

**POPULATION DYNAMICS OF *HARPODON NEHEREUS*
(HAMILTON) FROM ESTUARINE REGION OF
KAKDWIP, WEST BENGAL**

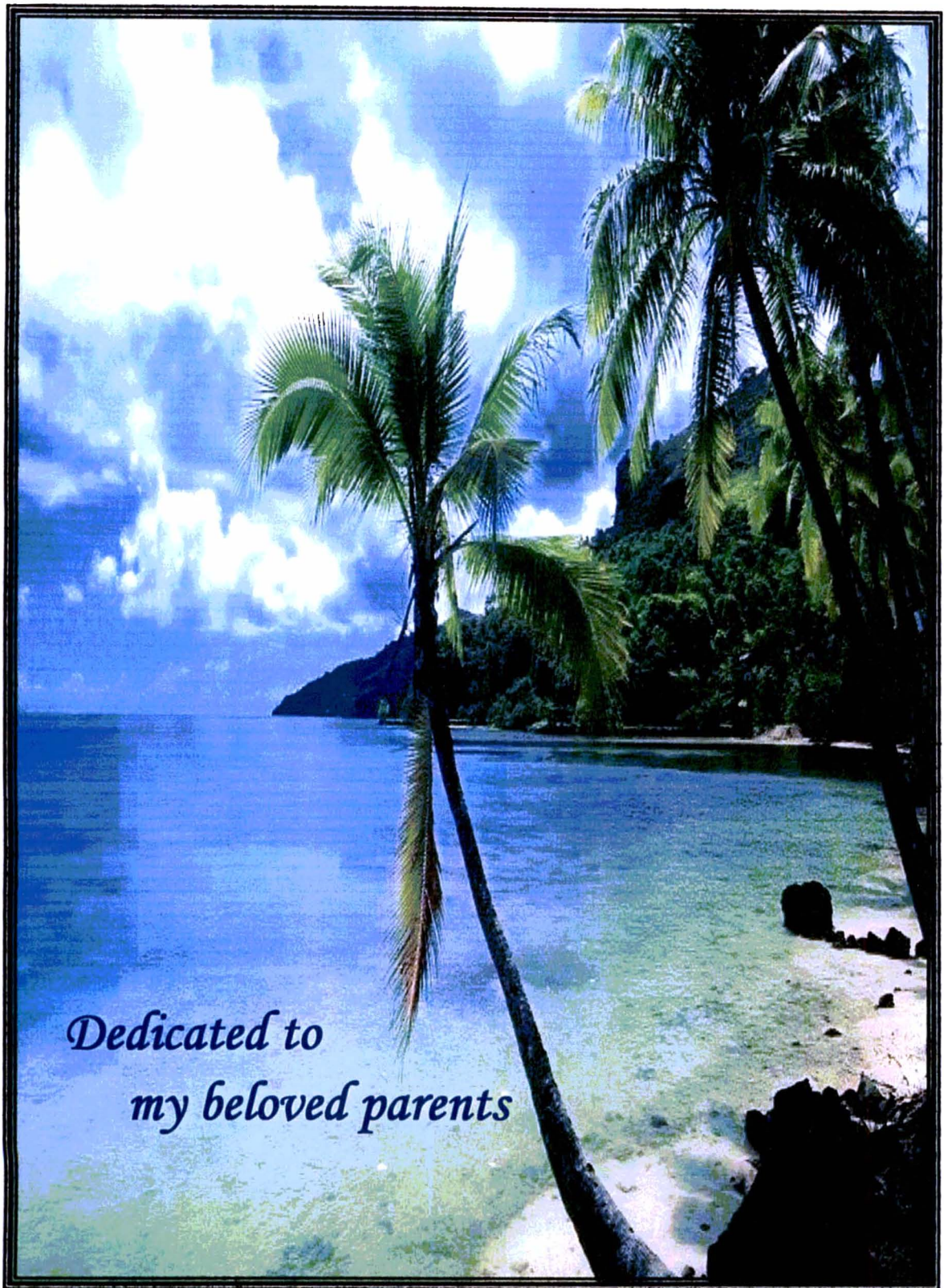
**A Thesis
Submitted to the
West Bengal University of Animal and Fishery Sciences
in partial fulfilment of the requirements for the award of the degree of
Master of Fishery Science
in
Fishery Biology and Resources Management**

By

Bijan Kumar Biswas, B.F.Sc.



**Department of Fishery Biology and Resources Management
Faculty of Fishery Sciences
West Bengal University of Animal and Fishery Sciences
5, Budherhat Road, ChakGaria, Kol-94
2006**



*Dedicated to
my beloved parents*

West Bengal University of Animal and Fishery Sciences



Faculty of Fishery Sciences

Department of Fishery Biology and Resources Management

5-Budherhat Road, P.O.-Panchyasayar

Chakgaria, kol-94

Dr. Samarendra Behera. M. F.Sc. Ph.D

Lecturer (S.S.)

Date: 01.12.2006

Ref.No:.....

Certificate

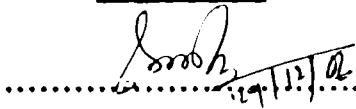
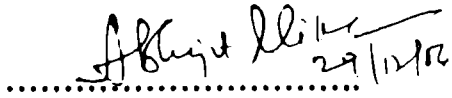
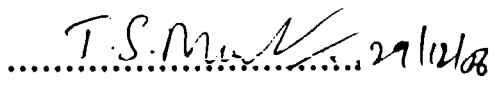

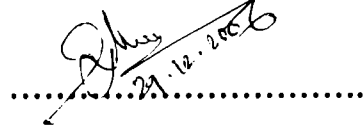
This is to certify that the work embodied in the thesis entitled “**Population dynamics of *Harpodon nehereus* (Hamilton) from estuarine region of Kakdwip, West Bengal**” submitted by Mr. Bijan Kumar Biswas in partial fulfillment of the requirements for the degree of Master of Fishery Science (**Department of Fishery Biology and Resources Management**) in the Faculty of Fishery Sciences, West Bengal University of Animal and Fishery Sciences, is the faithful and bonafied research work carried out under my supervision and guidance. The results of the investigation reported in this thesis have not so far been submitted for any other degree or diploma. The assistance and help received during the course of investigation have been duly acknowledged.

Chairman
Advisory committee

APPROVAL SHEET

Approval of the examiners for the award of the degree of Master of Fishery Science (Fishery Biology and Resources Management)

We, the undersigned have been satisfied with the performance of **Mr. Bijan Kumar Biswas** in the viva - voce examination, conducted today the 29th December 2006, recommended that the thesis be accepted for the award of the degree.

<u>Name</u>	<u>Signature</u>
1. Dr. S. Behera Chairman of the Advisory committee	
2. <u>Dr. Abhijit Mishra</u> External Examiner	
3. Dr. T. S. Nagesh Member of the Advisory committee	
4. Dr. S. K. Das Member of the Advisory committee	
5. Dr. G. Dash Member of the Advisory committee	

Acknowledgement

It is my profound privilege to acknowledge indebtedness to Dr. Samarendra Behera, Lecturer and Head, Department of Fishery Biology and Resources Management, Faculty of Fishery Sciences, West Bengal University of Animal and Fishery Sciences, for his persistent guidance, invaluable suggestions, encouragement and friendly discussions all of which helped me to accomplish this study.

I feel delighted to express my deep sense of gratitude to Dr. T. S. Nagesh, Lecturer, Department of Fishery Biology and Resources Management and member of Advisory committee, for his precious assistance and constant inspiration during the entire period of research work.

I also express my profound gratitude and sincerest appreciation to my advisor Dr. S. K. Das, Reader, Department of Fishery Biology and Resources Management and member of the advisory committee, for his valuable advice during the entire course of investigation.

I feel immense pleasure to express my heartfelt thanks to Dr. G. Das, Lecturer, Department of Fishery Pathology and Microbiology and member of the advisory committee for his immense help regarding discussion of several problems during the period of study.

I also wish to acknowledge my sincere indebtedness to the Hon'ble Vice-Chancellor, the Registrar, the Controller, West Bengal University of Animal and Fishery Sciences, for giving permission to submit the thesis.

I am grateful to the Dean, Faculty of Fishery Sciences, West Bengal University of Animal and Fishery Sciences, for his kind co-operation and providing necessary facilities to carry out this research.

Sincere appreciation is extended to Central Library, ICAR, Barrackpore, Central Library, W.B.U.A.F.S., Zoological survey of India, New Alipur for providing assistance regarding several literature studies and collection, which supported a lot to complete this study.

I wish to extend my sincere appreciation to Mr. Nirmal Das, owner of the trawler (Priya) for permitting me to carry out research work by providing his valuable time for the collection of the data, without which this work may be undone.

I would like to express my special thanks to Manojda, Swapanda, Nimaida, Prasunda, and Ganga Masi for their help during the entire study period.

I enunciate my deep sense of gratitude from the core of my heart to Brindaban, Soumendra, Nilamani, Joshita, Santanu, Tamal, Ismile da, for their timely help and co-operation during the study.

My sincere thanks also extend to my juniors Sanat, Nilotpal, Utsab, Tanmoy, Chandra, Mani, Bipul, Debkanta, Krishnakanta, and Samiran for their generous support.

I extend my indebtedness and heartiest thanks to my classmates Suman, Biplab, Satikanta, Mrinal, Satya, Amit, Kingshuk, Prafulla, Santa, Kallol, Krishnada, Shiurajda, Chamak, Rakesh da, Goutam, Jagannath, Papri, Veneeta, Joshita for their extreme co-operation rendered to me for time to time through out the period of study.

The professional printing of thesis by Chanchal da and binding by M/s Dhar Brothers is duly appreciated.

Lastly but not the least, I find no word to express my indebtedness to and owe to my beloved parents, my brother, my sisters for their most affectionate encouragement, moral support, selfless devotion, endurance, sacrifice, blessings and love without which it would not have been possible to achieve this goal.

Date: ...01.12.06.....

Place: ...chakaria.....

Bijan Kumar Biswas
.....

(Bijan Kumar Biswas)

Contents

Chapter no.	Particulars	Page No.
1	Introduction	1-4
2	Review of Literature	5-18
3	Materials and Methods	19-23
4	Results	24-32
5	Discussion	33-38
6	Summery	39-40
	References	i - ix

List of Tables

Sl. No.	Particulars	Page no.
1.	Pooled length –frequencies distribution for <i>Harpodon nehereus</i> collected from different gill-netter off Kakdwip	20
2.	Length-weight relationship of <i>Harpodon nehereus</i>	25
3.	Statistical; analysis to test deviation from cube law	26
4.	The mean relative condition factor (Kn) of <i>Harpodon nehereus</i> during different months	30
5.	Length group wise mean relative condition factor of <i>Harpodon nehereus</i>	31
6.	Value of growth parameters of Von-Bertalanffy growth model for <i>Harpodon nehereus</i> estimated from different length based methods	32
7.	Value of mortality parameters and exploitation level of <i>Harpodon nehereus</i>	32

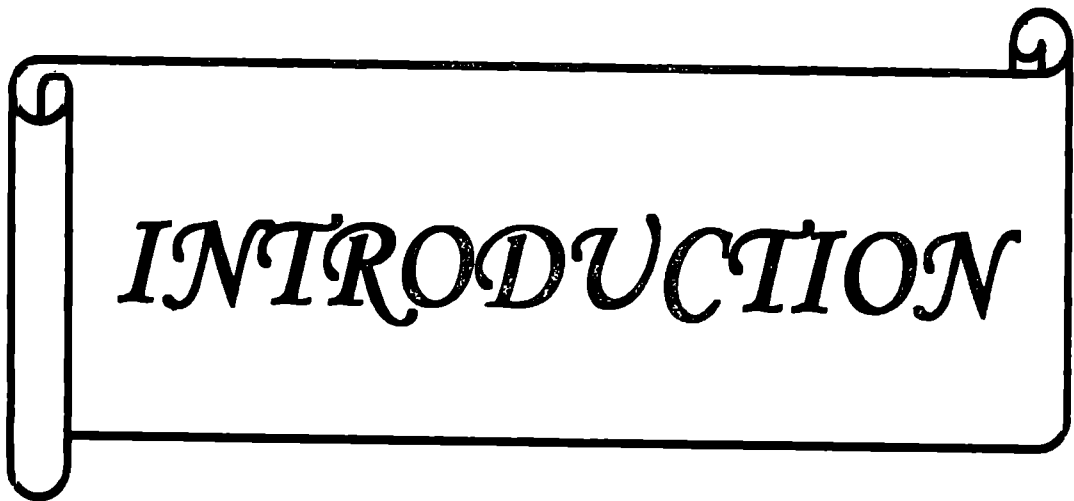
List of Figures

Sl. No.	Particulars.	Page no.
1.	Exponential (non-linear) form of total length-weight relationship of <i>Harpodon nehereus</i>	27
2.	Linear form of total length-weight relationship of <i>Harpodon nehereus</i>	27
3.	Exponential (non-linear) form of standard length-weight relationship of <i>Harpodon nehereus</i>	28
4.	Linear form of standard length-weight relationship of <i>Harpodon nehereus</i>	28
5.	Month wise fluctuation in mean relative condition factors (K _n) of <i>Harpodon nehereus</i>	30
6.	Total length group wise mean relative condition factor (K _n) of <i>Harpodon nehereus</i>	31

Abbreviations

a	Constant of length-weight relationship
b	Constant of length-weight relationship
E	Exploitation rate or level
ELEFAN	Electronic Length Frequency Analysis
F	Fishing mortality
FMSP	Fishery Management Science Programme
K	Curvature Parameters
K_n	Relative Condition Factor
LFDA	Length Frequency Data Analysis
LFSA	Length based Fish Stock Assessment
L	Length
L_∞	Asymptotic Length
M	Natural mortality
MSY	Maximum Sustainable Yield
ϕ'	Growth performance index
PROJMAT	Projection Matrix
R^2	Correlation Co-efficient
SLCA	Shepherd's Length Composition Analysis
SL	Standard Length
t_0	Age at zero length
TL	Total Length
VBGF	Von-Bartalanffy growth equation
W	Weight
Z	Total mortality

CHAPTER-1



INTRODUCTION

INTRODUCTION

Fish biodiversity of India is vast and varied. It comprises of about 2200 numbers of fish species in cold water, fresh water, brackish water and seawater. Each species bears ecological importance irrespective of its length, weight, growth rate and mortality rate. Hence, study of length weight relationship, growth parameters and mortality parameters of each species in different agro-ecological zones is needed. Temporal and spatial changes in environment influence all biological condition factors of the fishes. So, there is a need of study of periodical monitoring and estimation of relative condition factor of different fishes.

According to Sundararaj (1953) Bombay duck fish is distributed along the coasts like Zanzibar; from Gulf of Cambay to Ratnagiri on West Coast and from Madras to Chittagong on East coast of Indian sub continent; Arakkan coast of Irawady estuary in Burma; from penang to the straits of Malacca in Malayasia; coast of Singapore; coasts of Sumatra; Java and Borneo in Indonesia and coast of China, and caught rarely at the mouth of Indus, with extreme limits of distribution being 40°N to 10°S latitude and 40°E to 122°E longitude. Misra (1959) mentioned that Travancore of Cochin coasts and Malabar coasts among the places of its distribution in India. According to Rao (1969) Bombay duck forms a fishery on the east coast of Africa, Malaysia, Indonesia and China. Zafar Khan (1983) explained Bombay duck fishery is confined to three regions along the Gujarat namely; Siyal bet to Diu, Takkara to Madhwa and Umbergoan to Kavi. According to Lloyd (1907), Hornell (1916) and Moses (1922) gave most important information regarding its occurrence in Indian water body.

However, Bombay duck shows discontinuous distribution along the east and west coast of India. Hara (1934) suggested that three factors are responsible for this peculiar distribution of Bombay duck viz, (i) the distribution and movement of the favorite food organisms (ii) the variations in

salinity along the India coasts and (iii) the fluctuations of temperature in the surface sea water. He also suggested that distribution might be influenced due to the monsoon season. Chopra (1939) also observed that the wandering of the Bombay duck might be traced with the movements of its food items along the Indian coasts. Subsequent to the suggestions put forward by these authors considerable data on the biology of Bombay duck and the physical and chemical conditions of seawater along the coasts of India are available. Chopra (1939) also observed that the food of Bombay duck mainly consists of small non-penaeid shrimps and its migrations are traceable by the movement of shrimp shoals. Raj (1954) has made an attempt to correlate this peculiar distribution to the 80⁰F during July isotherm.

The fishery of Bombay duck is of considerable importance in the maritime state of Gujarat and Maharashtra, which together contributed nearly 92% of the total landing of this species in India. Hence the success of this fishery determines to large extent the well being of the fishery community in the Maharashtra and Gujarat state. The annual landing of Bombay duck does not show large fluctuation, especially after 1960. The increase in the catch was attributed to the increase in the fishing effort, which has been brought about by the mechanization of the indigenous fishing craft.

Bombay duck is one of the commercially important food fishes in the Hooghly estuarine system and ranks first in abundance in the commercial catches. Due to advent of mechanization of fishing crafts, the fishing activity off the West Bengal coast has considerably increased in recent years. Consequently the area of exploitation of fishery has increased and presently Bombay duck fishery is considered as a major fishery of West Bengal. The abundance of Bombay duck along the coast is gradually increasing.

Bombay duck fishery is under constant pressure due to various stresses like habitat destruction due to pollution, over-exploitation, indiscriminate killing of juveniles etc, which in turn helps for the shrinkage of this fish population. Hence, there is a great need to manage the fisheries more carefully

to ensure sustainable fish production in the future. In this regard fish Stock assessment plays an important role in the rational management and conservation of this fishery resource. Sparre and Venema (1992) proposed that the basic purpose of stock assessment is “to provide advice on the optimum exploitation aquatic living resources”. Probably the best modern definition comes from Hilborn and Walters (1992) “Stock assessment involves the use of various statistical and mathematical calculation to make quantitative predictions about the reactions of fish populations to alternative management choice”. However the main purpose of stock assessment in fishery of Bombay duck is maintained as follows.

- i) Quantitative predictions, dynamics and uncertainty.
- ii) The concept of MSY and its evaluation from an objective to a reference point.
- iii) Model complexity and the importance of cross-comparison in stock assessment.

The population Dynamics and stock assessment both help to know, how the fish grow, their mortality rate, spawning time, where they go at spawning time, how much fishermen catch the fish, how much money make of the fish, where maximum fishing is occurred, how fast the fish is grown etc. Ultimately main objective of stock assessment is to maintain the maximum sustainable yield of the fishes (Larkin, 1977). The mesh size regulation, close netting at the breeding season and quota system are the results of the stock assessment of the fishes. Stock assessment of tropical resources has developed rapidly in the last decade (Pauly, 1979; Pauly 1980; Saila and Roedel 1980; Pauly and David, 1981; Gracia and Le-Reste 1981 and Murno, 1983) due to rapid introduction of special software for fish stock assessment based on length frequency data. Presently the software package like ELEFAN (Gayanilo *et al.*, 1988) and LFSA (Sparre, 1987) are available for assessment of the fishes.

The present study was conducted with a title “**Population dynamics of *Harpodon nehereus* (Hamilton) from Esuarinet region of Kakdwip, West Bengal**” and with following objectives i.e. to find out the Length-Weight relationship, Relative condition factor, Growth parameters, Growth performance index, Mortality parameters and exploitation rate of *Harpodon nehereus*. Above parameters will help in formulating the Expansion programme of further research and the exploitation of *Harpodon nehereus* to estimate the value of its population dynamics, which is one of the major marine fishery resources of the State as well as of our country.

CHAPTER-2



*REVIEW
OF
LITERATURE*

REVIEW OF LITERATURE

The objectives of the Length-Weight relationship study of a fish have many applications in the field of fishery science. Since their outcome can successfully be applied in fishery biological know-how. The mathematical relation between the length and the weight has a worthy use in estimating the weight of fish of known length or vice versa. The condition factor of the relationship (LeCren, 1951) serves as a useful index for assessment of various important biological and nutritional cycles. The objectives of growth parameter & mortality parameter are generally help for management purpose of the fishes.

2.1 Length-Weight relationship

The Length – Weight relationship study of a fish is an essential aspect in fishery science and has gained gravity of attention only after the proclamation of cube law ($W=aL^3$). Allen (1938) stated that the weight of a fish equals to the cube of the length. It has been found by many workers (Brody, 1945; Roy, 1987) that Length – Weight relationship usually follows the **cube law**. However sometimes the growth pattern doesn't strictly agree with cube law. Deviation of hypothetical value from 3 has been reported by LeCren (1951) in *Perca fluviatilis*, Sorojini (1957) in *Mugil parsia*, Lal (1980) in *Schizothorax plagiostomus* and Lal & Mishra (1980) in *Schizothorax richardsonii*. According to Rickers (1958) stated that the deviation of hypothetical value from 3, it is either due to environmental factors (seasonal variation population dynamics, taxonomic differences etc.) or due to condition of the fishes (maturity, metamorphosis, spawning etc.). Fulton (1904) explained that inadequacy of cube law in finding the Length-Weight relationship or it can be also called the condition factor of many fishes. So, most of the scientist followed for the mathematical expression of Length – Weight relationship of fishes have followed the allometric law ($W = a L^b$). Beverton & Holt (1957) discussed the merit of both the allometric and **cube law**. Hensen (1899) in his observation found fluctuation of the constant 'a' value.

Ricker (1975) stated that in Length-Weight relationship, there was sometimes marked difference between the same population in different year or in different of life, presumably associated with their nutritional condition.

Therefore three important aspect of Length-Weight relationship are i) sex of the fish ii) furcal length of the fish and iii) the seasonal variation of fish were suggested (Phillip & Mathew, 1996; Jhingran, 1959; Roy, 1987; Narsimham, 1974; Kumari & Nair, 1978; Kumar & Lal, 1994; Pandey & Lal, 1994).

2.1.1. Length Weight relationship in other fishes

The length weight relationship of *cynoglossus macrostomus* at Calicut was represented as $W = 0.00003759 L^{2.6128}$ (Khan and Nandakumaran, 1993). At Mangalora the relationship is: $\text{Log } W = - 5.9242 + 3.3416 \text{ Log } L$; $r = 0.68$. Kutty and Qasim (1969) have observed that there is no marked difference in the growth rate of male and female *cynoglossus macrolepidotus* and that the length (in cm) relationship is $W = 0.001107 L^{3.4148}$. The length weight relationship of immature and mature *Upeneus tragula* arrived at by Thomas (1969) is $\text{Log } W = - 4.8776 + 2.9638 \text{ Log } L$ for the former and $\text{Log } W = - 5.3756 + 3.2015 \text{ Log } L$ for the latter.

The earliest study on the length-weight relationship of a carangid species from Indian waters was done by Tandon (1962) particularly on *Selaroides leptolepis*. He drew a common equation for both the sexes, as there was no significance difference between the sexes in their regressions. The studies on *Decapterus dayi* by Sreenivasan (1981) from Vizhinjan showed that the 'b' values of males and females did not vary significantly, but a pooled value (2.9886) for both the sexes was significantly different from that of the indeterminate (3.1691). The estimate by Murty (1991) was slightly higher (3.4076) compared to the observations of Sreenivasan (1981) and Reuben et al (1992). The 'b' values of length-weight regression of *Megalaspis cordyla* obtained for different regions by Reuben et al (1992) and by Sivakami (1995) for Cochin were found to be less than 3. In *Atropus atropus* the 'b' value

calculated by Reuben *et al.* (1992) for the northwest coast (2.8570) was slightly higher than that observed by Raje (1994) from Veraval region (2.6133). In *Caranx carangus* the studies by Reuben *et al.* (1992) and Kasim and Hamsa (1994) showed that the estimates of 'b' was almost identical and was less than 3. The length-weight relationship of *Alepes kalla* and *Atule mate* studied by Reuben *et al.* (1992) and the 'b' values estimated were 3.2443 and 3.0569 respectively. In all these studies significant difference in the 'b' values between sexes were not reported, but Sreenivasan (1981) observed that indeterminate and adults of *Decapterus dayi* differed significantly at Vizhingam.

The Length-Weight relationship of *Scomberomorus commerson* of the Gulf of Mannar and Palk Bay was studied by Silas (1962) Devaraj (1981), Kasim and Hamsa (1989), Pillai (1994) also worked out the Length-Weight relationship equations of this species from southwest coast of India. The only study made on the Length-Weight relationship of the other two species, *Scomberomorus guttatus* and *Scomberomorus lineolatus* was Devaraj (1981) from the above area. The relationship between the total length and standard length of the spotted seer (*Scomberomorus guttatus*) of the Rameswaram coast was studied by Krishnamoorthi (1958) as $\log Y = -0.0665 + 0.9771 \log X$ where Y and X are the total and standard lengths respectively.

The deviation of 'b' value has been noticed by Sultan (1981), Hoda (1987), and Sivakumar (1987) in *Mystus vittatus*, *Betepthalmus spp.* and *Ompok bimaculatus*. The seasonal changes notably in the post-spawning period affect the Length - Weight relationship. Total weight of fish may also be altered by the weight of the stomach content depending on the food ingested just before weighing (Muth & Smith, 1974).

Willams (1962) studied the Length - Weight relationship of seer fish, *Scomberomorus commerson* (Lecepede) from African waters. The relationship were $\log W = 3.125 \log L - 4.9590$ for male, $\log W = 2.978 \log L - 4.6860$ for female and $\log W = 3.0454 \log L - 4.8286$ for combined of the species.

Khulkhed (1967) studied the oil sardine, *Sardinella longiceps* (Val.) along the Mangalore coast. The equation were $W = - 6.3420 + 3.2665 \log L$ for female and $W = - 6.7010 + 3.1086 \log L$ for male.

Eggleston (1970) found a difference in the form of Length – Weight relationship between males & females of *Nemipterus virgatus* particularly when classified according to its length & spawning season, from the Northern part of the East China Sea. Krishnamoorthi (1971) found significant difference between male and female Length-Weight relationship for *Nemipterus japonicus* along Andhra-Orissa coast.

Narasimhim (1970) worked on the ribbonfish, *Trichiurus lepturus* (Linnaeus) in relation to their sex and reported the value of 'b' was more than 3 in both for male & female. The corresponding equation were $\log W = - 3.9552 + 3.4367 \log L$ for female and $\log W = - 3.9468 + 3.04169 \log L$ for male. Thus the grow at a higher rate than the cube of their length.

Mojumder (1971) could not find any difference between the relationship in male and female of the cat fish, *Trachysurus thalassinus* (Rupell) and hence used the common equation $W = a L^b$. Reuben *et al.* (1997) observed that the value of 'b' was above 3 for *Trichiurus lepturus*. The corresponding equation were $W = 0.000273 L^{3.298627}$ ($r = 0.9961$) for male and $W = .000223 L^{3.298627}$ ($r = 0.9950$) for female. These fishes found to be voracious carnivore and often exhibiting cannibalism.

Kagwade (1971) studied the Length-Weight relationship of *Polydactylus heptadactylus* and expressed that, $W = 0.00001089 L^{3.0832}$ for males and $W = 0.00001147 L^{3.0745}$ for females.

Rangaswamy (1976) studied the Length – Weight relationship of gray mullet from the Ennore & Adyar estuaries and examined through analysis of covariance to find out whether the regression differ between years and environment. The analysis indicated that the relationship did not differ significantly between years and environment. Hence a single regression ($\log W = -4.4981 + 2.7788 \log L$) may be used for conversion in catch statistics from

those estuarine. The regression coefficient was found to depart significantly from the cube value.

Grover & Juliano (1976) studied the Length – Weight relationship of the Milkfish in Philippines in a culture pond. The overall relationship were $\log W = - 5.0463 + 2.98895 \log L$.

In case of Lizardfishes, *Saurida tumbil* (Bloch) the corresponding relationship were established as $W = 0.000004363 L^{3.1989}$ for female and $W = 0.000005563 L^{3.1496}$ for male (Dighe, 1977).

Fawzy et al. (1987) described the relationship between the weight and the length of *Upeneus sulphureus*, which followed logarithmic equation ($\log W = - 4.385 + 2.90 \log L$) close to the cubic law ($n=2.89$) indicating the isometric growth of the fish in its natural habitat.

Al-Absy (1987) studied the Length – Weight relationship of the goatfish, *Mulloides flavolileatus* (Lacepede) from the Gulf of Aquaba and Red sea and represented as $W = 8.6040 * 10^{-3} * L^{3.0396}$.

Kumar and Lal (1994) had studied Length - Weight relationship in *Nemacheilus multifasciatus* in relation to their sex, place, season and year; and reported that the value of 'b' ranged between 1.814 and 3.659. However, Allen (1938) suggested that it would be '3' if a fish maintain the same shape throughout its life. The deviation of the 'b' values from 3 has been attributed to seasonal variations (LeCren, 1951) or change in body shape.

Abdul Hameed (1994) studied the Length - Weight relationship of Threadfin Bean (*Nemipterus bipunctatus*) where the length range from 9 to 25 cm and weight ranged from 22 to 350 gm in the Gulf of Mannar at the latitude $8^{\circ}48' N$ long $78^{\circ} 9' E$ of India. Rao and Rao (1972) studied the Length-Weight relationship in sexually unidentified *Labeo calbasu* with length range of 100-630 mm and weight range of 10-3712 gm from river Godavari. They observed a **curvilinear** relationship between these variables. Length-Weight ratio of 3 months old scale carp fingerlings from the sodic soil ponds at Faizabad area

was reported (Pandey and Sharma, 1995). The pooled regression equation that was worked out for the fingerling however does not follow the cubic law.

Philip & Mathew (1996) studied the length – weight relationship of *Priacanthus hamrur* (Forsskal) was estimated of Visakhapatnam fishing Harbour and given by the equation males $W = 0.000 L^{3.1133}$ & female $W = 0.00000811 L^{3.685}$. The ‘b’ value showed significant difference between males & females.

Mandal *et al* (1998) studied the Length-Weight relationship of *Polynemus paradiseus*. The relationship between total length and weight based on a sample of 198 observations was determined as $W = 0.004127 L^{3.120}$ ($r = 0.99$). The exponent value ($b = 3.120$) was tested statistically and did not differ significantly from ‘3’ indicating isometric growth i.e. the growth follows the cube law.

Volvich and Appelbaum (2001) determined the Length – Weight relationship of Sea Bass, *Lates calcerifer* (Bloch) reared for two years in a laboratory in a indoor circulating system, was determine as follows; $W = 0.0107 L^{3.0347}$, $r^2 = 0.9974$. The value found in this study correspond to Length – Weight relationship found for a natural population by other researches, indicating that sea bass cultivated in captivity under intensive conditions and at high stocking densities do not seen to differ in body appearance from those in nature.

Khan *et al.* (2001) studied the Length – Weight relationship of *Hilsa ilisha* which was $\log W = - 5.14433 + 3.076423 \log L$.

Doddamani *et al.* (2001) studied the Length-Weight relationship of *Stolephorus bataviensis* and revealed that the weight of fish increases at a rate lower than the cube of length. The values of ‘b’ were found to be 1.80955 in males, while it was 2.63931 in females.

Sandhya *et al.* (2003) analyzed the Length- Weight relationship of *Liza macrolepis* (Smith) from polluted and unpolluted waters of Visakhapatnam.

The result of the study indicated a high regression co-efficient value (b) for mullets from unpolluted waters as compared to those from polluted waters. The regression equations were $\text{Log (W)} = - 17.551 + 3.6811 \text{ Log L}$ ($r = 0.7804$), $\text{Log (W)} = - 5.8171 + 2.0656 \text{ Log L}$ ($r = 0.80609$) respectively. This study indicates that the growth and condition of the fish is affected by prevailing environmental conditions of the polluted waters. In the fish from the polluted waters 'b' value was much less than three indicating slender and lengthy bodies with poor growth and without much corresponding increase in the weight

The Length – Weight relationship of *Stolephorus devisi* (Whitley) and *Stolephorus bataviesis* (Hardenberg) did not differ significantly between sexes and combined equation is given by $W = 0.00003445 L^{2.6142}$ and $W = 0.00001963 L^{2.8324}$ respectively (Rai et al. 2004)

Das (2004) studied Length-Weight relationship in *Liza tade* and reported that the correlation between log values of length and weight was significant ($p < 0.01$). It was also found that 'b' value significantly ($p < 0.05$) deviate from isometric value of '3'. It indicated negative allometric growth pattern in the fish.

Saker et al. (2004) studied the Length - Weight relationship of *Megalaspis cardyla* from Mumbai coast. The result of study obtained for the two sexes separately and combined with indeterminate. The analysis of covariance showed no significant difference in the length weight relationship of male and female of *Megalaspis cardyla*.

Nath et al. (2004) studied the Length-Weight relationship of *Eleutheronema tetradactylum* from the Hooghly-Matlah estuarine system. The recorded 'a' and 'b' values were 0.003257 and 3.2138 respectively.

Rao et al. (2005) studied the Length - Weight relationship of *Liza parsia* in relation to industrial pollution and revealed that the weight increases as the cube of the length. Statistical analysis revealed that the length weight relationship of the fish when compared between the polluted Harbour and coastal waters, with unpolluted Gosthani estuary differed significantly. The co-

relation coefficient between log length and log weight relationship was 0.51 at polluted water and 0.66 at unpolluted station.

Kurup and Venu (2006) studied the Length – Weight relationship of *Priacanthus humrur* (Forsskal) along the West coast of India and represented the equation as for female $W = 0.0097 L^{3.01}$ and males $W = 0.025 L^{2.73}$. While comparing the 'b' it was understood that there is not significant difference among them.

2.1.2 Length-Weight relationship in Bombay duck

Bapat *et al.* (1951) studied on the Length - Weight relationship of *Harpodon nehereus* along the Bombay coastal area and the relationship was represented mathematically as $\log W = - 6.1448 + 3.2657 \log L$.

Krishnayya (1968) studied the length –weight relationship of Bombay duck, *Harpodon nehereus* from Hooghly-Matlah estuarine system in West Bengal, which was $\log W = - 6.1448 + 3.2657 \log L$.

Bapat (1970) studied the Length – Weight relationship of Bombay duck, *Harpodon nehereus* in different between the relationship in males and females. The corresponding linear equations were $W = 0.0000009795 L^{3.769}$ for male and $W = 0.0000002268 L^{3.444}$ for female.

Zafar khan (1989) studied the Length – Weight relationship of the *Harpodon nehereus* from the Saurashtra coast. The relationship was estimated for male $\log W = - 5.878 + 3.1446 \log L$ & for the female $\log W = - 5.7138 + 3.194 \log L$.

Kurian (1992) worked on the Length – Weight relationship different age group of the Bombay duck, *Harpodon nehereus* along the Maharashtra coast of India. He established the relationship for 0 – 1 year age group; $W = - 1.4094L^{1.1785}$, 1 – 2 year age group; $W = - 8.5429 L^{4.3531}$ and 2 – 3 year age group; $W = - 5.1214 L^{2.9561}$.

Nurul Amin (2001) also studied on the Length – Weight relationship of the *Harpodon nehereus* from the Kutubdia channel of Bangladesh. The

estimated relationship is $\log W = - 2.5967 + 3.051 \log L$ and the co-efficient of correlation (r) is 0.997.

2.2 Relative condition factor

LeCren (1951) stated that the value of Relative condition factor (K_n) being more than one indicate good health of the fish and less than one opposite. Lecren (1951) in his work on perch, *Perch fluviatilis* indicated that 'Kn' was a function of fatness and condition of gonads. He also pointed that the condition factor (K) was affected by length, food supply degree of parasitism etc. Thus making the correlation and interpretation of these results sometime difficult. To solve the problem regarding condition factor, he suggested that the use of Relative condition factor (K_n) ($K_n = W / \hat{W}$, where W = observed weight and \hat{W} = calculated mean weight) depends upon the stage, maturity of gonads & length of fish.

2.2.1 Relative Condition Factor in Other Fishes

Sorojini (1957) worked on *Mugil parsia* & Bhatt (1970) worked on *Mystus seenghala* and calculated that an increasing curve of 'Kn' value with increasing length was a good indicator at the length of which sexual maturity start.

Grover & Juliono (1976) studied the 'Kn' value of milkfish, where it showed high value during bigger size of fishes & low value during small size of fishes.

Kumar & Lal (1994) found that K_n value for male & female *Nemacheilus multifasciatus* (Day) was highest in the month of June and July, which coincides, with the spawning season of the fish. So, they concluded that the K_n value is only influenced by gonad weight & not of the visceral weight.

The seasonal changes taking place in K_n value mainly indicate that in *Priacanthus humrur* (Forsskal) it is greatly influenced by feeding intensity rather than the cyclic changes taking place in the gonads (Philip and Methew, 1996)

Goswami *et al.* (1996) reported the Kn values exhibit seasonal variation in close association with the Gonadal development and feeding intensity of the fish. Fluctuation in Kn value in relation to various size, length and months are observed in both sexes. The male fishes depict a comparatively better relative condition than females as indicated by Kn values during spawning period (May to August), which is attributed to lesser Gonadal mass in them. However females showed more or less a higher Kn values during pre spawning and post spawning periods.

Reuben *et al.* (1997) studied the Kn value of *Trichiurus lepturus*, where the female showed high value during May to November and low value during January to April & July to October.

Khan *et al.* (2001) working on the *Hilsa ilisha*, calculated the average Kn value as 1.0091. Then they divided the fish in different size groups (260 – 479 mm.). They concluded that the best condition of 1.137 was observed in the fishes in size range of 400mm. to 419mm. While for other groups, it fluctuated in a very narrow range (0.912 – 1.006). De (1980) worked on the same species and he observed that the highest value of 'Kn' being showed a steady increase from July onwards reaching maximum in November and thereafter registered a sudden falls. Piska *et al.* (1991) found the Kn value of silver fish, *Salmostoma phulo* (Ham.) increased gradually from April to July and thereafter decreased to reach the minimum during October.

Cakic *et al.* (2002) reported that there is no difference in the relative condition factor observed in the small pipefish specimens from river Donube and the black and Azov seas.

Sandhya *et al.* (2003) studied on the condition factor of *Liza macrolepis*, which revealed that the growth and condition of the fish is affected by the prevailing environmental conditions of the polluted waters. They found the higher mean Kn values in the fishes of unpolluted waters than of polluted waters. The condition factor of fishes indicate that it can be influenced by a number of factors such as the onset of maturity (Hoda, 1987), Spawning (De

Silva and Silva, 1979; Al - Daham and Wahab, 1991) environmental condition, breeding season, feeding (Dhanze and Dhanze, 1997), sex and maturity (Gowda *et al.* 1987, Doddamani, 2001) and pollution (Bakhoum, 1999).

Rai *et al.* (2004) reported that the low variation in relative condition factor of *Stolephorus devisi* during March, April and November indicated spawning activity. In *Stolephorus bataviensis*, low Kn values were recorded during January to March and October. Size dependent low Kn values at 61-65 mm in *Stolephorus devisi* and 71-75 mm in *Stolephorus bataviensis* indicated the size at first maturity. With sexual maturity a marked increase in relative condition of both males and females have been observe by Pantulu (1961) in *Mystus gulio* (Ham).

Rao *et al.* (2005) studied the condition factor of *Liza parsia* in relation to industrial pollution. The condition factor of the fish was less from station-I (polluted water) compared to fish from station-II (unpolluted water) and was significantly different. It is inferred that the industrial effluents containing heavy metals discharged at station-I, have a negative bearing on the growth rate of *Liza parsia*.

2.2.2 Relative Condition Factor in Bombay duck

Krishnayya (1968) worked on the relative condition factor of *Harpodon nehereus* (Hamilton) from Hooghly-Matlah estuary system in West Bengal. He stated that the high Kn value (2.57324) in October month and low Kn value (1.66173) in May month.

Nurul Amin (2001) studied on the Relative Condition factors (kn) of Bombay duck, *Harpodon nehereus* (Hamilton) along the Kutubdia canal of Bangladesh. The calculated Kn value ranged from 0.908 to 1.22. He also suggested that Kn values changed during various month; height peaks denoting the spawning periods that is March to June & September to November.

2.3 Growth parameters

The study of growth means basically the determination of the body size as a function of age (Sparre et al. 1989). Therefore all stock assessment methods work essentially with age composition data. In temperate water such data can usually be obtained through the growth rings in the hard parts, such as scales and otoliths.

In the tropical areas such drastic changes do not occur. So it is impossible to use this type of ring for age estimation. Fortunately several methods have been developed to convert length frequency data to age composition. The theory behind various growth models was reviewed (Beverton and Holt, 1957; Ursin, 1968; Ricker, 1975; Gulland, 1983; Pauly, 1984; and Pauly & Morgan, 1987) and observed that the Von – Bertalanffy growth equation is most commonly used for estimate of growth parameters.

2.3.1 Growth Parameters in Bombay duck

Krishnayya (1968) studied on the growth parameters of Bombay duck, *Harpodon nehereus* from the Hooghly – Matlah estuarine system in West Bengal. He calculated the value was asymptotic length (L_{α}) 730 mm, catabolic co-efficient (K) 0.17616 per year and age at zero length (t_0) 0.0805 year.

Zafar Khan (1985) worked on the growth parameters of the Bombay duck, *Harpodon nehereus* along the Saurashtra coast was calculated as $L_{\alpha} = 367$ mm, $K = 0.0634$ per year, and $t_0 = 0.28$ year and value $L_{\alpha} = 425.2$ mm, $K = 0.7618$ / year, and $t_0 = 0.00789$ year (Zafar Khan, 1989).

Fernandez & Devaraj (1996) studied on the growth parameters of *Harpodon nehereus* stock along the North West coast of India at different years. The growth parameters L_{α} ranged from 60.97 cm (1958) to 37.45 cm (1985), K ranged from 0.29 per year (1958) to 0.6 per year (1985), $t_0 = 0.12$ year (1948) to 0.06 year (1985) and while the weight growth parameters asymptotic weight (W_{α}) ranged from 319.14 gm (1948) to 1910.65 gm (1950).

Mustafa *et al.* (1998) studied the growth parameters and growth performance index ($\bar{\phi}$) of *Harpodon nehereus* from the Kutubdia channel of Bangladesh and calculated the value $L_{\infty} = 244.5$ mm, $K = 1.50$ per year, $t_0 = 0$ year and $\bar{\phi} = 2.953$.

Nurul Amin (2001) also describe same result of the growth parameters of Bombay duck, *Harpodon nehereus* along the Kutubdia channel of Bangladesh and calculated the value $W_{\infty} = 43.69$, $L_{\infty} = 244.8$ mm, $K = 1.50$ per year.

Mustafa *et al.* (1994) reported that the $L_{\infty} = 29$ cm. and $K = 0.9$ per year for *Harpodon nehereus* from the Kumira estuary. Islam (1995) also reported that the $L_{\infty} = 30$ cm of the *Harpodon nehereus* in the Karnafully estuary of Bangladesh.

2.4 Mortality parameters

Fish mortality can be defined as the rate at which individuals are being removed from the fishery. This mortality can be classified as natural mortality and fishing mortality. When the mortality occurs due to natural cases, such as stress, predation, old age and disease is called natural mortality. The mortality occurs due to fishing is called fishing mortality.

The relationship of total mortality (Z) with natural mortality (M) and fishing mortality (F) is express as $Z = M + F$. To estimate of the mortality parameters of fish various types of models are used (Beverton & Holt, 1956; Chapman & Robson, 1960; Robson & Chapman, 1961 and Ricker, 1975).

2.4.1 Mortality Parameters in Bombay duck

Zafar Khan (1986) estimated total mortality co-efficient (Z) of Bombay duck, *Harpodon nehereus* at Nawabunder varied between 2.443 / year and 2.939 per year of the periods 1976 – 1979. The natural mortality co efficient (M) vary from 1.575 - 1.462 per year and the exploitation level (E) is 0.422.

Zafar Khan (1989) worked on the mortality parameters of the Bombay duck *Harpodon nehereus* (Hamilton) along the Saurashtra coast and estimate

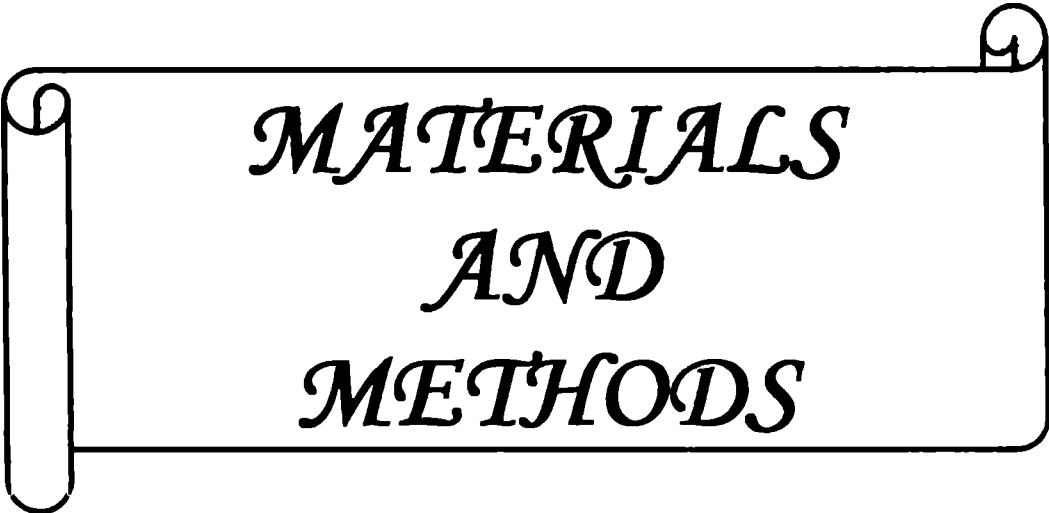
the total mortality co-efficient (Z) varied between 2.331 and 3.168 during the periods 1979 – 1984 and the natural mortality co efficient (M) was calculated as 1.572 per year by the help of Cushing's model (1968).

Kurian (1992) worked on the mortality parameters and exploitation level of the Bombay duck *Harpodon nehereus* along the Maharashtra coast of India during the period of 1986 to 1996. The total mortality ranged from 1.38 - 0.88 per year, natural mortality co efficient (M) ranged from 0.59 - 0.33 per year, fishing mortality co efficient (F) ranged from 0.82 - 0.32 per year and exploitation level (E) ranged from 0.28 – 0.54.

Fernandez & Devaraj (1996) studied on the motality parameters *Harpodon nehereus* stock along the North West coast of India during the period between 1947 and 1986. The annual total mortality co-efficient (Z) ranged from 3.32 - 8.29 per year, natural mortality co-efficient (M) ranged from 0.93 - 0.32 per year, fishing mortality co-efficient (F) ranged from 1.32 - 2.70 per year and average exploitation level (E) was 0.6.

Mustafa (1998) studied on the motality parameters and exploitation level of *Harpodon nehereus* (Hamilton) stock along the Kutubdia channel of Bangladesh. He also calculated of the values of M, F, Z and E were to be 2.46 per year, 3.27 per year, 5.73 per year and 0.5, respectively.

CHAPTER-3



*MATERIALS
AND
METHODS*

MATERIALS AND METHODS

3.1 Collection of data

Length-frequency data of *Harpodon nehereus* were collected at regular intervals from Nagendra Bazar Fish Market, Diamond Harbour, South 24 Parganas, West Bengal, India, which are brought from the commercial catches of gill netters (locally known as behundi) off Kakdwip, South 24 Parganas, West Bengal, India from January 2006 to August 2006. The total length (from the tip of the snout to the tip of the caudal fin) and standard length (from the tip of the snout to the mid point of caudal peduncle) of 550 fish were measured using a meter scale ($1\pm\text{mm}$) and weighed to the nearest 'g' using a mono pan balance. Total length and standard length varied in the size range of 7.3 cm to 32.1 cm and 6.0 cm to 26.9 cm, respectively, and the weight ranged from 2 g to 250 g. The data collected from different gill-netters were pooled and subsequently grouped into classes of three (3) centimeter intervals of total length (Table 1).

3.2 Analysis of data

3.2.1 Length-weight relationship

The length-weight relationship of *Harpodon nehereus* was estimated using the formula $W = a L^b$ (LeCren, 1951) where, W = total weight (g) of the fish, L = total length (cm) or standard length (cm) of fish and 'a' and 'b' are the constants or this equation can be linearly represented as $\text{Log } W = \text{Log } a + b \text{ Log } L$. The constants $\text{Log } 'a'$ and 'b' in the above equation were estimated using the methods of least square. The non-linear and linear equations were fitted separately for total length (TL) and standard length (SL). The co-efficient of determination (R^2) and standard error of 'b' (S_b) were calculated following standard statistical procedures. Analysis of co-variance was employed to test whether the 'b' values of two equations significantly differed at 5 % level (Snedecor and Cochran, 1967). The 't' test was used (by dividing the

Table 1. Pooled length- frequency distributions for *Harpodon nehereus* collected from different gill-netters off kakkwip.

Length intervals (cm)	Frequency													
	0.0547	0.1178	0.1560	0.2465	0.2712	0.3479	0.3726	0.4630	0.4849	0.5205	0.5589	0.5972	0.6356	
6-9	0	0	0	0	3	0	0	1	0	1	0	0	1	
9-12	0	0	0	0	3	0	0	0	2	1	0	0	0	
12-15	0	0	1	0	2	0	0	0	0	3	0	0	0	
15-18	7	0	0	1	21	0	0	1	4	3	2	2	3	
18-21	7	0	4	15	38	6	5	12	13	8	9	11	10	
21-24	23	0	2	6	11	40	38	13	7	10	12	10	12	
24-27	25	8	9	0	0	21	9	18	7	6	9	3	7	
27-30	2	6	11	0	0	0	1	6	1	3	1	7	2	
30-33	0	0	1	0	0	0	0	0	0	1	1	1	0	

differences between 'b' and '3' by standard error of 'b') to test whether the regression co-efficient significantly deviated from the expected cubic value (Snedecor and Cochran, 1967).

3.2.2 Relative condition factor (Kn)

The relative condition factor (Kn) of *Harpodon nehereus* was calculated using the formula $Kn = W/\hat{W}$ (LeCren, 1951) based on Total – Weight relationship, where Kn= relative condition factor; W= observed body weight; \hat{W} = calculated body weight. The monthly fluctuations of mean relative condition factor and variations of mean relative condition factor amongst length groups were also calculated.

3.2.3 Growth parameters of the Von-bertalanffy growth curve and growth performance index

The total length frequency distributions of *Harpodon nehereus* were analyzed using the Length Frequency Distribution Analysis (LFDA) Version 5.0, a PC-based computer package (Kirkwood *et al.* 2001) developed under (FMSP) for estimating growth parameters of the non-seasonal version of the Von-Bertalanffy growth curve. Two methods were used for estimating growth parameters namely Shepherd's Length Composition Analysis (SLCA) method (Shepherd, 1987) and the projection matrix (PROJMAT) method (Basson et al, 1988).

The Von-Bertalanffy growth parameters of *Harpodon nehereus* were used to fit the growth model as $L_t = L_\infty [1 - e^{-K(t-t_0)}]$ where, L_t = length of the fish at 't' age; e= exponential; L_∞ = Asymptotic length; K = curvature parameter or growth co-efficient; t_0 = initial condition factor or age at zero length.

3.2.3.1 Growth performance index (Φ')

Growth performance index (Φ') for *Harpodon nehereus* population in terms of length growth was computed using the index of Pauly and Munro (1984). i.e. $\Phi' = \text{Log}_{10}K + 2 \text{Log}_{10}L_\infty$, where, K = curvature parameter or

growth co-efficient; L_{∞} = asymptotic length. The growth performance index (Φ') was calculated separately by using the growth parameters obtained from PROJMAT and SLCA methods.

3.2.4. Mortality rates and exploitation level

3.2.4.1. Instantaneous rate of total mortality (z)

The instantaneous rate of total mortality (Z) of *Harpodon nehereus* was calculated using the Beverton and Holt formula (Beverton and Holt, 1956) as given below from the growth parameters obtained by SLCA method.

$$Z = K \left[\frac{L_{\infty} - \bar{L}_c}{\bar{L}_c - L_c} \right]$$

Where,

Z = total mortality co-efficient; L_{∞} = asymptotic length; \bar{L}_c = mean length of the fish longer than L_c (here it is 24.33 cm); L_c = the length at which fish are first fully recruited (here it is 20.00 cm) and K = catabolic growth co-efficient.

3.2.4.2 Instantaneous rate of natural mortality (M)

The instantaneous rate of natural mortality (M) of *Harpodon nehereus* was calculated using the Alagaraja method (Alagaraja, 1984) by using the curvature parameter (K) obtained from SLCA method and the longevity (t_{\max}) as per the following formula,

$$M = - \ln 0.01 / t_{\max} \quad \text{and} \quad t_{\max} = 3/K$$

Where, M = natural mortality; K = catabolic growth co-efficient; t_{\max} = longevity in terms of years.

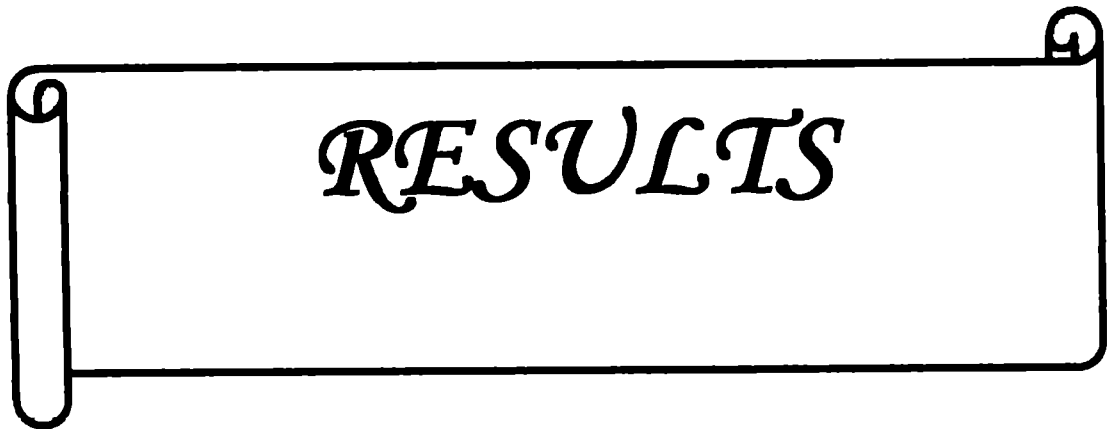
3.2.4.3 Instantaneous rate of fishing mortality (F)

The instantaneous rate of fishing mortality (F) of *Harpodon nehereus* was calculated by subtracting the instantaneous rate of natural mortality (M) from the instantaneous rate of total mortality (Z). i.e. $F = Z - M$.

3.2.4.4. Exploitation level

The exploitation level (E) is the ratio of instantaneous rate of fishing mortality co-efficient (F) to instantaneous rate of total mortality co-efficient (Z) (Gulland, 1971). The exploitation level of *Harpodon nehereus* was calculated by using the formula $E = F / Z$ where, E = exploitation level; F = instantaneous rate of fishing mortality co-efficient; Z = instantaneous rate of total mortality.

CHAPTER -4



RESULTS

4.1. Length weight relationship of *Harpodon nehereus*

The summary of total length-weight and the standard length-weight relationships of *Harpodon nehereus* based on 550 individuals ranging from the total length of 7.3 cm to 32.1 cm, standard length of 6.0 cm to 26.9 cm and weighing from 2 g to 250 g were given in the Tables 2. The log transformation of linear regression of total length-weight relationship of *Harpodon nehereus* and its corresponding exponential form are represented in Figs 1 and 2. The log transformation of linear regression and its corresponding exponential form of standard length-weight relationship of *Harpodon nehereus* are depicted in Figs 3 and 4. The total length - weight relationship of non-linear and linear forms were $W=0.0000004 TL^{3.4262}$ and $\ln W = - 14.636 + 3.4262 \ln TL$, respectively with the correlation co-efficient (R^2) of 0.9301. The standard length weight relationship of non-linear and linear forms were found to be $W=0.000001 SL^{3.3408}$ ($R^2=0.9204$) and $\ln W = - 13.529 + 3.3408 \ln SL$, respectively.

The analysis of co-variance between the 'b' values estimated for total length-weight and standard length-weight were in significant (Table 3). It was also revealed from the 't' test that the exponent 'b' values for both the forms were significantly different from hypothetical cube value 3 (Table 3) ($P > 0.05$; $t=10.6363$ for TL and $t= 8.1007$ for SL).

4.2. Relative condition factor (Kn) of *Harpodon nehereus*

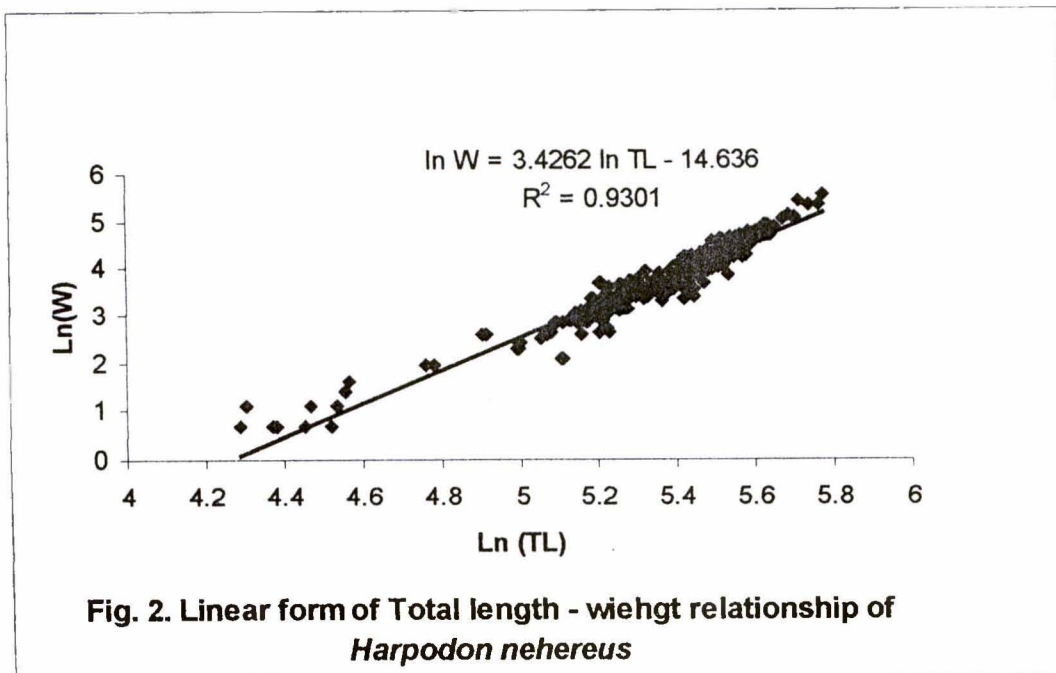
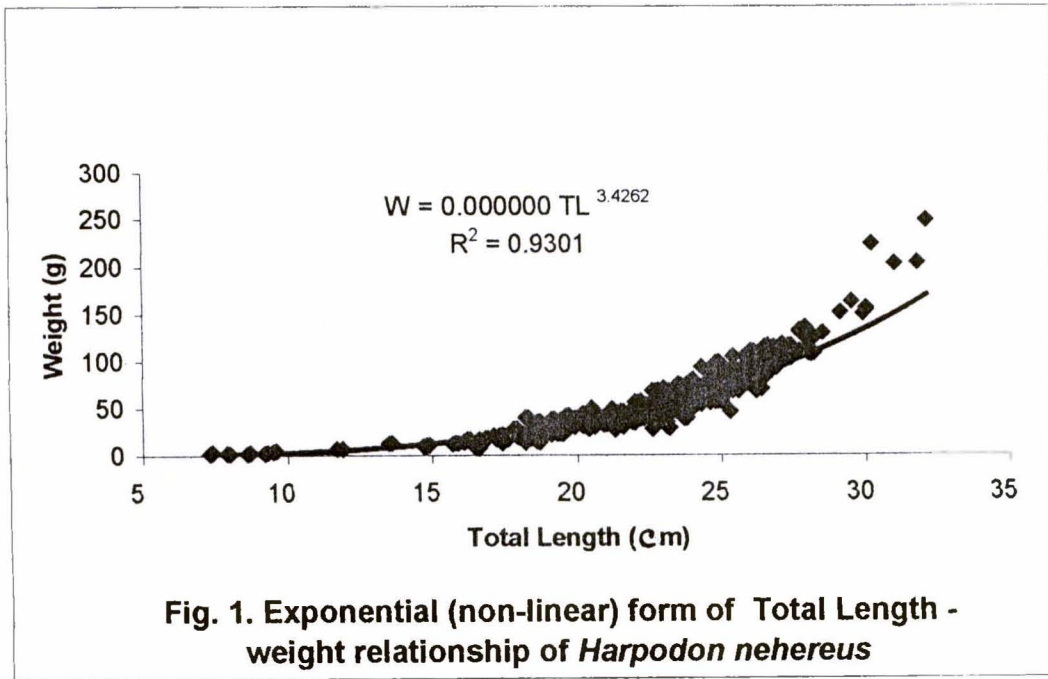
The mean relative condition factor (Kn) of *Harpodon nehereus* during different month is represented in Table 4 and fig 5. The mean Kn value of *Harpodon nehereus* calculated during January to August months was found to be 1.1196. The monthly fluctuation of the relative condition factor (Kn) showed the lowest condition (1.2202) in the month of April and the highest of condition (1.5537) in the month of February.

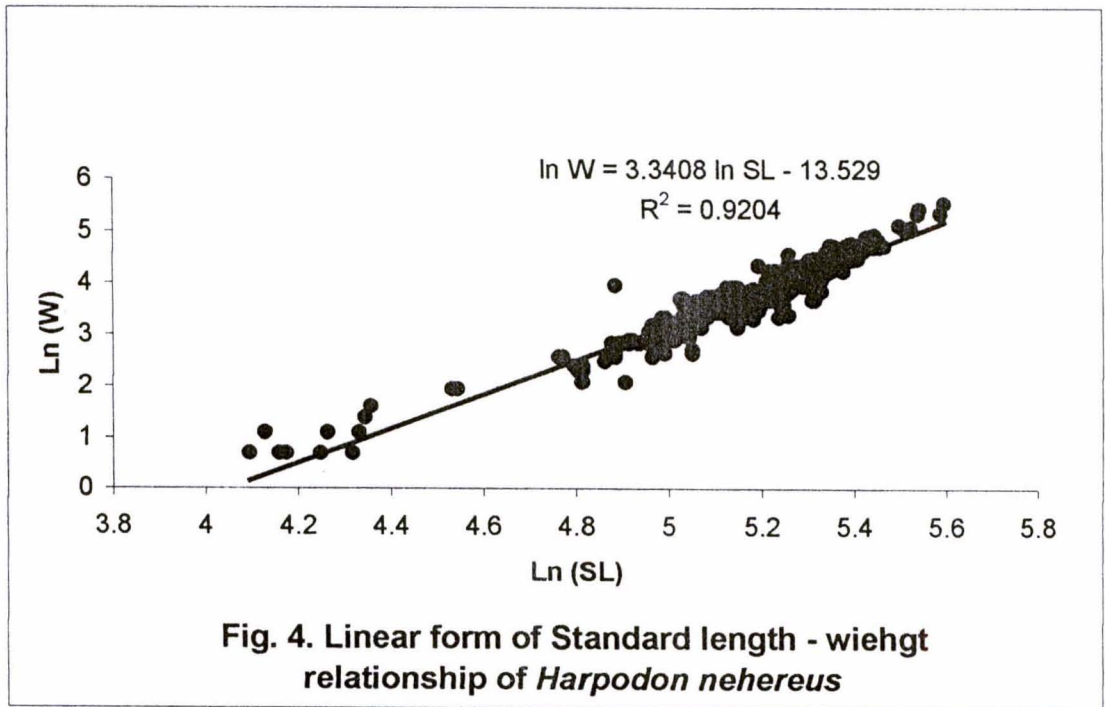
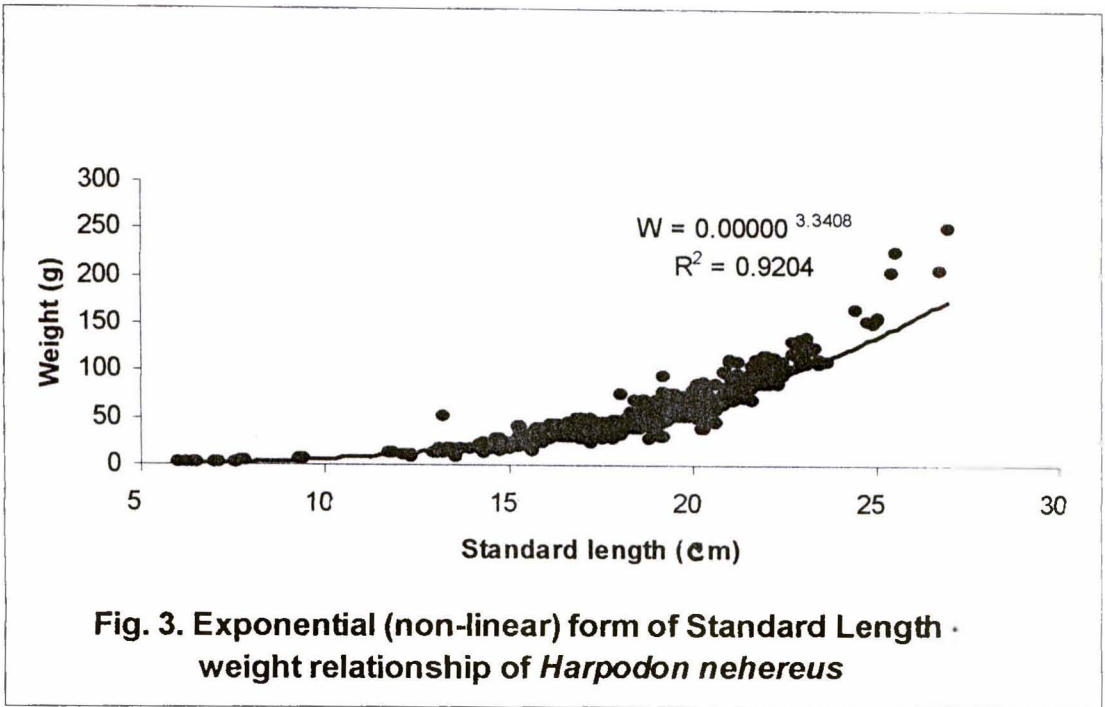
Table 2 : Length weight relationship of *Harpodon nehereus*

Length type	No. of individuals studied	Range of Length (cm)	Range of Weight (g)	Sex	Regression coefficient (b)	Exponential / non-linear form of equation	Linear / logarithmic equation	Correlation determination co-efficient (R ²)
Total length	550	7.3 -32.1	2- 250	Unsexed	3.4262	W=0.0000004 T.L ^{3.4262}	ln W= - 14.636+3.4262 ln TL	0.9301
Standard Length	550	6.0 -26.9	2 -250	Unsexed	3.3408	W=0.000001S.L ^{3.3408}	ln W= - 13.529+3.3408 ln SL	0.9204

Table 3. Statistical analysis to test deviation from cube law

Length type	Degrees of Freedom (n-2)	Regression coefficient (b)	Deviation from regression (S^2)	Standard deviation (S_b^2)	Standard error (S_b)	t	Probability at 5% level of significance
Total length	550	3.4262	0.035	0.001606	0.04007	10.6363	Significant
Standard length	550	3.3408	0.04016	0.00176	0.04207	8.1007	Significant





The mean relative condition factor (Kn) of *Harpodon nehereus* at different lengths are represented in Table 5 and fig 6. The mean Kn value was lowest in the length group of 15.0 - 18.0 cm and the highest in the length group of 6.0 - 9.0 cm. However, the mean Kn values recorded in the present investigation indicated that the species exhibit healthy condition showing good compatibility with the environment.

4.3 Growth parameters and Growth performance Index of *Harpodon nehereus*

The growth parameters obtained from different methods are represented in Table 6. The Von - Bertalanffy growth equation from SLCA and PROJMAT methods were to be $L_t = 40 [1 - e^{-0.997 (t+0.367)}]$ and $L_t = 45 [1 - e^{-0.997 (t+0.257)}]$, respectively. From the SLCA method the asymptotic length (L_∞), curvature parameters (K), age at zero length (t_0) and Growth performance index (\emptyset') were found to be 40 cm, 0.997 per year, - 0.367 year and 3.2028, respectively. From PROJMAT method the L_∞ , K, t_0 and \emptyset' were estimated as 45 cm, 0.997 per year, - 0.257 year and 3.3051, respectively.

4.4 Mortality parameters and exploitation level of *Harpodon nehereus*

The mortality parameters and exploitation level are shown in table 7. The growth parameters obtained from the SLCA method were used to calculate of mortality parameters and exploitation level of *Harpodon nehereus*. The total mortality co-efficient (Z) natural mortality co-efficient (M), Fishery mortality co-efficient (F) and exploitation level (E) were calculated as to be 3.6 per year, 1.53 per year, 2.07 per year and 0.575, respectively.

Table 4: The mean relative condition factor (Kn) of *Harpodon nehereus* during different months

Sampling Month	Mean relative condition factor (Kn)
January	1.3688
February	1.5537
March	1.4483
April	1.2202
May	1.2751
June	1.4409
July	1.4224
August	1.3439

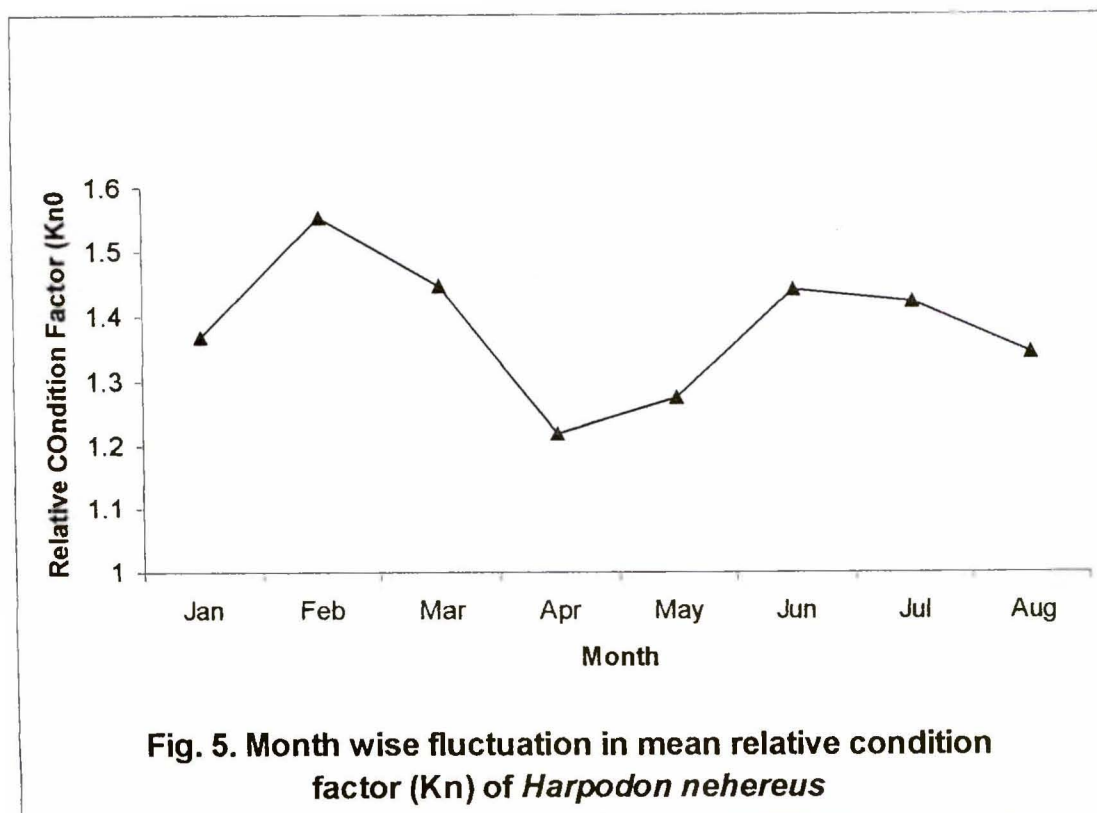


Fig. 5. Month wise fluctuation in mean relative condition factor (Kn) of *Harpodon nehereus*

Table 5: Length group wise mean relative condition factor (Kn) of *Harpodon nehereus*

Length group (cm)	Mean relative condition factor (Kn)
6.0 – 9.0	1.8299
9.0 – 12.0	1.4616
12.0 – 15.0	1.1788
15.0 – 18.0	1.0022
18.0 – 21.0	1.1003
21.0 – 24.0	1.0643
24.0 – 27.0	1.1655
27.0 – 30.0	1.2527
30.0 – 33.0	1.5644

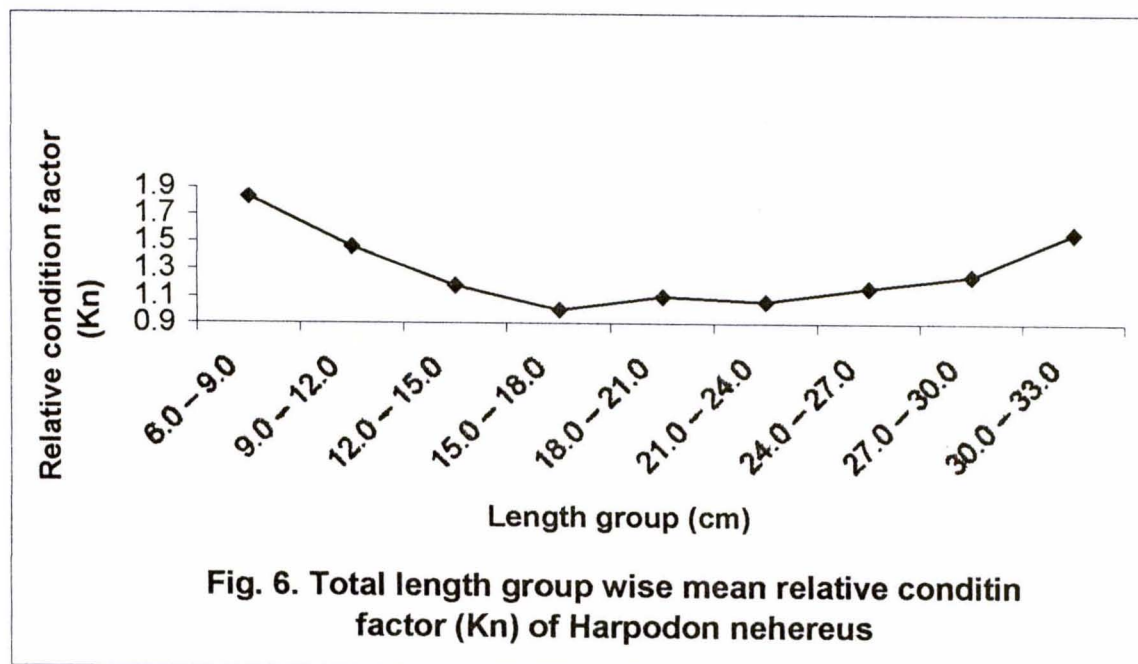


Table 6: Value of Growth parameters of Von-Bertalanffy growth model for estimated from different length based methods

Methods	Value of asymptotic length (L α)	Value of curvatures parameters (K)	Value of age at zero length (t $_0$)	Von - Bertalanffy growth model	Value of Growth performance index (\emptyset)
SLCA	40.00 cm	0.997 per year	- 0.367 year	$L_t = 40 [1 - e^{-0.997(t+0.367)}]$	3.2028
PROJMAT	45.00 cm	0.997 per year	- 0.257 year	$L_t = 45 [1 - e^{-0.997(t+0.257)}]$	3.3051

Table 7: Value of mortality parameters and exploitation level of *Harpodon nehereus*

Method	Value of total mortality coefficient (Z)	Value of natural mortality coefficient (M)	Value of Fishing mortality coefficient (F)	Value of exploitation rate /level (E)
SLCA	3.6 per year	1.53 per year	2.07 per year	0.575

CHAPTER-5



DISCUSSION

DISCUSSION

Fish stock assessment plays an important role in the rational management and conservation of the fishery resources. Effective management of any fishery requires considerable knowledge regarding population parameters such as length-weight relationship, growth and mortality rates, exploitation level and recruitment pattern. In the present study an attempt has been made to estimate the population parameters and to know the stock position of unsexed *Harpodon nehereus* (Ham.) by collecting length frequency data from the commercial catches caught off Kakdwip and brought at Diamond Harbour (Nagendra bazar), South 24 Pgs, West Bengal.

5.1 Length-Weight relationship

The length-weight relationship is usefully in differentiating small taxonomic units, biology, growth and predicting the potential yield, which in turn helps in fishery management. The exponential forms of equation obtained for the total length-weight and the standard length-weight relationship of *Harpodon nehereus* in the present study were found to be $W = 0.0000004TL^{3.4262}$ ($R^2=0.9301$) and $W = 0.000001 SL^{3.3408}$ ($R^2 = 0.9204$), respectively. The respective linear relationship could be expressed as $\ln W = -14.636 + 3.4262 \ln TL$ and $\ln W = -13.529 + 3.3408 \ln SL$. The exponent 'b' values for both the forms were significantly different from cube value 3 ($P>0.05$; $t = 10.6363$ for TL and $t = 8.1007$ for SL) indicating the allometric growth pattern of *Harpodon nehereus*. The 'b' value obtained for total length-weight and standard length weight did not differ significantly ($P>0.05$).

The present findings are in accordance with the earlier reports of Krishnayya (1968), Bapat (1970) and Kurian (1992) who have also reported allometric growth pattern in *Harpodon nehereus* from the Bay of Bengal ($b = 3.2657$) water, Arabian Sea (3.4444 in female and 3.7169 in males) and north west coast (2.0279), respectively. Contrary to the above results Nurul Amin (2001) and Bapat *et al.* (1951) have recorded the isometric growth pattern of

Harpodon nehereus with the 'b' values 3.051 and 2.889, respectively from Bay of Bengal and Arabian Sea.

According to LeCren (1951) the equation $W = a \cdot L^b$ is a better fit to express the relation between length and weight than the hypothetical cube law $W = a \cdot L^3$. Hence, the former equation was applied for the present study. The 'b' values are known to range between 2.5 and 4 in fishes (Hile, 1936 and Martin, 1949) and in majority of cases the value deviated from 3. According to Mitra (2001) the 'b' values in different species of Hooghly estuary ranged from 2.9615 to 3.3686. In general, adult fishes follow an isometric growth (Beverton and Holt, 1957). The variation in 'b' values could be attributed to environmental factors, food availability and the physiological factors including sex and life stage (LeCren, 1951; Ricker, 1975).

5.2 Relative condition factor (Kn)

The Ponderal Index or condition factor (K) and the relative condition factor (Kn) are the measures to study the condition of fish during different stages of growth and different seasons. They indicate the physiological state and general well being of fish (Brown, 1957). The monthly fluctuations of the mean relative condition factor (Kn) of *Harpodon nehereus* showed the lowest condition (1.2202) in the month of April and the highest condition (1.5537) in the month of February (Table; 4).

The Kn mean values exhibited an increased trend from April to July with a slight fall in August and reached the maximum in the month of February. Krishnayya (1968) recorded the lowest condition (1.7392 to 1.849) of *Harpodon nehereus* in the period between April and June. Further, he also noticed the Kn values of more than 2 from the month of October through March. However, Bapat (1970) reported an increased condition factor value of *Harpodon nehereus* in the month of April and low condition factor values during December to March.

Nurul Amin (2001) observed the Kn values of *Harpodon nehereus* in the range of 0.908 to 1.22. The lowest mean Kn value in the month of April as

noticed in the present study, might be due to the metabolic strain of spawning of the species as the main spawning season of the species reported to be is during December to March (Bapat, 1970). The highest mean Kn value observed in the month of February might be due to the fact that the fishes were in the peak spawning period and gonads were fully fecund. The increased Kn values after May could also attributed be to the peak feeding periods for the species, as observed by Bapat (1951). Such relations of high Kn values during peak spawning periods and low Kn values after spawning periods has also been reported in other fishes like *Tenualosa ilisha* (Khan *et al.*, 2001), *Osteobrama belangiri* (Singh, 2003) and *Puntius sophore* (Mitra *et al.*, 2005).

Amongst the individuals of different length groups of *Harpodon nehereus* the mean Kn value was lowest in the length group of 15-18 cm. The mean Kn value decreased gradually up to 15-18 cm and showed an increased trend from 24.0 – 27.0 cm onwards. Bapat (1970) recorded a consistent increment in the condition factor (K) value from 27 cm onwards. He also noticed downwards trend for females and upward trend in the males often 21.00 cm. Krishnayya (1968) observed a gradual increase in the Kn values after the fish reaches 19.5 cm. The highest Kn value of *Harpodon nehereus* was recorded for the length of 28.5 cm by him, which he attributed to the peak spawning size. Generally the low Kn values of *Harpodon nehereus* were observed in the length group of 9-15 cm (Krishnayya, 1968). Fluctuations in the Kn values are common in fishes due to differential feeding intensity, size of the fish and most importantly the textual cycle (Lecren, 1951; Thakur, 1975). The mean Kn values recorded in the present investigation indicated that the species exhibit healthy condition showing good compatibility with the environment.

5.3 Growth parameters and Growth performance index

The study of growth means basically the determination of body size as a function of age. Therefore, all stock assessment techniques require age composition data obtained through counting the year rings on the hard parts of the fish. However, such age determination is difficult in tropical waters. In such

cases the length frequency data analysis has been recommended and is used for fish stock assessment studies in tropical waters including India (Gayaniilo *et al.*, 1996; Pauly and David, 1981; Islam, 1995). Hence the Length Frequency Data Analysis (LFDA) Microsoft package developed under Fishery Management Science Programme (FMSP) was used as described by Hoggarth *et al.* (2005). Though several models have been used to express growth (Allen, 1971), the Von-Bartalanffy growth equation is most commonly used for the marine species as it fits the data from a wide range of species (Beverton and Holt, 1957). Therefore, the growth parameters (L_{∞} , K and t_0) estimated from different methods of LFDA were used to fit the VBGF equation.

The L_{∞} is the mean length that the fish would reach if they were to grow to a very old age (Rickers, 1975). The L_{∞} values (Table 5) of *Harpodon nehereus* calculated in the present study varied from 30.11 cm (ELEFAN) to 45.00 cm (PROJMAT). The values obtain SLCA (40.00 cm) and PROJMAT were almost similar. However it was low in the case of ELEFAN. There is a wide discrepancy in the L_{∞} value of *Harpodon nehereus* reported from earlier authors. Fernandez and Devaraj (1996) recorded L_{∞} value ranging 37.45 cm (1985) to 60.97 cm (1958), which they attributed to subtle variation in growth between span of about 25 and 30 days. The L_{∞} values of *Harpodon nehereus* recorded in the present study are almost in the range of those values recorded of 30 cm by Islam (1995) from Bay of Bengal and Zafar Knan (1985) recorded 36.7 cm from the Arabian Sea. However higher L_{∞} of 73.02 cm from the Bay of Bengal has also been reported (Krishnayya, 1968) for of *Harpodon nehereus* for the same species. Similarly, the lowest L_{∞} 24.48 cm has been also reported by Nurul Amin (2001). Keeping in the view of the maximum length 32.1 cm recorded during the present observation, the L_{∞} obtained from SLCA and PROJMAT was found to be more appropriate estimate and that of ELEFAN could not be considered for further analysis of mortality rates.

The curvature parameter (K) denotes how fast the fish approaches it's asymptotic length. In general, tropical fishes have higher K values than the

temperature ones. In the present study the K value was from 0.997 per year as estimated from SLCA and PROJMAT methods, thus indicating the compatibility of the method used. The K values of *Harpodon nehereus* from the earlier reports varied between 0.7616 per year from Hooghly estuary (Krishnayya, 1968) and 1.5 per year (Nurul Amin, 2001). The K values recorded (0.7618 per year to 0.9 per year) by (Zafar Khan, 1989; Mustafa *et al.*, 1994) were almost similar to the present observation along Saurashtra coast and Kumira estuary in Bangladesh. The variation in the K value is common in fishes depending on life stage, food availability and environment condition.

The initial condition parameters t_0 is the age the fish would have zero length if they had grown to the VBGF equation. The calculated t_0 in the present study was -0.257 year (PROJMAT) and -0.367 year (SLCA). The result obtained in the present study are almost similar t_0 of *Harpodon nehereus* the earlier observation (Zafar Khan, 1985; Farnandez and Devaraj, 1996) in which the t_0 range from -0.028 to -0.29 year. However Krishnayya (1968) and Zafar Khan (1989) have recorded a small positive value of 0.0805 year and 0.00789 year respectively for *Harpodon nehereus*. According to King (1996) the t_0 initially has a small positive or a negative factor. He also stated that the juveniles with negative t_0 values grow faster than the adults.

The growth performance Index (ϕ') explains the overall growth performance of the fish population intense of growth in length (Pauiv and Munro, 1984). In the present study the ϕ' values recorded were 3.2028 (SLCA) and 3.3051 (PROJMAT). Mustafa *et al.* (1998) reported ϕ' of *Harpodon nehereus* as 2.953, which is slightly lower than present study. This might be associated with differential fishing pressure and environmental condition prevailed during the study period.

5.4 Mortality rates and exploitation level

The instantaneous rate of total mortality (Z) explains the rate of reduction of fishes from the population due to death. This Z has two components namely the instantaneous rate of natural mortality (M) and

instantaneous rate of fishing mortality (F), which are due to natural process and by the fishing operation, respectively. The mean instantaneous mortality rates Z, M and F of *Harpodon nehereus* estimated in the present study were found to be 3.6 per year, 1.53 per year and 2.07 per year, respectively. The Z and M were obtained from the growth parameters resulted from SLCA method. The exploitation level (E) of *Harpodon nehereus* was computed as 0.575 from the present investigation area. Kurian (1992) in his study of *Harpodon nehereus* during the period between 1986 and 1995 reported the F values from 0.19 – 1.03 per year, Z values 0.75 – 1.59 per year and M values 0.25 – 0.65 per year along Maharashtra coast. Further, he recorded F value 0.22 – 0.67 per year, Z value 0.78 – 1.23 per year and E values 0.28 – 0.54.

Zafar Khan (1986) recorded total mortality rate of *Harpodon nehereus* at Nawabunder, which varied between 2.443 per year and 2.939/year for the period 1976 to 1979 with the exploitation rate 0.422. Mustafa *et al.* (1998) observed M, F and Z of *Harpodon nehereus* to be 2.46, 3.27 and 5.73, respectively with exploitation rate 0.57. Fernandez and Devaraj (1996) have reported the highest Z value of 8.29 during 1948 and the highest M values of 1.2 during the same year. They recorded the F value (2.70) during the year 1983 along the North West coast of India. Off Sourashtra coast the estimated Z of *Harpodon nehereus* varied between 2.331 and 3.168 during 1976 to 1984 (Zafar Khan, 1989). Thus it appears that the values recorded in the present study almost in the range of the earlier ones. According to Gulland (1971) the fishing yield is optimized when $F = M$, and when $E > 0.5$ the stock said to be over fished. Thus, in the present study the value of E (0.575) indicated the over exploitation of the species in the region studied.

CHAPTER-6



SUMMARY

SUMMARY

The present study was carried out on population dynamics of *Harpodon nehereus* (Hamilton) Collected at regular intervals from Nagendra Bazar Fish Market, Diamond Harbour, South 24 Parganas, West Bengal, India, which are brought from the commercial catches of gill netters off Kakdwip, South 24 Parganas, West Bengal, India during the period between January 2006 to August 2006. The objectives of the present study were to establish length-weight relationship & estimate relative condition factor, to estimate the growth parameters & growth performance index and to estimate the instantaneous rate of total mortality (Z), natural mortality (M), fishing mortality rates & exploitation level (E) of *Harpodon nehereus*.

A total of 550 numbers of fishes of size range 7.3 cm to 32.1 cm length (total length) and weight in the range from 2 g to 250 g were examined for the purpose. The analysis on the population dynamics of the species was carried out using Length Frequency Data Analysis (LFDA) a Microsoft Package developed by MARG Ltd. under Fisheries Management Science Program (Kirkwood et al., 2001). The statistical analysis was carried out following the standard methods.

The salient observations recorded in the present study were as follows:

1. The exponential forms of equations derived between total length & weight, and standard length & weight of *Harpodon nehereus* were $W = 0.000000TL^{3.4262}$ ($R^2 = 0.9301$) and $W = 0.000000 SL^{3.3408}$ ($R^2 = 0.9204$), respectively. The exponent 'b' values for both the forms were significantly different from 3 ($P > 0.05$; $t = 10.6363$ for TL and $t = 8.1007$ for SL) indicating the allometric growth i.e., deviation from the hypothetical cube law.

2. The monthly mean relative condition factor (Kn) was maximum in the month of February (Kn = 1.5537) and minimum in the month of April (Kn = 1.2202). The Kn values also express healthy condition showing good compatibility with the nature or environment.

3. The value of growth parameters resulted from SLCA and PROJMAT methods were estimated as $L_{\infty} = 40.00$ cm, $K = 0.997$ per year and $t_0 = -0.367$ years; $L_{\infty} = 45.00$ cm, $K = 0.997$ per year and $t_0 = -0.257$ years, respectively.

4. The values of growth performance index (Φ') resulted from SLCA and PROJMAT methods were to be 3.2028 and 3.3051, respectively.

5. The instantaneous rate of total mortality co-efficient (Z), instantaneous rate of natural mortality co-efficient (M), instantaneous rate of fishing mortality co-efficient (F) and exploitation level (E) were to be 3.6 per year, 1.53 per year, 2.07 per year and 0.575, respectively. All the mortality parameters mainly help to estimate the exploitation level of *Harpodon nehereus*. In the present study the value of exploitation level (E) mainly indicated over exploitation of the *Harpodon nehereus* in the Kakdwip estuarine region.



REFERENCES

REFERENCES

- Abdul Hameed, K. M. S. A. (1994). Length-weight relationship of thread fin bream (*Nemipterus bipunctatus*) in the gulf of Mannar, India. *ICLARM*, manila, 17 (4) : 40p.
- Al-Absy, Ahmad, H. (1987). The biometry, Weight-length relationship and growth of goat fish *Mulloidies flavolineatus* (Lacepede) from the gulf of Aquaba, Red Sea. *Matsya* 11 - 13, 148 - 152.
- Alagaraja, K. (1984). Simple methods for estimation of parameters for assessing exploited fish stocks. *Indian J. Fish.* 31: 17 - 208.
- Al-Daham, N. K. and Wahab, N. K. (1991). Age, growth and reproduction of the greenback mullet, *Liza subviridis* (Valenciennes), in an estuary in Southern Iraq. *J.Fish Biol.*, 38 : 81 - 88.
- Allen, K. B. (1938). Some observation on the biology of the trout (*Salmo trutta*) in windemer. *J. Anim. Eco.* 7 : 333 - 349.
- Allen, K. R. (1971). Related between production and biomass. *Journal of Fisheries Research Board of Canada*, 28:1573 - 1581.
- Bakhoun, S. A. (1999) Comparative study on length weight relationship and condition factor of the genus *Oreochromis* in polluted and non-polluted parts of lake Mariut, Egypt. *Bull. Nat. Inst. Oceanogr. Fish (Egypt)*.
- Bapat, S. V. (1970). The Bombay duck, *Harpodon nehereus* (Ham.). *Bull. Cent. Mar. Fish Res. Inst.*, 21 : 1 - 66.
- Bapat, S. V., Banerji, S. K. and D. V. Bal. (1951). Observation on the biology of *Harpodon nenereus* (Ham.). *J. Zool. Soc. India*, 3 : 441 - 356.
- Basson, M., Rosenberg, A. A. and Beddington, J. R. (1988). The accuracy and reliability of two new methods for estimating growth parameters from length-frequency data. *J. Cons. int. Explor. Mer.* 44:277 - 285.

- Beverton, R. J. H. and S. J. Holt. (1957). On the dynamics of exploited fish populations. *Fish. Invest. Minist. Agric. Fish. Food GB* (2 sea fish), **19**: 533p.
- Beverton, R. J. H., and Holt, S. J. (1956) A review of methods for estimating mortality rates in fish populations, with special reference to sources of bias in catch sampling. Rapp. P-v. Reun. *CIEM*. **17A**: 1 - 153.
- Brody, S. (1945). Bioenergetics and growth. Reinhold publishing corporation, New York, pp. 1023.
- Brown, M.R. (1957). Experimental studies on growth. In the physiology of Fishes. Vol-1 (Ed. Brown, M.E.) New York, Academic Press. 361 – 400.
- Cakic, p., Lehnhardt, M., Miekovic, D., Sekulic, N. and Budakov, L. J. (2002). Biometric analysis of *Syngnathus abaster* populations. *J. Fish. Biol.*, **60** : 1562 - 69.
- Chopra, B. N. (1939). Some food prawns and crabs of India and their fisheries. *J. Bombay nat. Hist. Soc.*, **41** : 221 - 234.
- Das (2004). Biology of length-weight and condition in brackish water fish *Liza tade* (Forsk.) *Indian J. Environ. Ecoplan.* **8** : 209 - 11.
- De Silva, S. S. and Silva, E. I. L. (1979). Biology of young mullet, *Mugil cephalus* L., of a coastal lagoon in Sri Lanka. *J. Fish Biol.*
- De. D. K. (1980). Maturity, fecundity and spawning of post monsoon run of Hilsa, *Hilsa ilisha* (Ham.) in the upper stretches of the Hooghly estuarine system. *J. Inland fish Soc. India*, **12 (1)** : 54 - 63.
- Devaraj, M. (1981). Age and growth of three species of seerfishes, *Scomberomorus commerson*, *S. guttatus* and *S. lineolatus*. *Indian J. Fish.*, **28** : 104 – 127.

- Dhanze, R. and Dhanze, J. R. (1997). Biology of Scale carp and grass carp (1) length-weight relationship and growth performance under the agro climatic zone 1 of Himachal Pradesh. *Indian J. Fish.* **44** (3) : 255 - 263.
- Dhulkhed, M. H. (1967). *Indian Journal of Fisheries* (1963), **10A** (1) : 40 - 47.
- Dighe, J. P. (1977). A study on a lizard fish *Saurida tumbil* (Bloch.), Ph.D. Thesis, Bombay University.
- Doddamani, M., Ramesha, T. J. and Shanbhogue, S. L. (2001). Length –weight relationship and relative condition factor (Kn) of *Stolepophorus bataviensis* from Mangalore area. *Indian J. Fish.* **48** (3) : 329 - 332.
- Eggleston, D. (1970). A symposium on the Japan Current edited. *J.C. Mar.* 417 - 424.
- Fawzy, A. B. and Faiza, M. S. (1987). Length – weight relationship and relative condition factor of the goatfish *Upeneus sulphureus* (Val.) in Safaga Bay of the Red Sea. *J. Inland Fish. Soc. India.* **19** (2) : 47 - 52.
- Fernandez, Irene, and Devaraj, M. (1996). Dynamics of the Bombay duck (*Harpodon nehereus*) stock along the northwest coast of India. *Indian Journal of Fishes*, **43** (1) : 11 - 11.
- Fulton, J. H. (1904). The rate of growth fishes. *Fish. Ed. Sept. Rept.* **22** (3) : 144 - 240.
- Garcia, S. and LeReste, L. (1981). Life cycle, dynamics, exploitation and management of coastal penaeid shrimp stocks. *FAO Fish. Tech. Pap.* **203** : 215p.
- Gayanilo, F. C. Jr. & Pauly, D. (1996). The FAO-ICLARM Assessment Tools (FiSAT) User's guide. *FAO Computerized Information Series (Fisheries)*. No.8 (FAO, Rome).

- Gayanilo, F.C., Soriano, M. and Pauly, D. (1988). A draft guide to the COMPLEAT ELEFAN. ICLARM software project 2 : 65p. and 10 diskettes [5.25 inches, 360k].
- Goswami, U. C. and Sharma, N. N. (1996). Food and certain aspects of feeding habit of *Clarius batrachus* (L.) from Brahmaputra river system. *Acta Univ. Carolina Biologica*. **40** : 77 - 85.
- Gowda, G., Shanbhogue, S. L. and Udupa, K. S. (1987). Length-weight relationship and condition of Grey mullet, *Valamugil seheli* (Forskal), from Mangalore waters. *Indian J. Fish.*, **34** (4) : 340 - 342.
- Grover, John. H. and Juliano, Rogelio. O. (1976). Length weight relationship of pond raised Milk fish in the Philippines. *Aquaculture*. **7**: 339 - 346.
- Gulland, J. A. (1971). The fish resources of the ocean. West By fleet, Survey, Fishing News (Books), Ltd., for FAO, 225p. *Revised edition of FAO Fisheries Technical Paper*. **17**: 425p (1970).
- Gulland, J. A. (1983). Fish stock assessment: a manual of basic method. Chichester, U.K. Wiley Interscience, FAO / wiley series on food and agriculture. **1** : 223p.
- Hensen, V. (1899). Remakung ZU Voratchender Arbeit. *Wiss. Meeresuntersuch*, *N.F.* **3**, **4** : 249 - 253.
- Hilborn, R. and Walters, C. J. (1992). Quantitative fisheries stock assessment; choice dynamics and uncertainty, Chapman & Hall.
- Hile, R.(1936). Age and growth of Cisco, *Leucichthyes artedi* (Le Surr) in the lakes of three northern highland, Wisconsin. *Wise Bull. U.S. Bus. Fish.* **48**: 211-317.
- Hoda, S. M. S. (1987). Relative growth of body parts and length-weight relationship in *Boleophthalmus dussumieri* and *B. dentatus* of Karachi coast. *Indian J. Fish.*, **34** (1) : 120 - 127.

- Hoggarth, D.D., Abeyasekera, S., Arthur, R., Beddington, J. R., Burn, R. W., Medley, P. Mees, C. C., & Welecomme, R. L. (2005). Stock assessment for fishery management – A framework guide to the use of the FMSP Fish Stock Assessment Tools. *FAO Fisheries Technical Paper*. No. 487. Rome, FAO. 259 pp.
- Hora, S. L. (1934). Wanderings of the Bombay duck, *Harpodon nehereus* (Ham.) in Indian waters. *J. Bombay nat. Hist. Soc.* 37 : 642 - 654.
- Hornell, J. (1916). Fishery statistics and information, West and East coast of Madras presidency. *Madras Fish. Bull. Madras.* 9 : 1 - 40.
- Islam, S. S. (1995). Population dynamics of some fishes and shrimp of karnafully river estuary based on large frequency data. M.Sc. Thesis, Dept. of Zoology, University of Chittagong, Bangladesh, 37 - 76 pp.
- Jhingran, V. G. (1959). Studied on the age and growth of *Cirrhina mrigala* (Ham.) from the river Ganga. *Proc. Nat. Inst. Sci. India (B)* 18 (5) : 449 - 460.
- Kagwade, P.V. (1971). *Indian J. Fish.*, 18 (1 & 2) : 33 - 51.
- Kasim, H. M. and Ameer, K. M. S. Hamsa (1994). Carangid fishery and population component species *Caranx carangus* from Tuticorin coast. *J. mar. biol. Asso. India*, 36 (1 & 2) : 63 - 71.
- Khan, M. A., Kumar, Dharendra and Sinha, Ranjana, (2001). On some biological aspects of *Tenulosa ilisha* (Hamilton-Buchanan) from Hooghly estuary, India. *J. Inland Fish. Soc. India*, 33 (1) : 38 - 44.
- Khan, M. F. and Nandakumaran, K. (1993). Population dynamics of Malabar sole *Cynoglossus macrostomus* Norman along Calicut coast. *Indian J. Fish.*, 40 (4) : 225 - 230.
- King, M. (1996). *Fisheries Biology, Assessment and Management*. P-117.

- Kirkwood, G. P., Aukland, R. and Zara, S. J. (2001). Length Frequency Distribution Analysis (LFDA). Version-5.0. MARG Ltd, London, U.K.
- Krishnamoorthi, B. (1971). *Indian J. Fish.*, **18** : 1 - 21.
- Krishnayya, C. H. (1968). Age and Growth of *Harpodon nehereus* (Ham.) and its fishery in the Hooghly. **20 (1 & 2)** : 129 - 147.
- Kumar, S. and Lal, M. S. (1994). Biology of *Nemacheilus multifasciatus* (Day)
1. Length-weight relationship. *J. Fresh water Biol.* **6 (4)** : 337 - 340.
- Kumari Rita, S. D. and Nair, N. B. (1978). Length-weight relationship of the loaches *Naemacheilus traingularis* (Day) and *Lepidocephalus thermalis* (cuv. And Val.). *Matsya*, **4** : 52 - 58.
- Kurian, Alexander and Kurup, K. Narayana (1992). Stock assessment of Bombay duck *Harpodon nehereus* (Ham.) off Mahasashtra coast. *Indian J. Fish.* **39 (3, 4)** : 243-248.
- Kurup, B. Madhusoodana, and Venu, S. (2006). Length weight relationship of *Priacanthus hamrur* (Forsskal) inhabiting the continental slopes beyond 300 meter depth along the west coast of India. *Fishery Technology*, **43 (1)** : 41 - 66.
- Kutty, M. K. and Qasim, S.Z. (1969). Theoretical yield studies on the large - scaled tongue sole *cynoglossus macrolepidotus* (Bleeker). *Proc. Nat. Inst Sci. India.* **33** : 94 - 110.
- Lal, M. S. (1980). Eco-biological studies of some hill stream fishes of Garhwal Himalayas IV. Length weight relationship of *Schizothorax plagiostomus* (Gray). *Indian J. Zoot.* **XXI** : 1-3, 79 - 81.
- Lal, M. S. and Mishra, M. (1980). Eco-biological studies of some hill stream fishes of Garhwal Himalyas. V. Length-weight relationship of *Schizothorax richosdsonii* (Heckel). *Indian J. Zoot.* **XXI** : 1-3, 83 - 85.

- Larkin, P. A. (1977). An epitaph to the concept of maximum sustainable yield. *Trans. Am. Fish. Soc.*, **106** : 1-11.
- LeCren, E. D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition of the perch, *Perea fluviatilis*. *J. Amin. Ecol.*, **20** : 210 - 219.
- Lloyd, R. E., (1907). Notes on a collection of marketable fish from Akyab with a description of a new species of *Lactarius*. *Ibid. Calcuta*. **1** : 219 - 230.
- Martin, W.R. (1949). The mechanisms of environmental control of body form in fishes. *University of Toronto Studied in Biology*. **58**:1 - 91.
- Misra, K. S. (1959). An aid to the identification of the common commercial fishes of India and Pakistan. *Rec. Indian Mus.* **27** : (Published in 1962).
- Mitra, K., Suresh, V. R., Vinch, G. K. and Naskar, B. (2005). Length – Weight relationship, reproduction characters and condition factor of *Pantius sopphre* (Hamilton) from a floodplain wetland in West Bengal. *J. Inland Fish. Soc. India*. **37(1)**. 16 - 22.
- Mitra, P. M. (2001). Length – Weight relationship of some commercially important fish species of Hooghly estuary. *J. Inland Fish. Soc. India*. **33(2)**, 12 - 14.
- Mojumdar, P. (1971). Length-weight relationship in the catfish *Tachysurus thalassinus* (Rupell.). *Indian J. Fish*, **18** : 179 -182.
- Mondal, S. K., Mitra, P. M. and Gupta, R. A. (1998). Population Dynamics and stock assessment of *Polynemus Paradiseus* of the Hooghly-Matla estuarine system, *J. Inland Fish, Soc. India*. **30 (2)** : 19 - 23.
- Moses, S. T. (1922). A statistical account of the fish supply of Madras. *Madras Fish. Bull. Madras*, **15** : 131 - 166.

- Munro, J.L. (ed.) (1983). Caribbean coral reef fishery resources. *ICLARM stud. Rev.*, **7** : 276p.
- Murty V. Sriramachandra (1991). Observation on some aspects of biology and population dynamics of the scad *Decapterus Russelli* (Ruppell) (Carangidae) in the trawling grounds off Kakinada. *J. mar. biol. Ass. India*, 1991, **33 (1 & 2)** : 396 - 408.
- Mustafa, M. G., Azadi, M. A. and Islam, M. S. (1994). ELEFAN based population dynamics of Bombay duck, paper presented 9th National 2001. *Conf. of the zoological society of Bangladesh*. 26-28 Jan., **(42)**.
- Mustafa, M. G., Zafar, M., Matin, A. K. M. A. and Amin, S. M. N. (1998). Population Dynamics of *Harpodon nehereus* (Ham.) from the Kutubdia channel of Bangladesh.
- Muth, K. and Simth, Jr. L. L. (1974). The burbut fishery in lake of the woods. *Tech. Bull.* **296** : 33.
- Narasimham, K. A. (1970). *Indian Journal of Fisheries*. **17** : pp. 90 - 96.
- Narasimham, K. A. (1974). Some observation on the biology of ribbonfish *Dupleurogrammus nutricus* (Gray). *Indian J. Fish.* **21** : 479 - 494.
- Nath, D., Misra, R. N. and Karmakar, H. C. (2004). Ecological flux, fishery resources and production potential of the Hooghly estuarine system.. Bull No. **130**. January 2004, 36 p.
- Nurul Amin, S. M. (2001). Studied on Age and growth VPA analysis and Relative condition factor of *Horpodon nehereus* (Ham.) from the Neretic water of Bangladesh. *Online J. of Biological Sci.* **1 (4)** : 192 - 194.

- Pandey, A. C. and Sharma, M. K. (1995). Length-weight relationship and condition factor of scale carp fingerlings from a polyculture fish pond. *Abst. Natl. Sem. on Curr. emerging trends in aqua.* 14 - 16 Feb. Rangailunda, 63p.
- Pandey, K. K. and Lal, M. S. (1994). Length-weight relationship of Hill trout Barilus species *B. bendelisis* (Ham.) and *B. Vagra* (Ham – Buch.) from Garhwal Himalaya. *J. Fresh water Biol.* **6 (4)** : 349 - 352.
- Pantulu, V. R. (1961). Determination of age and growth of *Mystus gulio* (Ham) by the use of the pectoral spine with observation on its biology & fishery in Hooghly estuary. *Proc. Nat. Inst. Sci. India*, **27 (B) (4)** : 198 - 225.
- Pauly, D. (1979). Theory and management of tropical multispecies stocks : a review with emphasis on the southeast Asian demersal fisheries. *ICLARM. Rev.* **1** : 35p.
- Pauly, D. (1980). A selection of simple method for the assessment of tropical fish stock. FAO Fish. Circ. 729, 54p. Issued also in French. Superseded by FAO Fish. *Tech. Pap.* (234).
- Pauly, D. (1984). Fish population dynamics in tropical waters : a manual for use with programmable calculators. *ICLARM stud. Rev.* **8** : 325p.
- Pauly, D. and David, N. (1981). ELEFAN 1, a BASIC program for the objective extraction of growth parameters from length-frequency data. *Meeresforschung*, **28 (4)** : 205-211.
- Pauly, D. and Murno, J. L. (1984). Once more on growth comparisons in fish and invertebrates. *Fishbyte*. **2(1)**. 21.
- Pauly, D. and Margan, G. R. (1987). Length-based method in fisheries research. *ICLARM conf. Proc.*, **13** : 468p.
- Philip, K. P. and Mathew, K. (1996). Length-weight relationship and relative condition factor in *Priacanthus humrur* (Forsskal). *Fishery Technology*, **33 (2)** : 79 - 83.

- Pillai, P.K. Mahadevan.(1983). *J. Indian Fish.* **30(1)**: 69 - 73.
- Piska, Ravi Shankar, Waqghray, Sarala and Prasad, M. Ravindra (1991). *Indian J. of Fisheries*, **38 (3)** : 157 - 164.
- Rai, Ashwin, Reddy, H. R. V. and Venkatesh Moorthy, K. S. (2004). Length-weight relationship of *Schizothoracichthys esocinus* and *S. bataviensis* from Mangalore waters, west of India, *Environment & Ecology*, **22 (1)** : 23 - 26 (2004).
- Raj, S. B. (1954). The problem of the apparent discontinuous distribution of *Harpodon nehereus* (Hams). *Proc. Indian Acad. Sci.*, **40** : 58 - 68.
- Raje, S. G. (1994). Fishery and biology of *Atropus atropus* (Bloch and Schnider) from Veraval. *J. mar. biol. Ass. India*, **36 (1 & 2)** : 181 - 187.
- Rangaswamy, C. P. (1976). The length-weight relationship in the grey mullet, *Mugil cephalus* linnaeus, *Matsya*, **2** : 19 - 22.
- Rao, G. R. M. and Rao, L.H. (1972). On the biology of *Labeo calbasu* (Ham. Buch.) from the river Godavari. *J. Inland Fish. Soc. India*, **IV** : 74 - 86.
- Rao, K. Virabhadra, (1969). Distribution pattern of the major exploited marine fishery resources of India. *Bull. Cent. Mar. Fish. Res. Inst.* **6** : 1-69.
- Rao, L. M., Bharatha Lakshmi, B. and Bangaramma, Y. (2005). Length - weight relationship and relative condition factor (Kn) of *Liza parsia* (Hamilton- Buchanan) in relation to industrial pollution. *Indian J. Fish.* **52 (3)** : 345 - 349.
- Reuben, K., Vijayakumaran, Acharya, P. and Prabhakar, P. V. D. (1997). Biology and exploitation of *Trichiurus lepturus* (Linnaeus) from Vishkhapatnam waters. *Inland J. Fish*, **4 (2)** : 101 - 110.

- Reuben, S., Kasim, H.M., Sivakami, S., Radhakrishnan Nair, P. N., Kurup, K. N., Sivadas, M., Noble, A., Somasekharan Nair, K. V., Raje, S. G. (1992). Fishery, Biology and stock assessment of carangid resources from the Indian seas. *Indian J. Fish.*, **39** (3, 4) : 195 - 234.
- Ricker, W. E. (1975). Computation and interpretation and biological statistics of fish populations. *Bull. Fish. Res. Board can.* **191** : 382p.
- Roy, P. K. (1987). Length-weight relationship of a major carp, *Cirrhinus mrigala* (Ham.), *Matsya* . **12-13** : 39 - 44.
- Saila, S.B. and Roedel, P. (1980). Stock assessment for tropical small scale fisheries. Proceedings of an International workshop held 19-21 September 1979, at the University of Rhode Island, Kingston R.I., International center for Marine Resource Development, University of Rhode Island, 198p.
- Saker, Y., Jaiswar, A.K., Chakrabarty, S.K. and Swamy, R.P. (2004). Morphometry and Length –weight relationship of *Megalaspis cardyla* (Linnaeus, 1758) from Mumbai coast. *Indian J. Fish.*, **51** (4) : 481 - 486.
- Sandhya, V. and Shameem, U. (2003). Length –weight relationship and condition factor of *Liza macrolepis* (smith) from polluted and unpolluted waters of Visakhapatnam. *Indian J. fish.*, **50** (4) : 543 - 546.
- Shepherd, J. G. (1987) A weakly parametric method for the analysis of length composition data. Pages 113 - 120.
- Silas, E. G. (1962). Tuna Fishery of the Tinnevely coast, Gulf of Mannar, *Proc. Symp. Scombroid Fishes*, MBI, **3** : 1083 - 1118.
- Singh, O. S. (2003). and condition factor of *Osteograbrama belangeri* (Vol.) in Manipur. *J. Inland Fish. Soc. India.* **35**(1), 8 - 12.

- Sivakami, S. (1995). Fishery and biology of the carangid fish *Megalaspis cordyla* (Linnaeus) off Cochin. *J. mar. biol. Ass. India*, 1995, **37 (1 & 2)**: 237 - 248.
- Sivakumari, S. (1987). Length-weight relationship and relative condition in *Ompok bimaculatus* (Bloch). from Bhavanisagar reservoir (T. Nadu.) *Indian J. Fish.* **34 (2)** : 202 - 207.
- Snedecor, C. W. and Cochran, W. G. (1967). Statistical methods. Oxford and IBH Publishing Company. New Delhi. 435p.
- Sorojini, K. K. (1957). Biology and fisheries of the grey mullet of Bengal. 11. Biology of *Mugil cunnesius* (Vol.). *Indian J. Fish.* **5 (1)** : 56 - 76.
- Sparre, P. (1987). Computer programs for fish stock assessment. Length-based fish stock assessment for Apple II computer. *FAO Fish. Tech. Pap.* (101) Suppl. **2** : 218p.
- Sparre, P., Ursin, E. and Venema, S.C. (1989). Introduction to tropical fish stock assessment Part-I Manual. *FAO Fish. Tech. Pap.* Pp-306.
- Sparre, P. and Venema, S. (1992). Introduction to tropical fish stock assessment. Part-I. Manual FAO, Fish, *Tech. Paper*, 306/1 rev 1. FAO., Rome.
- Sreenivasan, P. V. (1981). Length-weight relationship in *Decapterus dayi* Wakiya. *Indian J. Fish.*, **28 (1& 2)** : 283 - 286.
- Sultan, S. (1981). Length-weight relationship in the catfish *Mystus vittatus* (Bloch). *Giobios* **8**, 140 - 141.
- Sundararaj, B. (1953). The problem of the apparent discontinuous distribution of *Harpodon nehereus* (Hamilton), *Proc. Indian Acad. Sci.*, **40 (B), (2)** : 58 - 68 (Published in 1954).
- Tandon, K. K. (1962 a). Biology and fishery of chooparai – Part- II. Biology and fishery. *Indian J. Fish.*, **8 (1)** : 127 - 144.

- Thakur, N. K. (1975). On the Length – Weight relationship and relative condition factor in *Clarias batrachus* (Linn.). Proc. Natl. Inst. Sci. India, **45(B)**. 197 – 202.
- Thomas, P.A. (1969). The goatfishes (family Mullidae) of the Indian seas. Memmoir 3, *Marine Biological Association of India, Mandapam Camp*.
- Ursin, E. (1968). A mathematical model of some aspect of fish growth, respiration and mortality. *J. Fish. Res. Board Can.* **24** : 2355 - 2453.
- Volvich, L. and Appelbaum, S. (2001). Length to weight relationship of sea bass *Lates calcarifer* (Bloch) reared in the closed recirculating system, *The Israeli of Aquaculture – Bamidgeh*, **53 (3-4)** : 158 - 163.
- Willams, F. (1962). Proc. Symp. on scombroid fishes. *Mar. Biol. Ass. India*, **2** : 107 - 164.
- Zafar Khan, M. (1983). Preliminary observations on the fishery of Bombay duck, *Harpodon nehereus* in the Gulf of Kutch. *Indian J. Fish.*, **30 (1)** : 110 - 115.
- Zafar Khan, M. (1985). Observation on the fishery of Bombay duck, *Harpodon Nehereus* (Ham.) along the Savrashtra coast. *Indian J. Fish.* **32 (4)** : 431 - 438.
- Zafar Khan, M. (1986). Mortality and stock size estimates of the Bombay duck, *Harpodon nehereus* (Ham.) off Nawabunder, Gujarat, *Indian J. Fish.*, **33 (3)** : 354 - 358.
- Zafar Khan, M. (1989). Population Dynamics of Bombay duck, *Harpodon nehereus* (Ham.) off Saurashtra coast. *Indian. J. Fish.* **36 (2)** : 93 - 101.