3}^{\text{rd}}$ of the length of the body cavity, pinkish creamy to yellow in colour, distinctly granular in appearance, medium sized, whitish, opaque ova. The ova ranged in size between 0.15 mm and 0.30 mm.

Stage IV –Late Mature

Ovaries are yellow in colour, occupying nearly $\frac{3}{4}$ of the body cavity. Blood vessels are seen on dorsal side. Maximum size of the ova was 0.41 mm and the mode of the largest group was at 0.59mm.

Stage V - Ripe

Ovaries are very much enlarged, swollen yellow in colour and occupy the entire body cavity displacing the alimentary canal. The ovarian wall is very thin and transparent. Blood vessels are prominent and slight pressure intrudes eggs. Intraovarian eggs large, transparent with single oil globule, free from follicles, perivitelline space prominent. The ova ranged in size between 0.75 mm and 0.91 mm.

Stage VI – Spent

The ovaries are blood-shot, shrunk, flaccid and baggy as a result of spawning. They occupy nearly $\frac{1}{2}$ of the body cavity. The size ova varied from 0.06 – 0.09mm.

4.4.2 Development of ova to maturity

Typical ovaries belonging to the six stages of maturity described above were selected and the ova diameter frequency polygons were drawn. The data are presented in Table 9 and Fig. 8. In stage I, the size of ova ranged from 0.04 mm to 0.08 mm with majority of them in the size range of 0.05 mm. The size of ova in stage II varied from 0.07 mm – 0.11 mm. The frequency polygon for this stage indicated the withdrawn of a batch of ova with a modal size

of 0.3 mm from the general egg stock to undergo maturation. The maturing group had a modal value at 0.3 mm, while the largest ova measured was at 0.11mm. In stage III, this progresses to 0.15 mm, the maximum size being 0.30 mm. The mode of the largest group being at 0.21 mm. The mode in the stage III at 0.21 mm moved to 0.41 mm in stage IV with a maximum size at 0.59 mm. In stage V, maximum size of ova was 0.91 mm and the mode shifted from 0.75mm to 0.81 mm from the previous stage. In the stage VI the maximum size of the ova was found to be 0.06 mm with the mode at 0.09 mm.

4.4.3 Spawning habits

M. maculate may be considered as spawning in a season for a prolonged period as evidenced from the ova diameter studies.

4.4.4 Spawning season

The spawning season was determined on the basis of occurrence of individuals in mature, ripe and spent stages of maturity in each month. For the study, a total of 227 male and 225 female fishes were examined and seasonal changes occurrence of gonads of the same in different stages of maturity was presented in Table 10 and Fig.9 and 10. The results of the gonadal maturity of female, the data revealed that, in October month I to III and VI stages of maturity were observed, among which, stages I and II were predominant. In the month of November I, II and VI stages were observed and stage I was predominant. In the month of December I to IV stages were observed and stage II was dominant. In January and February, except stage VI, all other stages were observed; stage IV and V were dominant. In March, all stages were present and predominant stages are I followed by IV, V, VI and III. In the month April, except stage VI all stages were recorded with the stage V being dominant. In May, stages I to VI were noticed with stage II and I dominating.

In case of male, the data revealed that in the month of October and November stages I, II and VI, were present with dominance of stages I and VI. In the month of December stages I to IV were noticed among which stage I was dominant. During January, stages II to V were present, stage III was dominant and February was dominated by stage II followed by III and V. In March all stages were recorded with a dominance of stage I. In the month of April except VI stage all other stages were recorded with a dominance of stage I. In May, stage I was dominated followed by III, II and IV.

4.4.5 Size at first maturity

For determination of size at first maturity of *M. maculata*, a total of 227 male and 225 female were used.

4.4.6. Relation between the size of fish and maturity stage

Fishes were grouped sex-wise into 2 cm size groups to calculate percentage occurrence of fish in various stages of maturity. Fish from the stage III onwards were considered mature. The data is presented in Table 11 and Fig. 11 and 12. In case of male, the data revealed that immature and maturing stages were found up to size range 11-13, 13-15 cm and 15-17cm (Stage I, II). From the size 17 cm onwards maturity stages appeared. The percentage of mature fish crossed 50 % at the size group 19 - 21 cm. Hence, it is clear that the size at first maturity for male 19 and 21 cm with an average size 20 cm. In case of female, all were in immature stage in the size range of 11-13 and 13-15cm. From size group 15-17cm, the maturing stages appeared and the percentage occurrence increased with increase in size. The 50 % percent occurrence of mature fish crossed in the size group 19 - 21 cm (TL). From the above data the size at first maturity for female was found to be 19-21 cm. with an average of 20 cm (TL).

4.4.7 Size at first maturity as determined by cumulative percentage frequencies

In order to determine the size at first maturity, cumulative percentage stage III to V were considered (Table.12). Cumulative percentage frequencies of fish belonging to the above stages were plotted against size group. The size at 50 % cumulative percentage frequency was considered to indicate the overall reproductive maturity of the population as a whole. It revealed from Table 12 and Fig 13, male and female fish mature at 19.0 cm (TL) and 21.0 cm (TL), respectively.

4.4.8 Gonado-Somatic Index

In this study, both male and female were taken into consideration separately. The Gonado-Somatic Index (GSI) was calculated for each individual fish and was averaged for each month. The average GSI values were plotted against each month and the results are presented in Table 13 and Fig.14. Monthly changes in GSI for male and female were noticed. The GSI values ranged between 0.3794 to 2.5485 in male fish with an average of 1.5665. The lowest GSI values were recorded in October and November, while the highest was in February. In case of female, the GSI values fluctuated between 0.4245 to 3.3315 with an average of 2.1744. The lowest value of GSI was in the month of October and November it gradually increased and continues till February, after decline gradually. Maximum value of GSI was in the month of February indicating the occurrence of maximum number of mature fish during pre-monsoon months.

4.4.9 Fecundity

Only the mature ova were considered for the estimation of fecundity. In *M. maculata* a clear demarcation of mature and immature ova was noticed from stage IV onwards. Hence, for fecundity studies fishes of stage IV and V were taken into consideration, the details of

fecundity counts are presented in the Table 14. The fecundity of *M. maculata* ranged from 1,01,051 - 2,38,875 eggs with an average of 1,66,962eggs. The minimum weight of the mature *M .maculata* was 98.12g and the maximum weight was 167.46g, with total length varying between 18.5 cm to 23 cm. The number of ova generally increased with increase in length and weight. However, variations in fecundity with respect to length and weight and ovary weight were also noticed.

4.4.10 Relation between fecundity and length of fish

When the logarithmic values of fecundity (Y) were plotted against logarithmic values of length (X), it showed a linear relationship between the two variables (Fig. 15). The relationship between length and fecundity as $Y = 3.627 + 1.138X$. Where, Y=Log Fecundity, X=Log Length of fish, The correlation coefficient (r) between fecundity and length of fish is found to be 0.79.

4.4.11 Relationship between fecundity and weight of fish

The relationship between the log weight (X) and the log fecundity (Y) of *M. maculata* (Fig.16) were linear. The linear form of regression between weight of fish and fecundity was calculated as $Y = 2.794 + 1.073X$, Where Y=Log Fecundity, X=Log Weight. The correlation coefficient (r) between fecundity and weight of fish is found to be 0.80.

4.4.12 Relationship between fecundity and gonad weight

The logarithmic values of the fecundity (Y) when plotted against logarithmic gonad weight (X) of the fish (Fig.17) indicated a linear regression equation of the form $Y= A+BX$. The calculated regression equation as $Y = 4.239 + 1.362X$. Where, Y= Log Fecundity, X= Log Gonad weight. The correlation coefficient (r) between fecundity and gonad weight of fish is found to be 0.84.

4.5 Sex-ratio

In the present study a total of 452 specimens of *M. maculata* belonging to a wide range were examined to find out the sex-ratio. The sex-ratio of male: female was 1.00:0.99. There was an overall predominance of male in the population.

4.5.1 Sex-ratio on month wise

The data on number of male and female fish sampled in different months are given in Table 15 and Fig.18. It revealed that, equal proportionate of male and female were noticed in the month of January and March. Dominance of female observed in the month of November, February and April. In case of male predominance was observed in the month of December, April and May. The data were analyzed by Chi-square test, to test the equality of males and females in different month. At 0.05 probability level, Chi-square value indicated no significant difference in the number of male and female in all the months.

4.5.2 Sex-ratio size wise

The sex-ratio of fish sampled in different size groups are given in Table 16 and Fig.19. Equal sex-ratio was noticed in the size range of 15-17 cm and 23-25 cm however, predominance of female in the size group of 25-27cm and in male the size group of 11-13cm, 13-15 cm, 17-19 cm, 19-21 cm and 21-23 cm was recorded. Chi-square test was used to test the equality of males and females in various size groups. At 0.05 probability level, Chi-square value indicated no significant difference in the number of male and female in all the size groups except 21-23cm.

4.6 Proximate composition

The major constituents in the edible portion of fish are water, protein, lipid (fat or oil) and ash (minerals). Analysis of these basic constituents is often referred to proximate analysis.

Results are presented in Table 17 and Fig 20. The data showed that, the protein content was varied from 18.95 % to 25.52 % with an average of 23.29 %. Month wise data revealed that, protein content was high in the month of April and lowest in the month of November. Fat content varied from 2.30 % to 1.11 % and highest fat content was observed in the month of April (2.30 %) and least in the month of November (1.11 %). The average fat content of the study period about 1.91 %. Ash content was highest in the month of October and lowest in December and it varied from 3.12 % to 4.74 % with an average of 3.97 %. Moisture content was varied from the 67.80 % to 76.39 % with an average of 71.10 %, highest moisture content was observed in the month of November and lowest in April.

5. DISCUSSION

The results obtained during the present study on various aspects of the biology of *M. maculata* are discussed below.

5.1 Length – weight relationship

The length-weight relationship is one of the standard methods yielding authentic biological information with two objectives: firstly, it establishes the mathematical relationship between the two variables, length and weight, so that unknown variable can be computed from the known variable. Secondly, to know the variations from the expected weight, for the known length groups, this in turn reflects its fatness, general well-being, gonad development and suitability of environment of the fish (Le Cren, 1951). It's having unique importance in the marine fisheries management because, it estimate the biomass, condition (Petrakis and stergiou, 1995), growth rate (Kohler *et al.*, 1995) and maturity of the species. It is generally determined by collecting data on both the length and the weight of the fish in different phases of life and calculating the relationship existing between the two by using the formula $W = aL^b$, where 'W' is the weight of the fish, 'L' is the length of the fish and 'a' and 'b' are constants to be determined empirically from the data. In fishes, weight is an exponential function of length (or any linear dimension); under conditions of isometric growth, the regression follows the cube law (Rounsefell and Everhart, 1953; Lagler, 1956; Ricker, 1958). But in reality, the actual relationship between the variables, length and weight may depart from this, either due to environmental conditions or condition of fish (Le Cren, 1951). In nature fish body proportions continually change with ageing. The form and specific gravity do not remain constant throughout the life history of the fish, which often causes the regression coefficient of

weight on of length, depart from 3. Hence, the formula $W = aL^b$ will be more useful in describing the length-weight relationship. The value of the exponent 'b' in the parabolic equation may lie between 2.5 and 4 (Hile, 1936; Martin, 1949). However, in some of the fishes, reported "b" value up to 5.4 was observed by Antony raja (1967).

In length-weight relationship, slop value 'b' indicates the rate of weight gain relative to growth in length and varies among different populations of the same species or within the same species. The correlation coefficients indicate the degree of association between length and weight of the fish. High values of correlation coefficients of both sexes will indicates there is perfect relationship between the two variables in the species (Jhingran, 1968 a &b and Frosta *et al.*, 2004).The present study, 'b' value was 2.8519 for male and 2.8756 for female. F – ratio reveled that there was no significant difference between male and female at 5% level. Similarly, for the same fish in other water bodies it was found that the b value of 2.8415 and 2.939 in China and Taiwan waters respectively (Shi-qiang, 2012; Hwang *et al.*, 2002). Thus, allometric pattern ($b < 3$) growth is observed in *M. maculata* which indicated that the rate of increase in body length is not proportional to the rate of increase in body weight. Kalayci *et al.* (2007) observed that, in ten important demersal and pelagic fish species caught with bottom trawl and mid water trawl showed negative allometric ($b < 3$, $P < 0.05$) and opied that functional regression "b" value represents the body form and it is directly related to the weight affected by ecological factors such as temperature, food supply, spawning conditions and other factors, such as sex, age, fishing time, area and fishing vessels (Pauly, 1984). Also, it can be inferred that, same sized individuals of length-weight relationship may vary from species to species of the same genus (Garabi and Katri, 1981) same size inviduals can vary from it clearly indicates

that, occurrence of absolute isometric growth in nature is occasional (Bagenal and Tesch, 1978; Bassey and Richardo, 2003).

5.2 Relative condition factor:

The coefficient of condition or condition factor given by the formula $K = 100 W/L^3$ (Hile, 1936), where W = weight of fish; L = length of fish, K = Ponderal index has been used to indicate the condition, fitness or general wellbeing of fish. The value of 'K' is directly affected if fish does not obey the cube law. Hence, Le Cren (1951) has suggested calculation of relative condition factor (K_n) based on length – weight relationship in order to eliminate the effect of length and other factors such as age, sex, maturity, feeding intensity, selection in sampling etc.

The present investigation showed that, there was a definite seasonal cycle in the K_n of both the sexes of *M. maculata* with having high K_n value during February to June. This may be attributed directly to feeding activity and also maturity of gonads in these months. Gradual decline in K_n from October to January with minimum value in November coincided with the post spawning season. The K_n value variation may be due to seasonality, gonadal development, feeding activity and several other factors (Doddamani *et al.* 2001). To support, the K_n values recorded less than 1.0 in certain months among male and female *Upeneus sundaicus* and *Upeneus tragula* may be due to poor feeding, breeding or non-availability of suitable food items in the ambient environment (Mohanraj, 2008). However, it is difficult to explain the changes in the condition of the fish based on the intake of food and sexual cycle (Baragi and James, 1980). Similarly, in *G. filamentosus* the high K_n values observed in some months neither coincide with spawning activity nor feeding intensity (Thomas, 1969). However, normally increased condition factor will be observed during the breeding season and spawning

season and normalization occurs immediately after spawning (Mde and Ambrosio, 2002). Strong correlation between relative condition factor and gastro-somatic values observed in some of the fishes (Philip, 1994).

Fluctuations of K_n values with respect to size, the fishes belonging to size groups 13-15cm to 19-21 cm TL in the case of male and female comprised mostly of immature and maturing fishes and high K_n values were observed, because of high feeding intensity. The point of inflection in the K_n curve of different length groups indicates the length at which sexual maturity of fish starts (Hart, 1946). The present study indicated that the commencement of maturation in the size group 19-21 cm TL. The first sharp increase of K_n at 19-21 cm length in both males and females respectively, may reflect the length at first maturity. Lower K_n values beyond 21-23 cm and 25-27 cm TL size class indicated the appearance of spent individuals. However, the changes in K_n values were more or less similar in both sexes during different seasons, and also in different size groups indicating that the metabolic activity undergone by males as well as females is almost the same.

5.3 Food and feeding habits

Knowledge of feeding regimes of fish species is great importance in understanding their ecological interaction (Alberto *et al.*, 2003). Feeding behavior of species is a characteristics formed during its evolutionary history (Nikolsky, 1963). From Indian waters most of the studies on food and feeding habit of fish have described only qualitative/quantitative aspects of diet composition (Qasim, 1972). But, Lack of information is available for some of the marine species in Indian coast. This will help in the management of fishery resources of the country.

Qualitative and quantitative analyses of diet of *M. maculata* in different months indicated that this species fed mainly on crustaceans (30.39 %) followed by fishes (28.19 %). Molluscs (16.97 %). Sand and debris (12.69 %), miscellaneous items (11.76%). The data on percentage occurrence of food items in different size groups of *M. maculata* recorded the highest percentage of crustaceans (30.76%) followed by fishes (27.62%). Molluscs (18.13%). Sand and debris (12.07%), miscellaneous items (11.42%). The present study revealed that, *M. maculata* is carnivorous species feeding mainly on crustaceans, fishes and occasionally fed on mollusks. The various components of the food spectrum indicated that, species mainly feed on benthic invertebrates, benthic crustaceans, mollusks and small fish.

High percentage of occurrence of the mud and sand particles in the guts of the species along with major food items confirmed that they are bottom feeders. A similar conclusion was drawn by Thomas (1969). From the pooled data, Monthly variation in the gut contents confirmed that both the sexes are identical feeding habits, consuming the same food items, but with slight variations in magnitude. The percentage of occurrence of different food items in the diet showed that these fishes select their food from the bottom living organisms and the first preferable food item is crustaceans (shrimp). Thus, *M. maculata* is demersal carnivores, the diet content is mainly composed of crustaceans (shrimps & crabs), fish larvae and bivalve mollusks followed by sand and debris and miscellaneous item.

Maximum feeding intensity was observed in the months of November and December, it coincide with the breeding periodicity. Because, most active feeding period was found in the gonad maturing second and the third stage of the sexual cycle (Hynes, 1950; Krishnamoorthi, 1971; Goncalves and Almada (1997). Hasek and Felder (2006) suggested that in second and third stages fishes fed more voraciously because of a higher energy demand associated with

gonad development. Feeding intensity was found to be less during the pre-spawning and spawning periods in females as indicated by the low gastro-somatic index with low degrees of fullness. Low feeding activity was observed during February and April. The occurrence of poor feeding coincident with peak breeding in other fishes has been reported by Karekar and Bal (1958), Thomas (1969), Desai (1970), Pisolkar and Karamchandani (1981), Khan *et al.* (1988), Kurup (1993) and Bhuiyan *et al.* (2006). Just after spawning in the month of October, November and March the largest number of spent individuals were encountered and feeding intensity gradually increased. Based on the present study observation, high feeding intensity in spent fish may be suggestive of high food requirements for building up of the gonads.

Active feeding was reported during the gonad maturation process whereas, increased feeding intensity noticed during maturation and spawning period indicated that energy needs largely are met by increased dietary intake and not depending on body reserves. Selective predation on larger high energy prey by maturing fish which enables them to continue to grow rapidly while developing gonads has been reported (Milton *et al.*, 1994). Malhotra (1967) reported that fasting in *Botia birdi* during the pre-spawning stage might be due to the pressure exerted by the voluminous ovary against the alimentary canal.

5.4 Reproduction:

It is a known fact that in most fishes there is a marked seasonal periodicity in egg production. Based on ova diameter studies of ovaries well advanced towards spawning, teleost fishes have been found to exhibit different types of spawning habits (Hickling and Rutenberg, 1936; Dejong, 1940; Prabhu, 1956; Qasim 1966). These studies indicated that there are at least four major groups of fishes depending on their spawning habit.

Group- I

Fishes in this group have a short spawning season, usually once in a year. The ova diameter frequency polygon of the mature ovaries of such fishes show only two distinct groups of ova, the immature and the mature, well separated from each other.

Group-II

Fishes in this group spawn only once, but over a long period of time, wherein the range in size of mature ova would be approximately half the total in the size of all ova.

Group-III

This group is constituted by fishes which spawn twice in a season wherein, apart from the mature and immature groups of ova, one more group of ova following the mature group is seen which has undergone about half the maturation process. This represents the maturing group of ova.

Group-IV

Fishes of this group spawn intermittently over a long period. In the ovaries of such fishes, the successive batches of ova are not clearly differentiated, indicating that the maturation process is a continuous one.

Ova diameter frequency studies of *M. maculata* indicated that the mature ovaries were well advanced towards spawning. Ripe fishes of *M. maculata* (Stage IV) found in the month of January to April this indicated that this species have a prolonged spawning season. However the earlier studies for *M. maculata* in South China Sea by Shi-qiang (2012) revealed that the spawning begins in August and October. From the present study, it can be inferred that spawning season of *M. maculata* appears from January to April with a peak in February. It is

evident that the Gonado-Somatic Index (GSI) remained relatively high in these months with a peak in February.

Present study the size at first maturity was determined by cumulative frequency method. The cumulative percentage of fishes belonging to stage III, IV and V were taken into consideration to calculate the size at first maturity. The results indicated that both male and female attain the maturity at the size range of 19-21cm with an average of 20 cm. Shi-qiang (2012) studied on size of fish maturity of *M. maculata* from South China Sea and recorded that the size at first maturity at 13.4-14 cm size range. From the above observations, it appears that the size at first maturity of *M. maculata* reaches sexual maturity varies considerably and these variations may be related to ecological factors, food supply and assimilation. In addition, the size at first maturity was determined by cumulative percentage frequency method. It revealed that, male and female fish attain the maturity at 19.0 cm (TL) and 21.0 cm (TL), respectively.

Gonado- Somatic index of *M. maculata* were carried out in different months to confirm the spawning period. The GSI values ranged between 0.3794 to 2.5485 in male fish with an average of 1.5665. The lowest GSI value was recorded in October and November, while the highest was in February. In case of female, the GSI values fluctuated between 0.4245 to 3.3315 with an average of 2.1744. The lowest value of GSI was in the month of October and November it gradually increased and continues till February, after decline gradually. Increased GSI indicated that occurrence of spawning season of the *M. maculata* extends from January to April with a peak in February along the Mangalore coast. The peak spawning season indicated by GSI is coinciding with percentage occurrence of maturity stages in different months. In contrast, GSI values for the same fish in China Sea reported to be high

from the month of August to October. Also, it indicated the close relationship of spawning period and water temperature (Shi-qiang *et al.*, 2012).

Knowledge on total number of eggs produced by individual fish during one year is important for determining the spawning potential of the fish. Fecundity is usually determined from the number ova of the mature group in the ovary (just prior to spawning stage). Hence, in the present study, stage IV and V ovaries were taken into consideration for the fecundity estimation. The absolute fecundity of *M. maculata* was found to vary from 1,01,051-2,38,875 egg/female with an average 1, 69,963 eggs per female depending upon the size of the fish. Also, it is observed that, variations in fecundity with respect to length and weight and ovary weight of fish were also noticed. Similar observation were made by several authors in different species (Anjaneyappa, 2008; Someshekara, 2009; Zacharia and Nataraja, 2003; Manojkumar, 2004; Chuen-chi *et al.*, 2008).

The logarithmic relations between fecundity and total fish length, fecundity and fish weight and fecundity and gonad weight of *M. maculata* were found to be linear. The correlation coefficient found out using the log fecundity and log total length, was 0.79. While the correlation observed between log fecundity and log weight and log fecundity and log ovary weight was 0.80 and 0.84, respectively. The correlation of two variables in each relationship was highly significant, showed that fecundity of *M. maculata* depends on length, weight and gonadal weight to a great degree.

Sex ratio of fish population may be due to differential fishing (Kestevan, 1942) or due to difference in growth rate of two sexes (Qasim, 1966). In the present study, sex-ratio indicated that there was almost same proportion of male and female. The sex-ratio of male: female was found to be 1:0.99 showed a slight dominance of male in the population. Overall,

Chi-square test showed that there is no significance difference from the theoretical ratio of 1:1. The diversity might be due to partial segregation of mature forms, either through habitat predominance or because of school formation, thus rendering one sex more easily caught than the other (Reynolds, 1974).

An examination of the sex-ratio in different size groups showed that, male fishes were dominant in the smaller size groups (11- 13 cm), while female were dominant in the larger size groups (25- 27 cm). The dominance in the higher size groups of male and female i.e., after attaining first maturity could be attributed to differential growth pattern. In the present study, it inferred that, *M. maculate* size-wise and month wise sex-ratio did not show any significant difference, except in the size range of 21-23cm.

5.5 Proximate composition

A series of recent studies initiated by the Ocean and Atmospheric Sciences and Technology Cell (OASTC) of Ministry of Earth Sciences, Government of India, involving various fishery research institutions of India also reported higher amounts of discards and impacts of bottom trawling (Meenakumari *et al.*, 2008). Discarding, particularly from the shrimp trawlers in tropical waters, represents not only losses in economic opportunities for using such items in the production of fish by-products, but also denies protein for human consumption in malnourished countries (Borges *et al.*, 2001; Bijukumar and Deepthi, 2006). In countries like India, where the per capita protein availability is below the recommended level, the proper utilization of by catch from trawlers is important, as it is found to be a good source of protein and minerals (Zynudheen *et al.*, 2004). Since the ‘appearance’ of many fish species in the trawl bycatch and discards is not flattering for consumers, production of value added products from the bycatch should be given priority.

Therefore, major constituents in the edible portion of fish are water, protein, lipid (fat or oil) and ash (minerals) was analysed and referred as proximate analysis. Results of the present study revealed that, the moisture (71.10%), followed by protein was (23.29%), ash (3.97%), and fat content was about (1.91%). The above findings were in conformity with the observation of Palanivel *et al.* (2014) percentage of protein was high in tissue (23.16%), Carbohydrate (1.3%), lipid (2.62%) and Vitamin A. Month wise data revealed that, protein content was high in the month of April and least in the month of November. Fat content varied from 2.30 % to 1.11 % and highest fat content was observed in the month of April (2.30 %) and least in the month of November (1.11 %). With an average fat content was 1.91 %. Ash (mineral content) content was highest in the month of October and lowest in December, and it varied from 3.12 % to 4.74 % with an average of 3.97 %. Moisture content was varied from the 67.80 % to 76.39 % with an average of 71.10 %. Highest moisture content was observed in the month of November and lowest in April. During these months somatic growth, lipid, protein and ash are typically accumulated while protein and lipid are depleted during gonadal growth. It is reported that, proximate composition of fish is found to be influenced, although marginally by geographical location, sex, age maturity and feeding condition. The muscle composition is mainly influenced by the type of food ingested by an animal (Remers and Maske, 1977). Similar observations were also made by (Tanasichuk and Mackay, 1989; Dygert, 1990; Jorgensen *et al.*, 1997).

6. SUMMARY

The present study deals with some of the biological aspects of the moon fish, *M. maculata* from Mangalore waters. The study is based on the examination of fish catches landed between October 2016 and May 2017 from Mangalore landing center. The important findings of the investigation are as follows-

1. The length-weight relationship of *M. maculata* did not show any significant difference between sexes. Hence, the pooled equation for male and female was obtained at $\text{Log } W = 0.0276 + 2.8567 \text{ Log } L$
2. Data on seasonal variation in condition factor (Kn) of both male and female during the study period showed that the values were more or less similar in both the sexes, indicating almost identical metabolic activity in male and female. Thus available data suggest that the monthly variations in Kn values may be related to maturity and feeding intensity.
3. The qualitative and quantitative analyses of gut content of *M. maculata* revealed that this species fed mainly on crustaceans, fishes, molluscs, sand debris and miscellaneous items. Highest percentage of occurrence of mud and sand particles in the gut along with major food items indicated that they are bottom feeders.
4. Studies on spawning season showed that *M. maculata* is prolonged spawner with two peaks in the month of February and January along the Mangalore coast.
5. Size at first maturity was determined by cumulative percentage frequency method, it revealed that the male and female attain the maturity at 19.0 cm (TL) and 21.0 cm (TL), respectively.

6. Male always recorded lower Ganado-Somatic Index (GSI) values than female due to greater ovary weight compared to testes. The GSI values were high during February indicating the spawning period along Mangalore coast.
7. The fecundity of *M. maculata* was found to vary from 1,01,051-2,38,875 eggs, with an average of 1,66,962 eggs/female. Log linear relationships were established between fecundity and total length, fecundity and body weight of the fish as well as fecundity and gonad weight.
8. The sex-ratio of male: female was 1.00:0.99. There was an overall predominance of male in the population.
9. The proximate composition studies revealed that *M. maculata* has higher protein content (23.29%) from this it can be concluded that this fish has a good nutritive value which could serve as an ideal dietetic fish food as well as play a significant nutritional role in human health.

7. Bibliography

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8. Abstract

The moon fish, *Mene maculata* is belonging to the genus *Mene*, family Menidae, and order Perciforms, popularly called moon fish. The present study based on the observation of a 452 total individuals ranging from 11 to 27 cm size, comprising 227 males and 225 females were collected fortnightly from Mangaluru landing centre. The length-weight relationship of *M. maculata* did not show any significant difference between sexes and pooled equation were drawn $\text{Log } W = 0.0276 + 2.8567 \text{ Log } L$. The relative condition factor (K_n) values for male and female varied from 1.055-1.059 respectively. The qualitative and quantitative analysis of gut content showed that the fish mainly fed on crustaceans, fishes and occasionally on mollusks, occurrence of the mud and sand particles in the gut indicated that the fish is bottom feeder. Active feeding observed during November and December which coincides with the post-spawning season, poor feeding was noticed in the month of February and April which indicates breeding season of the fish. The overall Sex- ratio was estimated as male: female = 1:0.99. The length at 50 % maturity was found to be 19-21 cm (TL), for male and female respectively. The Gonad-Somatic Index values ranged from 0.3794 to 2.5485 in male and in case of female, it fluctuated between 0.4245 to 3.3315. Fecundity of *M. maculata* varied from 1,01,051 to 2,38,875 eggs with an average of 1,66,962 eggs/female depending upon the size of the fish. The ova diameter ranged from 0.04 to 0.91mm. The species is a prolonged spawner. The proximate composition revealed that the Moisture has 71.10 %, followed by protein 23.29 %, ash 3.97 %, and fat 1.91 %.

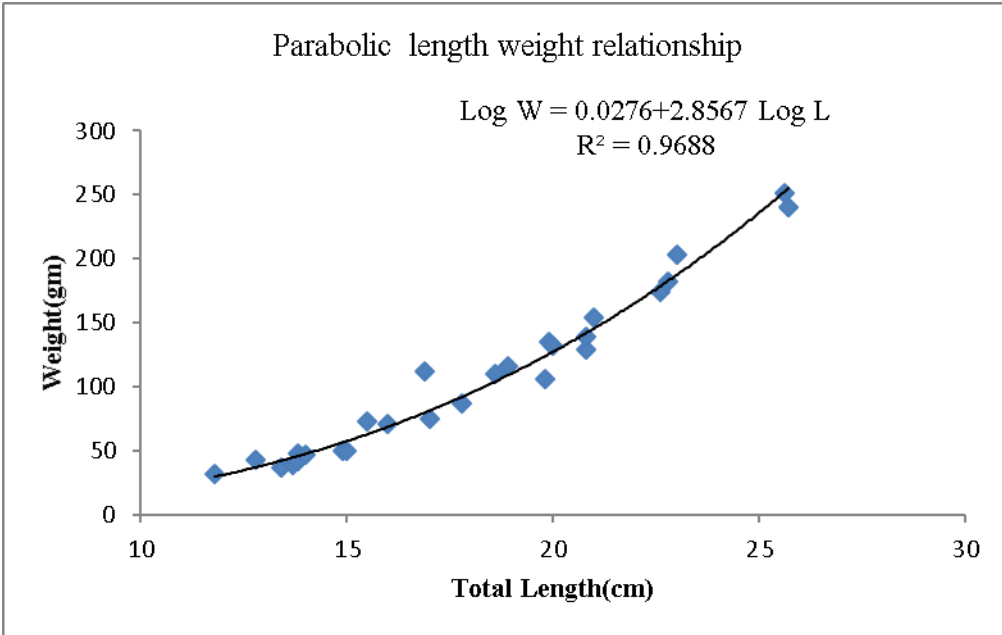
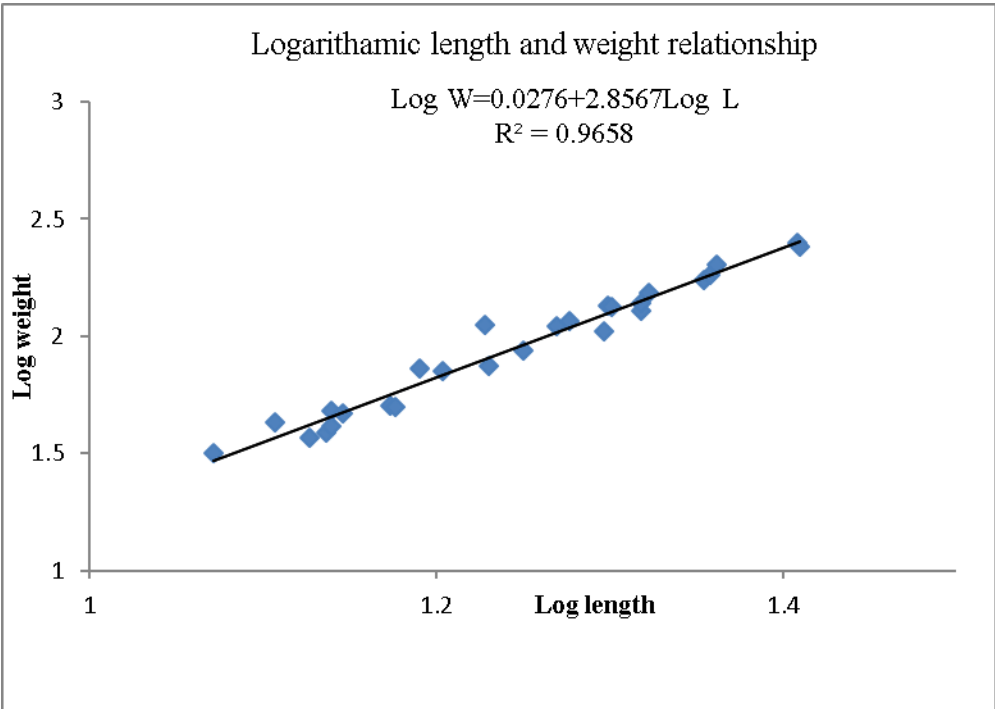


Fig. 1 (a) Logarithmic and (b) Parabolic length-weight relationship of *M. maculata*

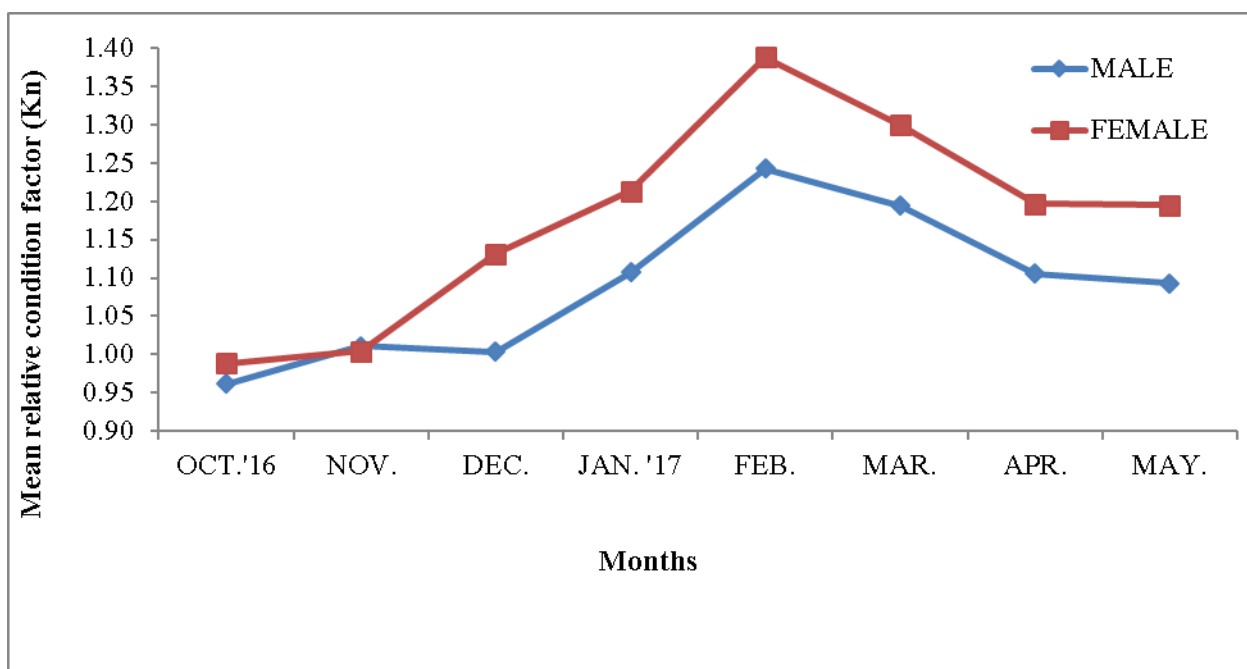


Fig.2. Monthly variation in relative condition factor (K_n) of *M. maculata*

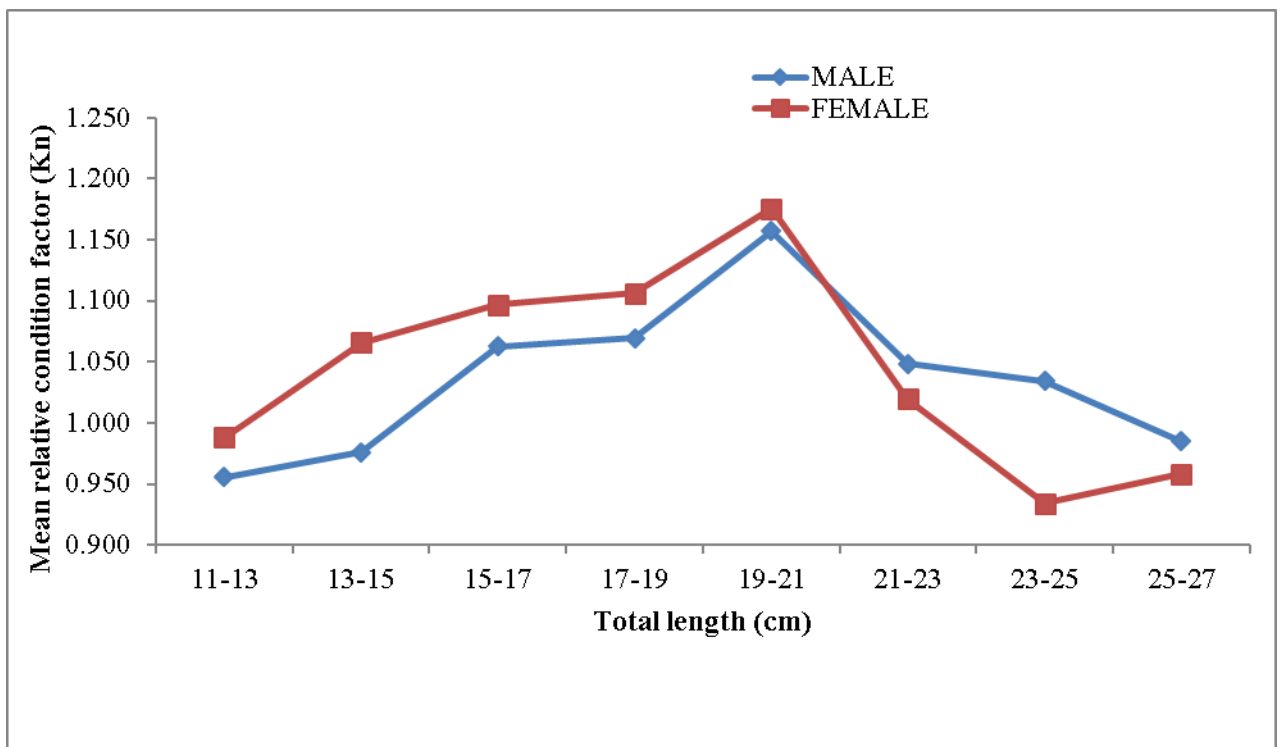


Fig.3. Mean values of relative condition factor (K_n) of *M. maculata* at different size groups

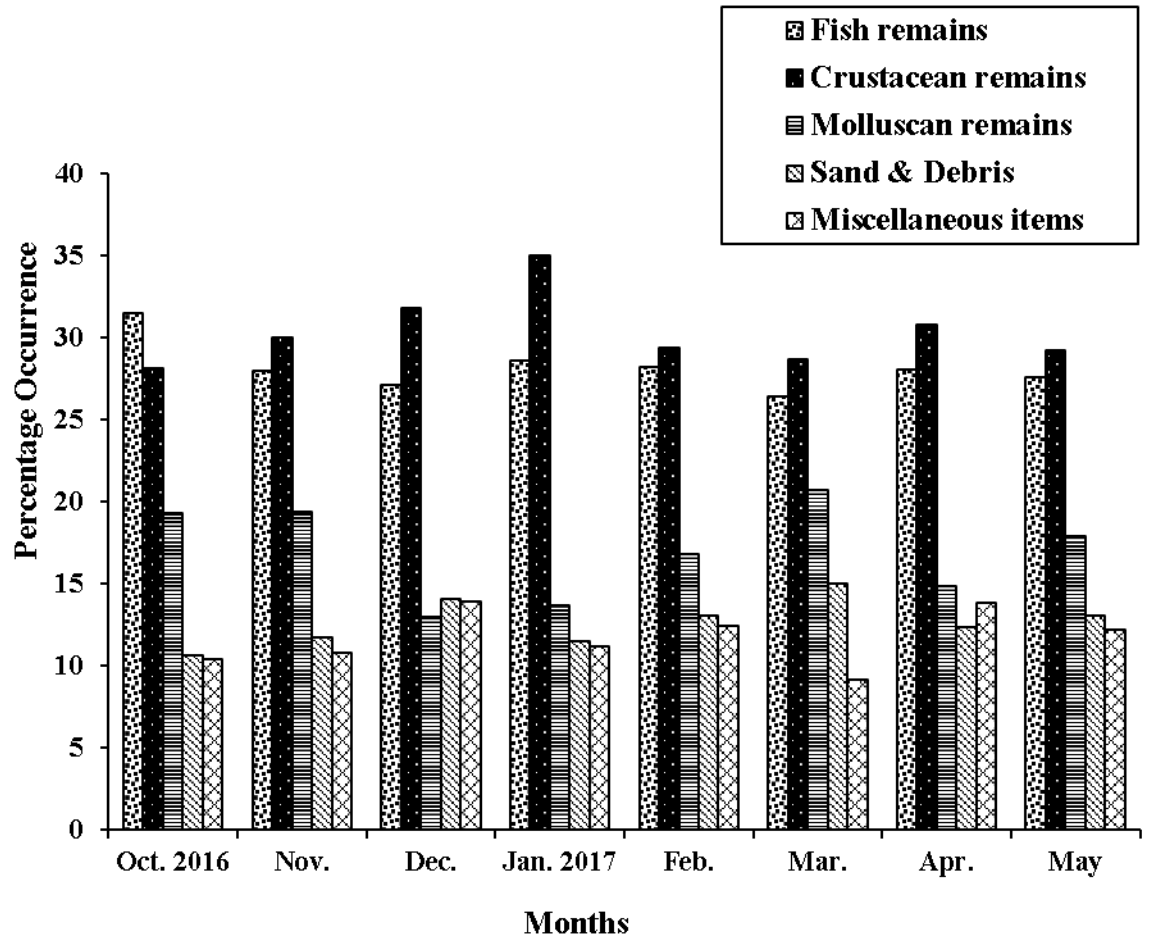


Fig. 4. Monthly percentage occurrence of food items recorded in *M. maculata*

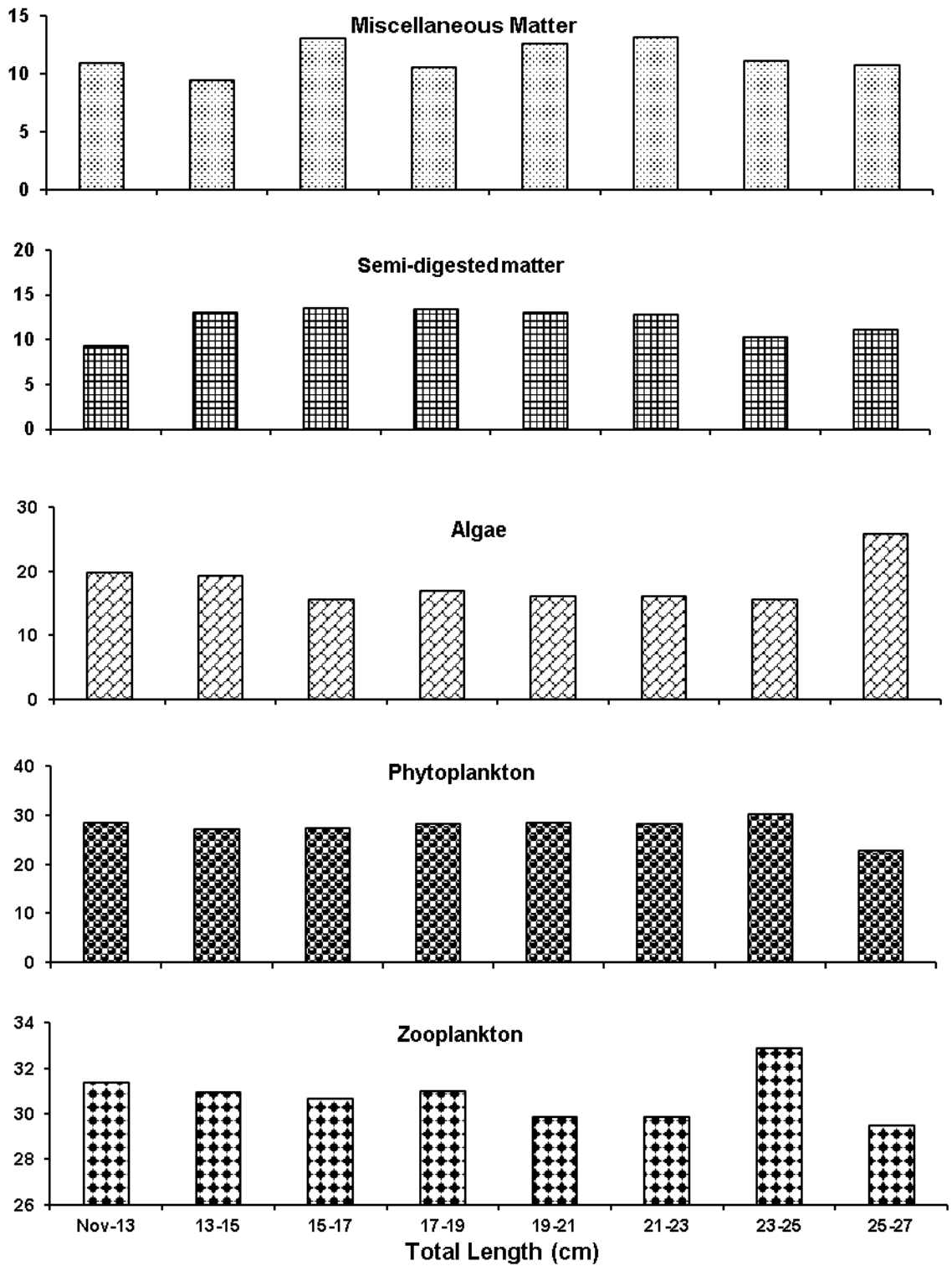


Fig. 5. Percentage occurrence of food items in different size groups recorded in *M. maculata*

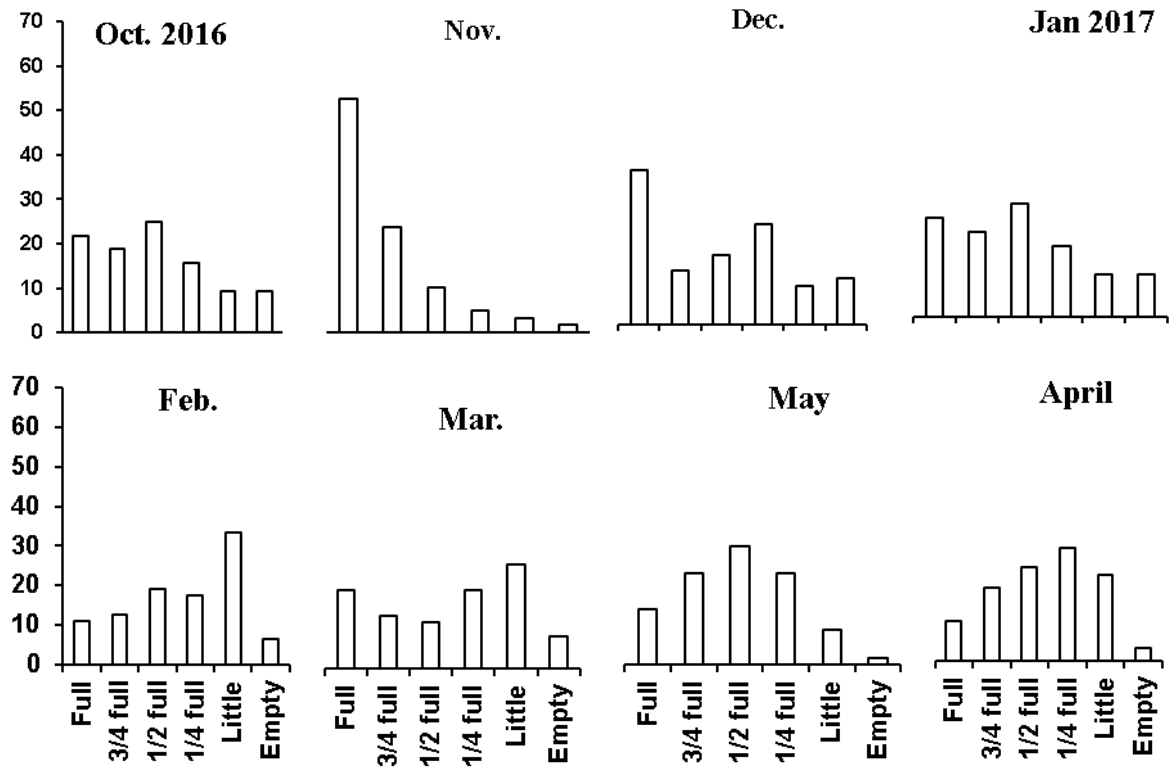


Fig.6. Monthly percentage occurrence of various degree of fullness of stomach in *M. maculata*

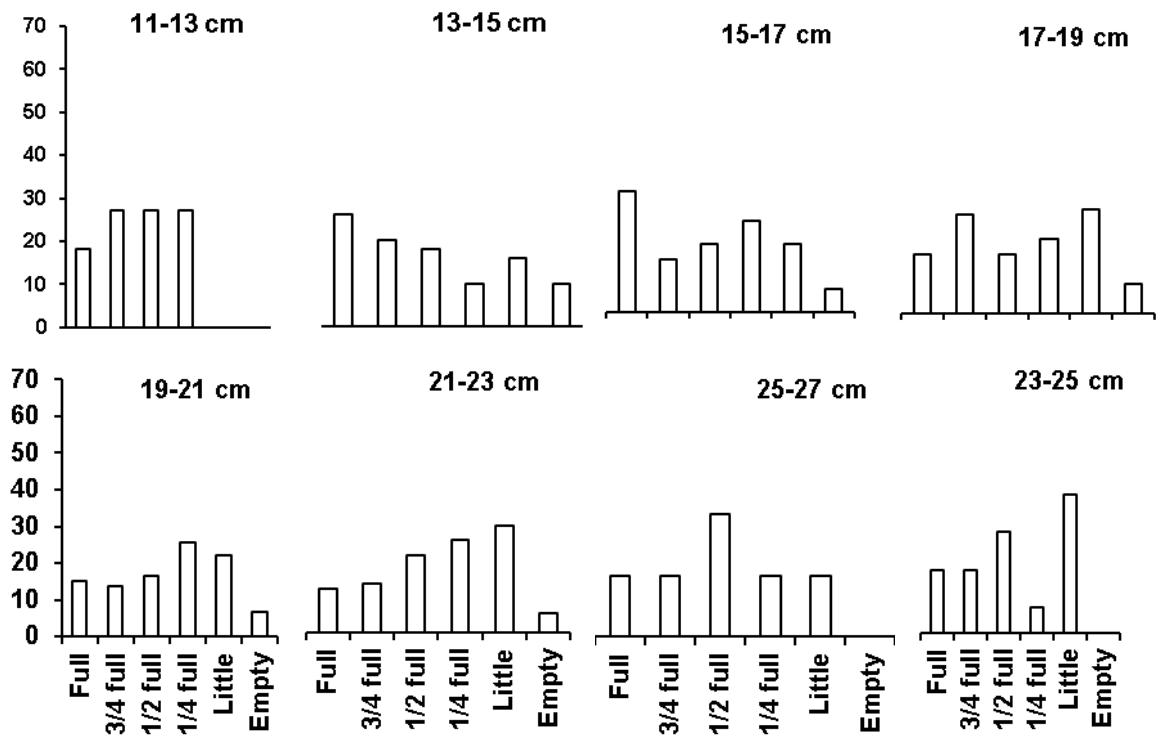


Fig .7. Percentage occurrence of various degree of fullness of stomach in different size groups of *M. maculata*

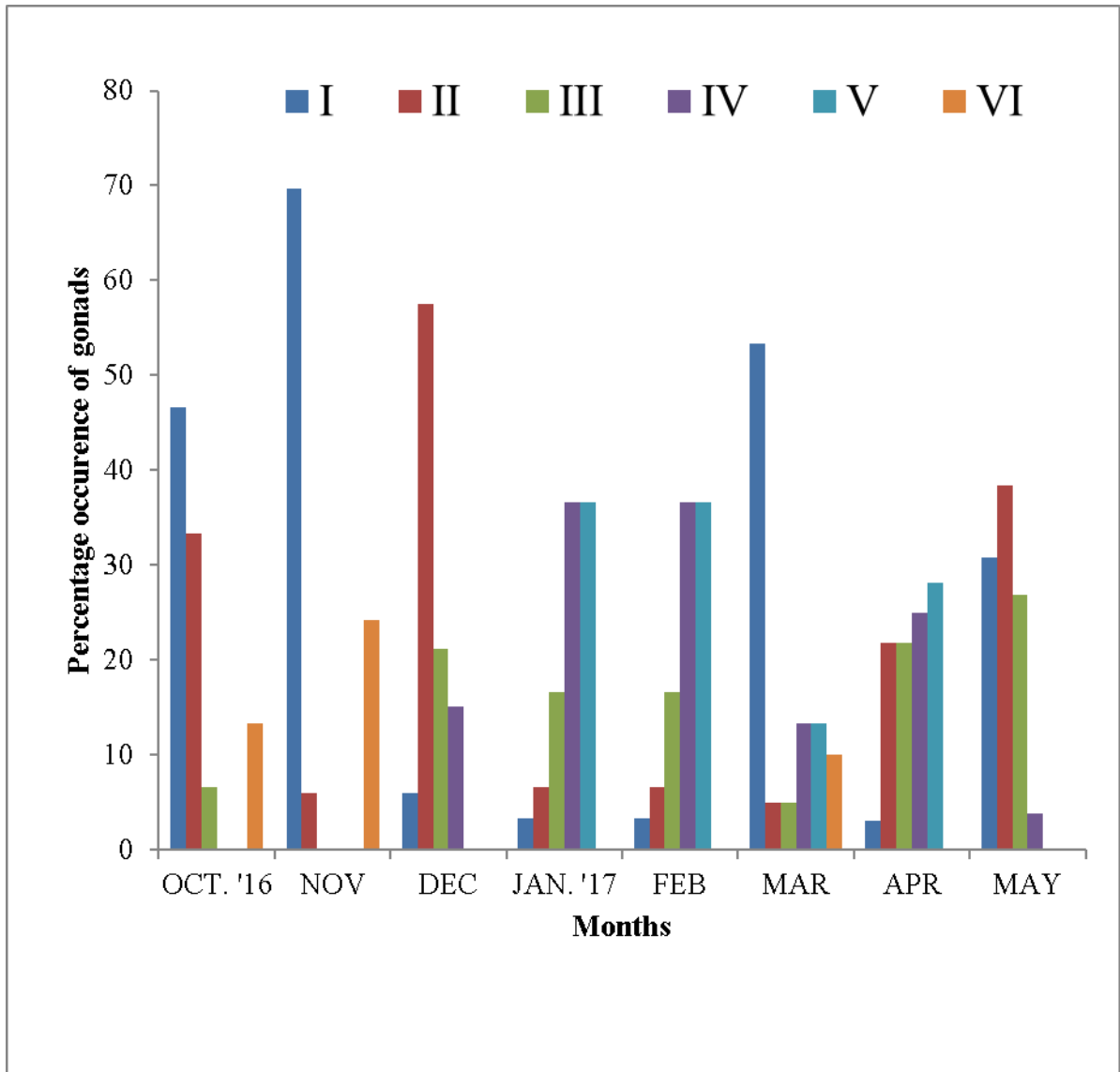


Fig. 9.Month- wise percentage occurrence of gonads in different stages of maturity of *M. maculata*-female

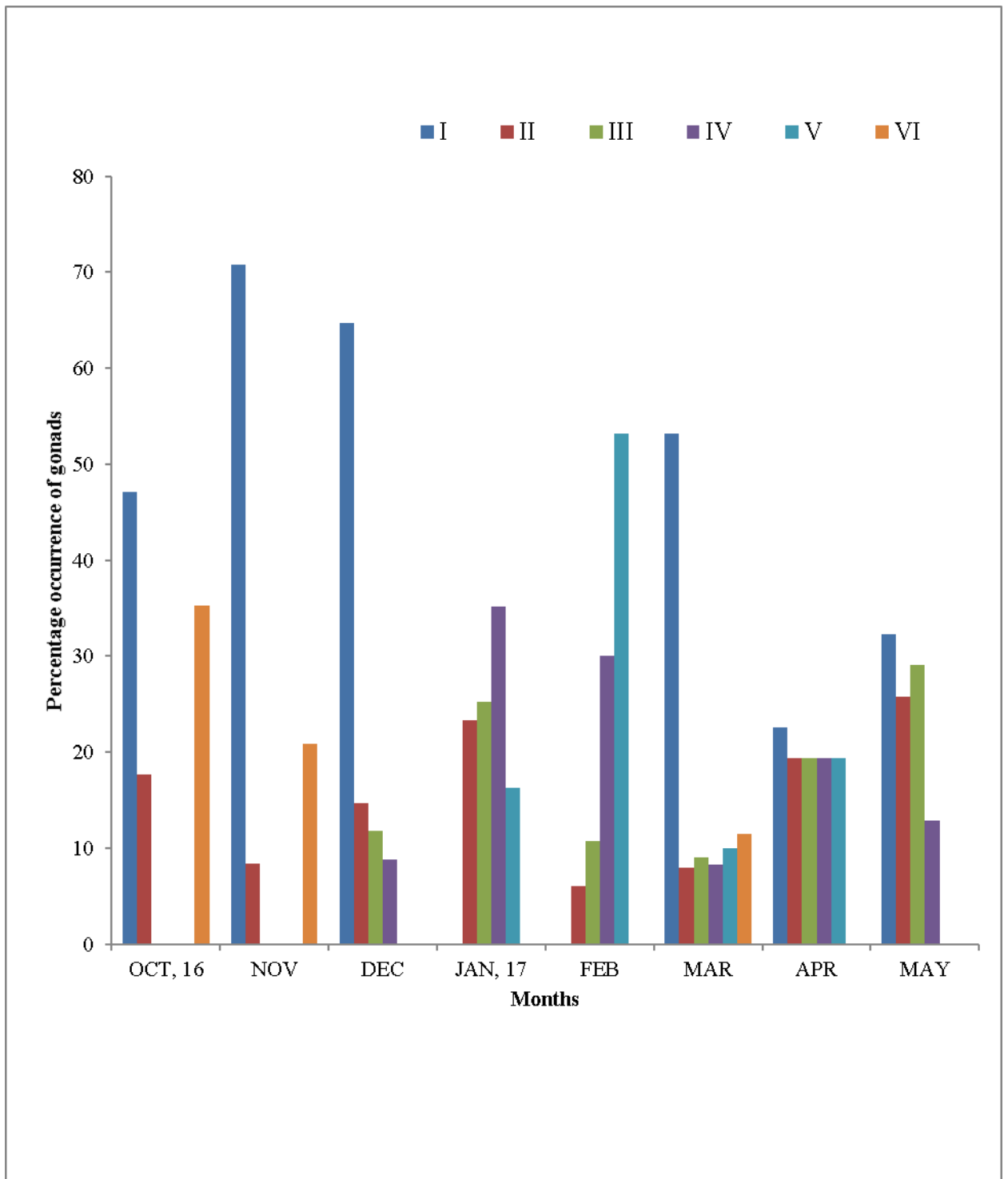


Fig. 10. Month- wise percentage occurrence of gonads in different stages of maturity of *M. maculata*-male

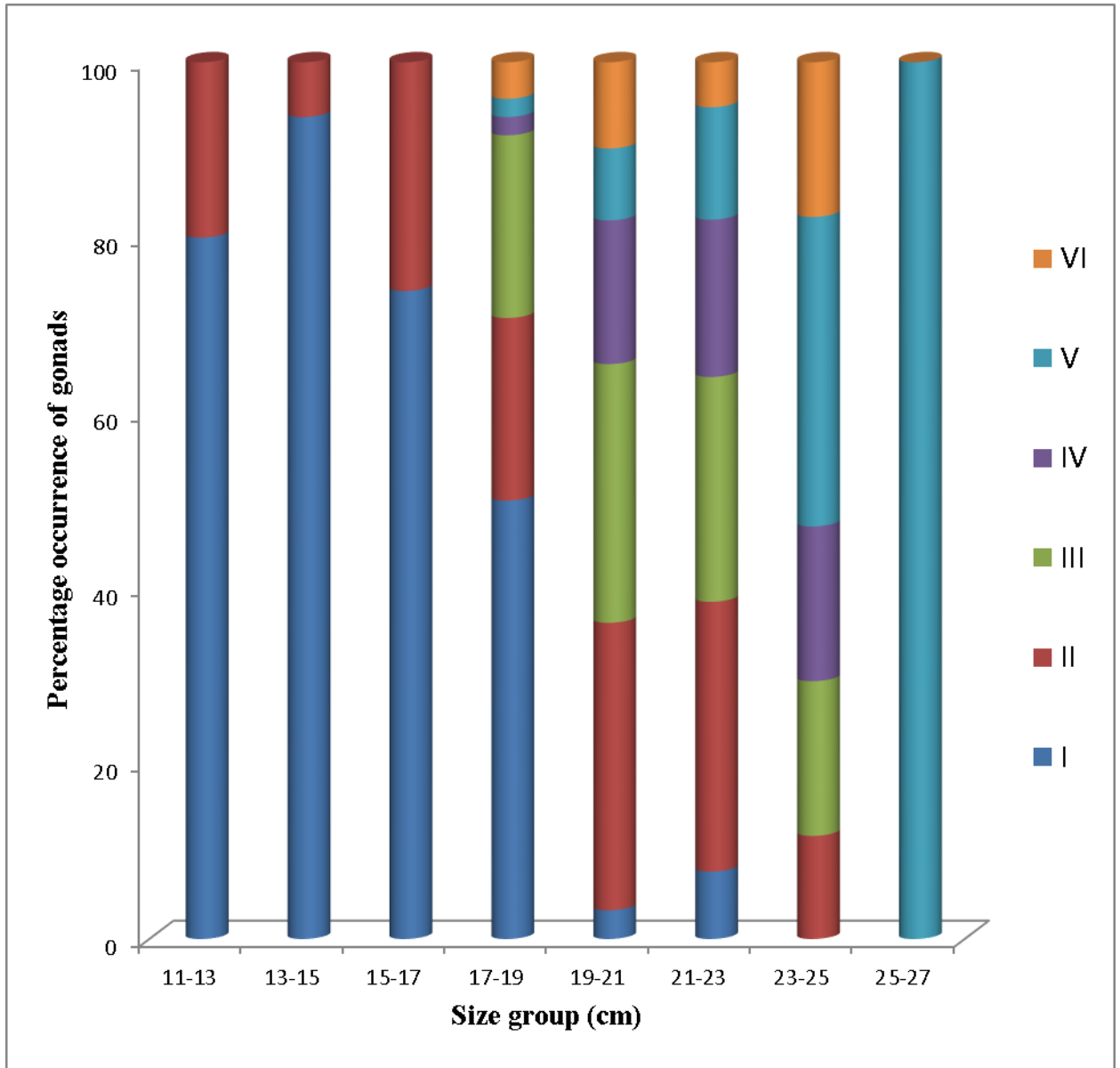


Fig.11.Size- wise percentage occurrence of gonads in different stages of maturity of *M. maculata*-male

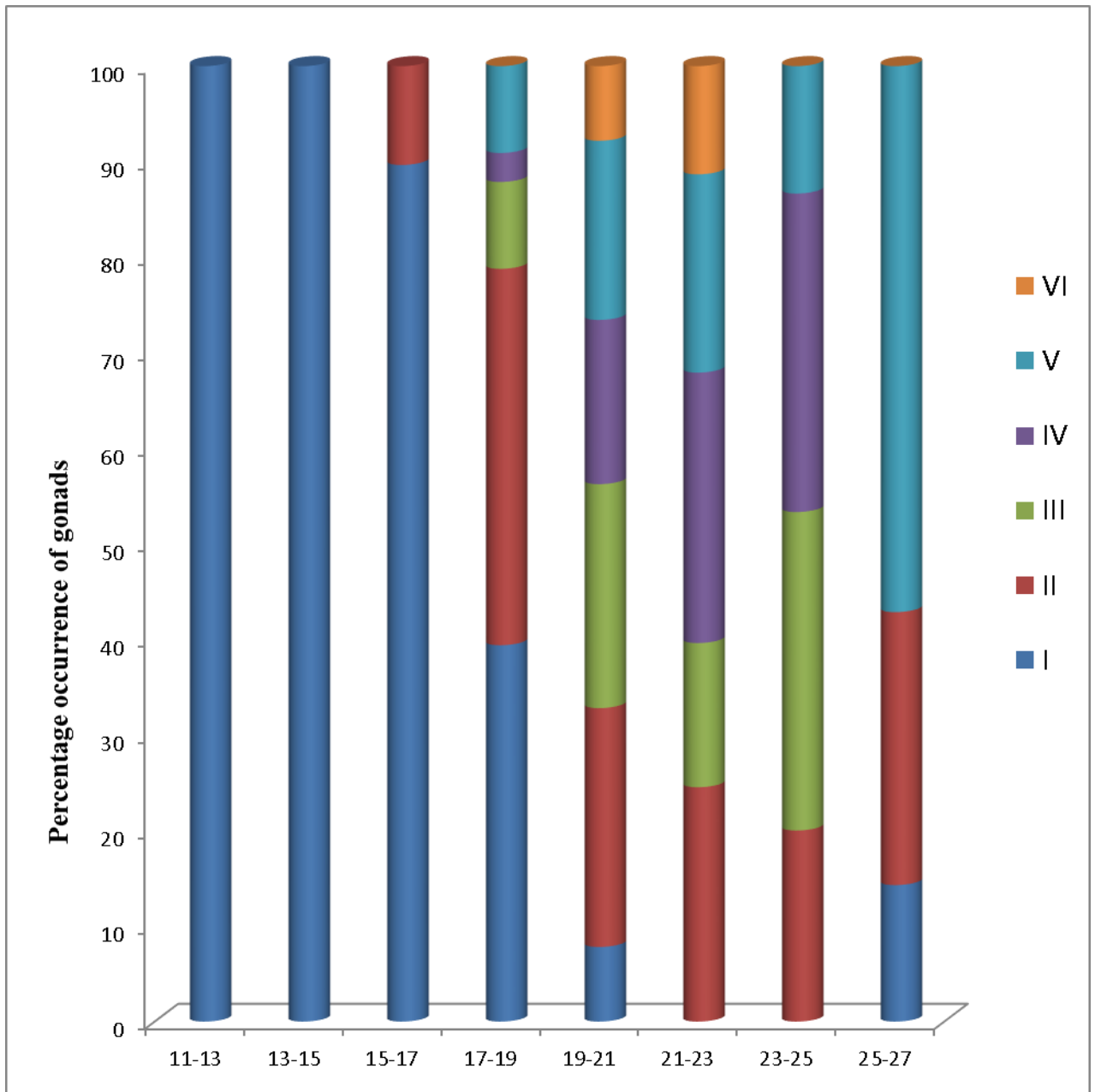


Fig.12.Size- wise percentage occurrence of gonads in different stages of maturity of *M. maculata*-female

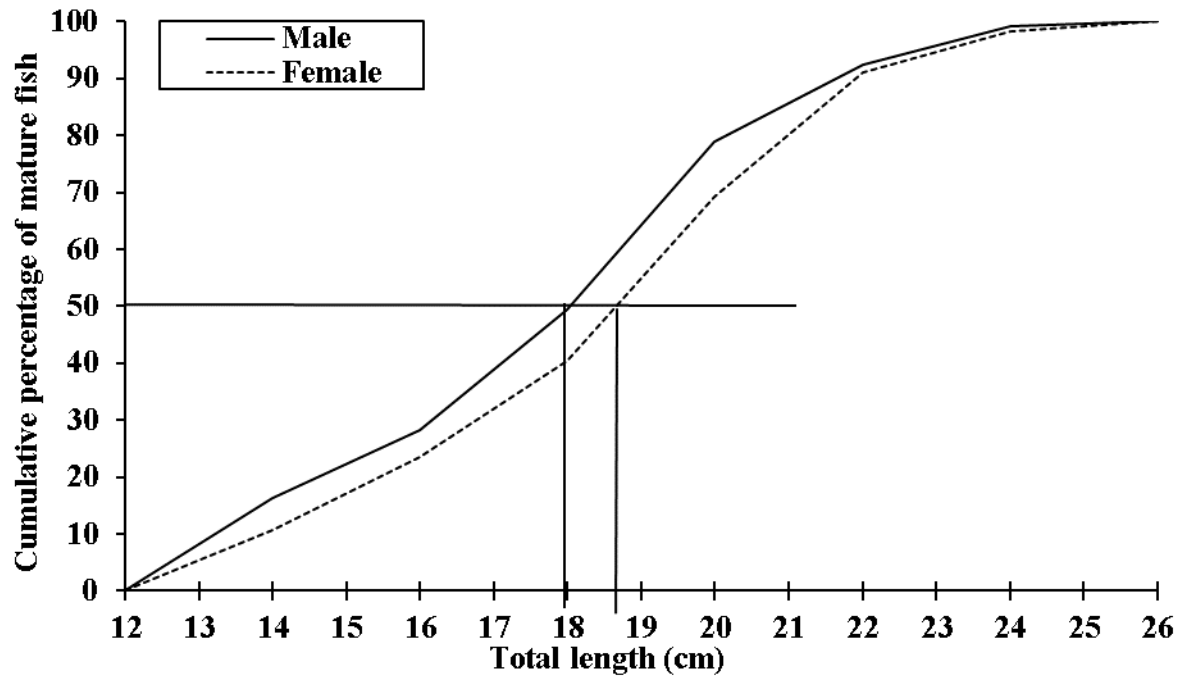


Fig.13. Size at first maturity of *M. maculata*

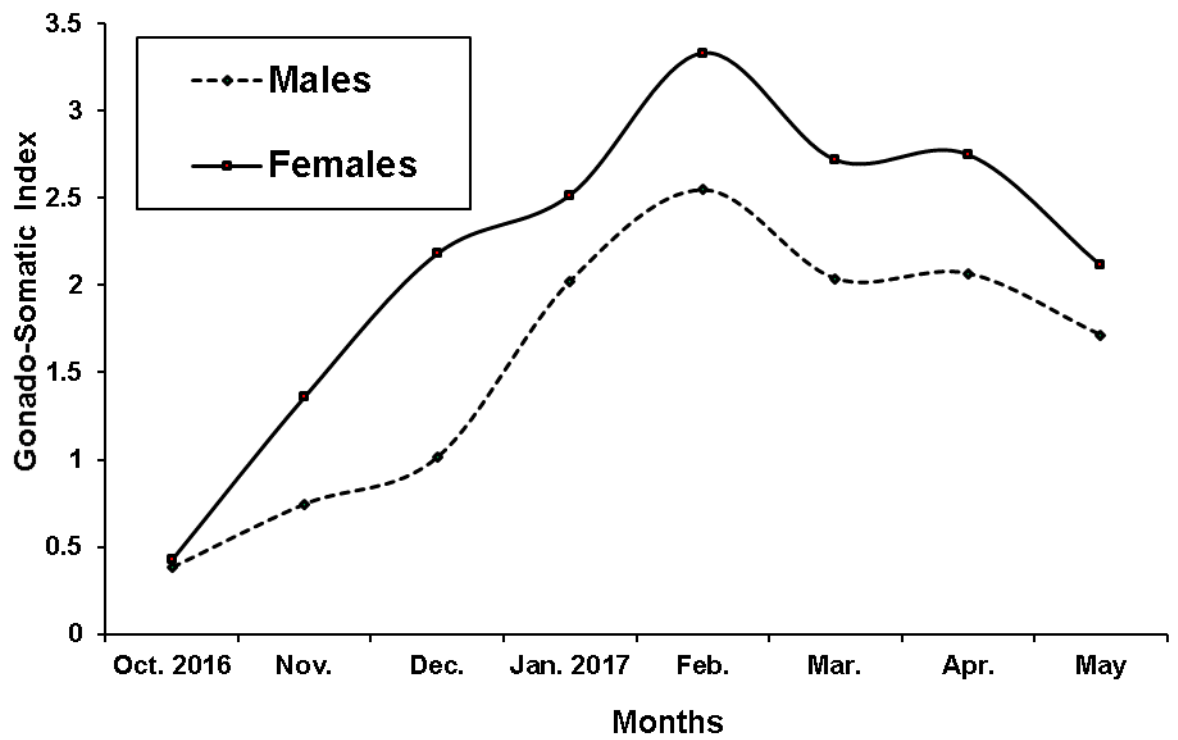


Fig.14.Monthly variation in the Gonado-Somatic index of *M. maculata*

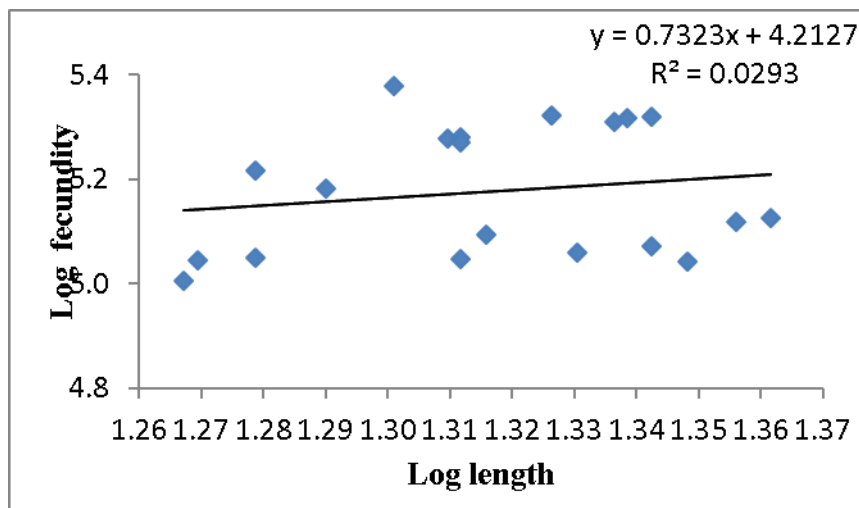


Fig.15. Relationship between log fecundity and log length of *M. maculata*

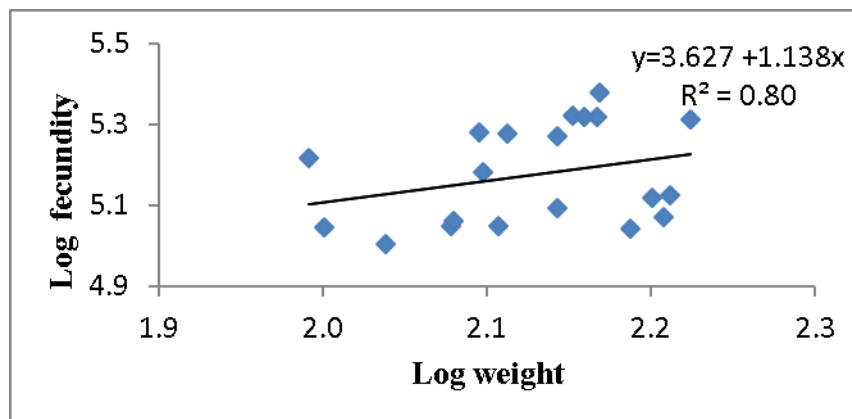


Fig.16. Relationship between log fecundity and log weight of *M. maculata*

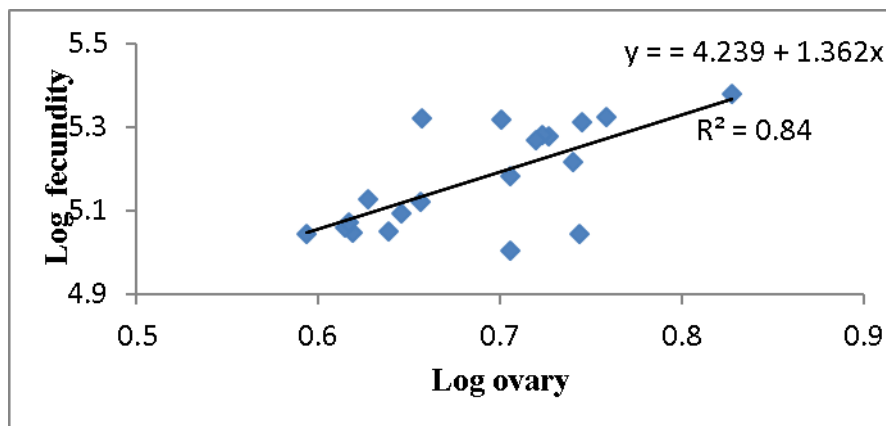


Fig.17. Relationship between log fecundity and log ovary weight of *M. maculata*

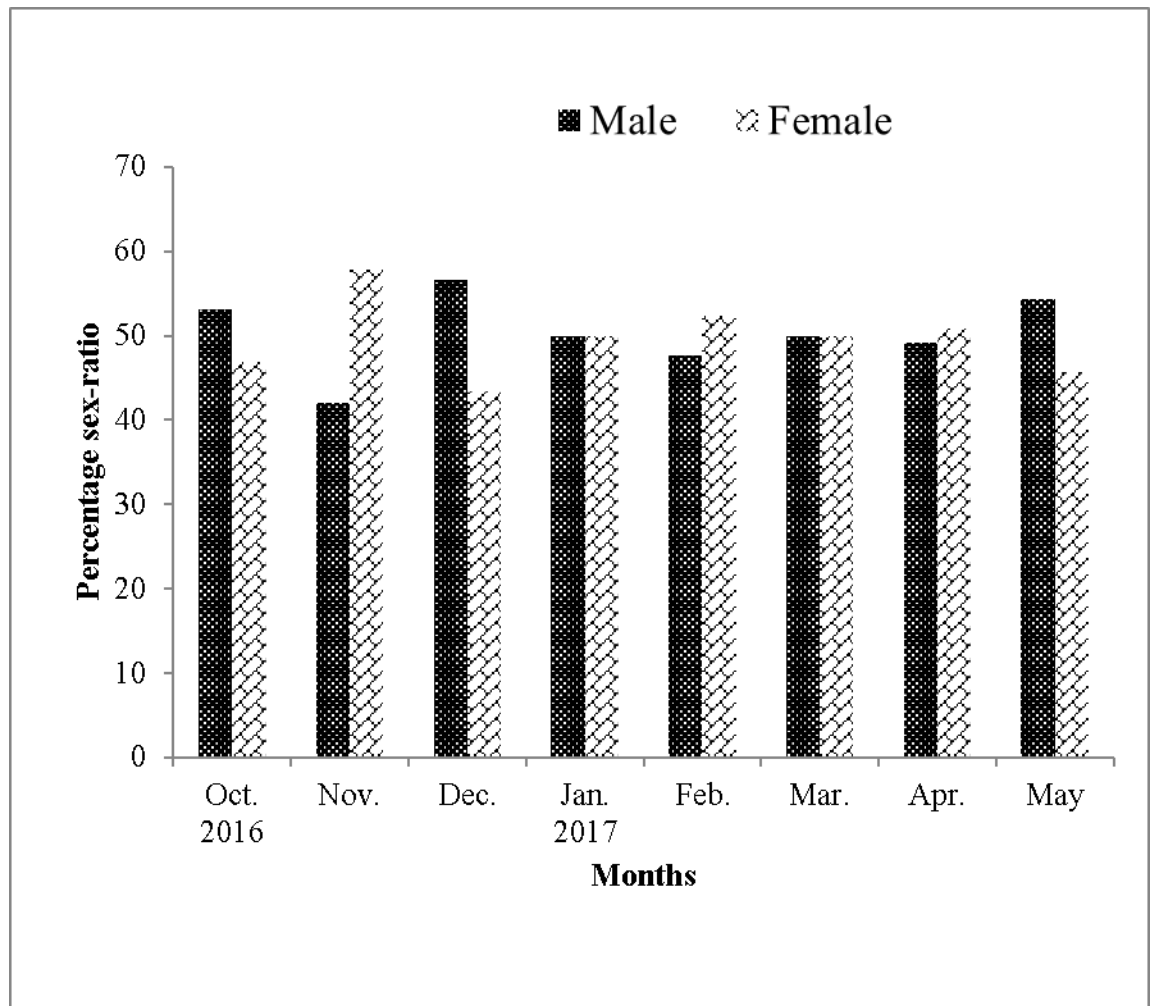


Fig.18 .Monthly percentage occurrence of sex-ratio recorded in *M. maculata*

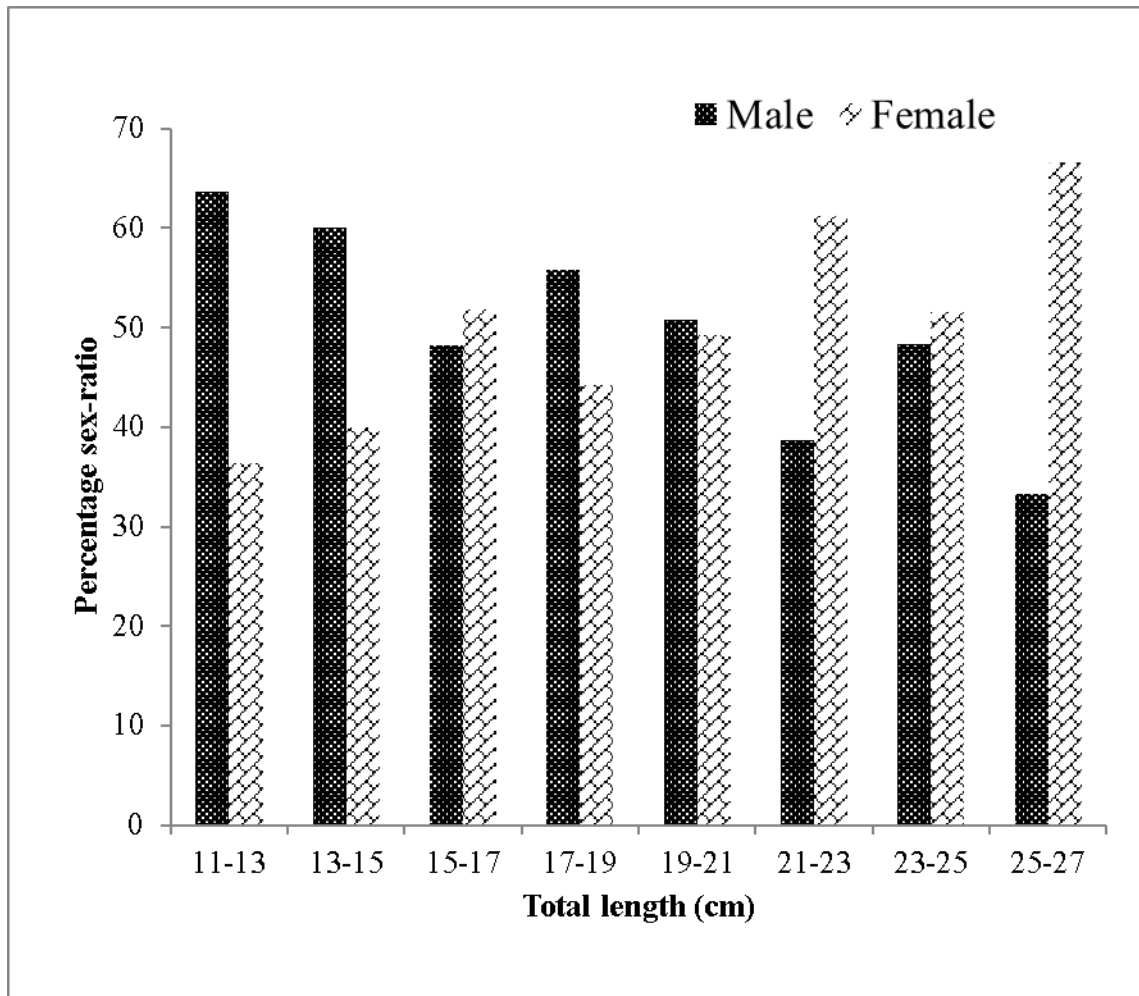


Fig. 19. Percentage occurrence of sex-ratio in different size groups recorded in *M. maculata*

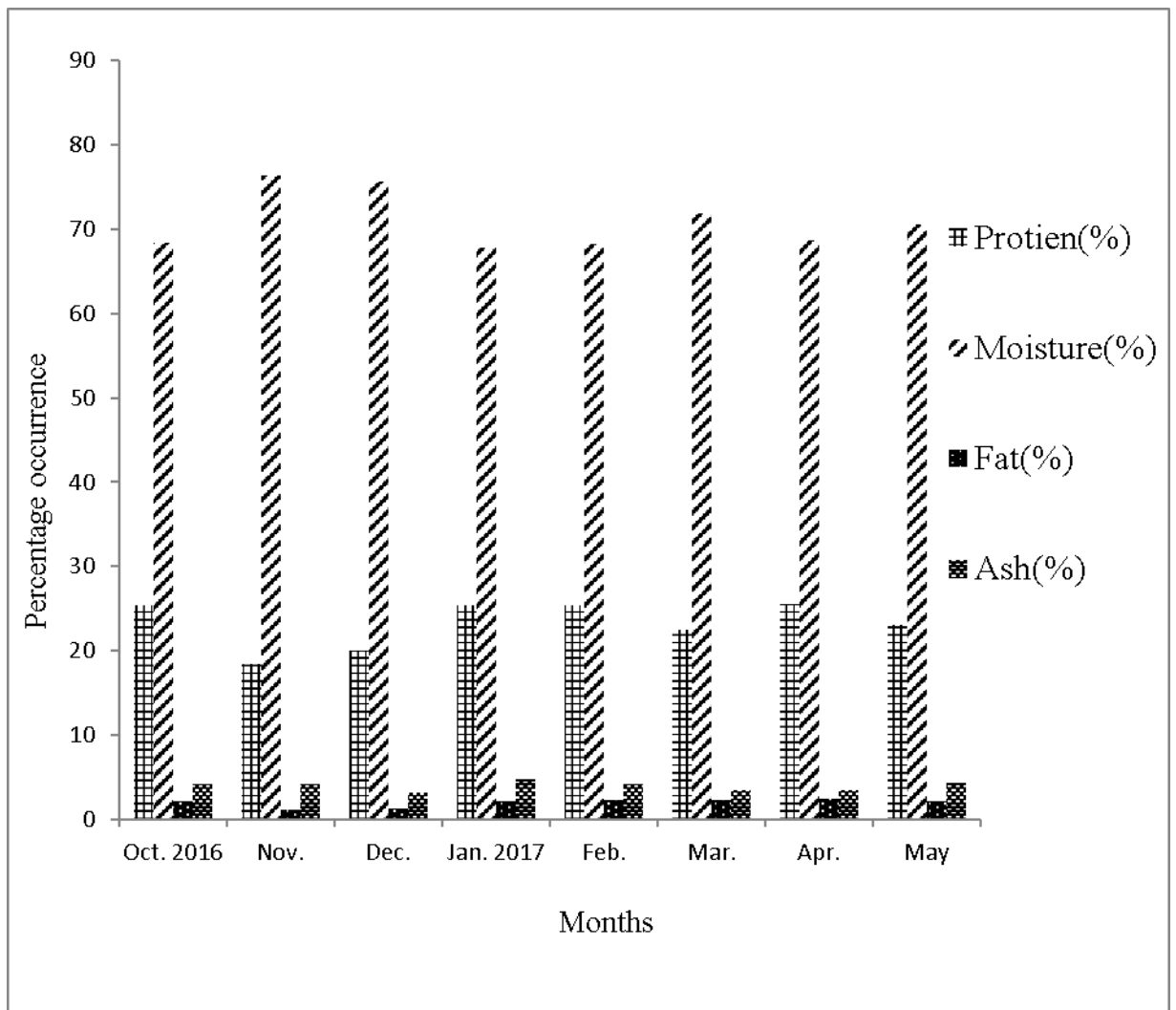


Fig.20. Monthly variation in proximate composition of *M. maculata*

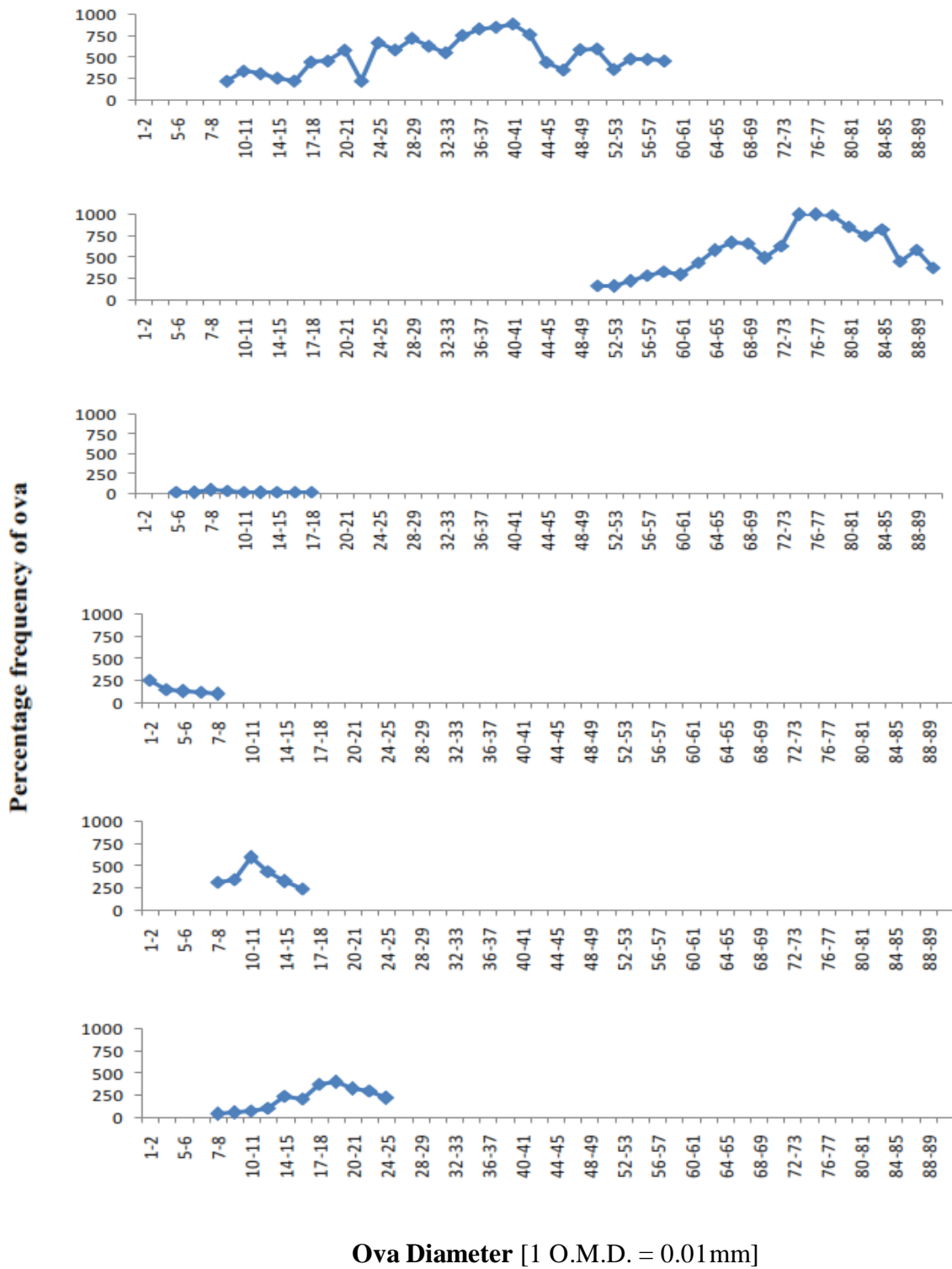


Fig.8. Ova diameter frequency polygons of *M. maculata* in different maturity stages



Plate: 1 *M. maculata* collected from Mangaluru fish landing center

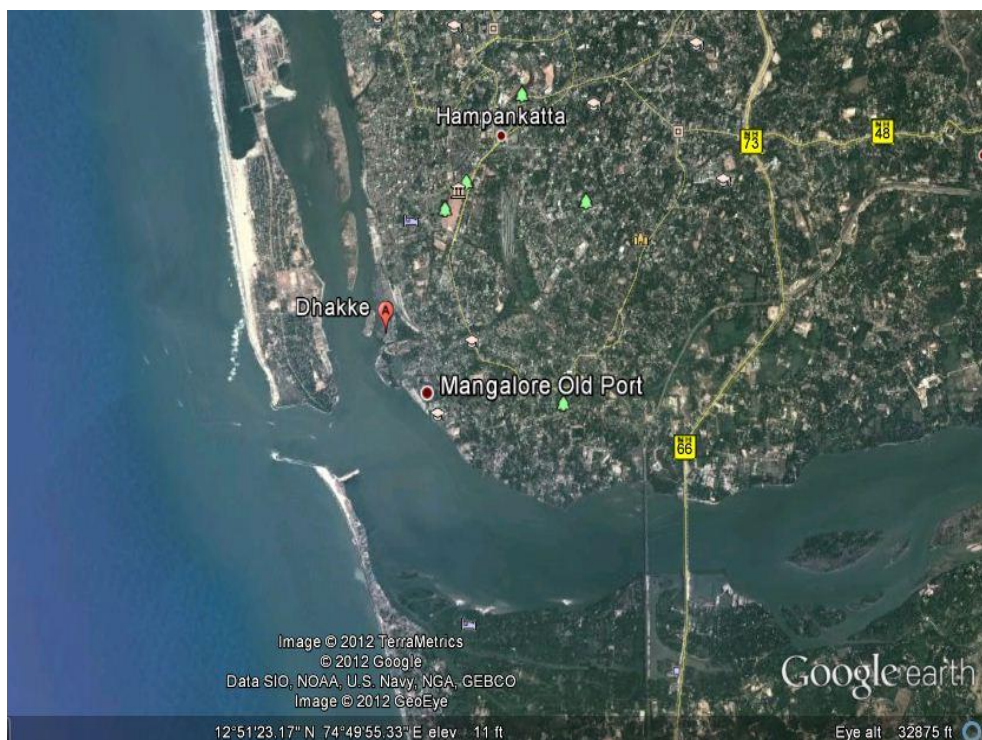
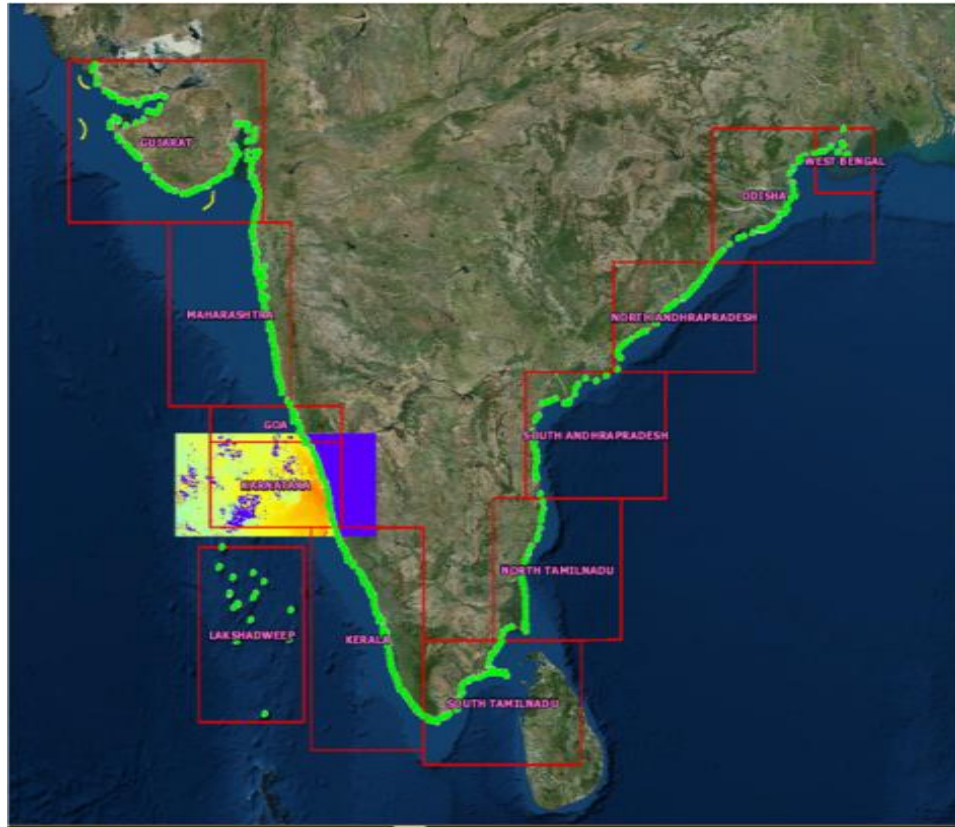


Plate: 2. Mangaluru fish landing centre (Jetty) Lat. 12°50'54"N; Long. 74°50'11"E



Plate: 3 Collection of fish sample from Mangaluru fish landing centre



Plate: 4 Biology work in laboratory

Table 1. Sum of squares and cross products of log length and log weight for male and female of *M.maculata*

MONTHS	ΣX	ΣY	ΣX^2	ΣY^2	ΣXY	n	b	A	a	$W=a.L^b$
MALES										
OCT.2016	21.78191	34.89292	27.97491	72.30458	44.91603	17	3.1532	-1.9876	0.0067	$0.0067L^{3.1532}$
NOV.	29.75408	47.58074	36.9511	94.85524	59.163	24	2.7547	-1.4326	0.03403	$0.03403L^{2.7547}$
DEC.	42.38543	66.68355	52.94331	131.6106	89.1809	34	2.7327	-1.4453	0.0359	$0.0359L^{2.7327}$
JAN.2017	39.35206	64.88118	51.6741	157.3722	85.26524	30	2.8982	-1.6389	0.0229	$0.0229L^{2.8982}$
FEB.	39.00385	63.3606	50.74899	134.2821	82.49468	30	3.0215	-1.8163	0.0153	$0.01526L^{3.0215}$
MAR.	36.58587	55.50015	42.82454	104.242	68.24648	30	2.717	-1.4635	0.0346	$0.0346L^{2.7170}$
APR.	39.7495	63.01372	51.25153	130.1203	81.5478	31	2.6461	-1.3602	0.0421	$0.0421L^{2.6461}$
MAY	39.42429	61.89712	50.36972	125.5788	79.38804	31	2.8914	-1.6804	0.0209	$0.0209L^{2.8914}$
TOTAL	288.037	457.81	364.7382	950.3659	590.2022	227	2.85185	-1.6031	0.026554	0.0266 L^{2.8519}
FEMALES										
OCT.2016	18.99255	29.85509	24.06687	59.59915	37.857	15	2.9043	-1.6869	0.0154	$0.0154L^{2.9043}$
NOV.	41.7801	67.09419	53.00177	137.3306	85.25195	33	2.9045	-1.6441	0.0227	$0.02269L^{2.9045}$
DEC.	32.75904	51.95416	43.33575	104.2461	65.61473	26	2.7326	-1.1796	0.05429	$0.0541L^{2.524972}$
JAN.2017	39.53691	64.45478	52.1314	138.7568	85.02733	30	3.1972	-2.0651	0.0085	$0.0085L^{3.1972}$
FEB.	43.07719	69.84709	56.31817	155.7192	91.43589	33	3.0009	-1.8007	0.0158	$0.0158L^{3.0009}$
MAR.	36.97777	56.34703	45.77927	107.5622	73.76329	30	2.8999	-1.6962	0.0217	$0.0217L^{2.8999}$
APR.	42.65433	69.05248	56.9472	149.6499	92.27592	32	2.6449	-1.2409	0.0574	$0.0574L^{2.5499}$
MAY	33.0577	51.73749	42.27534	104.7748	66.4457	26	2.7201	-1.4689	0.03399	$0.03399L^{2.7201}$
TOTAL	288.8356	460.3423	373.8558	957.6385	597.6718	225	2.87555	-1.5978	0.028723	0.0287 L^{2.8756}

Table. 2: Analysis of Co-variance for comparison of length-weight relationship of male and female of *M. maculata*

Source of variation	Degrees of freedom (d.f.) (n-1)	$\sum X^2$	$\sum Y^2$	$\sum XY$	b	Deviation from regression			
						d.f.	Sum of squares (SSQ)	Mean sum of squares (MSSQ)	F-ratio
Within male	226	2.3650	6.7234	22.9765	2.8429	225	3.8627	0.017168	0.0947*
Within female	224	1.4188	4.0859	13.5893	2.8798	223	1.8226	0.008173	
Deviation from the individual regression within sex						448	5.6853	0.01269	
Pooled data	450	3.7838	10.8093	36.5658	2.8567	449	5.6865	0.012665	
Difference between slopes						1	0.0012	0.0012	

*Not significant at 5% level

Table 3. Seasonal variation in relative condition factor (K_n) of *M. maculata*

MONTHS	MALE		FEMALE	
	No. of fishes	K_n	No. of fishes	K_n
Oct. 2016	17	0.9616	15	0.9886
Nov.	24	1.0108	33	1.0046
Dec.	34	1.0036	26	1.1317
Jan. 2017	30	1.1076	30	1.2139
Feb.	30	1.2430	33	1.3886
Mar.	30	1.1945	30	1.2998
Apr.	31	1.1057	32	1.1971
May	31	1.0930	26	1.1950
Pooled	227	1.0900	225	1.1774

Table 4. Mean values of relative condition factor (K_n) in different size groups of *M.maculata*

Size group(cm)	MALE		FEMALE	
	No .of fishes	K_n	No. of fishes	K_n
11-13	17	0.9555	15	0.9879
13-15	24	0.9761	33	1.0659
15-17	34	1.0625	26	1.0968
17-19	30	1.0696	30	1.1061
19-21	30	1.1574	33	1.1755
21-23	30	1.0483	30	1.0196
23-25	31	1.0346	32	0.9339
25-27	31	0.9849	26	0.9583
Pooled	227	1.0361	225	1.0430

Table 5. Percentage occurrence of food items recorded during different months in *M.maculata*

Food Items						
Months	No. of Fishes	Fish remains	Crustacean remains	Molluscan remains	Sand & Debris	Miscellaneous items
Oct. 2016	32	31.50	28.13	19.31	10.63	10.44
Nov.	57	28.00	30.05	19.39	11.73	10.82
Dec.	60	27.13	31.85	12.98	14.11	13.93
Jan. 2017	60	28.59	35.04	13.68	11.52	11.18
Feb.	63	28.23	29.39	16.85	13.08	12.44
Mar.	60	26.41	28.71	20.71	15.00	9.16
Apr.	63	28.08	30.77	14.89	12.37	13.89
May	57	27.57	29.21	17.92	13.09	12.21
Pooled	452	28.19	30.39	16.97	12.69	11.76

Table 6. Percentage occurrence of food items recorded in different size groups of *M.maculata*

Food Items						
Size groups(cm)	No. of Fishes	Fish remains	Crustacean remains	Molluscan remains	Sand & Debris	Miscellaneous items
11-13	32	28.55	31.36	19.82	9.36	10.91
13-15	57	27.25	30.95	19.28	13.06	9.45
15-17	60	27.28	30.66	15.62	13.49	13.04
17-19	60	28.18	31.01	16.93	13.34	10.55
19-21	63	28.47	29.85	16.03	13.07	12.58
21-23	60	28.29	29.87	16.03	12.83	13.08
23-25	63	30.20	32.90	15.50	10.30	11.10
25-27	57	22.83	29.50	25.83	11.17	10.67
Pooled	452	27.62	30.76	18.13	12.07	11.42

Table 7. Percentage occurrence of various degree of fullness of stomach in *M. maculata*

MONTHS	No. of fishes examined	Feeding intensity					
		FULL	$\frac{3}{4}$ full	$\frac{1}{2}$ full	$\frac{1}{4}$ full	LITTLE	EMPTY
Oct. 2016	32	21.88	18.75	25	15.61	9.38	9.38
Nov.	57	54.39	24.56	10.53	5.26	3.51	1.75
Dec.	60	33.33	11.67	15	21.67	8.33	10
Jan. 2017	60	30	11.67	16.67	25	8.33	8.33
Feb.	63	11.11	12.71	19.04	17.46	33.33	6.35
Mar.	60	20	13.33	11.67	20	26.67	8.33
Apr.	63	9.52	17.46	22.23	26.98	20.64	3.17
May	57	14.04	22.81	29.81	22.81	8.77	1.76
Pooled	452	24.28	16.62	18.74	19.35	14.87	6.13

Table 8. Size wise percentage occurrence of various degree of fullness of stomach in *M.maculata*

Size group(cm)	No. of fishes examined	Feeding intensity					
		FULL	$\frac{3}{4}$ full	$\frac{1}{2}$ full	$\frac{1}{4}$ full	LITTLE	EMPTY
11-13	32	18.18	27.27	27.27	27.28	0	0
13-15	57	26	20	18	10	16	10
15-17	60	28.57	12.5	16.07	21.43	16.07	5.36
17-19	60	13.95	23.26	13.95	17.44	24.42	6.98
19-21	63	15.15	13.64	16.67	25.75	21.97	6.82
21-23	60	11.25	12.5	20	23.75	27.5	5
23-25	63	16.13	16.13	25.81	6.45	35.48	0
25-27	57	16.67	16.67	33.33	16.66	16.67	0
Pooled	452	18.24	17.75	21.39	18.69	19.76	4.27

Table 9. Classification of maturity stages of *M.maculata*

Stages of maturity	Description of ova	Mode of largest group of ova (mm)	Maximum size of ova (mm)
I	Immature	0.04	0.08
II	Maturing	0.07	0.11
III	Early mature	0.15	0.30
IV	Late mature	0.41	0.59
V	Ripe	0.75	0.91
VI	Spent	0.06	0.09

Table 10. Month- wise percentage of gonads in different stages of maturity of *M.maculata*

Month	No. of fish	Sex	Maturity Stages					
			I	II	III	IV	V	VI
Oct. 2016	M	17	47.06	17.65	0.00	0.00	0.00	35.29
	F	15	46.67	33.33	6.67	0.00	0.00	13.33
Nov.	M	24	70.83	8.33	0.00	0.00	0.00	20.83
	F	33	69.70	6.06	0.00	0.00	0.00	24.24
Dec.	M	34	64.71	14.71	11.76	8.82	0.00	0.00
	F	26	3.33	6.67	16.67	36.67	36.67	0.00
Jan. 2017	M	30	0.00	23.33	36.67	16.67	23.33	0.00
	F	30	3.33	6.67	16.67	36.67	36.67	0.00
Feb.	M	30	0.00	60.00	30.00	0.00	10.00	0.00
	F	33	6.06	57.58	21.21	15.15	0.00	0.00
Mar.	M	30	56.67	10.00	10.00	10.00	10.00	3.33
	F	30	53.33	0.00	10.00	13.33	13.33	10.00
Apr.	M	31	22.58	19.35	19.35	19.35	19.35	0.00
	F	32	3.13	21.88	21.88	25.00	28.13	0.00
May	M	31	32.26	25.81	29.03	12.90	0.00	0.00
	F	26	30.77	38.46	26.92	3.85	0.00	0.00

Table 11. Percentage occurrence of different stages of maturity in relation to different size groups of *M.maculata*

Size (cm)	No. of fish	Sex	Maturity Stages					
			I	II	III	IV	V	VI
11-13	17	M	80	20	-	-	-	-
	4	F	100	-	-	-	-	-
13-15	24	M	93.75	6.25	-	-	-	-
	20	F	100	-	-	-	-	-
15-17	34	M	73.913	26.087	-	-	-	-
	29	F	89.6551	10.3448	-	-	-	-
17-19	30	M	50	20.8333	2.0833	2.0833	4.1667	-
	33	F	39.3939	39.3939	9.0909	3.0303	9.0909	-
19-21	30	M	3.2787	32.7869	29.5082	16.3934	8.1967	9.836
	64	F	7.8125	25	23.4375	17.1875	18.75	7.8125
21-23	30	M	7.6923	30.7692	25.641	17.9487	12.8205	5.1282
	53	F	-	24.5283	15.0943	28.3019	20.7547	11.3208
23-25	31	M	-	11.7647	17.647	17.647	35.2941	17.647
	15	F	-	20	33.3333	33.3333	13.3333	-
25-27	31	M	-	-	-	-	100	-
	7	F	14.2857	28.5714	-	-	57.1429	-

Table .12: Estimation of size at first maturity by cumulative percentage frequency method for *M.maculata*

Size group (cm)	Mid length (cm)	Cumulative percentage frequency	
		Male	Female
11-13	12	0	0
13-15	14	16.2996	10.666
15-17	16	28.1938	23.555
17-19	18	49.3392	40.4444
19-21	20	78.855	69.3333
21-23	22	92.511	91.1111
23-25	24	99.1189	98.2222
25-27	26	100	100

Table. 13: Monthly variation in the Gonado-Somatic Index of *M.maculata*

Months	Male		Female	
	No. of fish	G.S.I.	No. of fish	G.S.I.
Oct. 2016	17	0.3794	15	0.4245
Nov.	24	0.7434	33	1.3597
Dec.	34	1.0125	26	2.1806
Jan. 2017	30	2.0243	30	2.5164
Feb.	30	2.5485	33	3.3315
Mar.	30	2.0395	30	2.7189
Apr.	31	2.0687	32	2.7493
May	31	1.7156	26	2.1145
Pooled	227	1.5665	225	2.1744

Table 14: Number of mature ova in individuals of *M. maculata*

Sl. No.	Total length(cm)	Body weight(g)	Gonad weight(g)	Fecundity	Stages of maturity
1	18.5	109.2	5.08	101,051	IV
2	18.6	100.25	5.54	1,10,755	IV
3	19	119.66	4.35	1,11,768	IV
4	19	98.12	5.5	1,64,956	V
5	19.5	125.18	5.08	1,52,389	V
6	20	147.47	6.72	2,38,875	V
7	20.4	129.47	5.33	1,89,582	V
8	20.5	127.88	4.16	1,11,712	IV
9	20.5	124.62	5.29	1,91,101	V
10	20.5	139.05	5.24	1,85,962	V
11	20.7	139	4.42	1,23,760	IV
12	21.2	142.03	5.73	2,09,975	V
13	21.4	120.03	4.12	1,14,923	IV
14	21.7	167.46	5.56	2,04,452	V
15	21.8	144.3	5.02	2,07,888	V
16	22	161.32	4.14	1,17,807	IV
17	22	146.9	4.54	2,08,690	V
18	22.3	153.98	3.92	1,10,206	IV
19	22.7	158.7	4.53	1,31,578	IV
20	23	162.67	4.24	1,33,750	IV

Table. 15: Seasonal variation in sex – ratio of *M. maculata*

Months	Total no. of fish	Male		Female		Chi – square values	Male: Female
		n	%	n	%		
Oct. 2016	32	17	7.49	15	6.67	0.125	1:0.89
Nov.	57	24	10.57	33	14.67	0.7106	1:1.39
Dec.	60	34	14.98	26	11.56	1.067	1:0.77
Jan. 2017	60	30	13.22	30	13.33	0	1:1
Feb.	63	30	13.22	33	14.67	0.1428	1:1.11
Mar.	60	30	13.22	30	13.33	0	1:1
Apr.	63	31	13.66	32	14.22	0.0079	1:1.04
May	57	31	13.66	26	11.56	0.4385	1:0.85
Pooled	452	227	100	225	100	0.3115	1:0.99

Table 16: Sex –ratio in different size groups of *M.maculata*

Size group (cm)	Total no. of fish	Male		Female		Chi – square values	Male : Female
		No. of Fish	%	No. of Fish	%		
11-13	11	7	3.08	4	1.78	0.8182	1:0.5714
13-15	50	30	13.21	20	8.89	2	1:0.6667
15-17	56	27	11.89	29	12.89	0.0714	1:1.0740
17-19	86	48	21.15	38	16.89	1.1628	1:0.4419
19-21	132	67	29.52	65	28.89	0.0303	1:0.4924
21-23	80	31	13.66	49	21.78	4.05	1:0.6125
23-25	31	15	6.60	16	7.11	0.0322	1:1.0667
25-27	6	2	0.88	4	1.78	0.6667	1:2
Pooled	425	227	100	225	100	1.103	1:0.87

*Significant at 5% level

Table 17: Monthly variation in proximate composition of *M. maculata*

Months	Protein (%)	Moisture(%)	Fat(%)	Ash(%)
Oct. 2016	25.38	68.39	2.11	4.74
Nov.	18.95	76.39	1.11	4.14
Dec.	19.97	75.67	1.24	3.12
Jan. 2017	25.47	67.80	2.19	4.72
Feb.	25.38	68.62	2.24	4.00
Mar.	22.51	71.92	2.10	3.37
Apr.	25.52	68.65	2.30	3.46
May	23.12	71.38	2.00	4.24
Average	23.29	71.10	1.91	3.97