Studies on some aspects of biology of goby fish, *Parachaeturichthys ocellatus* (Day 1873) from Mumbai coast.

Dr Bindu Panicker

Department of Biology,

Maharashtra College of Arts, Science and Commerce,

J.B.B Marg, Mumbai Maharashtra India

Rs.300/-
ISBN: 978-81-949552-3-8
First Edition: New Delhi, 2021

Printed by **ISARA SOLUTIONS**
B-15, Vikas Puri, New Delhi 110018

STATEMENT BY THE CANDIDATE

As required by the University Ordinance 770, I wish to state that the work embodied in this thesis titled "Studies on some aspects of biology of goby fish, *Parachaeturichthys ocellatus* (Day 1873) from Mumbai coast" forms my own contribution to the research work carried out under the guidance of Dr. (Mrs.) V. I. Katchi at the Department of Zoology, Bhavan's College, Andheri (W), Mumbai- 400058 for the Ph.D. Degree in Zoology.

This work has not been submitted for any other degree of this or any other University. Whenever references have been made to previous works of others, the same have been clearly indicated as such and included in the Bibliography.

Signature of candidate
(Mrs. Bindu Ajaykumar Panicker)

Certified by:-

_____
Signature of Guide

Name: Dr. (Mrs.) V.I. Katchi

Acknowledgement

I owe my deepest gratitude to my guiding teacher, Dr. (Mrs.) V.I. Katchi, Head Department of Zoology and Principal, Bhavan's College, Andheri (West), whose valuable guidance enabled me to successfully complete the present piece of research work. I don't have any words to express my feelings of appreciation and admiration for my guide, whose guidance and hard work has inspired me all throughout my work.

I sincerely express my gratitude to Dr. B.M. Gore, Bhavan's College, Andheri (West) for his invaluable guidance which has enabled me to take this work and complete it successfully.

I take this opportunity to thank all teaching and non teaching staff members of Zoology and Botany department of Bhavan's College for their help in completing my experimental work. I specially thank Mrs. Manisha Kawlekar Laboratory Assistant and Mr. Ramesh Rathodfrom Bhavan's College for assistance in the laboratory work.

I am extremely thankful to Principal Dr. M.A. Waheed, Maharashtra College of Arts, Science and Commerce for providing me all the facilities of Maharashtra College to carry out my experimental work. I sincerely thank all my colleaguesfrom Maharashtra Junior college: Mrs. Manisha, Mrs. Tazeen, Mrs.Rumana, Mr. Zafar and Ms. Umaira for their support in carrying out my research. My special thanks to Dr.

Jayashree Menon for helping me unconditionally during the entire course of work. I also thank all teaching staff members of Zoology and Botany department from Maharashtra Collegefor their support and encouragement. I thank all nonteaching staff members of Maharashtra College fromBiology Jr. College, Zoology and Botany Department for their assistance in laboratory work. My special thanks to Mr. Abdul Hamid Mukadam Laboratory Assistant,Biology Department for his timely help in preparing chemicals for my experimental work. I am thankful to myretired supervisor Mr. Abid Hasan and present supervisor Mr Imam Khan for providing support and help as and when required. I am thankful to all staff members of Maharashtra College for their constant encouragement and moral support.

I am extremely grateful to Principal Dr. (Mrs) M.K Pejawar, Bandodkar College and all the staff members of Zoology department for allowing me to refer some of their research work and helping me in my work. My sincere thanks to Prof. Sudhesh Rathod, Bandodkar College for his guidance and help that has been of great value during the course of study. I extend my thanks to Mrs. Lalna Khot from National College for her valuable advice on histological pictographs. I am extremely thankful to Mr. Vinay Jagade and Mrs. Rena Quadrosfor assisting me in computer graphics and Mr. Rajesh Das and Mr. Gopal for printing and binding my thesis.

I extend my deep gratitude to all my friends whose has encouraged and supported me to complete this work. My deepest gratitude and affection goes to my husband Adv. Ajaykumar for his unconditional love and support which has enabled me to take this work and complete it successfully. I am greatly indebted to my children Lavanya and Varun for bearing in silence with no complaints. I am extremely thankful to

my house maid Ammukutty for taking care of my household chores during my period of study.

I thank my father, mother, brother and sister for their support, encouragement, prayers and blessings. I also thank my beloved father-in-law late Mr. Janardhanan for hisencouragement and support.I would like to thank everyone who has helped me to successfully complete this work and express my apology if I have missed any one.

Above all I thank God, the Almighty for me giving courage and strength to overcome all my personal problems during the period of study and enabling me to complete my work successfully.

Mrs Bindu Panicker.

CONTENTS

Title	Page Nos.
Chapter 1: General Introduction	**1 – 19**
Chapter 2: Taxonomy and Systematics	**20 – 38**
Chapter3: Morphometric characters	**39 – 80**
Chapter 4: Meristic characters	**81 – 90**
Chapter 5: Length-weight Relationship	**91 – 101**
Chapter 6: Relative Condition Factor	**102 – 112**
Chapter 7: Food and Feeding habits	**113 – 152**
Chapter 8: Reproductive biology	**153– 229**
Chapter 9: Biochemical Composition of muscles	**230 – 250**
Chapter 10: Condition Indices	**251 – 270**
Chapter 11:Comprehensive profile growth and reproduction	**271 – 279**
Chapter 12:Summary and Conclusion	**280– 289**
Bibliography	**290 - 334**
Synopsis	

List of abbreviations

a: intercept	PAL: Pre anal length
AL: Anal length	PL: Pectoral length
ANCOVA:Analysis of covariance	PPL: Pre pectoral length
ANOVA: Analysis of variance	PPvL: Pre pelvic length
Ao: Atretic oocyte	psc: primary spermatocyte
b: coefficient of regression	Psg: primary spermatogonia
BD: Body depth	PvL: Pelvic length
Ca: Cortical alveoli	r: coefficient of correlation
C.S: Cross section	r^2: coefficient of determination
CD: Caudal depth	RCF: Relative condition factor
CL: Caudal length	RGL: Relative gut length
Df: degree of freedom	RNA: Ribonucleic acid
DNA: Deoxyribonucleic acid	S: significant
ED: Eye diameter	sc: spermatocyte
F: Fecundity	SDL: Second dorsal length
FDL: First dorsal length	SD: standard deviation
FI: Feeding Index	Se: Standard error
FPDL: First pre dorsal length	sg: spermatogonia
GaSI: Gastrosomatic index	SL: Standard length
GSI: Gonadosomatic index	SntL: Snout length
H&E: Haemotoxylin & Eosin	SPDL: Second pre dorsal length
HL: Head length	SS: sum of squares
IOL: Inter orbit length	ssc: secondary spermatocyte
IoP: Index of preponderance	ssg: secondary spermatogonia
K: Pooled Chi-square	st: spermatids
Kn: Relative condition factor	sz: spermatozoa
Lc: Leydig cell	SV: Seminal vesicles
LWR: Length weight relationship	TA: Tunica albuginea
Min: Minimum	TB: Touilidine Blue
Max: Maximum	TL: Total length
MS: Mean square	TW: Total weight
n: number of fish in the sample	Vi: percentage volume index of the food item
Nu: Nucleus	Vo: Vitelline oocyte
Ni: Nucleoli	Ve: Vitelline envelope
NS: Not significant	W: observed weight
Oi: Percentage of occurrence index of the food item	W´: calculated weight
OL: Ovarian length	X^2: Chi-square
OW: Ovarian weight	Zp: Zona pellucida

List of Tables

Chapter 3	**Morphometrics**
Table no.3.1.	Morphometric measurements in male and female *P.ocellatus*
Table no.3.2.	Morphometric measurements in juvenile *P.ocellatus*.
Table no.3.3.	Various morphometric characters as a function of TL in male and female *P.ocellatus*- statistical analysis.
Table no.3.4.	Various morphometric characters as a function of TL in juvenile *P.ocellatus*- statistical analysis.
Table no. 3.5	Various morphometric measurements in male *P.ocellatus*- correlation matrix
Table no. 3.6	Various morphometric measurements in female *P.ocellatus*- correlation matrix
Table no.3.7	Various morphometric measurements in juvenile *P.ocellatus*- correlation matrix
Table no. 3.8	Ontogenic changes in morphometric characters as a function of TL in male *P.ocellatus*
Table no. 3.9	Ontogenic changes in morphometric characters as a function of TL in female *P.ocellatus*
Table no. 3.10	Ontogenic changes in morphometric measurements as a function of total length in juvenile *P.ocellatus*
Table no.3.11	Comparison of regression coefficient of various morphometric characters on TL in male and female *P.ocellatus*.
Table no. 3.12.	Coefficient of correlation between TL and various morphometric measurements in male *P.ocellatus* from different stations.
Table no. 3.13.	Coefficient of correlation between TL and various morphometric measurements in female *P.ocellatus* from different stations.
Chapter 4	**Meristic characters**
Table no. 4.1	Profile of meristic characters in male *P. ocellatus*.
Table no.4.2	Profile of meristic characters in female *P. ocellatus*.
Table no. 4.3	Profile of meristic characters in juvenile *P. ocellatus*.
Table no. 4.4	Variations in meristic chatacters of male *P.ocellatus* from different stations.
Table no.4.5	Variations in meristic chatacters of female *P.ocellatus* from different stations.
Table no.4.6	Comparative data of Meristic characters of *P.ocellatus* by different authors
Table no. 4.7	Comparative study of fin formula of *P.ocellatus* by different authors
Chapter 5	**Length weight Relationship**
Table no.5.1	LWR studies in *P.ocellatus* male, female, and juvenile-statistical analysis.
Table no.5.2	Analysis of Variance (ANOVA) on the regression of the LWR in males of *P.ocellatus*
Table no.5.3	Analysis of Variance (ANOVA) on the regression of the LWR in females of *P.ocellatus*
Table no. 5.4	Analysis of Variance (ANOVA) on the regression of the LWR in juveniles of *P.ocellatus*
Table no.5.5	Comparison of regression lines of males and females of *P.ocellatus* by ANCOVA

Tale no. 5.6	Comparison of regression coefficients of males and females *P.ocellatus* using t- test
Table no. 5.7	Significance of variations in the estimates of regression coefficient value 'b' from 3 using t test
Chapter 6	**Relative condition factor**
Table no. 6.1	Relative condition factor 'Kn' of male, female and juvenile *P. ocellatus* values during different months.
Table no. 6.2	Relative condition factor 'Kn' of male and female *P.ocellatus* values in different length groups.
Chapter 7	**Food and feeding habits**
Table no. 7.1	Average Index of Preponderance of various food items in the gut of *P.ocellatus.*
Table no. 7.2a	Index of preponderance of various food items in the guts of male *P.ocellatus* during different months
Table no. 7.2b	Index of preponderance of various food items in the guts of female *P.ocellatus* during different months
Table no. 7.2c	Index of preponderance of various food items in the guts of juvenile *P.ocellatus* during different months
Table no. 7.3a	Index of preponderance of various food items in the guts of male *P.ocellatus* in different length groups.
Table no. 7.3b	Index of preponderance of various food items in the guts of female *P.ocellatus*in different length groups.
Table no. 7.4a	Feeding index in *P.ocellatus*, maleduring different months
Table no. 7.4b	Feeding index in *P.ocellatus*, femaleduring different months
Table no. 7.4c	Feeding index in*P.ocellatus*, juvenileduring different months
Table no. 7.5a	Feeding index in *P.ocellatus*, male in different length groups
Table no. 7.5b	Feeding index in *P.ocellatus*, female in different length groups
Table no. 7.6a	Gastro somatic index in *P.ocellatus*male, female and juvenile, during different months
Table no. 7.6b	Gastro somatic index in*P.ocellatus* male, female and juvenile *P.ocellatus*, in different length groups.
Table no. 7.7	Monthly variation in general diet composition of *P.ocellatus* male, female and juvenile
Table no. 7.8	Length wise variation in general diet composition of *P.ocellatus*male and female
Chapter 8	**Reproductive biology**
Table no. 8.1	Sex ratio of *P. ocellatus* during different months
Table no.8.2	Sex ratio of *P ocellatus* in different length groups
Table no.8.3a	Maturity stages of testes in *P.ocellatus* male during different months
Table no.8.3b	Maturity stages of ovary in *P.ocellatus* female during different months
Table no.8.4a	Maturity stages of testes *P.ocellatus*male in different length groups
Table no.8.4b	Maturity stages of ovaries of *P.ocellatus*female in different length groups .
Table no. 8.5	Ova diameter in different stages of maturity of *P.ocellatus.*
Table no.8.6a	Gonadosomatic index of *P.ocellatus*during different months
Table no.8.6b	Gonadosomatic index of *P. ocellatus* in different length groups
Table no.8.7	Observed and calculated fecundity in *P.ocellatus*
Chapter 9	**Biochemical composition**

Table no.9.1a	Biochemical composition of muscles in male *P.ocellatus* during different months
Table no.9.1b	Biochemical composition of muscles in female *P.ocellatus* during different months
Table no.9.1c	Biochemical composition of muscles in juvenile *P.ocellatus* during different months
Table no.9.2a	ANOVA on moisture content in the muscles of male and female *P.ocellatus*
Table no.9.2b	ANOVA on protein content in the muscles of male and female *P.ocellatus*
Table no.9.2c	ANOVA on lipid content in the muscles of male and female *P.ocellatus*
Table no.9.2d	ANOVA on carbohydrate content in the muscles of male and female *P.ocellatus*
Tbale no.9.2e	ANOVA on ash from the muscles of male and female *P.ocellatus*
Table no.9.3	Correlation between moisture, protein, carbohydrate and ash of muscles in male, female and juvenile *P.ocellatus*
Table no.9.4	Biochemical composition of muscles in male and female*P.ocellatus* in different length groups
Table no. 9.5	Biochemical composition of muscles in different fishes from creeks of Mumbai**.**
Chapter 10	**Condition Indices from muscles**
Table no.10.1a	RNA, DNA, RNA: DNA, RNA: protein, RNA:lipids from muscles of male *P.ocellatus* during different months
Table no. 10.1b	RNA, DNA, RNA: DNA, RNA: protein, RNA: lipids from muscles of female *P.ocellatus* during different months
Table no. 10.1c	RNA, DNA, RNA: DNA, RNA: protein, RNA: lipids from muscles of juvenile *P.ocellatus* during different months
Table no. 10.2a	RNA, DNA, RNA: DNA, RNA: protein, RNA: lipid from muscles of male *P.ocellatus* in different length groups
Table no. 10.2b	RNA, DNA, RNA: DNA, RNA: protein, RNA: lipid from muscles of female *P.ocellatus* in different length groups
Chapter 11	Summary and Conclusion
Table no.11.1	Monthly variation in maturity stages and GSI of male *P.ocellatus*
Table no.11.2	Length wise variation in maturity stages and GSI of male *P.ocellatus*
Table no.11.3	Monthly variation in RCF, feeding index, GaSI, biochemical composition and condition indices of male *P.ocellatus*
Table no.11.4	Length wise variation in RCF, feeding index, GaSI, biochemical composition and condition indices in male *P.ocellatus*
Table no.11.5	Monthly variation in maturity stages and GSI of female *P.ocellatus*
Table no.11.6	Length wise variation in maturity stages and GSI of female *P.ocellatus*
Table no.11.7	Monthly variation in RCF, feeding index, GaSI, biochemical composition and condition indices of female *P.ocellatus*
Table no.11.8	Length wise variation RCF, feeding index, GaSI, biochemical composition and condition indices in female *P.ocellatus*
Table no.11.9	Monthly variation in RCF, feeding index, GaSI, biochemical composition and condition indices in juvenile *P.ocellatus*

List of Figures

Chapter 1	**General Introduction**
Fig 1.1	Map showing creeks of Mumbai
Chapter 2	**Taxonomy and Syatematics**
Fig 2.1	Classification of Gobiidae (Day 1878)
Fig 2.2	Classification of Gobiidae (Larson and Murdy 2001)
Fig 2.3	Classification of Gobiinae (Larson and Murdy 2001)
Chapter 3	**Morphometrics**
Fig 3.1a to 3.1f	Relationship between various morphometric measurements and total length in male P. *ocellatus.*
Fig 3.2a to 3.2f	Relationship between various morphometric measurements and total length in female*P.ocellatus*.
Fig 3.3a to 3.3f	Relationship between various morphometric measurements and total length in *P.ocellatus*.
Chapter 5	**Length weight Relationship**
Fig 5.1	LWR between total length and total weight in male *P.ocellatus.*
Fig 5.2	LWR between total length and total weight in female *P.ocellatus*.
Fig 5.3	LWR between total length and total weight in juvenile *P.ocellatus*.
Fig 5.4	LWR between total length and total weight in male and female (pooled)*P.ocellatus*.
Fig 5.5	LWR of male, female and pooled*P.ocellatus.*
Chapter 6	**Relative Condition Factor**
Fig 6.1	Relative condition values of male, female and juvenile *P.ocellatus* in different months.
Fig 6.2	Relative condition factor of male and female *P.ocellatus*in different length groups
Fig 6.3	Relative condition factor of juvenile *P.ocellatus*in different length groups.
Chapter 7	**Food and Feeding**
Fig 7.1a	Diet of male *P.ocellatus*, composition of food item in the gut.
Fig 7.1b	Diet of female *P.ocellatus*, composition of food item in the gut.
Fig 7.1c	Diet of juvenile *P.ocellatus*, composition of food item in the gut.
Fig 7.2a	Index of Preponderance of various food items in the gut of male *P.ocellatus* during different months.
Fig 7.2b	Index of Preponderance of various food items in the gut of female *P.ocellatus* during different months.
Fig 7.2c	Index of Preponderance of various food items in the gut of juvenile *P.ocellatus* during different months.
Fig 7.3a	Index of Preponderance of various food items in the guts of male *P.ocellatus* in different length groups.
Fig 7.3a	Index of Preponderance of various food items in the guts of female *P.ocellatus in* different length groups.
Fig 7.4a	Feeding index in male *P.ocellatus* during different months.
Fig 7.4b	Feeding index in female *P.ocellatus* during different months.
Fig 7.4c	Feeding index in juvenile *P.ocellatus* during different months.
Fig 7.5a	Feeding index in male *P.ocellatus* in different length groups

Fig 7.5c	Feeding index in female *P.ocellatus* in different length groups
Fig 7.6	Gastrosomatic index of male, female and juvenile *P.ocellatus* in different months.
Fig 7.7	Gastrosomatic index in male and female *P.ocellatus* of different length groups.
Fig 7.8a	Feeding index of male *P.ocellatus* during different months
Fig 7.8b	Feeding index of female *P.ocellatus* during different months
Fig 7.8c	Feeding index of juvenile *P.ocellatus* during different months
Fig 7.9a	Feeding index of male *P.ocellatus* in different length groups.
Fig 7.9b	Feeding index of female *P.ocellatus* in different length groups.
Chapter 8	**Reproductive biology**
Fig 8.1	Variation in sex ratio of *P.ocellatus*during different months.
Fig 8.2	Variation in Sex ratio of*P. ocellatus* in different length groups
Fig 8.3a	Maturity stages of testes of male *P. ocellatus*during different months expressed as percentage.
Fig 8.3b	Maturity stages of ovariesof female *P.ocellatus*during different monthsexpressed as percentage
Fig 8.4a	Maturity stages of testes of male *P.ocellatus* in different length groups expressed as percentage.
Fig 8.4b	Maturity stages of ovaries of female *P.ocellatus* in different length groups expressed as percentage.
Fig 8.5a	Minimum size at which fifty percent of population attain maturity in male *P.ocellatus*
Fig8.5b	Minimum size atwhich fifty percent of population attain maturity in female *P.ocellatus*
Fig 8.6	Ova diameter frequency polygon of female *P.ocellatus* in different stages of maturity..
Fig 8.7	Ova diameter frequency polygon of female *P.ocellatus* during different months.
Fig 8.8a	Variations in gonadosomatic index of male *P.ocellatus* during different months.
Fig 8.8b	Variations in gonadosomatic index of female *P.ocellatus* during different months.
Fig 8.9a	Variations in gonadosomatic index of male P.ocellatus in different length groups.
Fig 8.9b	Variations in gonadosomatic index of female P.ocellatus in different length groups.
Fig 8.10a	Fecundity in relation to total length in *P.ocellatus*
Fig8.10b	Fecundity in relation to total weight of *P.ocellatus*
Fig 8.10c	Fecundity in relation to ovarian weight of *P.ocellatus*
Fig 8.10d	Fecundity in relation to ovarian length in *P.ocellatus*.
Chapter 9	**Biochemical Composition of muscles**
Fig 9.1a	Variations in moisture content in the muscles of male, female and juvenile *P.ocellatus*during different months.
Fig 9.1b	Variations in protein content in the muscles of male, female and juvenile *P.ocellatus* during different months.
Fig 9.1c	Variations in lipid contentin the muscles of male, female and juvenile *P.ocellatus* during different months.

Fig 9.1d	Variations in carbohydrate contentin the muscles of male, female and juvenile *P.ocellatus* during different months.
Fig 9.1e	Variations in ash content from incinerated muscles of male, female and juvenile *P.ocellatus* during different months.
Fig 9.2a	Variations in the percentage composition of moisture in the muscles of male and female *P.ocellatus in* different length groups.
Fig 9.2b	Variations in proteincontent in the muscles of male and female *P.ocellatus in* different length groups.
Fig 9.2c	Variations in lipid content in the muscles of male and female *P.ocellatus in* different length groups.
Fig 9.2d	Variations in carbohydrate content in the muscles of male and female *P.ocellatus in* different length groups.
Fig 9.2e	Variations in ash content from incinerated muscles of male and female *P.ocellatus in* different length groups.
Chapter 10	**Condition Indices from muscles**
Fig10.1a	Variations in RNA content from the muscles of*P.ocellatus*male, female and juvenile during different months.
Fig 10.1b	Variations in DNA content from the muscles of*P.ocellatus* male, female and juvenile during different months.
Fig 10.1c	Variations in RNA: DNA ratio from the muscles of*P.ocellatus* male, female and juvenile during different months.
Fig10.1d	Variations in RNA: protein ratio from the muscles of*P.ocellatus* male, female and juvenile during different months
Fig10.1e	Variations in RNA content from the muscles of*P.ocellatus* male, female and juvenile during different months
Fig 10.2a	Variations in DNA content from the muscles of*P.ocellatus* male and female in different length groups
Fig 10.2b	Variations in RNA: DNA ratio from the muscles of male, female *P.ocellatus*in different length groups
Fig 10.2c	Variations in RNA: DNA ratio from the muscles of male, female *P.ocellatus*in different length groups.
Fig 10.2d	Variations in RNA: protein ratio from the muscles of male, female *P.ocellatus*in different length groups.
Fig 10.2e	Variations in RNA: lipid ratio from the muscles of male, female *P.ocellatus*in different length groups.

List of Plates

Plate 1.1	Station I: Vasai creek
Plate 1.2	Station II: Malad creek
Plate 1.3	Station III: Thane creek
Plate 1.4	Station IV: Mahul creek
Plate 2.1	*Parachaeturichthys ocellatus*
Plate 2.2	*Parachaeturichthys ocellatus (ventral view)*
Plate 3.1	Morphometric character of *P.ocellatus*
Plate 8.1	Male and female *P.ocellatus*
Plate 8.2	Male and female *P.ocellatus*(ventral view)
Plate 8.3	Male *P.ocellatus,*Testes in different stages maturity
Plate 8.4	Male *P.ocellatus,*Testes in situ
Plate 8.5a,b&c	Male *P.ocellatus,* C.S of testisshowingstage I, Immature stage,
Plate 8.6 a, b, c	Male *P.ocellatus,*C.S of testis showing stage II, Developing stage
Plate 8.7 a, b ,c	Male *P.ocellatus,*C.S of testis showing stage III Mature stage
Plate 8.8a, b, c & d	Male *P.ocellatus,*C.S of testis showing stage IV Ripe stage
Plate 8.9a, b	Male *P.ocellatus,*C.S of testis showing stage V Spent stage
Plate 8.10	Female *P.ocellatus,* ovariesin different stages of maturity
Plate 8.11	Female *P.ocellatus,*mature ovaries in situ.
Plate 8.12a,b	Female *P.ocellatus,* C.S of ovary showing stage I, Immature stage
Plate 8.13a,b&c	Female *P.ocellatus,* C.S of ovary showing stage II, Developing stage
Plate 8.14 a,b,c&d	Female *P.ocellatus,* C.S of ovary showing stage III, Mature stage
Plate 8.15a,d,c&d	Female *P.ocellatus,* C.S of ovary showing stage IV, Ripe stage
Plate 8.16a, b &c	Female *P.ocellatus,* C.S of ovary showing stage V, Spent stage

Chapter 1

General Introduction

1.1 Introduction

1.2 Aims and objectives

1.3 Review of Literature

1.4 General organization of thesis

1.1 Introduction

The coast of Maharashtra harbours a significant diversity of natural resources. It stretches about 720 km from the river Tapi in the north up to the river Terekhol in the south and encompasses six districts viz Thane, Greater Mumbai, Mumbai, Raigad, Ratnagiri and Sindhudurg. The coastal zone of Maharashtra extends between latitude of 15º43´to 20º10´N and longitude between 72º39´E to 73º30´E. The coastline is indented by numerous river mouths, creeks, small bays, headlands, sandy and rocky beaches, promontories, cliffs etc. The coast is indented with number of beaches, 15 rivers, 5 major estuaries and over 30 backwater regions. The coastal belt of Maharashtra experiences tropical warm, humid and maritime climate throughout the year. The average atmospheric temperature varies from 25-36º C with the average humidity ranging between 60-90%. During monsoon the rainfall ranges between 2286-2540mm.The coastal belts are very rich with 58 creeks along the coast. These creeks are rich sources for large number of flora and fauna(Shindikar,http://mangrovecell.org/attachments/conservationof_mangroves_ maharashtra 15/10/2012).

Mumbai lies on the western coast of Maharashtra on the bank of Arabian Sea and is formed from group of seven islands called Salsette islands. Towards the north of Mumbai, the coast is wide up to 100 km which gradually decreases towards Vengurla in south to about 40 km. The city of Mumbai is situated at the mouth of river Ulhas off western coast in the Konkan region of India which is just south of the Tropic of Cancer. It is located at 0º altitude at sea level. Three fourth part of Mumbai is above the sea level and its elevation is approximately 10-15 meters. Its northern

part is hilly and the highest point is about 1450 ft high. Mumbai is located at 18.96º North latitude and 72.82º East longitude. It spans over 437.77 sq km in area. Mumbai has a warm and humid climate throughout the year and the average temperature varies between 25ºC and 35ºC. According to the influence of the southwest monsoon and other associated meteorological conditions the year is split into three well defined periods with characteristic hydrographic conditions- monsoon (June-September), post-monsoon (October-January) and pre-monsoon (February-May). The annual rainfall is 2500 mm which keeps on fluctuating year after year (http://www.mumbai.org.uk/geographical.locat. 20/7/2013).

Thane is located to the northeast of Mumbai, partly on Salsette island which it share with Mumbai city and partly on the mainland across Thane creek (http:/en.wikipedia.org/wiki/thane. 20/7/2013). The coastline of Mumbai and Thane is inundated by bays and creeks. In Mumbai and Thane mangroves are dominant along the tidal estuaries and creeks. Estuaries are highly productive ecosystems that sustain valuable biological and economic resources (Costanza, *et al* 1997; McLusky and Elliot, 2004). These transitional environment support fundamental ecological links between fresh water and marine environments with a diverse fish assemblage of resident, occasional, early life stage and migratory organisms (Beck *et al.,* 2001; Able, 2005; Franco *et al.,* 2008). Estuaries provide various habitats for feeding, refuge from predators, nursery areas, reproduction and migration routes for species that are resilient to the highly dynamic environment (Haedrich, 1983; McLusky and Elliot, 2004; Elliot *et al.,* 2007). Estuarine systems are characterized by highly dynamic environmental conditions such as varying water temperature, salinity and dissolved oxygen concentration, chiefly due to the influence of tidal regimes, freshwater input and sea water intrusion. The tides in the estuarine areas of Mumbai and Thane are semidiurnal characteristically having two high tides and two low tides per day in the creek with maximum movement of water during the spring tide every fortnight. Along the coastal Mumbai a wide spread mangrove forest can be seen along Vasai, Thane, Manori, Malad, Mahim, Bandra, Versova, Sewri and Mumbra-Diva. Mangrove forests and their waterways are important in supporting many species of fishes. The north-south coastline along the mainland has small inlets of creeks. Mumbai and Thane have around 15 estuaries and creeks. These creeks have defined catchment area with limited supply of freshwater

and silt forms the major component of the sediment. The creeks of Mumbai and Thane include Colaba, Mahim, Bandra, Danda, Thane, Madh, Malad, Vasai, Mahul, Sewri, Panvel and Dharamtar. The common fishes observed in the creeks include *Mystis gulio, Arius spp, Therapon jarbua, Therapon theraps, Meglops cyprinoids, Lates calcarifer, Mugil spp, Elops saurus, Sciaena spp, Chrysophyrs datnia, Tilapia spp, Equula fasciata, Eleotridae spp,* Mudskippers like *Boleopthalmus dussumeiri, Boleophthalmus boddaerti,* gobies like *Glossogobius guiris, Parachaeturichthys ocellatus, Parachaeturichthys polynema, Gobius criniger, Acentrogobius neilli, Awaous stamineus, and Trypauchen vagina etc.* By any measure, fishes are among the world's most important natural resources (Sebastian, 2011). Additionally, with over 25,000 known species, the biodiversity and ecological roles of fishes are being increasingly recognized in aquatic conservation, ecosystem management, restoration and aquatic environmental regulation (Ormerod, 2003)

The Gobiidae is the largest family of marine fishes and comprises more than 220 genera and 1500 species in the Western central pacific (Murdy and Hoese, 2004) and around 1875 around the world (Jonna, 2004). Gobies represent 100 genera and approximately 500 species. They inhabit shallow tropical and subtropical waters and have invaded all benthic habitats from freshwater to the shoreline depths exceeding 500m (Murdy and Hoese, 2004). The gobioid fishes are distributed throughout the temperate and tropical zones of the world (Weber and De Beaufort, 1953). They occur in fresh to saline waters of the world and in all types of aquatic habitats. Most inhabit coastal marine environments, where they occupy relatively specialized niches but a number of species enter or live primarily in estuaries or freshwater rivers and streams (Nelson, 1976; Berra, 1981). Gobiids are one of the most abundant groups of species in marsh edge habitats and presumably play important role in the ecology of coastal environment (Baltz *et al.,* 1993, Hendon *et al.,* 2000). Some of them spend their lives in freshwater, others migrate back and forth between fresh water and brackish water environments or between marine and brackish waters (Larson and Murdy, 2001).

'Gobi' or 'goby' is a Latin word which means a fish of small value, gudgeon and from Greek word 'Kobios' (http://www.fishbase.org 20/7/2013). Gobiid fishes dwell on a variety of substrata from mud to rubble and coral reefs. Some gobies associate with

other organisms such as shrimps, sponges, soft corals and other fishes. Most are flat-bottomed often sheltering in rock or coral or burrows in sand and live on the substrate (Berra, 1981; Moyle, 1993). Some gobies are catadramous species and lead a symbiotic relationship with shrimps and sponges (Nelson, 1976). The smallest gobies are *Paudaka pygmaea* from Japan and some species of genus Mistichthys which mature at 6mm and reach a length of 12mm (Nelson, 1976). Two of the largest gobies are *Gobioides broussentii* from the Caribbean Sea and *Glossogobius giuris* from Indo-Pacific Ocean reaching 50cm in length (Jordhan, 1905).

Gobies are typically small but distinctive, elongated with a slender body, thick lips distended cheeks characterized by bulging eyes with two dorsal fins, one spiny and other soft. Their pectoral fins placed anteriorly which are fused to form a sucker or grasping organ. The most distinctive gobiid character is the fusion of the ventral fins into a pelvic sucker forming sucking disc which is capable of maintaining the fish's position against water currents and wave action (Murdy and Hoese, 2004). Colouration in gobies is vivid, those in reef are brilliantly neon coloured to where as estuarine species are usually drab while some are pallid or translucent. The scales in gobies may be cycloid or ctenoid or totally absent, lateral line may also be absent (Nelson, 1994; Berra, 2001). Female gobies lay a small mass of eggs attached by an adhesive stalk to the underside of dead shells, rocks or corals whereas the eggs are guarded and tended by male (Thresher, 1984). In most gobies eggs hatch in a period of about one to five days and grow rapidly within few days (Hoese, 1998).

Although small, gobies are of considerable importance ecologically and commercially. They can be very abundant at certain localities, where they form an important component of the food web (De Sylva, 1975). Skazkina and Kostyuchenko (1968) reported that *Neogobius melanostomus* consumes up to 13 percent of the total benthos production of the Sea of Azov each year. Kovtun (1976) found that *Pomatoschistus microps* is an important food competitor of the anchovy in the Sea of Azov and may determine the strength of anchovy year-classes. Petersen (1917) observed that gobies are among the most common fishes of Denmark and play an extremely important role in the nourishment of larger fishes. Blegvad (1917) supported the claim with a report of gobies from the guts of several

important Danish food fishes. Dawson (1966) found that at least ten species of fishes and one species of bird prey on Gobiosoma species in eastern North America, though the importance of these gobies as forage for food and sport fishes is underestimated.

Several species of gobies are fished commercially for food, especially in the Far East. The black goby, *Gobius niger Linneaus*, is fished commercially (Fabi and Froglia, 1984). Goby fishes are considered as delicacy and precious food in some countries like Italy, India, Burma, Nepal and France (Joadder, 2009). Western Europe and Japan have been the main areas where there is high demand for goby (Pillay, 1990). At least six species of freshwater gobies contribute to the goby fry fishery in the Philippines (Smith, 1901; Manacop, 1953; Dotu and Mito, 1955a; Marquez, 1968). Fry of the goby *Sicydium plumieri* are fished in Puerto Rico (Erdman, 1961). Adult goby *Acanthogobius flavimanus* are considered delicacies in Japan (Miyazaki, 1940). The majority of goby fishes, being small constitute a small fishery in Bangladesh but *Glossogobius giuris* which attains a length of about one foot forms a fishery of some magnitude in southern part of Bangladesh (Islam, 2004). *Oxyeleotris marmoratus* commonly called 'Marble gobies' are highly prized nutritionally by Asian consumers as they are lean, boneless and their firm white flesh has no off-flavour taste (Sompong, 1980). These gobies are considered a species of high economic value and fetch the highest price of any edible fresh water fish (Bundit, 2007).

Gobies are popular aquarium fishes often due to their bright colours, interesting behaviour and general hardiness, with many species appearing in the commercial aquarium trade. Most common species sold are the neon gobies, *Gobiosoma oceanops* from Florida coral reefs. *Gillichthys mirabilis* is the basis for a live-bait fishery in southern California and Mexico (Fitch and Lavenberg, 1975). A number of gobies have been successfully bred in captivity and some are popular in the aquarium trade (Allen and Robertson, 1994; Hoese, 1998).

In India about 150 species of gobiids have been reported by Day (1876), Jones and Kumaran (1980) and Murty (2002). Many species of gobies from coasts of India has been reported by various authors like Glossogobius minutus from South west

coast of India (Geevarghese and John, 1983), *Oxyurichthys paulae* from South western India (Pezold, 1998), eel goby *Odontamblyopus spp* from Indo West Pacific region (Murdy and Shibukawa, 2001), *Boleophthalmus dussumieri, Periophthalmus barbarous, P.waltoni, P.septemradiatius, Scartelaos tenius* from Gujarat coast by (Barman *et al*., 2000) *Trypauchen vagina* from Tranquebar, India (Murdy, 2006), *Stenogobius gymnopomus* from southern Kerala (Lekshmi *et al.,* 2010), *Apocruptes bato and Scatelaos histophorus* from Gujarat coast (Vachhrajani *et al.,*2014).

Closer home twenty one species of gobiidae were reported from different creeks of Mumbai by Mutsaddi and Bal (1973) including *Boleophthalmus dussumeiri* (Mutsaddi, 1964), *Boleophthalmus detatus* (Shettu, 1993), *Boleophtalmus boddaerti* (Gore, 2007) and *Parachaeturichthys ocellatus* (Day, 1878). Mutsaddi and Bal (1973) reported that *Parachaeturichthys ocellatus* occurs in the muddy creeks of Colaba, Worli, Mahim, Danda, Madh, Mahul, and Thane. *P.ocellatus* forms a part of fishery along Mumbai and Ratnagiri coast (The Gazetteers Dept of Ratnagiri 1962 and Kolaba, 1964). It was identified by Day (1873). It inhabits demersal marine environment in deep waters (www.fishbase.org.20/7/2014). A brief description of the species is available in The Fishes of India (Day, 1878), Gobiidae (Larson and Murdy, 2001) and Catalogue of Fishes (Eschmeyer, 2003).

Though in terms of value, goby fishes cannot compete with commercial fishes along the Mumbai coast, during monsoon which is a lean period for commercial fisheries; goby fishes do fetch a good price. The local communities residing in the vicinity of the creeks rely on the creek fisheries for their nutritional requirement. Fishing of gobiid fishes is carried by Dol net, Bokshi net, seines and traps operated by small boats. The gobiid fishes are sold in the local markets of Vasai, Malad, Thane and Mahul creek.

A survey undertaken by the candidate revealed that *Parachaeturichthys ocellatus* was sold in the market in a local measure 'Vata' which consists of 6-8 fishes depending on the size. The cost of *P.ocellatus* is in the price range of Rs 100-200 per vata. Large sized fish fetch still higher price. Juveniles are sold at a very cheaper rate of Rs 40-60 per vata. In some markets of Thane mudskippers are sold as 'Kodi' which consists of 22 pieces with a price range of Rs 100-150 irrespective of size

and depending on availability of fishes (Rathod, 2005). The *P.ocellatus* is very much relished by the poor as well as rich due to high nutritious value. The small sizes ones are usually eaten whole along with their bones which are very soft. It is prepared by boiling along with tomatoes and tamarind along with spices. It is also often cooked with mudskippers and prawns by the local people and often served as soups to small children, recuperating patients and elderly people. It has a very soft flesh with a sweet taste similar to prawns and crabs.

Along the Mumbai creeks during monsoon due to heavy rainfall, sea and riverine discharge, large number of gobiid fishes enter in the creek. A pilot survey was carried out by the candidate on *Parachaeturichthys ocellatus*. During the present study *P.ocellatus* was found a plenty along with other gobiids during monsoon. The size group of *P.ocellatus* in the catch was highly variable. The post monsoon period from late December to mid March has stable environmental conditions and has increasing benthic population (Parulekar *et al.,* 1980). *P.ocellatus* obtained during this period were uniformly bigger in size and were found to be reproductively mature. Juveniles were obtained in large numbers in the catch from June to January. Rathod (2005) has recorded similar observations in *Boleophthalmus dussumieri*.

The biology of fish has been the subject of vast study for many decades. In recent years, 4000-5000 original research papers have been published annually in over 400 journals covering all aspects of fish biology (Cvancara, 1992). Knowledge of fish biology, and the principal factors which determine growth and body composition, is important when considering the role of fish as a source of nutrition (Sebastian, 2011). So far no study on the biology of *Parachaeturichthys ocellatus* has been reported in the literature survey carried out by the candidate. The fact that not much data about the biology of the fish or its fishery was available has provided an impetus to select *P.ocellatus* for the present study which reflects on various aspects of fish biology. Thus some of the aspects of biology which the present study elucidates are: Taxonomy and Systematics, Morphometric and meristic characters, Length weight relationship and Relative condition factor, Food and feeding habits and Reproductive biology.

Taxonomy and Systematics forms the very fundamental of all research in the biology of any species. Taxonomic documentation is only first step in understanding biodiversity without which other research is impossible (Sebastian, 2011). Systematics gives an understanding of the evolutionary history of a species and its diversity and relationship with other species. Morphometric characters are useful in identification of a fish species and for detecting variations in the fish population. It also reflects the proportionate growth of different body parts. Meristics characters are useful to detect the variations among the population of fish and whether the variations exhibit any significance to be grouped as a separate population. Length weight relationship is useful to explore any deviation from the established length weight relationship as a measure of effect of ecological factors like disease, food scarcity as an indicator of stress due to exposure to pollutants. The length weight relationship is used as basic parameter for monitoring study of fisheries since it provides important information concerning the structure and function of populations (Anderson and Neumann, 1996). The relative condition factor 'Kn' (LeCren, 1951) reflects the state of well being of the fish. It varies according to physiological factors and stages of development of fish. Food and feeding habits of the fish are of great importance to understand the niche, behavioural patterns, life history and growth of the fish as well as in management of commercially important fisheries (Bal and Rao, 1984). The study of reproduction involves various aspects such as sexual dimorphism, sex ratio, maturation, spawning season, spawning frequency, fecundity and gonad morphology and histology. This knowledge is useful in successful management of fishery and in protecting the unduly vulnerable species.

Fish is a rich source of protein with composition of amino acid which is well suited to human dietary requirements, comparing favourably with egg, milk and meat in the nutritional value of its protein (Waterman, 1976). The biochemical constituent of any species of fish is essential to evaluate its quality in terms of nutrition and energy. Macromolecular indices like RNA concentration, RNA : DNA ratios, RNA : Protein ratios and Protein: DNA ratios are frequently measured as indicators of protein synthesis potential and growth in marine fishes and invertebrates (Bulow, 1970; Carter *et al.,* 1998; Buckely *et al.,* 1999). These indices are particularly useful for evaluating environmental conditions as they reflect on differences in growth rates over a period of several days (Rooker and Holt, 1996; Buckley *et al.,* 1999; Vrede

et al., 2002). The nucleic acids study provide useful tool for assessing the instantaneous growth rate and condition of fish (Fukuda *et al.,* 2001).

Nature of habitat

Gobies are extremely successful in their ability to exploit habitats inaccessible to other fishes. Hoese (1998) and Moyle and Cech (2000) have reported that gobies are found in subarctic streams to mountain streams at altitudes of 2000 m on islands to ocean depths of 800m. The authors further reported that they occur in coral reefs, tide pools, mudflats mangrove swamps, holes along sandy beaches, estuaries, inland seas and continental shelf. The creeks of Mumbai like Vasai, Malad, Thane and Mahul are fringed by mangrove forest on one side and by river and sea on other sides. These creeks are regularly inundated by tides and divided into three zones namely upper intertidal zone, middle intertidal mudflat and lower sub tidal zone. The goby fishes are found mostly in the lower sub tidal zone which is always submerged under water and middle intertidal mudflat which gets submerged only during high tides. The tidal water brings in many phytoplankton, zooplankton, variety of fishes and crustaceans. The creeks have their own phytoplankton, zooplankton nematodes, oligochaetes, polycheates, mollusks and arthropods. *P.ocellatus* was found in plenty towards the seaward end of the Thane creek and Ulhas river estuary (Rathod *et al.,* 2002). During the present study *Parachaeturichthys ocellatus* was obtained from the local fishermen who fished it from the lower sub tidal and middle intertidal mudflats during high tides in the creeks of Vasai, Malad, Thane and Mahul.

Geographical distribution of *P.ocellatus*

Parachaeturichthys ocellatus is native to Western Indian Ocean and Western Central Pacific ocean at 30º E - 80º E and 45º S - 30º N. According to Global Biodiversity Information Facility (http://www.discoverlife.org) location of *Parachaeturichthys ocellatus* was recorded 50 km southwest of Karachi in salt flats, 400m North west of Bonbhoe excavation site in Sind provice, south of Karachi, 6-8 km of Hajambo creek and Turshian creek and 15-18 km east of Korangi creek of Pakistan (Swift *et al.,* 1979). Closer home its occurrence was recorded by Day in 1875 from Mumbai coast between longitude18.93º and latitude 72.85º.

Figure 1.1 Map showing creeks of Mumbai

The present study on *P.ocellatus* deals with some aspects of biology of the fish.

1.2 Aims and Objectives

The aims and objectives of the present study on *Parachaeturichthys ocellatus* from four different creeks of Mumbai namely: Vasai, Malad, Thane and Mahul creek are as follows:

1) To study the taxonomy and systematic position of the fish with its historical account and salient features of the order, family, genus and species.
2) To study 19 different morphometric characters of the fish of different sizes and the relationship of those characters with one another.
3) To study meristic characters like the number of fin rays and spines in dorsal, anal, pectoral, pelvic, caudal fin, longitudinal scales, transverse scales, gill rakers and vertebrae.
4) To determine length weight relationship in the fish separately for males, females and juveniles.
5) To assess the relative condition factor 'Kn' which is the ratio of observed weight and calculated weight separately for each sex and to calculate the fluctuations in the condition factor in different months.
6) To study food and feeding habits of the fish by analyzing the gut content to ascertain the food composition, to determine degree of preference and feeding status of fish in different months.
7) To study the reproductive biology of the fish with respect to different parameters like sexual dimorphism, sex ratio, spawning periodicity, gonadosomatic index, fecundity; morphology and histology of gonads.
8) To elucidate nutritional status and edible value of *P.ocellatus* by estimating its proximal composition and its analysis with reference to length, sex and energy value, and to compare these parameters with those of few other fishes from the selected creeks.
9) To determine nucleic acid derived condition indices like content of RNA, DNA, ratio of contents of RNA/DNA, RNA/protein and RNA/lipid in male, female and juvenile fishes during various seasons to establish their relation to growth and nutritional conditions.

The creeks of Mumbai where the present study of *P.ocellatus* was under taken are as follows:

Station I: Vasai creek

Vasai creek is an estuarine creek, one of the two main distributaries of the Ulhas River in Western coast. It lies between 18º 45´ to 19º 20´ N & 72º 42´ to 73º 20´E. The Ulhas River splits at the north east corner of Salsette Island into main distributaries, Vasai creek and Thane creek. Vasai creek forms the northern boundary of Salsette Island and empties west into the Arabian Sea. The fishes observed in Vasai creeks during the present study along with *Parachaeturichthys ocellatus* were *Lates calcarifer, Mystis spp, Arius spp, Therapon sps,* perches, snake head fishes, mugils, and gobies like *Boleoptthalmus dussumeiri, Boleoptthalmus boddaerti and Glossogobius guiris* to name a few.

Plate 1.1: Station I, Vasai creek

Station II: Malad creek

The estuarine creek of Malad is about 5km in length with Madh island onits west and versova on its east. It occurs between longitude 72º8´ E to 72º48´E and latitude 19º8´ N to 19º 13´ N. The river Oshiwara River drains into it. Earlier it was surrounded by a 1000 acre area of mangroves, but now it has shrunk to 400 acres (Menzes, 2005) The fishes of Malad creek observed along with *P.ocellatus* during the present study were mugils, catfishes, puffer fishes, *Tilapia spp*, guppy, snake head fishes, barbs, eel, pipe fish, ribbon fish, anchovies, mudskippers like

Boleophthalmus dussumeiri, gobies like *Glossogobius guiris, Parachaeturichthys polynema, Gobius criniger, Awous spp, Trypauchen vagina* etc.

Plate no. 1.2 Station II, Malad creek

Station III: Thane creek

The estuarine creek of Thane which is situated on the central west coast of India occurs between longitude 72º2´E to 73º55´E and latitude 19º to 19 º 15´N. Thane creeks is part of the estuary of the Ulhas river opening into Mumbai harbour. It comprises of 26 km from Trombay till Thane stretching from Mumbra Retibunder to the Mankhurd-Vashi Bridge. Rathod *et al.* (2002) observed the following fin fishes in the creeks of Thane like Stromatidae, Scombridae, Carangidae, Sclerodermi, Squamipinnes, Scopelidae, Muraenidae, Pleuronectidae, Polynemidae, Gymnodontes, Sciaenidae, Cyprinadae, Siluridae, Cichlidae, Percidae, Batrachidae, Mugiladae, Cyprinodontidae, Sparidae, Chromidae, Clupidae, Trachinidae and Gobiidae. Along with *P.ocellatus* other goby fishes observed in Thane creek were *Boleophthalmus dussumieri, Boleophthalmus boddaerti, Glossogobius giuris, Parachaeturichthys ocellatus, Parachaeturichthys polynema* etc.

Plate 1.3: Station III, Thane creek

Station IV: Mahul creek

The estuarine creek of Mahul is on the east coast of Mumbai along the Arabian Sea and is situated in Chembur suburb and 17 km from Sasson dock. It occurs between latitude 19º13´ to 19º 14´N & longitude 72º 46´ to 72º53´E. It is surrounded by mangrove forest. Bordering the Mahul creek on its west is the village of Anik, with saltpans and lands flooded by the sea during high tides. These swamps are populated by migratory birds. The wetlands also act as sponges absorbing excessive surface runoffs during the rainy season. Fishes of Mahul creek along with *P.ocellatus* included *Megalops spp, Guppy poecilia,* catfish *Clarius spp, Tilapia oreochronis Tilapia mossambicus,* mullet *Mugil cephalus*, mudskippers like *Boleophthalmus boddarti, Boleophthalmus dussumieri* and gobies like *Glossogobius guiris, Parachaeturichthys polynema* etc.

Plate 1.4: Station IV, Mahul creek

1.3 Review of Literature

Extensive studies on gobioid fishes are available from many regions of world. Code goby Gobiosoma robustum in the Tampa bay Florida was studied by Springer and Mcerlean (1961). Miller (1961, 1969) also studied aspects of the life histories of *Gobius pagnellus* (Linnaeus) and *Gobius ephippiatus* (Lowe). Jones and Miller (1966) gave an account of the migration activities of *Pomatoschistus microps* (Kroyer). Healey (1971) studied the population dynamics of *Gobius minutus Linnaeus* and the age structure and life-span of the same was examined by Miller(1975). In estuarine gobies the lunar cycle is thought to play a role in spawning behaviour as well as larval recruitment. (Hoese,1998; Thresher,1984). Torricelli *et al.* (1985) studied the acoustic displays of the freshwater goby, *Padogobius martensi*. Nellbring (1986) carried out a quantitative investigation of the spawning activities of the sand goby, *Pomatoschistus minutus*, and the common goby, *Pomatochistus microp*.

Numerous studies on abundance, distribution, biology, growth, ecology and behaviour of gobies are reported from different regions of the world. Oriental goby *Acanthogobius flavimanus* in New South Wales (Bell *et al.,* 1987); Tubenose goby *Proterorhinus marmoratus* in Lake Basin (Jude *et al.,* 1992); *Lubricogobius exigus*

from Taiwan (Cheng and Fang, 1997); *Neogobius malanostomus* in the upper Detroit river (Macinnis and Corkum, 2000); *Crystallogobius linearis* from the Adriatic sea (La Mesa, 2001); *Parioglossus species* from western Pacific and Indian oceans (Wang, 2001); genus Pseudogobius from Indo-West Pacific region (Larson, 2001); coral reef goby, *Asterropteryx semipunctatain* Kaneohe Bay, Hawaii (Privitera, 2002); Neotropical gobies *Elacatinus gemmatus, Elacatinus palleus, Elacatinus dileps* (Taylor and Tasseli, 2002); *Knipowitschia longicaudata* from Lake Manya Turkey(Turan *et al.,* 2005); *Papulogobius uniporus* from northeastern Laos (Chen and Kottelat, 2003); fresh water gobi *Glossogobius guiris* of the river Padma (Islam, 2004); *Eviota hoesei* and *Eviota readerae* from Southwest Pacific (Gill and Jewett, 2004); sex changing marine goby *Coryphopterus personatus* from atoll-fringing reef in Belize (Allsop and West, 2004); cleaner goby *Gobiosoma evelynae* (Olivotto *et al.,* 2005); *Vanderhorstia bella* from Fijii (Greenfield and Longnecker, 2005); *Neogobius melanostomus* as alien invasive species from north European and Baltic sea (Sapota, 2006);three Butis species in a mangrove estuary southern Thailand (Yokoo *et al.,* 2006); shrimp goby *Vanderhorstia opercularis* from northern red sea (Randall, 2007); sicydiine goby *Sicyopterus lagocephalus* (Smith and Spark, 2007); gobies of genus Rhinogobius in Central Asia and Kazakhstan(Vasil'ev and Kuga, 2007); a new species of Lubrigobius from Nha Trang Bay, Vietnam (Prokofiev, 2007); *Neogobius fluviatilis, Neogobius gymnotrachelus, Neogobius melanostomus and Proterorhinus marmoratus* in Yantra river Bulgaria (Vassilev *et al.,* 2008); a cleaner goby *Elacatinus phthirophagus* from southwestern Atlantic (Sazima *et al.,* 2008); fresh water goby *Gobius nigricans* in Mediterranean stream (Sealici and Gibertini, 2009); chameleon goby *Tridentiger trigonocephalus* from Mediterranean sea (Goren *et al.,* 2009); bumble bee goby *Brachygobius mekongensis* from Mekong basin Central Laos (Marioka and Sano, 2009) and burrowing goby *Trypauchen vagina* in the north-eastern Mediterranean sea (Akamca *et al.,* 2011). A new species of goby Obliquogobius from Ryukyu Islands Japan was described based on its morphometric and meristic characters by Chen *et al.* (2012). A new species of mudskipper *Boleophthalmus poti* was described from Gulf of Papua New Guinea by Polgar *et al*. (2013).

Studies on Indian gobioid fishes are very few and those available are restricted mostly to few species of mudskippers and large size goby *Glossogobius giuris*.

Fowler (1929) carried out the study on gobiids from Bombay waters. The taxonomic description of the various species of gobies from different habitats of India has been provided by Day (1889) Annandale (1919), Hora (1924,1934,1935,1936,1940,1941) Koumans (1942, 1953) Pillai (1929), Panikkar (1937) and Mutsaddi and Bal (1973). Rao (1939) studied burrowing habits of a gobiid fish of genus Taenioides from Andamans. Pillay and Sarojini (1950) elucidated the larval development of the Indian transparent goby *Gobiopterus chuno*. Silas (1952) published notes on the bionomics of red goby *Trypauchen vagina*. Koumans (1941, 1953) has done excellent work on the gobioids of India and Pacific.

The *Glossogobius giuris* (Hamilton) is widely distributed in the freshwater and estuaries of Bangladesh, India, Pakistan, Burma and Far East (Bhuiyan, 1964; Srivastava, 1968). Tandon (1962) studied the feeding biology of the *G.giuris* in the river Ganga. Geevarghese (1976) carried out a detailed study of *G.giuris* from Lake Veli, Kerala, India. *Glossogobius mintus* and a new goby *Ctenogobius veliensis* from the south western coast of India (Geevarghese and John, 1983), *Oxyurichthys paulae* from South western India (Pezold, 1998), eel goby *Odontamblyopus spp* from IndoWest Pacific region (Murdy and Shibukawa, 2000), gobiid fish *Trypauchen vagina* from Tranquebar, India (Murdy, 2006), *Stenogobius gymnopomus* from southern Kerala (Lekshmi *et al.,* 2010).

P.ocellatus was recorded by Murty (1969) in Catalogue of fishes as a specimen recorded from Mumbai coast. Mutsaddi and Bal (1973) recorded it from the muddy creeks of Colaba, Worli, Mahim, Danda, Madh, Mahul and Thane. Karbhari (1982) has recorded *P.ocellatus* in his list of marine fishes from Maharashtra and Gujarat coast. *P.ocellatus* was collected from Madras coast by as reported by Venkateswarlu and Ramarao, 1986. It was recorded from Ketibunder in Pakistan (DEA report, 2008) during winter. It has been photographed and published in fish base by Khan (2007, 2011) (http://www.fishbase.org 20/7/2013).

1.4 Genaral organization of the Thesis

The thesis is organized into twelve chapters:

First chapter comprises introduction, aims and objectives, Literature review and brief note on general organization of thesis.

Second chapter describes history of gobioid classification with details of family and genera by Day (1878), key to subfamilies and genera proposed by Larson and Murdy (2001), followed by systematic position, local name, unambiguous synonym and valid name of *P.ocellatus*. The chapter concludes with morphology of *P.ocellatus*.

The **third** chapter gives a brief account of various morphometric characters of *P.ocellatus* and the relationship of these characters with one another.
The study of meristic characters of *P.ocellatus* is reflected in the **fourth** chapter. It also gives a comparison of meristic counts by various researchers.

The **fifth** chapter gives a detailed account of length weight relationship in male, female and juvenile *P.ocellatus*.
The relative condition factor 'Kn' in male, female and juvenile in different months is exhibited in chapter **sixth**. It also gives the relative condition value in adult fishes of different length groups.

The **seventh** chapter gives a detailed account of food and feeding in *P.ocellatus* like morphological features, relative gut length, monthly variation in food composition, lengthwise variation in food compostion, feeding intensity and gastrosomatic index.

The **eighth** chapter incorporates various aspects of reproductive biology like sex ratio, sexual dimorphism, spawning periodicity, gonadosomatic index, fecundity, morphology and histology of gonads.

The **ninth** chapter evaluates the nutritive value of *P.ocellatus* by analyzing its biochemical composition. Seasonal variations in moisture, protein, carbohydrates, lipids and ash were estimated. Similar estimations were recorded in male and female fish of different length groups. The comparative account nutritive value of *P.ocellatus* with few other commercial fishes is also estimated.

The **tenth** chapter records month wise variation in RNA and DNA content and the ratios of RNA : DNA, RNA : protein, RNA : lipids in male, female and juvenile *P.ocellatus*. The values are also recorded in different length groups of male and female.

The **eleventh** chapter gives a comprehensive profile of growth and reproduction in *P.ocellatus*.

The **twelfth** chapter gives the summary of all chapters. It also includes a discussion a comprehensive discussion on the various aspects of biology studied in *P.ocellatus*.

Each chapter has been organised into a brief introduction, material and method, review of literature, results and discussion. Data represented in the form of tables, graphs, charts and photographs are inserted at appropriate places in the relevant chapters. The bibliography is enclosed at the end of the thesis.

Chapter 2

Taxonomy and Systematics

2.1 Introduction

2.2 Identification keys

2.3 Systematic position

2.4 Morphology

2.1 Introduction

The Gobies belong to the suborder Gobioidei which comprises nearly 2000 extant species (Eschemeyer, 2013) occurring in fresh water, brackish water and marine water with a worldwide distribution. Order Perciformes, the most diversified of fish order contain 18 suborders, 148 families 1496 genera and about 9293 species (Gore, 2007). Of the 18 suborders of order Perciformes, the suborder Gobioidei is an important one. Gobioidei is one of the largest suborders of teleost fishes (Agorreta *et al*.,2013) They exhibit a spectacular diversity in morphology, ecology and behaviour (Patzner *et al*., 2011).They are increasingly used as model organisms in many comparative studies aimed at understanding the evolutionary processes underlying diversification (Ruber and Agorreta, 2011). Nelson (1994) has observed that 8-9% of all fishes belong to suborder Gobioidei and comprises of eight families namely: Rhyacichthyidae, Odontobutidae, Eleotridae, Gobiidae, Kraemeriidae, Xenisthmidae, Microdesmidae and Schidleriidae. Family Gobiidae is the largest family of suborder Gobioidei with more than 2000 species.

The family Gobiidae includes small gobies. These fishes have separate dorsal fins which may be spinous and rayed whereas their pelvic fins are usually fused. Colour pattern of gobies ranges from brightly coloured to drab and camouflaged (Thacker, 2011). The taxonomy of gobies is considerably difficult. Phylogenetic studies have been limited to familial levels. Exact identification of species is often difficult because the gobies are generally small and look morphologically alike (Van Tassell, 1998).

History of Gobioid Classification

Survey of literature revealed that substantial amount of morphological data is available and osteology of gobioid fishes has been reported. Van Tassell (1998) has reviewed the morphological and oteological features of gobioids. The history of gobioid classification is very interesting. The earliest reports were by Linnaeus (1758) who recognized one genus (Gobius) in the family having seven species. Subsequently the number of genera have seen remarkable increase during the span of 75 years from 1800-1874. In 1800 Lacepede reported seven genera whereas immediately in 1801, Bloch and Schneider recognised eleven genera; the number then rose to 23 genera (Gunther, 1861b), and 99 genera Bleeker (1874). These systems of classification were based primarily on the structure of the fins, numbers and types of scales, teeth and placement of eyes.

Gunther (1861b) proposed four distinct groups of gobioids to which 23 genera belong namely: the Gobiinae, the Amblyopina, the Trypauchenina and the Callionymina. On the other hand Bleeker (1874) proposed that the 99 genera of gobies belong to four subfamilies namely: Eleotriformes, Gobiiformes, Amblyopodiformes and Luciogobiiformes.

Based on osteological studies, to be specific, bones of cranium, pectoral girdle and number of vertebrae, Regan (1911) classified Gobioidei into three families: Eleotridae, Gobiidae and Psammichthyidae. The Eleotridae was separated by Regan (loc.cit.) from Gobiidae on the basis of shape of palantine, greater development of mesopterygoid and the scapula in the eleotrids. The family Gobiidae was further divided by the author into two subfamilies namely Gobiinae and Periophthalminae, who proposed the third family Psammichthyidae and placed it within the Gobioidei.

Jordan (1923) raised the number of families proposed by Regan (loc.cit.) from 3 to 8: by adding 5 families namely: Rhyacichthyidae, Periophthalmidae, Gobioididae, Trypauchenidae, Doliichthyidae to the 3 described by Regan (loc.cit.) namely: Eleotridae, Gobiidae and Psammichthyidae. However, Duncker (1928) recognized only four families namely: Eleotridae, Gobioididae, Periophthalmidae and Gobiidae whereas Berg (1940) in fact proposed that the Gobioidei be grouped into two super families: Eleotrioidae with one family and Gobioidae with three families namely:

Gobiidae, Periophthalmidae and Kraemeriidae. Webber and DeBeaufort (1953) proposed that the order Gobioidae to be further divided into four families with constituent subfamilies: family Gobiidae, subfamilies namely: Goiodontinae, Gobiinae, Periophthalminae, Sicydiaphiinae and Apocrypteinae; family: Taenioididae subfamilies namely: Taenioininae and Trypaucheninae; family: Eleotridae and family: Rhyacichthdae. Gasoline (1955) and Regan (1911) based their classification of Gobioidei on osteological studies and gave sufficient evidence for placement of microdesmids and kraemeriids among the gobioids. Gosline (1955) demonstrated that the shape of the palantine along with the presence or absence of the scapula did not adequately separate the Eleotridae and the Gobiidae. He based his separation of these two families on the presence of six brachiostegal rays in eleotrids and only five in gobiids.

Ginsburg (1933a) and Koumans (1953) pointed out inadequacies of the earlier classification system for gobioids. Gobiod lateralis system was studied by Sanzo (1911) who described it as follows: the external neuromast organs called sensory papillae form a distinct pattern on head region which can be divided into two basic groups one which the neuromast are in longitudinal rows and the other in which the same are in transverse rows. These patterns have been useful in defining genera and species (Hoese, 1971,1983; Gill *et al*.,1992) and have been used by Miller (1963,1973,1992b) in defining taxa and arranging systems of classification.

Takagi (1967) made an extensive study of the cephalic sensory canal systems of gobies from Japan. A portion of the study was published in 1967 and the complete work was published in 1988. Takagi examined 82 species of 54 genera from Japanese waters and amended the terminology of the cephalic sensory canals, head pores and sensory papillae patterns.

Miller (1963) briefly outlined the major differences between gobiids and eleotrids, commenting that the occurrence of separate pelvic fins was not sufficient to distinguish between eleotrids from gobiids. His classification was based largely following osteological characters like: number of epurals, hypural connection, the presence or absence of the endopterygoid, the number of branchiostegal rays, development of the scapula, the number of pectoral radials, presence or absence of the post eleithrum, a metapterygoid bridge to the quadrate, a preoperculum-

symplectic bridge, and the extent of development of the oculoscapular and preopercular canals. Greenwood *et al.* (1966) concluded that the suborder Gobiodei comprised six families: Gobiidae, Microdesmidae, Gobioididae, Kraemeriidae, Rhyacicthydae and Trypauchenidae. Akhito (1963, 1967) extensively studied the scapula of gobioids and in 1969, proposed classification of gobioid fishes based on oosteology into 71 genera with 85 species.

Miller (1973) divided the suborder Gobioidei into two families: Rhyacichthyidae with only one species and Gobiidae with 200 species. Gobiidae has one or two epurals and a reduced cephalic lateralis system.
Miller divided Gobiidae into seven subfamilies: Eleotrinae, Pirskeninae, Xenisthminae, Gobionellinae, Tridentigerinae, Gobinnae and Kraemeriinae. He included Pholidichthyidae within Gobiinae. Lindberg (1974) in his comprehensive review of the fishes of the world concluded that there were five families in the Gobioidei: Eleotridae, Gobiidae, Gobioididae, Periopthalmidae and Microdesmidae. Springer (1983) studied the Gobioidei cladistically and proposed following four synapomorphies for all gobioids: Parietals absent, pelvic intercleithral cartilage present, dorsal end of interhyal fails to meet the dorsal end of the symplectic and basibranchial one cartilaginous. Miller (1992a) added the presence of a sperm duct gland to this list of synapomorphic character.

Hoese and Gill (1993) presented phylogenetic problems within the lower members of the Gobioidei. They defined three families: Rhyacicthyidae, Odontobutidae and Gobiidae. The Gobiidae was divided into subfamilies Butinae, Eleotridinae and Gobiinae based on sixteen characters. The Gobiidae was distinguished according to the following set of synapomorphies: 1) no autogenous middle radial in the first pterigiophore of second dorsal fin 2) upper proximal radial of the pectoral fin usually in contact with the cleithrum and extending well above the scapula. 3) anterior elongation of the procurrent caudal cartilage 4) scales without transforming ctenii.

Pezold's (1993) studied the cephalic pore configuration of a comprehensive sample of Gobiidae and proposed a diagnostic character for the group Gobiinae: a single cephalic inter orbital pore, rather than a pair of pores. He also noted that most of

those taxa possess a common dorsal fin pterygiophore pattern and vertebral number.

Phylogenetic analysis of morphological characters has been performed in some subgroups of Gobioidei by Gill (1994) and Thacker (2000) and other subgroups of Gobioidei have been investigated with molecular data by Ruber *et al.* (2003) and Taylor and Hellberg (2003, 2005). A combination of both phylogenetic and molecular data have been used by Thacker and Cole (2002) and Harold *et al*. (2008) and gobiids have been included in larger molecular phylogenetic hypothesis by Thacker (2003, 2009)and by Thacker and Hardman (2005). Thacker (2009) recognised six families and later several sub familial units for two of the families (Thacker and Roje 2011, Thacker 2013). Re evaluation of gobiod systematic based on molecular data have shown that the smaller distinctive families historically separated from the bulk of gobioid taxa are actually nested within the larger groups (Akihito *et al.,* 2000, Wang *et al.,* 2001, Thacker, 2003, Ruber and Agorreta, 2011).

Gill and Mooi (2012) described a new family Thalasseleotrididae and redefined the family Gobiidae to encompass Gobiidae and Gobionellidae in contrast with the classification given by Thacker (2009) based on five brachiostegal rays. Thacker (2011) stated that the development of gobiid systematics seems to be progressing in the same pattern as seen for the entire Gobioidei: distinctive groups are delineated and singled out from the majority of taxa and as data accumulate, it is revealed that this perceived distinctiveness is simply a part of the range of diversity in the larger group and comprehensive surveys of both morphology and molecular data will be required to further evaluate gobiid relationships, and to reveal the systematic of this diverse group.

Day (1876) has reported 150 species of gobiids from the waters of India. Taxonomic description of various species of gobies from the different habitats occurring in India was provided by Annandale (1919); Pillai (1929); Panikkar (1937); Here (1939, 1940); Hora (1924, 1934, 1936, 1940, 1941) and many others. Mutsaddi and Bal (1973) classified 21 species of gobies from waters of Mumbai under twelve genera within the sub family Gobiinae. The authors reviewed the systematic position of these fishes with special reference to salient features such as fin-ray formula,

morphology, coloration of fish in live and preserved condition and range of distribution.

2.2 Identification Keys

Family Gobiidae

Family Gobiidae has been described extensively by Day (1878), the salient features of which as described by Day are reproduced below.

Pseudobranchiae present, sometimes rudimentary. Gill openings varying from extremely narrow to wide with the gill membranes attached to the isthmus: four gills. Body generally elongated. Eyes lateral, occasionally prominent and mostly without free orbital margins, the skin being continued directly over their surface. The infra orbital ring of bones does not articulate with the pre opercle. Teeth of varying characters, canines present or absent: inferior pharyngeal bones may be separated, or coalesced with a median suture. A single rayed dorsal fin, sometimes divided into two portions, the spines are flexible, and this part of the fin has less rays than the remainder: anal similar to the soft dorsal: ventral's sometimes united so as to form a disk, or arising close together. Scales and lateral line present or absent. Air-vessel generally absent, Pyloric appendages, if present are few.

The family Gobiidae has been subject to numerous subdivision, due to the great variations observed amongst those species of which it is composed. Following subdivisions have been recognised based on dorsal and ventral fins:
Gobiina: Ventrals forming a disk being united along their whole extent, or only in their basal halves, two separate dorsal fins**.**
Eleotrina: Ventrals not united together.
Amblyopina: Ventral fins united, a single dorsal occupying the whole length of the back
Within subdivision Gobiina are placed seven genera namely: *Gobius, Gobiodon, Sicydium, Apocryptes, Apocryptichthys, Periophthalmus, Boleophthalmus*.
Genus *Gobius* (Artedi) describes the following identifying characters: Brachiostegals five, pseudobranchae, gill openings of moderate width, body low and elongated, Opercles.

The subdivision Gobiina is further divided into five subfamilies namely: Brachygobii, Platygobii, Eugobii, Chaeturichthyi and Gobionelli which are described along with genera comprising these subfamilies.

Gobiini: Teeth in jaws simple, their spaces being neither clubbed nor incised in or two rows in upper, in two or more in lower jaw.

I. Brachygobii: no canines

1. *Lophogobius* (Gill). Body compressed, teeth in both jaws in many villiform rows, the outer the longer, scales ctenoid.

II. Platygobii: Teeth in many rows in both jaws, no true canines.

2. *Gillichthys* (Coop) *Gillia*, (Gunther). Teeth villiform in both jaws, scales small, cycloid.
3. *Gobiopsis* (Steind): Teeth, the outer row the larger. Scales large ctenoid.
4. *Glossogobius* (Gill) *Cephalogobius* (Bleeker). Outer row of teeth the longer, curved not crowded together, unequal upper jaw not produced posteriorly.
5. *Platygobius* (Bleeker). Teeth, outer row in pre maxillaries scarcely enlarged.

III. Eugobii: Teeth in jaws fixed.

a) <u>Teeth in both jaws sharp, in many rows, with the outer one enlarged: canines.</u>

6. *Gobius* (Artedi) *Pomatoschistus* (Gill). Teeth in the outer row conical and subequal: caudal obtuse, scales ctenoid, abdomen scaled, snout short.
7. *Acanthogobius* (Gill). Teeth in the outer row subequal: caudal obtuse scales ctenoid, snout conical.
8. *Brachygobius* (Bleeker) = *Hypogymnogobius* (Bleeker). Teeth in the outer row sub equal, abdomen scale less.
9. *Eucyclogobius* (Gill). Teeth in the outer row sub equal. Scales cycloid none on the head.
10. *Lepidogobius* (Gill)= Cyclogobius (Steind). Teeth in the outer row sub equal. Scales cycloid. Head scaled.
11. *Callogobius* (Bleeker). Teeth in the outer row, slender sub equal.

Caudal lanceolate, head depressed convex.

12. *Stenogobius* (Bleeker). Teeth in the outer row, conical, sub equal caudal obtusely lanceolate, longer than the head.

13. *Actinogobius* (Bleeker). Teeth in the outer row unequal. Caudal acute, shorter than the head.

b) Teeth in each jaw in many rows, the outer the longer: some truncated.

14. *Hemigobius* (Bleeker). Some of the middle teeth of the outer row in the premaxillaries truncated.

c) Teeth in each jaw in many rows, pointed, sub equal, the outer row erect and not elongated, no canines.

15. *Awaous* (Val). Scales 50 to 60.

16. *Rhinogobius* (Gill) = Chonophorus (Poey) Scales 28

d) Teeth in either jaw in many pointed rows, the outer the longer: in the lower jaw, laterally a posterior curved canine.

17. *Ctenogobius* (Bleeker). Head scale less, scales 14 to 30.

18. *Centrogobius* (Bleeker) = Oplopomus (Steind). First dorsal spine pungent.

19. *Acentrogobius* (Bleeker) = Porogobius (Bleeker). Head scaled, no pungent dorsal spine, caudal lanceolate.

20. *Amblygobius* (Bleeker) = Odontogobius (Bleeker). Scales 52 to 56

21. *Cryptocentrus* (Ehr) = Paragobius (Bleeker). Scales 85 to more than 100.

e) Teeth in both jaws pointed, and in two rows.

22. *Zonogobius* (Bleeker). Outer row of teeth in upper and inner in lower jaw the longer

23. *Lophiogobius* (Gunther) =Teeth in two rows in each jaw, the outer row the longer, placed wide apart and sub-horizontal, no canines.

f) Teeth pointed, in one or less than two rows in the upper and many in the lower jaw, canines present or absent.

24. *Stigmatogobius* (Bleeker). Teeth in one row in the upper jaw: outer row in the lower jaw the longer, and posteriorly above the symphysis two canines.

25. *Euctenogobius*, (Gill). A single row of teeth in the premaxillaries, few

rows in lower jaw: no canines.

26. *Oxyurichthys*, (Bleeker)= Gouchthys (Klunz). Teeth in pre maxillaries in one or less than two rows, the inner of which is rudimentary: many rows in the lower, the outer being the longer: no canines, caudal lanceolate.

IV. *Chaeturichthyi*: No canine: barbels on lower jaw.

27. *Chaeturichthys* (Rich). Teeth in two rows in either jaw, the outer row close together, the longest, and consisting of fixed curved, subulate teeth directed obliquely inwards.

28. *Amblychaeturichthys* (Bleeker). Teeth in the premaxillaries in few rows, the outer the longer, fixed, straight, subulate: three or] laterally two rows in the lower jaw, the outer the longer, moveable, straight, and directed obliquely inwards.

29. *Parachaeturichthys* (Bleeker). Many rows of teeth in both jaws, the outer row close together, consisting of elongated straight and fixed ones.

V. Gobionelli: Teeth in both jaws in many rows.

30. *Synechogobius* (Gill). Pointed fixed teeth in both jaws, the outer the longer.

31. *Gobionellus* (Gir) = Samaragdus (Poey). Teeth small, the outer row setaccous moveable.

Day (1878) has recorded thirty five species under genus *Gobius*. Description of *Gobius ocellatus* according to Day (1873) is as follows:

Length of head 4 1/3 to 4 ½ of caudal 5 to 6, height of body 6 to 7 in the total length. Eyes some what superior, diameter 5to 6 in the length of head, 1 ½ diameters from end of snout, and 1 apart. Head slightly broader than high, its greatest width being equal to the length of its postorbital portion, the summit of which is somewhat flat and snake- shaped. No occipital crest, nor warts on the head: a pair of short barbels under the symphysis of the lower jaw. Cleft of mouth somewhat oblique, commencing opposite the middle of the eye: the lower jaw a little the longer: the posterior extremity of the maxilla extends to beneath the anterior margin of the orbit. Teeth- several rows in both jaw, an enlarged outer one in the mandibles, the external of which on either side is a moderately or small recurved canine in large

specimens. Fins- the two dorsal not widely separated, the distances of the first dorsal from the orbit equals the distance from the snout to the base of the pectoral fin, its second spine is elongated in some specimens, being nearly as long as the head, last dorsal ray divided to its base. Pectoral rays silk-like, second dorsal and anal about equally developed and highest posteriorly; caudal wedge-shaped, rounded behind; ventral reaches half way to the vent. Scales ctenoid on body, cycloid on head, much smaller anterior to the dorsal fin than posterior to it: they cover the cheeks, opercles and top of the head to snout and are in irregular rows. Colour olive, a dark green spot above upper margin of opercle, about six indistinct blotches along sides; dorsal and caudal fins stained dark and indistinctly spotted or barred; a yellow ocellus with a black centre, at the top of the caudal fin in its last half; anal whitish, basal half covered with fine black dots; ventrals yellow.

Family Gobiidae (Larson and Murdy 2001)

The Family gobiidae was further reviewed and described by Larson and Murdy (2001). The salient features of which are described here:

Small gobioid fishes (to 30cm, usually less than 10 cm); body typically stout (but with many exceptions). Head short and broad, often scaly, typically with a series of sensory canals and pores, and cutaneous papillae. Snout rounded. Teeth usually small, sharp and conical, in one to several rows in jaws. Gill membranes broadly joined to isthmus. Two separate dorsal fins, the first with V to X weak spines, the second with I weak spine and 5 to 37 soft rays; anal fin with I weak spine and 5 to 36 soft rays(typically terminal ray of second dorsal and anal fins divided to its base, but only counted as a single element); pectoral fins broad with 12 to 25 rays; pelvic fins long with I spine and 5 soft rays, pelvic-fin spines usually joined by fleshy membrane (frenum), and innermost, pelvic-fin rays usually joined by membrane, forming a disk (gobies with pelvic fins not united typically found in coral-reef areas): caudal fin broad and rounded with 16 or 17 segmented rays. Scales are large, either cycloid or ctenoid. Lateral line is absent on body. Colour: variable.

Key to subfamilies of Gobiidae

The subfamilies of Gobiidae according to Larson and Murdy (2001) are as follows:

1a. Dorsal and anal fins connected to caudal fin, both dorsal fins united by

membrane mud-burrowing, elongate gobies with pink to purple ……..*Amblyopinae*

1b. Dorsal and anal fins separated from caudal fin, both dorsal fins typically separate.....→2

2a. Lower jaw typically possessing only a single row of teeth.....→3

2b. Lower jaw typically possessing more than 1 row of teeth.....→4

3a. Pelvic frenum with fleshy lobes over spines; eyes lateral.....*Sicydiinae*

3b. Pelvic frenum without fleshy lobes; body elongate; eyes located mostly dorsally.....*Oxudercinae*

4a. Paired anterior interorbital pores present or head pores present or head pores completely lacking; pelvic frenum simple, not folded forward, frenum without fleshy lobes around pelvic-fin spines; if head pores absent, then 1 or more of the following conditions also exist:1) pelvic frenum present, 2) body fully scaly or mostly scaly, and/or 3) no barbels present on chin [except for 1 genus, Gnatholepis, only non-coral reef gobies are included here, Gnatholepis possesses head pores].....*Gobionellinae*

4b. Usually a single anterior inter orbital pore present or head pores completely lacking; If 2 anterior inter orbital pores present, then pelvic frenum folded forward and a fleshy lobe present around each spine; if head pores absent, then 1 or more of the following conditions also exist: 1) pelvic frenum absent, 2) body naked or with a few scales on caudal peduncle, and/or 3) barbels present on chin [although exceptions exist head pores are typically absent only in a few small coral-reef gobies]..... *Gobiinae*

Key to genera of Gobiinae

According to Larson and Murdy (2001) the key to genera of Gobiinae are as follows:

1a. First gill slit closed by membrane distinctive transverse papillae pattern on head (coralreefs) ..... .*Hetereleotris*

1b. First gill slit open; pappilae pattern longitudinal or transverse.....→2

2a. Body naked or with a few scales on caudal peduncle.....……..→3

2b. Body scaled at least on posterior half .....→8

3a. Pelvic fins separate and slender ……..……...→4

3b. Pelvic fins united……..……....→5

4a. Body deep and robust, eyes small (coral reefs) ...……...*Austrolethopso*

4b. Body slender, eyes moderate to large (coral reefs)……*Trimmatom*

5a. Teeth tricuspid; body slender (rocky shores)……*Kelloggella*

5b. Teeth pointed…….....→6

6a. Body elongate; anal fins with 13 elements, including spine (sandy shores).....*Parkraemeria*

6b. Body short and/or compressed; anal fin with 10 or fewer elements, including spine.....→ 7

7a.Head and body deep and compressed: body and fins with thick mucus pelvic fins short and fleshy (coral reefs) coat not generally developed..... ..... *Gobiodon*

7b.Body short and robust, compressed posteriorly but head usually rounded; mucus coat not greatly developed; pelvic fins not fleshy (deep water).....*Lubrigobius*

8a.Thin dermal crest on top of head anterior to first dorsal fin…..…..→9

8b. No dermal crest anterior to first dorsal fin…….....→11

9a. Sensory papillae on head transverse; body relatively plain dark brown, with dark blotch on shoulder just above pectoral-fin base (estuaries, shallow reefs)..... *Lophogobius*

9b. Sensory papillae on head longitudinal; colour pattern variable, often with small dark spots …….....……..…….. →10

10a.Dermal crest low, less than pupil diameter; body elongate; second dorsal fin and anal fin with 1 spine and 12 soft rays (estuaries, shallow reef) ..... *Cryptocentroides*

10b. Dermal crest high, more than pupil diameter; body deep; second dorsal fin and anal fin with 1 spine and 9 soft rays (estuaries)……..... *Cristatogobius*

11a. Barbels present on ventral surface of head (may be on chin only), barbels distinctly larger than any elongate papilla.....→12

11b. Papillae on underside of head may be elongate, but no barbells present .....→16

12a. Large black spot present dorsally on caudal fin; cheek and opercle covered with scales (deepwater) ..... ***Parachaeturichthys***

List of species under genus *Parachaeturichthys* recorded by Larson and Murdy (2001) are as follows:

Parachaeturichthys ocellatus (Day, 1873)

Parachaetutichtys polynema (Bleeker, 1853)

State wise local name of gobies

Maharashtra: Kharbi, Karpa, Gavati Mori, Nevta

Gujarat: Nevta, Lepta

Tamil nadu: Uluvai, Nullatan

Karnataka: Abbrony, Mannuli

Kerala: Wartoe, Poolah, Pooan, Kurudan

Andhra Pradesh: Isakee doondoo

Punjab: Gooloowah, Boulla

Orissa: Gulah

Andaman Islands: Poodah

Unambiguous Synonyms

1. *Gobius ocellatus* Day,1873
2. *Parachaeturichthys ocellatus* Day,1873 (Larson and Murdy, 2001)
3. *Aulopareia ocellatus* by Helen Larson 1981 (Ferraris *et al.,* 2000)

Valid name

Parachaeturichthys ocellatus Day, 1873

Member of genus *Parachaeturichthys*

1. *Paracheaturichthys ocellatus* Day,1873

2. *Paracheaturichthys polynema* Bleeker 1853 (tail eyed goby)

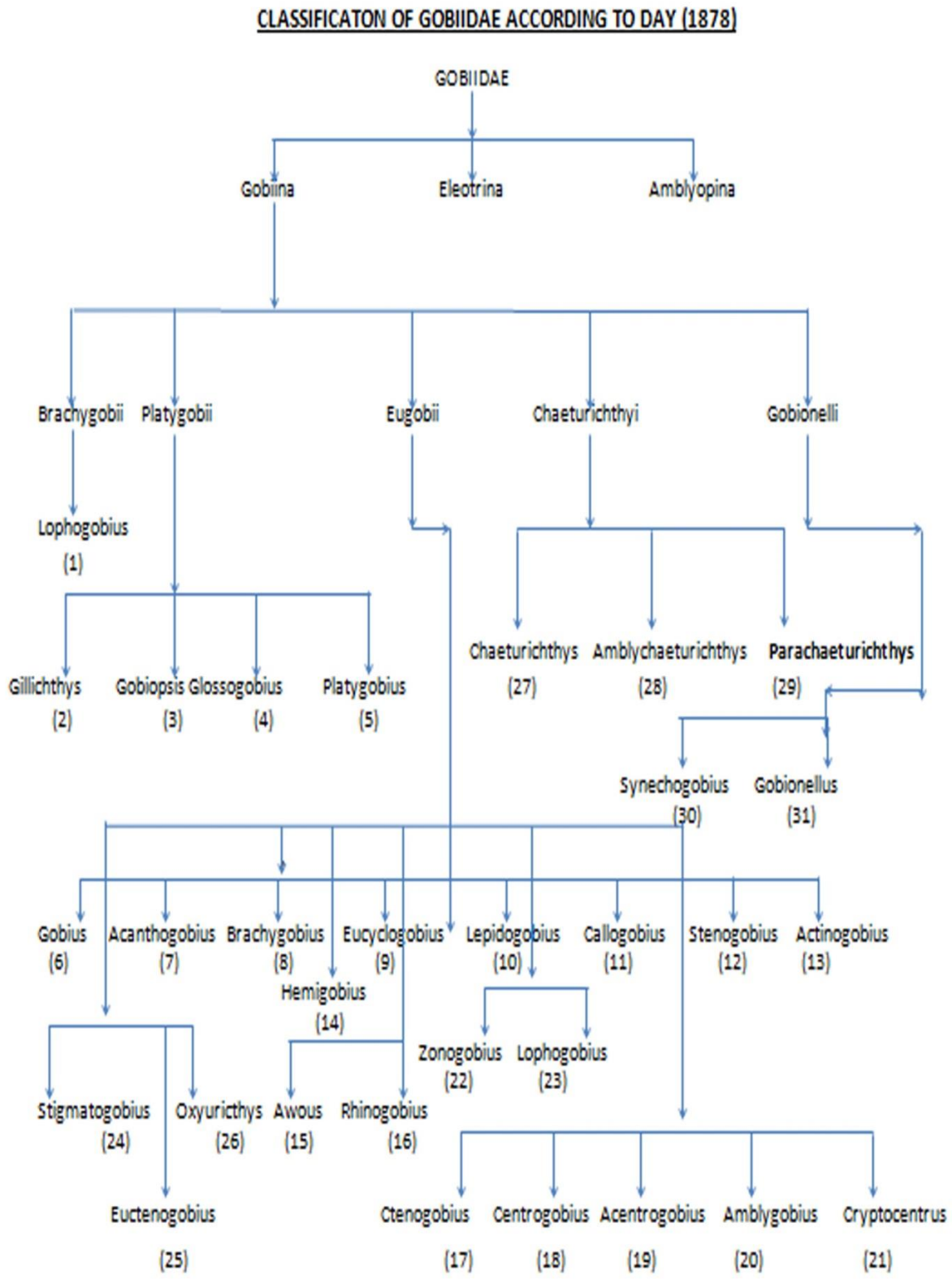


Fig 2.1 Classification of Gobiidae Day (1878)

KEY TO SUB FAMILIES OF GOBIIDAE (LARSON & MURDY, 2001)

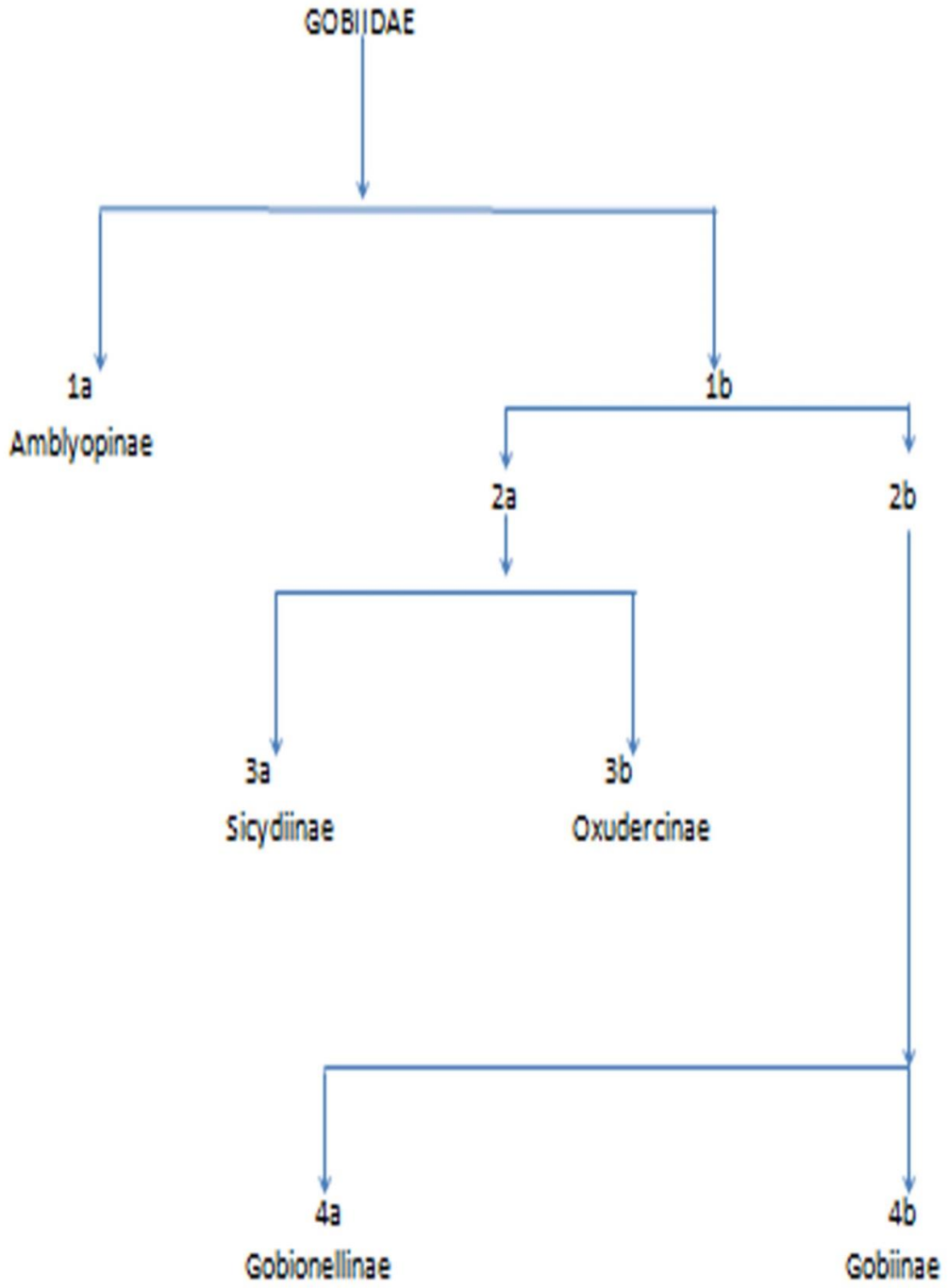


Fig 2.2: Classification of Gobiidae Larson and Murdy (2001)

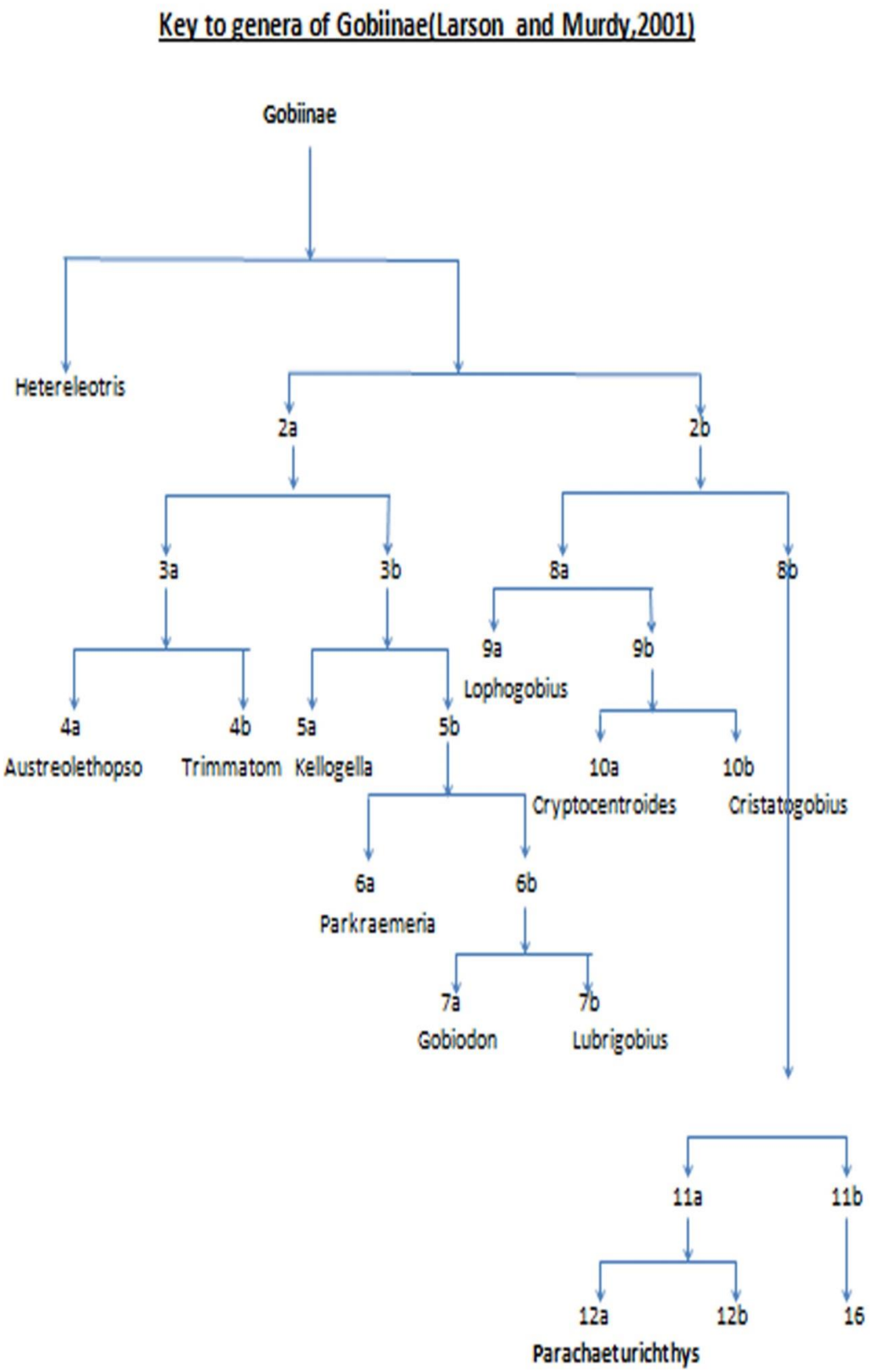


Fig 2.3: Classification of Gobiinae Larson and Murdy (2001)

2.3 Systematic position of *Parachaeturichthys ocellatus* Day (1873)

Natura: nature

Mundus: Plinius physical world

Naturalia

Biota

Domain: Eukaryota- eukaryotes

Kingdom: Animalia C. Linnaeus, 1758 animals-

Subkingdom: Bilateria (Hatschek1888) Cavalier-Smith,1983 bilaterians

Branch: Deuterostomia Grobben, 1908-deuterostomes

Infrakingdom: Chordonia (Haekel, 1874) Cavalier-Smith 1998

Phylum: Chordata Bateson,1885- chordates

Subphylum: Vertebrata Cuvier, 1812-vertebrates

Class: Osteichthyes Huxley, 1880

Infraphylum: Gnathostomata- auct jawed vertebrates

Subclass: Actinopterygii-ray finned fishes

Infraclass: Actinopteri

Superdivision: Neopterygii

Division: Halecostomi

Subdivision: Teleostei

Infradivision: Elopocephala

Cohort: Clupeocephala

Subcohort: Euteleostei

Infracohort: Neognathi

Division: Neoteleostei

Subdivision: Eurypterygii

Infradivision: Ctenosquamata

Superorder: Acanthopterygii

Series: Percomorpha

Order: Perciformes

Suborder: Gobiodei

Family: Gobiidae- gobies

Genus: Parachaeturichthys

Parachaeturichthys ocellatus

2.4 Morphology of *Parachaeturichthys ocellatus* (Plate no. 2.1 and 2.2.)

Body was elongated, anteriorly cylindrical and posteriorly compressed. Head dorsoventrally flattened. Eyes slightly protruding. Mouth was cresent shaped and wide, extending below the eye orbit. Lower jaw was projecting with many minute barbels on the chin. Maxilla extended to the lower part of the eye. Teeth were present in four rows in both upper and lower jaw. In the upper jaw the outer row had larger teeth with the central four teeth largest recurved inside slightly. The remaining teeth decreased in size on both the sides. In the lower jaw also teeth were larger in the outer row while inner rows had small villiform teeth. The number of teeth decreased from outer to inner rows. Ventral and dorsal pharyngeal tooth plates were present in both jaws. Tongue was rounded.

Four pair of gill arches with 16-18 short gill rakers were present on each arch and were spaced a part. A pair of dorsal fins were placed together on dorsal side and pointed posteriorly. First dorsal fin had six fin rays, second fin ray was longer and was almost double of the fin first ray and reached till the head. Second dorsal fin had nine to eleven fin rays. Second dorsal fin was dark spotted or barred. A pair of pectoral fins one on each side of body was stronger and larger and had 16-20 soft rays. Pelvic fins were on the ventral side of body. They were fused together to form a sucking device and reached till the middle of the vent with 8-12 fin rays. The pectoral and pelvic fin rays were light yellow. Anal fin pointed posteriorly similar to dorsal and was lighter in colour.

Ctenoid scales were present on upper head, cheeks, opercles, belly and breast whereas cycloid scales were present on lower head and body and other parts of body not covered by ctenoid scales. Caudal fin was wedge shaped. Caudal fins showed the presence of yellow ocellus with a black centre towards the posterior side of the upper end. The lower end of the posterior side of the caudal fin was black. Lateral line scales ranged between 32-36 while transverse scales ranged between 8-11. The fish was olive green. The upper half of the body was dark and

lower half was lighter in colour. The lateral side of body showed six alternating rows of dark blotches.

Fin formula according to the present study of *P.ocellatus*:

Bv, D1 6, D2 1/ 9-11, P16-20, V8-12, A 1/8-11, C22-26, Ll 32-36, Ltr 8-11.

Plate 2.1: ***Parachaeturichthys ocellatus***

Plate 2.2 : ***Parachaeturichthys ocellatus*** **(ventral view)**

Chapter3

Morphometric characters

3.1 Introduction

3.2 Review of Literature

3.3 Materials and methods

3.4 Result

3.5 Discussion

3.1 Introduction

The word morphometry is derived from two greek words: morph meaning shape or form and metron meaning measurement. Daly (1985) defined 'morphometrics' as a measurement and quantitative analysis for morphology or shape. Rohlf (1990a) defined morphometry as the qualitative description, analysis and interpretation of shape and shape variation in biology. The complete set of measurements used to describe a form is a morphometric character set (Strauss and Bond, 1990). Morphometric characters represent one of the major keys for determining the systematics, growth variability, ontogenic trajectories and various population parameters of the fish (Kovac *et al.,* 1999).

An accurate identification of any organism depends upon understanding its taxonomy thoroughly along with morphometric and meristic characteristics. Fishery biologists have noticed differences in morphological characters in fishes due to change in habitat and other environmental factors (Mayr *et al*, 1953). For identification of species and raciation of fish, several researchers have resorted to analysis of morphometric characters. Marr (1955) used morphometric data for systematic, racial and relative growth studies in fishes. Morphometry and meristic counts are considered as earliest and authentic methods for the identification of species in different region (Nayman, 1965). An analysis of morphometric characters indicates the degree of closeness or remoteness of a particular species of a particular locality with the same or similar looking species (Acharya, 1980). Morphometric study is a powerful tool for characterizing strains of the same species which involves detection of subtle variation of shape, independent of size (Strauss and Bond, 1990).

Morphological characters like morphometrics and meristics have been frequently used to delineate stock of fish species (Haddon and Wills, 1995). Morphometric investigations of a species reveal the inter-relation between the various bodily parameters like length, weight, fecundity etc (Carpenter *et al*, 1996). The shape and structure are unique to the species and the variations in its features are probably related to the habit and habitat among the variants of the species (Cavalcanti *et al.,* 1999). Morphometric studies are essential to understand not only taxonomy but health and reproduction of a species in the given environment. Morphometry provides substantial information with regard to exact identification key of the species (Dhanya *et al.,* 2004).

3.2 Review of literature

Morphometric studies in many species of fishes have been carried out by a number of authors, a few of which are cited here: *Mugil cunnesius* (Sarojini, 1958), *Gadusia chapra* (Banerjee and Venkateswarlu, 1968), *Hilsa kanagurta* and *Hilsa toli* (Sarma, 1973), *Solea vulgaris* (Ezzat *et al.,* 1979), *Wallago attu* (Ohol, 1981), *Salmostoma clupeoides* (Piska, 1990), *Etroplus suratensis* (Rao, 1990). A straight line relationship was observed between total length and each of other body measurements by many of above workers in different fishes. Morphometric characters show high plasticity in response to differences in environmental conditions such as food abundance and temperature (Allendorf 1988; Swain *et al.,* 1991; Wimberger, 1992). Reiss (1989) proposed that organisms are not usually isometric, even when organised on similar patterns, instead certain proportions change in a regular fashion. Even within a single growth stage, different parts of a fish may grow at different rates (Ricker, 1975).

Many authors have reported on the morphometrics in goby fishes around the world. Kulkarni (1936) has described bionomics of goby *Periophthalmus barbus* along with a special note on respiration. A study of morphometric characters was carried out in *Boleophthalmus dentatus* by Shettu (1993), *Periophthalmus barbarus* by Udo (2002), *Periophthalmus argentilineatus* Kruitwasen *et al.* (2006), *Boleophthalmus boddaerti* by Ravi (2000) and Gore (2007). The morphological, morphometric and meristic characters of the goby *Glossogobius minutus* from south west coast of India were studied by Geevarghese and John (1983) who compared it with two other species namely *Glossogobius giuris* and *Glossogobius biocellatus* The morphometric characters of *Glossogobius giuris* from the Ganges of north western Bangladesh were

found to be highly correlated by Hossain *et al.* (2009b). The morphometric measurement of *Periophthalmus papilion* from Lagos Lagoon Nigeria was carried out to ascertain the possibility of genetic diversity by Lawson (2010). The morphometry of many species of gobies was studied by number of authors like *Rhinogobius hongkonghensis* (Chen *et al.,* 1999); *Gobius kolombatovici* (Kovacic and Miller, 2000); *Buenia affinis* (Kovacic, 2002) *Gobius vittatus* (Kovacic, 2006) from Adriatic Sea. *Neogobius melanostomus* (Leslie and Timmins, 2004), *Chromogobius zebratus* (Engin and Dalgic, 2008), *Tryssogobius spp* from China and Taiwan (Larson and Chen, 2007), *Neogobius platyrostris* from Black sea (Engin and Bektas, 2010), frill fin goby *Bathygobius soporator* from Badgary creek, Nigeria (Lawson *et al.,* 2011) and Lagos Lagoon Nigeria (Adeboyejo, 2011), *Obliquogobius* (Chen *et al*., 2012), *Microgobius urraca* (Tornabene *et al*., 2012). Morphometric characters of native and non native populations of round goby *Neogobius melanostomus* from river Danube were compared by Polacik *et al.* (2011) who concluded that the differences between populations were due to differing environments. Idris *et al.* (2012) found that morphometric features have significant value in sexual determination of marble goby *Oxyeleotris marmoratus*. Corpuz *et al.* (2013) studied morphometric and morphomeristic variations in five populations of the goby *Glossogobius celebius* and found that the morphological divergence was environmentally induced (phenotype plasticity) due to differences in flow rate of water and temperature of the study sites.

No reports on morphometry of *P.ocellatus* could be found in the survey of literature carried by the candidate. The present study on morphometry has therefore been undertaken to determine the interrelationship of various morphometric characters in *P.ocellatus*.

3.3 Materials and Methods

The fishes for the present study were collected every fortnight at regular intervals from four different coastal locations in Mumbai: viz Malad, Vasai, Thane and Mahul creeks over a period of 16 months from June 2010 to September 2011.The fishes were collected from the fishermen and were brought to the laboratory in an icebox. They were thoroughly washed and cleaned in the laboratory. Morphometric measurements were recorded carefully in millimetres using a pair of fine dividers on a measuring board. The standard methods described and adopted by Snedecor (1946), Dwivedi

and Menezes (1974), Acharya (1980), Rao (1985) were used. In all nineteen morphometric characters (Plate 3.1) were studied as follows:

1. **Total length (TL):** The distance from the tip of the snout to the tip of longest ray of caudal fin.
2. **Standard length (SL**): The distance from the tip of the snout to the origin of caudal fin.
3. **Head length (HL):** The distance from the tip of the snout to the posterior point of operculum.
4. **Snout length (SntL):** The distance from the tip of upper jaw to the front margin of the orbit.
5. **Inter orbit length (IOL):** The distance between the dorsal margins of the eyes.
6. **Eye diameter (ED):** The maximum distance between the free orbital rims.
7. **First pre dorsal length (FPDL):** The distance from the tip of the snout to the anterior end of the first dorsal fin base.
8. **First dorsal length (FDL):** The distance from the anterior end of first spine or ray to the posterior end of the last spine or ray of first dorsal fin.
9. **Second pre dorsal length (SPDL):** The distance from the tip of the snout to the anterior end of second dorsal fin.
10. **Second dorsal length (SDL):** The distance from the anterior end of first ray to the posterior end of last ray of second dorsal fin.
11. **Pre pectoral length (PPL):** The distance from the tip of the snout to the insertion of the pectoral fin.
12. **Pectoral length (PL):** The distance from the insertion of pectoral fin to the tip of the longest ray of pectoral fin.
13. **Pre pelvic length (PPvL):** The distance from the tip of the snout to the insertion of the pelvic fin.
14. **Pelvic length (PvL):** The distance from the insertion of pelvic fin to the tip of the longest ray of pelvic fin.
15. **Pre anal length (PAL):** The distance from the tip of the snout to the insertion of the anal fin.
16. **Anal length (AL):** The distance from the anterior end of first fin ray to the posterior end of last fin ray of anal fin.

17. Body depth (BD): The distance from the anterior end of first dorsal fin to the ventral surface of the fish at the deepest part.

18.Caudal depth (CD): The minimum distance between the dorsal and ventral caudal peduncle.

19.Caudal length (CL): The distance from the insertion of caudal fin to the tip of the longest caudal fin ray.

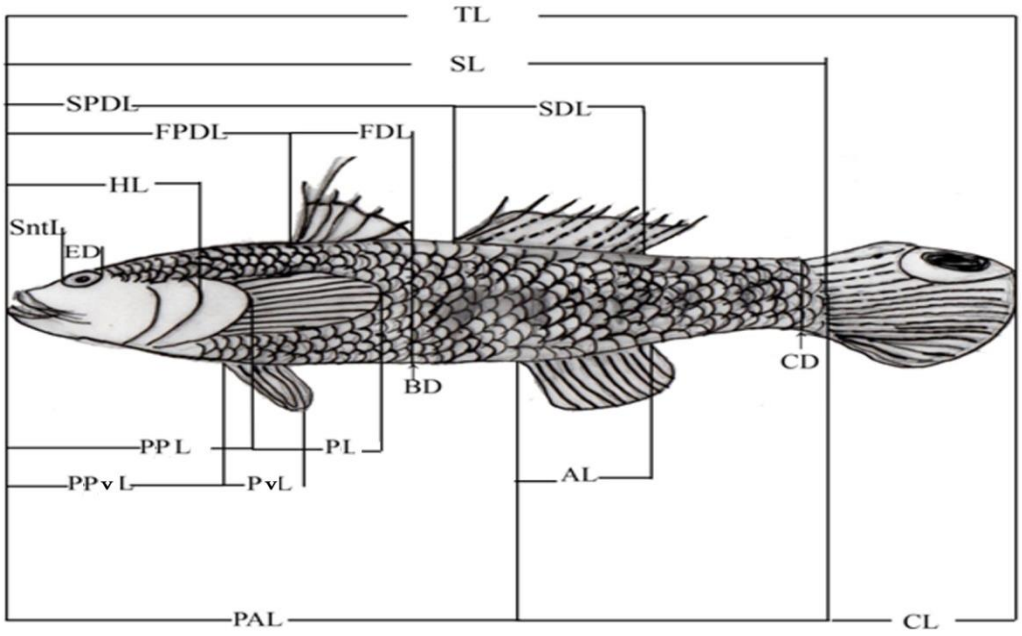


Plate 3.1 Morphometric Characters in *P.ocellatus*

Statistical parameters like mean, standard deviation, standard error, correlation coefficient and regression coefficient were calculated. Standard deviation was calculated by the formula:

$$SD = \sqrt{\frac{(X - \overline{X})^2}{(n-1)}}$$

where X refers to individual values recorded for the morphometric characters and $\overline{X}$ refer to the mean of all the X values and n is the total number of fishes studied in the sample. The standard error was calculated by the following formula:

$$\text{Std error (Se)} = \frac{\text{S.D}}{\sqrt{n}}$$

In order to determine the degree of association between various morphometric measurements the correlation coefficient (r) was calculated by the following formula of Bailey 1959:

$$r = \frac{\sum XY - n\,\overline{X}\,\overline{Y}}{(\sum X^2 - n\,\overline{X}^2)(\sum Y^2 - n\,\overline{Y}^2)}$$

The coefficient of determination r^2 is calculated by the square of 'r'.

The various morphometric measurements were plotted against total length. Linear regression was applied and the statistical relationship between total length and other morphometric characters were derived through the regression equation

$Y = a + bX$

where 'Y' denotes dependent variable and 'X' denotes independent variable (total length), 'a' constant and 'b' the regression coefficient.

The values of a and b were calculated by the following formula

$$b = \frac{\sum XY - n\,\overline{X}\,\overline{Y}}{\sum X^2 - n\,\overline{X}^2}$$

$$a = \frac{\sum Y - b \sum Y}{n}$$

To analyse the allometric relationship between total length and other morphometric measurements, total length was log transformed and the regression slopes were calculated. The morphometric measurements were divided into positive allometry (A+) when slope was greater than 1, negative allometry (A-) when the slope was less than 1 and isometry when the slopes showed a non significant difference from 1.

To examine differences in morphometric dimensions between males and females, the regression slopes of each variable versus total length were tested by means of student's t-tests. The test statistics t is calculated as follows:

$$t = \frac{(b1-b2)}{(Se1-Se2)}$$

where b1 is the slope of regression lines of male and b2 is the slope of regression lines of female and Se1 is the standard error of b1 in male and Se2 is the standard error of b2 in female.

The regression coefficient of males and females from four different creeks of Mumbai were analysed by student's t test to find any significant difference in morphometric characters and was tested at 5% level of significance with $p<0.05$.

3.4 Results:

Various morphometric measurements of *Parachaeturichthys ocellatus* from the Malad, Vasai, Thane and Mahul creeks of Mumbai were recorded from June 2010 to September 2011. The range and the standard error, for each of the nineteen morphometric characters are presented for the males and the females in Table no. 3.1 and for the juveniles in Table no. 3.2. For statistical analysis involving correlation coefficient, regression coefficient, intercept reports are available in which either total length or standard length is used as reference parameters (Akombe et al., 2013). In

the present study, total length has been used as the reference for statistical analysis. The summary of statistics of various morphometric characters as a function of TL for male and female *P.ocellatus* are presented in Table no.3.3 while the same for the juvenile is presented in Table no.3.4. The total length ranged between 66-182mm in male, 66-153mm in female and 52-65 in juvenile.

The data on correlation coefficient 'r' for measurements in male, female and juvenile is presented in Table no. 3.5, 3.6 and 3.7. There was a high degree of positive correlation between standard length and total length with' r' value being 0.9943 for male and 0.9511 for female. The positive correlation with coefficient 'r' value was found to be between 0.7-1 for different morphometric characters at $p<0.01$.

Figure 3.1, 3.2 and 3.3 a, b, c, d, e and f represents scatter plots of various regression lines of males, females and juveniles. The linear relationship observed between TL and other parameters are as mentioned below:

Total length (TL) and standard length (SL):

The equations obtained for standard length and total length were as follows:
Male SL = 9.5743+0.7099TL, Female SL= 26.936+0.5054TL, Juvenile SL=25.4372+ 0.4365TL. The regression coefficient 'b' was significant at $p\leq0.001$ and showed an average increase in standard length at 0.71mm in male, 0.51mm in female while in juvenile or immature fishes it was only 0.44mm per 1mm increase in total length. There was a high degree of positive correlation between total length and standard length with 'r' values at 0.9943, 0.9511and 0.9061 for male, female and juvenile respectively. The coefficient of determination showed that the percentage increase of standard length to total length was 98.86, 90.46 and 82.10 in male, female and juvenile respectively.

Total length (TL) and head length (HL):

The equations obtained for head length and total length were as follows:
Male HL= -4.8540+0.2852TL, Female HL= -3.4594+0.2521TL, Juvenile HL= -13.7696+0.48886TL. The regression coefficient 'b' was significant at $p\leq0.001$. There was an average increase of 0.29mm for male, 0.25mm for female and 0.49mm in juvenile of head length per 1mm increase in total length of fish. The correlation value 'r' was 0.9528, 0.9059, and 0.9556 for male, female and juvenile respectively. The

coefficient of determination showed that the percentage rate of increase in head length to total length was 90.78, 82.06 and 91.32 in male female and juvenile respectively.

Total length (TL) and snout length (Snt L):

The equations obtained for snout length and total length were as follows:

Male Snt L =-4.3505+0.1037TL, Female Snt L= -5.807+0.1184TL, Juvenile SL= -5.5905+ 0.1488TL. The regression coefficient value 'b' was significant at p≤0.01 and showed an average increase of snout length of 0.10mm in male, 0.12mm in female and 0.15mm in juvenile or immature fishes per 1mm increase in of total length. There was a high degree of positive correlation between total length and snout length as the 'r' values are 0.9493, 0.9097and 0.8345 for male, female and juvenile respectively. The coefficient of determination showed that the percentage rate of increase of snout length to total length was 90.12, 82.76 and 69.63 in male, female and juvenile respectively.

Total length (TL) and inter orbit length (IOL):

The equations obtained for inter orbit length and total length were as follows:

Male IOL = -1.2984+0.0752TL, Female IOL= -2.4675+0.0823TL, Juvenile IOL= -4.2749+0.1305TL The regression coefficient value 'b' was highly significant at p≤0.01 and showed an average increase of inter orbit length of 0.07mm in male, 0.08mm in female and 0.13mm in juvenile per 1mm increase in of total length. There was a high degree of positive correlation between total length and inter orbit length as the 'r' values are 0.8808, 0.9664and 0.7997 for male, female and juvenile respectively. The coefficient of determination showed that the percentage rate of increase of inter orbit length to total length was 77.58, 93.39 and 63.95 in male, female and juvenile respectively.

Total length (TL) and eye diameter(ED):

The equations obtained for eye diameter and total length were as follows:

Male ED =0.1566+0.306TL, Female ED=-2.009+0.0372TL, Juvenile ED= -6.7724+0.1522TL.The regression coefficient value 'b' was highly significant at p≤0.01 and showed an average increase of eye diameter of 0.03mm in male, 0.04mm in

female 0.15mm in juvenile per 1mm increase in total length. There was a high degree of positive correlation between eye diameter and total length as the 'r' values are 0.8796, 0.8445 and 0.8415 for male, female and juvenile respectively. The coefficient of determination showed that the percentage rate of increase of eye diameter to total length was 77.38, 71.32 and 70.80 in male, female and juvenile respectively.

Total length (TL) and first pre dorsal length (FPDL):

The equations obtained for first pre dorsal length and total length were as follows: Male FPDL = -2.8185+0.3120TL, Female FPDL=-7.7035+0.3625TL, Juvenile FPDL= -9.2275+0.3711 TL. The regression coefficient 'b' was significant at p≤0.001. There was an average increase of 0.31mm for male, 0.36mm in female and 0.37mm in juvenile pre first dorsal length per 1mm increase in total length. The correlation value 'r' was 0.9887, 0.9208 and 0.9358 for male, female and juvenile respectively. The percentage rate of increase of first pre dorsal length to total length was 97.76, 84.79, and 87.58 in male, female and juvenile respectively.

Total length (TL) and first dorsal length (FDL):

The equations obtained for first dorsal length and total length were as follows: Male FDL =-9.5810+0.2061TL, Female FDL=-12.4102+0.2584TL, Juvenile FDL= -16.9085+0.3711TL The regression coefficient value 'b' was significant at p≤0.001 and showed an average increase of first dorsal length of 0.21mm in male, 0.26mm in female 0.37in juvenile or immature fishes per 1mm increase in total length. There was a high degree of positive correlation between total length and first dorsal length as the 'r' values are 0.9454, 0.9450 and 0.9198 for male, female and juvenile respectively. The coefficient of determination showed that the percentage rate of increase of first dorsal length to total length was in 89.37, 89.30 and 84.61 in male, female and juvenile respectively.

Total length (TL) and second pre dorsal length (SPDL):

The equations obtained for second pre dorsal length and total length were as follows: Male SPDL=-13.2502+0.5698TL, Female SPDL=-4.5219+0.509 TL, Juvenile SPDL= -9.8613+ 0.5458TL. The regression coefficient value 'b' was significant at p≤0.001 and showed an average increase of standard length of 0.57mm in male, 0.51mm in female and 0.55 in juvenile or immature fishes per 1mm increase in total length. There

was a high degree of positive correlation between total length and second pre dorsal length as the ‘r’ values are 0.9583, 0.9853 and 0.9530 for male, female and juvenile respectively. The coefficient of determination showed that the percentage rate of increase of second pre dorsal length to total length was 91.84, 97.07 and 90.81 in male, female and juvenile respectively.

Total length (TL) and second dorsal length (SDL):

The equations obtained for second dorsal length and total length were as follows:

Male SDL =-10.1623+0.2675TL, Female SDL=-426++0.2017TL, Juvenile SDL= -27.4437+0.665TL The regression coefficient value ‘b’ was highly significant and showed an average increase of standard length of 0.27mm in male, 0.20mm in female and 0.67 in juvenile or immature fishes it was per 1mm increase in total length. There was a high degree of positive correlation between total length and second dorsal length as the ‘r’ values are 0.9228, 0.9884 and 0.9075 for male, female and juvenile respectively. The coefficient of determination showed that the percentage rate of increase of second dorsal length to total length was 85.17, 97.69 and 82.35 in male, female and juvenile respectively.

Total length (TL) and pre pectoral length (PPL)

The equations obtained for pre pectoral length and total length were as follows:

Male PPL =2.3234+0.2556TL, Female PPL=2.7169+0.2765TL, Juvenile PPL= -7.3398+ 0.3872 TL. The regression coefficient value ‘b’ was significant at $p \leq 0.001$ and showed an average increase of standard length of 0.26mm in male, 0.28mm in female while in juvenile or immature fishes it was 0.39mm per 1mm increase in total length. There was a high degree of positive correlation between total length and pre pectoral length as the ‘r’ values are 0.9793, 0.9878 and 0.9437 for male, female and juvenile respectively. The coefficient of determination showed that the percentage rate of increase of pre pectoral length to total length was 95.90, 97.56 and 89.05 in male, female and juvenile respectively.

Total length (TL) and pectoral length (PL)

The equations obtained for pectoral length and total length were as follows:

Male PL = -18.2084+0.4163 TL, Female PL= -1.4541+0.164 TL, Juvenile PL= -14.9747+0.4254 TL. The regression coefficient value ‘b’ was highly significant and

showed an average increase of pectoral length of 0.19mm in male, 0.16mm in female while in juvenile or immature fishes it was 0.43mm per 1mm increase in total length. There was a high degree of positive correlation between total length and pectoral length as the 'r' values are 0.9132, 0.9841and 0.9437 for male, female and juvenile respectively. The coefficient of determination showed that the percentage rate of increase of pectoral length to total length was 83.40, 96.85 and 89.05 in male, female and juvenile respectively.

Total length (TL) and pre pelvic length (PPvL)

The equations obtained for pre pelvic length and total length were as follows:

Male PPvL =-18.2084+0.4163TL, Female PPvL=1.0933+0.2333TL, Juvenile PPvL= 25.4372+ 0.6073TL.The regression coefficient value 'b' was significant ($p \leq 0.001$) and showed an average increase of pre pelvic length of 0.42mm in male, 0.23mm in female and 0.61 in juvenile or immature fishes per 1mm increase in total length. There was a high degree of positive correlation between total length and pre pelvic length as the 'r' values are 0.9665, 0.9839 and 0.6073 for male, female and juvenile respectively. The coefficient of determination showed that the percentage rate of increase of pre pelvic length to total length was 93.41, 96.79 and 92.69 in male, female and juvenile respectively.

Total length (TL) and pelvic length (PvL)

The equations obtained for pelvic length and total length were as follows:

Male PvL =-11.8800+0.2493 TL, Female PvL=-1.7019+0.1396 TL, Juvenile PvL= 19.7344+0.4857 TL. The regression coefficient value 'b' was highly significant at $p \leq 0.01$ and showed an average increase of pelvic length of 0.25mm in male, 0.14mm in female and 0.49 in juvenile or immature fishes per 1mm increase in total length. There was a high degree of positive correlation between total length and pelvic length as the 'r' values are 0.9074, 0.9516 and 0.9588 for male, female and juvenile respectively. The coefficient of determination showed that the percentage rate of increase of pelvic length to total length was 82.34, 90.55 and 91.92 in male, female and juvenile respectively.

Total length (TL) and pre anal length (PAL)

The equations obtained for pre anal length and total length were as follows:

Male PAL =-3.9322+0.5345TL, Female PAL=5.0444+0.4617TL, Juvenile PAL= -9.8016+0.596TL. The regression coefficient value 'b' was significant at p≤0.001 and showed an average increase of pre anal length of 0.53mm in male, 0.46mm in female and 0.60mmin juvenile or immature fishes per 1mm increase in total length. There was a high degree of positive correlation between total length and pre anal length as the 'r' values are 0.9902, 0.9863 and 0.9184 for male, female and juvenile respectively. The coefficient of determination showed that the percentage rate of increase of pre anal length to total length was 98.06, 97.28 and 84.35 in male, female and juvenile respectively.

Total length (TL) and anal length (AL)

The equations obtained for anal length and total length were as follows:

Male AL= -9.2233+0.2447TL, Female AL= -3.3885+0.1900TL, Juvenile AL= -14.9989+ 0.4147TL. The regression coefficient value 'b' was significant at p≤0.001 and showed an average increase of standard length of 0.24mm in male, 0.19mm in female and 0.41mm in juvenile or immature fishes per 1mm increase in total length. There was a high degree of positive correlation between total length and anal length as the 'r' values are 0.9479, 0.9775 and 0.9335 for male, female and juvenile respectively. The coefficient of determination showed that the percentage rate of increase of anal length to total length was 89.86, 95.55 and 87.14 in male, female and juvenile respectively.

Total length (TL) and body depth (BD)

The equations obtained for body depth and total length were as follows:

Male BD = -14.0774+0.3057 TL, Female BD = -6.7697+0.2579TL, Juvenile BD = -10.8558+ 0.3472TL The regression coefficient value b was significant at p≤0.001 and showed an average increase of body depth of 0.31mm in male, 0.26mm in female and 0.35mm in juvenile or immature fishes per 1mm increase in total length. There was a high degree of positive correlation between total length and body depth as the 'r' values are 0.9622, 0.9841 and 0.9297 for male, female and juvenile respectively. The coefficient of determination showed that the percentage rate of increase of body depth to total length was 92.58, 96.85 and 86.43 in male, female and juvenile respectively.

Total length (TL) and caudal depth (CD)

The equations obtained for caudal depth and total length were as follows:

Male CD =-1.9395+0.1385 TL, Female CD=-0.4616+0.1119TL, Juvenile CD= -13.6333+0.3325TL. The regression coefficient value 'b' was significant at p≤ 0.001 and showed an average increase of caudal depth of 0.14mm in male, 0.11mm in female and 0.33 in juvenile or immature fishes per 1mm increase in total length. There was a high degree of positive correlation between total length and caudal depth as the 'r' values are 0.9602, 0.9748 and 0.9293 for male, female and juvenile respectively. The coefficient of determination showed that the percentage rate of increase of caudal depth to total length was 92.21, 95.03 and 86.36 in male, female and juvenile respectively.

Total length (TL) and caudal length (CL):

The equations obtained for caudal length and total length were as follows:

Male CL= -9.5744+0.2900TL, Female CL=-26.9361+0.4956TL, Juvenile CL= -25.4373+ 0.5634TL The regression coefficient value b was significant ($p \leq 0.001$) and showed an average increase of caudal length of 0.29mm in male, 0.50mm in female and 0.56 in juvenile or immature fishes per 1mm increase in total length. There was a high degree of positive correlation between total length and standard length as the 'r' values are 0.9672, 0.9495 and 0.9403 for male, female and juvenile respectively. The coefficient of determination showed that the percentage rate of increase of caudal length to total length was 93.55, 90.16 and 88.42 in male, female and juvenile respectively.

As revealed in Table no. 3.10 the comparison of regression coefficient in males and females, the caudal length showed a statistically significant difference at $p<0.05$ between male and female fish while the difference between total length and other body parameters between male and female were not significant at $p<0.05$.

Ontogenic and morphometric changes

Table no.3.8, 3.9 and 3.10 shows the ontogenic changes in the morphometric measurements of male, female and juvenile *P.ocellatus.* In male isometric growth was observed in standard length while all other characters showed negative allometry. In female isometric growth was observed in three measurements (second dorsal length, pre pectoral length and pre anal length) while standard length showed positive allometry and all other characters showed negative allometry. In juveniles standard

length showed positive allometry while all other characters showed negative allometry. Table no.3.11 presents the comparison of regression coefficient of various morphometric measurements on TL in male and female *P.ocellatus*

Table no. 3.12 and 3.13 presents the comparison of correlation coefficient of fishes (males and females) from the different stations studied. The students t test applied between stations revealed no significant difference in morphometric characters at $p<0.05$.

Table no. 3.1: Morphometric measurements in male and female *P.ocellatus*

Morphometric characters	Male (N=684)			Female (N=489)		
	Min	Max	Mean ± SE	Min	Max	Mean ±SE
TL	66	182	100.13±0.65	66	153	101.92±0.64
SL	59	137	80.55±0.46	60	103	78.33±0.34
HL	10	46	23.65±0.19	13	32	22.23±0.17
Snt L	4	13	6.01±0.07	3	11	6.26±0.08
IOL	4	14	6.21±0.05	3	10	5.92±0.05
ED	2	5	3.21±0.02	2	5	3.59±0.05
FPDL	18	53	28.37±0.20	18	46	29.24±0.25
FDL	4	26	11.02±0.14	6	19	13.93±0.17
SPDL	21	78	43.71±0.38	22	69	47.36±0.33
SDL	10	36	16.56±0.18	12	32	20.98±0.13
PpecL	15	43	27.87±0.17	16	40	25.46±0.18
PecL	8	26	13.15±0.13	9	26	15.26±0.10
PpelL	13	48	23.41±0.28	16	36	24.87±0.15
PelL	6	31	13.04±0.17	8	21	12.52±0.09
PAL	24	87	49.50±0.35	30	75	52.11±0.30
AL	9	32	15.24±0.16	9	24	15.98±0.12
BD	8	35	16.48±0.20	10	32	19.51±0.16
CD	5	24	11.90±0.09	7	17	10.94±0.07
CL	6	45	19.41±0.19	6	50	23.58±0.33

Table no. 3.2: Morphometric measurements in juvenile *P.ocellatus*. (N=338)

Morphometric characters	Minimum	Maximum	Mean ± SE
TL	52	65	61.57
SL	48	54	52.32
HL	12	20	16.32
Snt L	3	4	3.57
IOL	3	5	3.76
ED	2	4	2.60

FPDL	14	21	17.46
FDL	4	9	5.94
SPDL	20	28	23.75
SDL	10	19	13.55
PpecL	14	19	16.50
PecL	8	15	11.22
PpelL	10	20	15.31
PelL	7	13	10.17
PAL	23	32	26.90
AL	8	13	10.54
BD	8	13	10.52
CD	8	13	6.84
CL	4	11	9.25

Table no. 3.3: Various morphometric characters as a function of TL in male and female *P.ocellatus*- statistical analysis.

Morphometric characters	**Male**				**Female**			
	a	**b**	**r**	**r^2**	**a**	**b**	**r**	**r^2**
SL/TL	9.5743	0.7099	0.9886	0.9886	26.936	0.5043	0.9511	0.9046
HL/TL	-4.8540	0.2852	0.9078	0.9078	-3.4594	0.2521	0.9058	0.8206
SntL/TL	-4.3505	0.1037	0.9012	0.9012	-5.807	0.1184	0.9097	0.8276
IOL/TL	-1.2984	0.0752	0.7758	0.7758	-2.4675	0.0823	0.9664	0.9339
ED/TL	0.1566	0.0306	0.7738	0.7738	-2.009	0.0372	0.8445	0.7132
FPDL/TL	-2.8185	0.3120	0.9776	0.9776	-7.7035	0.3625	0.9208	0.8479
FDL/TL	-9.5810	0.2061	0.8937	0.8937	-12.4102	0.2584	0.9450	0.8930
SPDL/TL	-13.2502	0.5698	0.9184	0.9184	-4.5219	0.509	0.9853	0.9707
SDL/TL	-10.1623	0.2673	0.8517	0.8517	0.426	0.2017	0.9884	0.9769
PPL/TL	2.3234	0.2556	0.9590	0.9590	-2.7169	0.2765	0.9878	0.9756
PL/TL	-5.9294	0.1909	0.8340	0.8340	-1.4541	0.164	0.9841	0.9685
PPvL/TL	-18.2084	0.4163	0.9341	0.9341	1.0933	0.2333	0.9839	0.9679
PvL/TL	-11.8800	0.2493	0.8234	0.8234	-1.7019	0.1396	0.9516	0.9055
PAL/TL	-3.9322	0.5345	0.9806	0.9806	5.0444	0.4617	0.9863	0.9728
AL/TL	-9.2233	0.2447	0.8986	0.8986	-3.3885	0.19	0.9775	0.9555
BD/TL	-14.0774	0.3057	0.9258	0.9258	-6.7697	0.2579	0.9841	0.9685

CD/TL	-1.9395	0.1385	0.9221	0.9221	-0.4616	0.1119	0.9748	0.9503
CL/TL	-9.5744	0.2900	0.9355	0.9355	-26.9361	0.4956	0.9495	0.9016

Table no.3.4: Various morphometric characters as a function of TL in juvenile *P.ocellatus*- statistical analysis.

Morphometric measurements	**a**	**b**	**r**	**r^2**
SL/TL	25.4372	0.4365	0.9061	0.8210
HL/TL	-13.7696	0.4886	0.9556	0.9132
SntL/TL	-5.5905	0.1488	0.8345	0.6963
IOL/TL	-4.2749	0.1305	0.7997	0.6395
ED/TL	-6.7724	0.1522	0.8415	0.7080
FPDL/TL	-9.22758	0.4334	0.9358	0.8758
FDL/TL	-16.9085	0.3711	0.9198	0.8461
SPDL/TL	-9.8613	0.5458	0.9530	0.9081
SDL/TL	-27.4437	0.6658	0.9075	0.8235
PPL/TL	-7.3398	0.3872	0.9437	0.8905
PL/TL	-14.9747	0.4254	0.9437	0.8905
PPvL/TL	25.4372	0.6073	0.9628	0.9269
PvL/TL	-19.7344	0.4857	0.9588	0.9192
PAL/TL	-9.8016	0.596	0.9184	0.8435
AL/TL	-14.9989	0.4147	0.9335	0.8714
BD/TL	-10.8558	0.3472	0.9285	0.8643
CD/TL	-13.6339	0.3325	0.9293	0.8636
CL/TL	-25.4373	0.5634	0.9403	0.8842

Table no. 3.5: Various morphometric measurements in male *P. ocellatus*- correlation matrix.

Characters	TL	Std L	Snt L	IOL	ED	HL	FPDL	FDL	SPDL	SDL	PPL	PL	PPvL	PvL	PAL	AL	BD	CD	CL
TL	1																		
Std L	0.9943	1																	
Snt L	0.9493	0.9500	1																
IOL	0.8808	0.8513	0.8907	1															
ED	0.8796	0.8748	0.8230	0.7528	1														
HL	0.9528	0.9345	0.9562	0.9578	0.8176	1													
FPDL	0.9887	0.9809	0.9643	0.8957	0.8539	0.9640	1												
FDL	0.9454	0.9400	0.9654	0.8779	0.8816	0.9529	0.9565	1											
SPD	0.9583	0.9535	0.8652	0.8482	0.8267	0.8927	0.9300	0.8461	1										
SDL	0.9228	0.9157	0.9563	0.8722	0.8465	0.9434	0.9485	0.9819	0.8091	1									
PPL	0.9793	0.9744	0.9296	0.8562	0.8974	0.9395	0.9624	0.9448	0.9382	0.908	1								
PL	0.9132	0.9059	0.9611	0.8979	0.8358	0.9544	0.9315	0.9805	0.8033	0.9763	0.9141	1							
PPvL	0.9665	0.9689	0.9722	0.8572	0.8753	0.9450	0.9741	0.9816	0.8778	0.9784	0.9564	0.9669	1						
PPvL	0.9074	0.8969	0.9498	0.9111	0.8217	0.9543	0.9296	0.9744	0.8090	0.9722	0.9051	0.9876	0.9562	1					
PAL	0.9902	0.9801	0.9222	0.8637	0.8684	0.9395	0.9742	0.9162	0.9598	0.8857	0.9759	0.8799	0.9385	0.8701	1				
AL	0.9479	0.9456	0.9584	0.8465	0.8507	0.9324	0.9600	0.9723	0.8519	0.9772	0.9348	0.9597	0.9855	0.9436	0.9180	1			
BD	0.9622	0.9722	0.9412	0.7711	0.8360	0.8890	0.9579	0.9249	0.8889	0.9131	0.9440	0.8921	0.9653	0.8676	0.9495	0.9588	1		
CD	0.9602	0.9517	0.8998	0.8044	0.8978	0.9032	0.9503	0.9355	0.8875	0.9137	0.9599	0.8935	0.9469	0.8778	0.9541	0.9486	0.9485	1	
CL	0.9672	0.9346	0.9037	0.9101	0.8505	0.9522	0.9615	0.9143	0.9255	0.8972	0.9455	0.8884	0.9159	0.8903	0.9685	0.9097	0.8937	0.9360	1

Table no. 3.6: Various morphometric measurements in female *P. ocellatus*- correlation matrix.

Characters	TL	SL	Snt L	IOL	ED	HL	FPDL	FDL	SPDL	SDL	PP L	PL	PPvL	Pv L	PAL	A L	BD	CD	C L
TL	1																		
SL	0.9511	1																	
SntL	0.9097	0.8879	1																
IOL	0.9664	0.9137	0.8806	1															
ED	0.8445	0.7265	0.7146	0.8484	1														
HL	0.9059	0.8906	0.8836	0.8736	0.7058	1													
FPDL	0.9208	0.8651	0.8601	0.8972	0.7690	0.8495	1												
FDL	0.9450	0.9131	0.8661	0.9227	0.8305	0.8866	0.8460	1											
SPDL	0.9853	0.9414	0.9063	0.9544	0.8062	0.9175	0.9127	0.9537	1										
SDL	0.9884	0.9369	0.9127	0.9618	0.8166	0.9120	0.9196	0.9382	0.9864	1									
PP L	0.9878	0.9330	0.9095	0.9593	0.8076	0.9115	0.9244	0.9273	0.9855	0.9899	1								
PL	0.9841	0.9179	0.8932	0.9625	0.8449	0.8869	0.9063	0.9361	0.9708	0.9780	0.9800	1							
PPvL	0.9839	0.9269	0.9103	0.9642	0.8151	0.9079	0.9173	0.9295	0.9830	0.9860	0.9870	0.9757	1						
PL	0.9516	0.9042	0.8969	0.9555	0.7549	0.8854	0.9021	0.8826	0.9527	0.9616	0.9669	0.9502	0.9750	1					
PAL	0.9863	0.9458	0.9132	0.9579	0.7932	0.9117	0.9108	0.9262	0.9859	0.9890	0.9863	0.9726	0.9866	0.9688	1				
AL	0.9775	0.9014	0.8742	0.9520	0.8867	0.8654	0.9103	0.9375	0.9619	0.9615	0.9582	0.9661	0.9584	0.9113	0.9490	1			
BD	0.9841	0.9329	0.9037	0.9626	0.8254	0.9115	0.9084	0.9555	0.9858	0.9849	0.9867	0.9824	0.9870	0.9636	0.9821	0.9617	1		
CD	0.9748	0.9073	0.8965	0.9542	0.8206	0.8932	0.9113	0.9293	0.9694	0.9758	0.9733	0.9758	0.9757	0.9544	0.9737	0.9550	0.9731	1	
CL	0.9495	0.8063	0.8409	0.9232	0.8799	0.8308	0.8854	0.8829	0.9312	0.9418	0.9445	0.9530	0.9433	0.9046	0.9287	0.9571	0.9376	0.9459	1

Table no.3.7: Various morphometric measurements in juvenile *P.*ocellatus- correlation matrix.

Characters	TL	SL	SntL	IOL	ED	HL	FPDL	FDL	SPDL	SDL	PPL	PL	PPvL	Pv L	PAL	A L	BD	CD	CL
TL	1																		
SL	0.9061	1																	
SNTL	0.8345	0.8577	1																
IOL	0.7997	0.6170	0.6644	1															
ED	0.8415	0.8460	0.9478	0.7090	1														
HL	0.9556	0.8937	0.8166	0.8033	0.8222	1													
FPDL	0.9358	0.8500	0.7891	0.7906	0.7957	0.9377	1												
FDL	0.9198	0.8853	0.7823	0.7059	0.8057	0.9127	0.9183	1											
SPDL	0.9530	0.8872	0.8074	0.7647	0.8117	0.9400	0.9558	0.9553	1										
SDL	0.9075	0.9028	0.7590	0.6748	0.7687	0.9206	0.9335	0.9586	0.9511	1									
PpecL	0.9437	0.8738	0.8186	0.7803	0.8146	0.9502	0.9603	0.9032	0.9469	0.9198	1								
PecL	0.9437	0.8603	0.7633	0.8229	0.7808	0.9462	0.9440	0.9104	0.9495	0.9268	0.9249	1							
PpelL	0.9628	0.9166	0.8045	0.7477	0.8173	0.9593	0.9417	0.9581	0.9592	0.9652	0.9409	0.9518	1						
Pel L	0.9588	0.9223	0.8211	0.7520	0.8281	0.9674	0.9278	0.9293	0.9394	0.9503	0.9457	0.9433	0.9691	1					
PAL	0.9184	0.8668	0.7665	0.7145	0.7684	0.9109	0.9539	0.9564	0.9764	0.9628	0.9281	0.9301	0.9466	0.9185	1				
AL	0.9335	0.9003	0.8314	0.7901	0.8250	0.9569	0.9524	0.9174	0.9460	0.9344	0.9603	0.9255	0.9417	0.9413	0.9283	1			
BD	0.9297	0.8889	0.8196	0.7410	0.8097	0.9444	0.9521	0.8940	0.9364	0.9233	0.9725	0.9175	0.9353	0.9416	0.9201	0.9466	1		
CD	0.9293	0.8742	0.7976	0.7310	0.8184	0.9291	0.9147	0.9647	0.9470	0.9358	0.9097	0.9030	0.9460	0.9388	0.9234	0.9323	0.8953	1	
CL	0.9403	0.7081	0.7031	0.8386	0.7241	0.8762	0.8784	0.8233	0.8771	0.7886	0.8724	0.8832	0.8698	0.8585	0.8358	0.8341	0.8364	0.8481	1

Table no. 3.8: Ontogenic changes in morphometric characters as a function of TL in male *P.ocellatus*

Morphometric	Log a	b	SE	Increement
SL/TL	0.1848	0.9482	0.0032	I
HL/TL	0.9289	0.8017	0.0130	A-
SntL/TL	1.6029	0.5188	0.0239	A-
IOL/TL	1.6325	0.4891	0.0242	A-
ED/TL	1.7281	0.5407	0.0285	A-
FPDL/TL	0.9102	0.7506	0.0109	A-
FDL/TL	1.4212	0.5423	0.0218	A-
SPDL/TL	0.5325	0.8856	0.0070	A-
SDL/TL	1.4177	0.4441	0.0137	A-
PPL/TL	0.7888	0.8660	0.0118	A-
PL/TL	1.3285	0.5720	0.0161	A-
PPvL/TL	0.9332	0.7684	0.0120	A-
PvL/TL	1.4648	0.4902	0.0177	A-
PAL/TL	0.7192	0.7536	0.0064	A-
AL/TL	1.3936	0.5083	0.0158	A-
BD/TL	1.3112	0.5465	0.0146	A-
CD/TL	1.4034	0.5775	0.0188	A-
CL/TL	1.6670	0.2652	0.0153	A-

Table no. 3.9: Ontogenic changes in morphometric characters as a function of TL in female *P.ocellatus*

Morphometric	Log a	b	SE	Increement

characters				
SL/TL	-0.63256	1.393531	0.003501	A+
HL/TL	1.049082	0.712477	0.015356	A-
SntL/TL	1.679304	0.41799	0.028176	A-
IOL/TL	1.504974	0.653883	0.028301	A-
ED/TL	1.662348	0.623396	0.033119	A-
FPDL/TL	0.992337	0.693732	0.012788	A-
FDL/TL	1.498983	0.448841	0.020442	A-
SPDL/TL	0.506506	0.896578	0.008112	A-
SDL/TL	0.666351	1.0150	0.015771	I
PPL/TL	0.722838	0.914541	0.013959	A-
PL/TL	0.948207	0.89583	0.01891	A-
PPvL/TL	0.553014	1.042421	0.014117	I
PvL/TL	1.06665	0.858055	0.02084	A-
PAL/TL	0.130433	1.093443	0.0021	I
AL/TL	1.095598	0.75907	0.018553	A-
BD/TL	1.069358	0.728733	0.016665	A-
CD/TL	1.045959	0.926155	0.022128	A-
CL/TL	1.506891	0.369001	0.003501	A-

Table no. 3.10: Ontogenic changes in morphometric characters as a function of total length in juvenile *P.ocellatus*

Morphometric characters	Log a	b	SE	Increement
SL/TL	-0.99013	1.617135	0.002109	A+
HL/TL	1.189588	0.494921	0.015821	A-
SntL/TL	1.642266	0.267157	0.033844	A-
IOL/TL	1.623857	0.288613	0.033205	A-
ED/TL	1.711287	0.19091	0.037781	A-
FPDL/TL	1.065185	0.58329	0.014992	A-
FDL/TL	1.616047	0.22569	0.028034	A-
SPDL/TL	0.891095	0.653123	0.011358	A-
SDL/TL	1.461917	0.290109	0.018193	A-
PPL/TL	1.032665	0.621673	0.015645	A-
PL/TL	1.389043	0.381845	0.020293	A-
PPvL/TL	1.336763	0.38248	0.016647	A-
PvL/TL	1.475513	0.312423	0.021532	A-
PAL/TL	0.871335	0.64224	0.009897	A-
AL/TL	1.417639	0.364064	0.021042	A-
BD/TL	1.353023	0.427258	0.021005	A-
CD/TL	1.548228	0.289811	0.026216	A-
CL/TL	1.606151	0.190984	0.022952	A-

Table no.3.11: Comparison of regression coefficient of various morphometric characters on TL in male and female *P.ocellatus*.

Morphometric measurements (mm)	Male		Female			
	b1	Sb1	b2	Sb2	t test	Significance
SL/TL	0.7099	0.4674	0.5043	0.3426	-0.71165	NS
HL/TL	0.2852	0.1959	0.2521	0.1798	-1.18148	NS
SntL/TL	0.1037	0.0715	0.1184	0.0841	-1.63634	NS
IOL/TL	0.0752	0.0558	0.0823	0.055	-1.45471	NS
ED/TL	0.0306	0.0227	0.0372	0.055	-1.66317	NS
FPDL/TL	0.312	0.2065	0.3625	0.2544	-1.69785	NS
FDL/TL	0.2061	0.1427	0.2584	0.1767	-1.78139	NS
SPDL/TL	0.5698	0.3892	0.509	0.3339	-1.07191	NS
SDL/TL	0.2673	0.1896	0.2017	0.1319	-0.92842	NS
PPL/TL	0.2556	0.1708	0.2765	0.1809	-1.54415	NS
PL/TL	0.1901	0.1368	0.164	0.1077	-1.11643	NS
PPvL/TL	0.4163	0.2819	0.2333	0.1532	-0.5645	NS
PvL/TL	0.2493	0.1798	0.1396	0.0948	-0.62192	NS
PAL/TL	0.5345	0.3533	0.4617	0.3025	-1.07482	NS
AL/TL	0.2447	0.1689	0.19	0.1256	-1.00583	NS
BD/TL	0.3057	0.2079	0.2579	0.1693	-1.1041	NS
CD/TL	0.1385	0.0944	0.1119	0.0741	-1.12098	NS
CL/TL	0.29	0.1965	0.4956	0.3373	-2.56944	S

($t_{1172} = 2$ at $p \leq 0.05$) , NS is not significant at 5% level of significance, S is significant at 5% level of significance

Table no. 3.12: Coefficient of correlation between TL and various morphometric measurements in male *P.ocellatus* from different stations.

Characters	Malad	Vasai	Thane	Mahul
TL/SL	0.9375	0.9377	0.9378	0.9379
TL/HL	0.8384	0.8387	0.8395	0.8389
TL/Snt L	0.7574	0.7566	0.7564	0.7569
TL/IOL	0.6959	0.6977	0.6917	0.6936
TL/ED	0.4798	0.4786	0.4787	0.4783
TL/FPDL	0.8712	0.8725	0.8720	0.8715
TL/FDL	0.6818	0.6823	0.6814	0.6819
TL/SPDL	0.8152	0.8154	0.8168	0.8158
TL/SDL	0.6330	0.6360	0.6330	0.6303
TL/PPL	0.8238	0.8252	0.8216	0.8275
TL/PL	0.6170	0.6180	0.6173	0.6167
TL/PPvL	0.7871	0.7860	0.7875	0.7874
TL/PvL	0.5034	0.5018	0.5011	0.5007
TL/PAL	0.8316	0.8308	0.8336	0.8353
TL/AL	0.6373	0.6395	0.6378	0.6386
TL/BD	0.7744	0.7758	0.7680	0.7740
TL/CD	0.6352	0.6330	0.6350	0.6341
TL/CL	0.6488	0.6489	0.6486	0.6486

t values for males

Stations	*Malad/ Vasai*	*Malad /Thane*	*Malad/Mahul*	*Vasai/Thane*	*Vasai/Mahul*	*Thane/ Mahul*
t statistical value	*-0.155*	*1.245*	*0.1325*	*1.4501*	*0.7100*	*-1.06*

t critical = 1.7396 the values are not significant

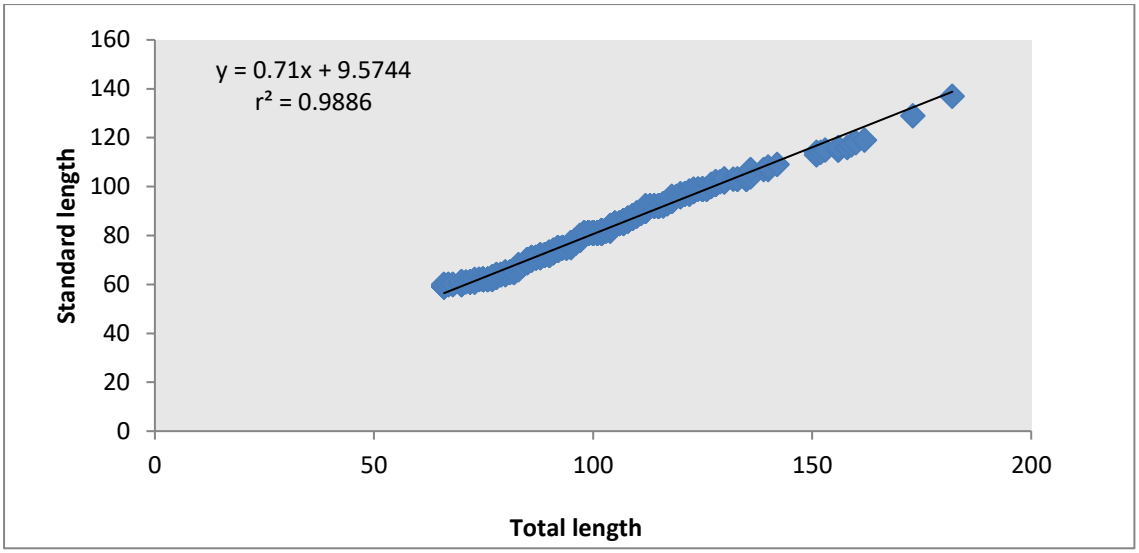
Table no. 3.13: Coefficient of correlation between TL and various morphometric measurements in female *P.ocellatus* from different stations.

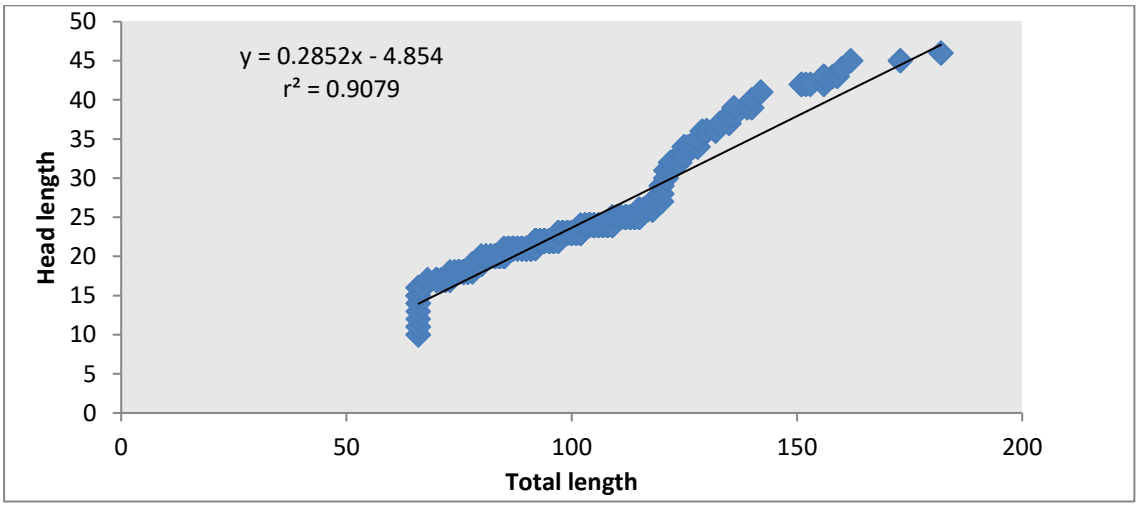
Characters	**Malad**	**Vasai**	**Thane**	**Mahul**
TL/SL	0.9381	0.9376	0.9386	0.9366
TL/HL	0.8344	0.8417	0.8408	0.8387
TL/Snt L	0.7576	0.7546	0.7583	0.7567
TL/IOL	0.6943	0.6954	0.6942	0.6950
TL/ED	0.4793	0.4779	0.4786	0.4799
TL/FPDL	0.8729	0.8638	0.8764	0.8739
TL/FDL	0.6808	0.6887	0.6769	0.6813
TL/SPDL	0.8149	0.8151	0.8171	0.8162
TL/SDL	0.6359	0.6337	0.6327	0.6301
TL/PPL	0.8243	0.8235	0.8249	0.8251
TL/PL	0.6165	0.6176	0.6179	0.6169
TL/PPvL	0.7855	0.7856	0.7875	0.7898
TL/PvL	0.5020	0.5003	0.5022	0.5023
TL/PAL	0.8326	0.8336	0.8326	0.8325
TL/AL	0.6372	0.6384	0.6373	0.6403
TL/BD	0.7716	0.7724	0.7749	0.7729
TL/CD	0.6328	0.6338	0.6370	0.6334
TL/CL	0.6481	0.6473	0.6547	0.6448

t values for males

Stations	*Malad/ Vasai*	*Malad /Thane*	*Malad/Mahul*	*Vasai/Thane*	*Vasai/Mahul*	*Thane/ Mahul*
t statistical value	*0.1812*	*-1.5901*	*-0.6080*	*-0.7989*	*-0.2198*	*0.9604*

t critical = 1.7396 not significant.





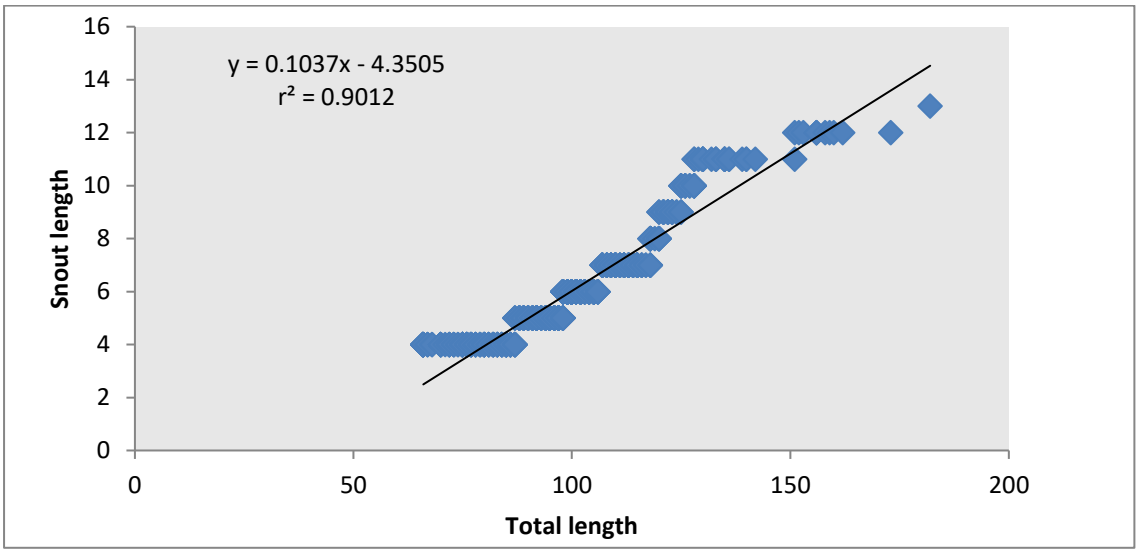


Fig 3.1a: Relationship between various morphometric measurements and total length of *P.ocellatus* male

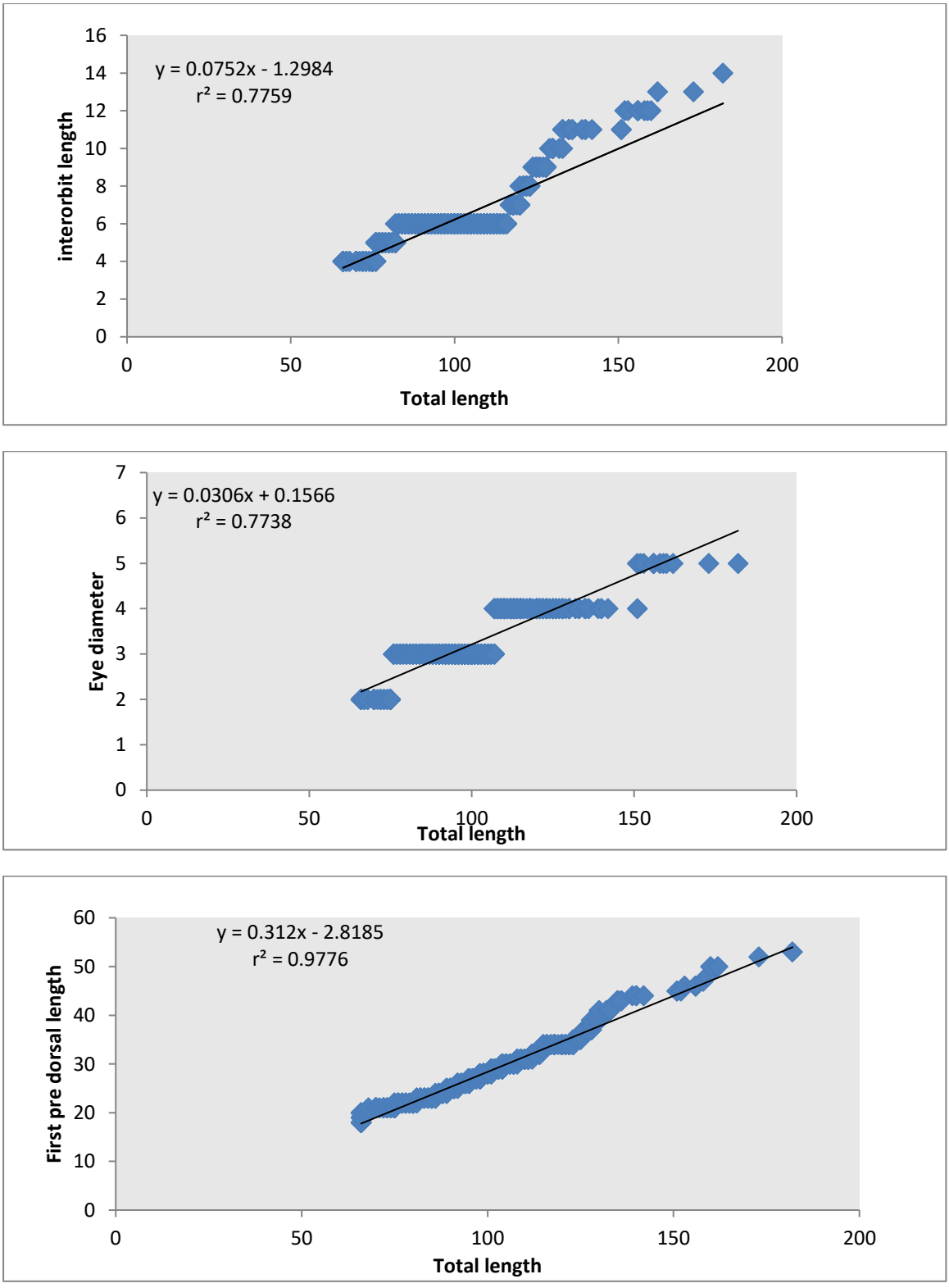
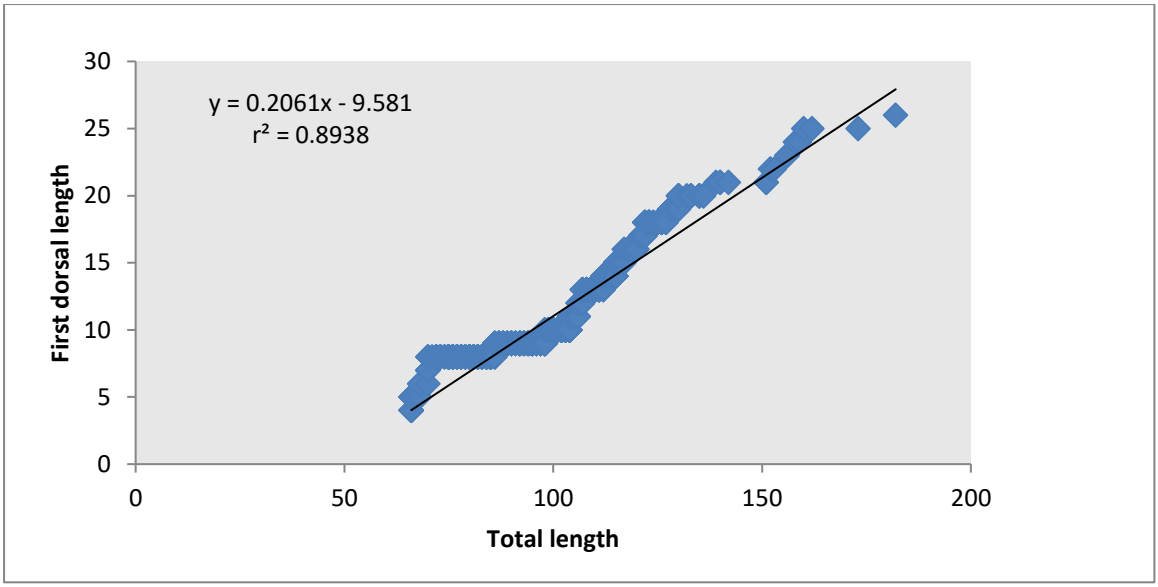
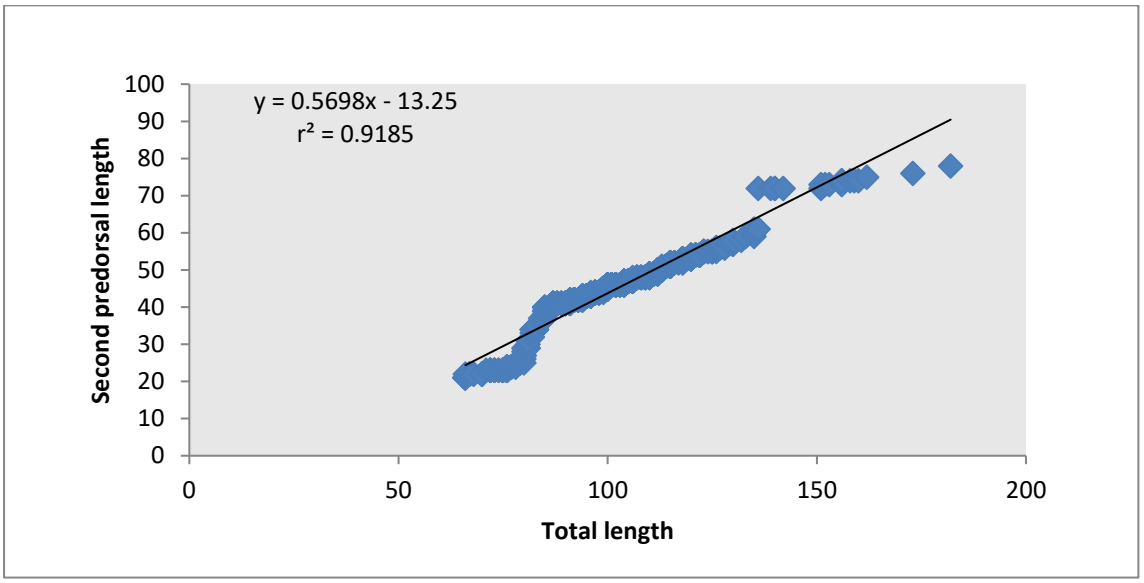


Fig 3.1b: Relationship between various morphometric measurements and total length of *P.ocellatus* male





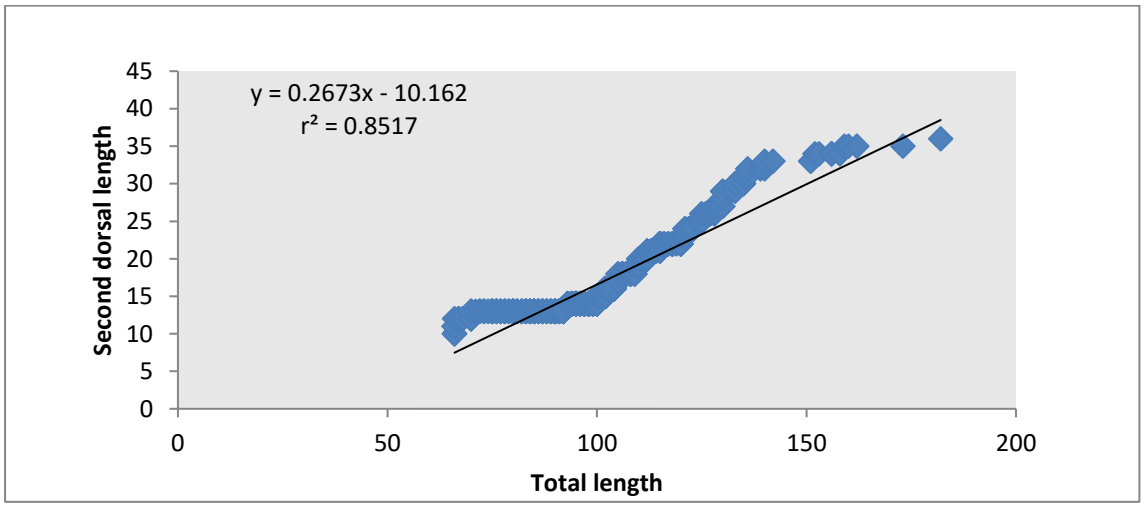
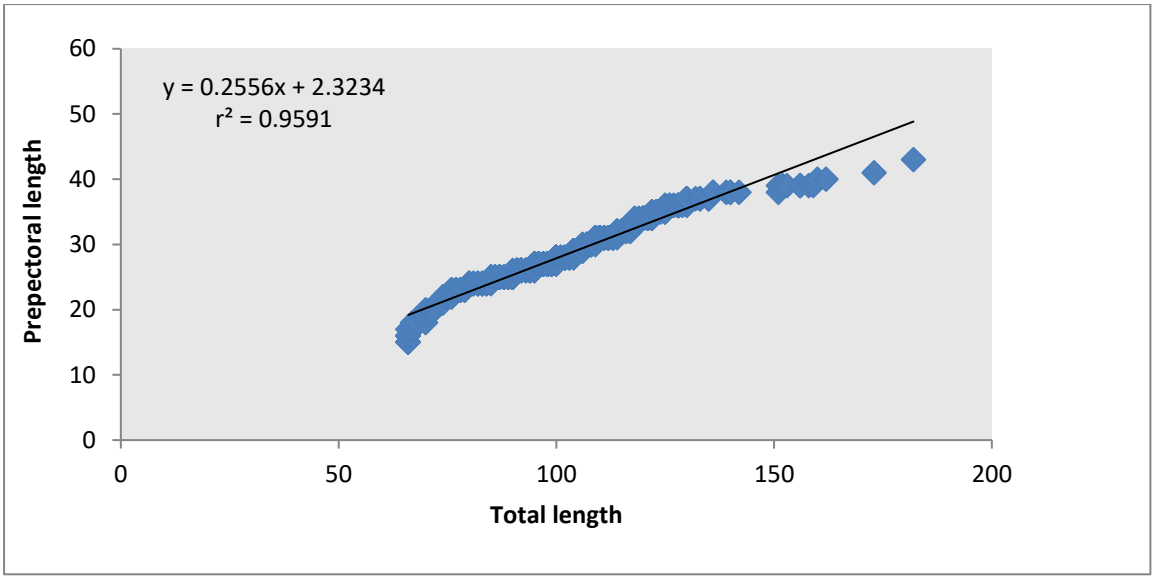
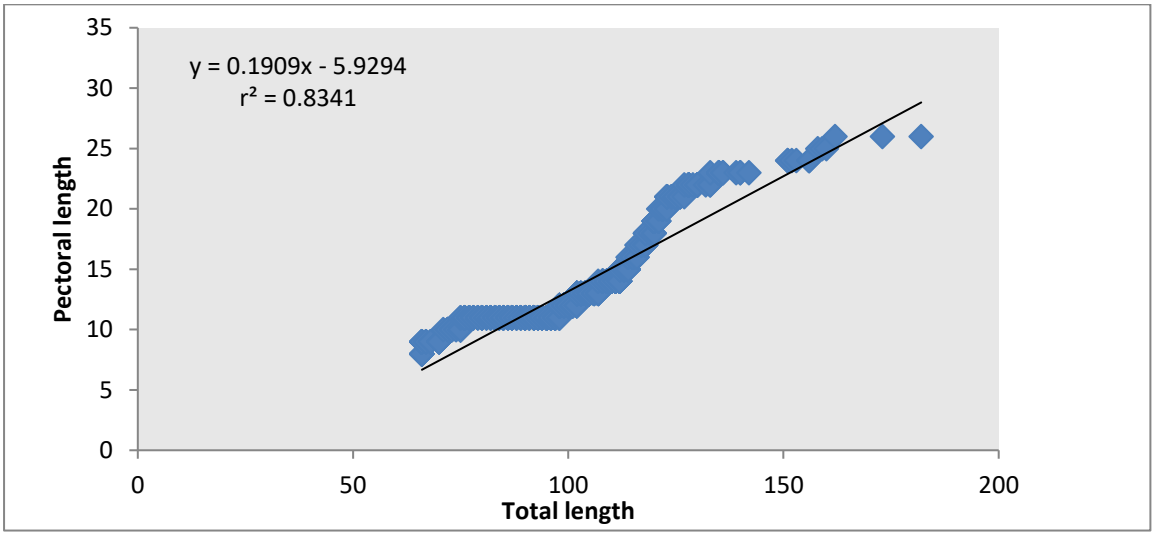


Fig 3.1c: Relationship between various morphometric measurements and total length of *P.ocellatus* male





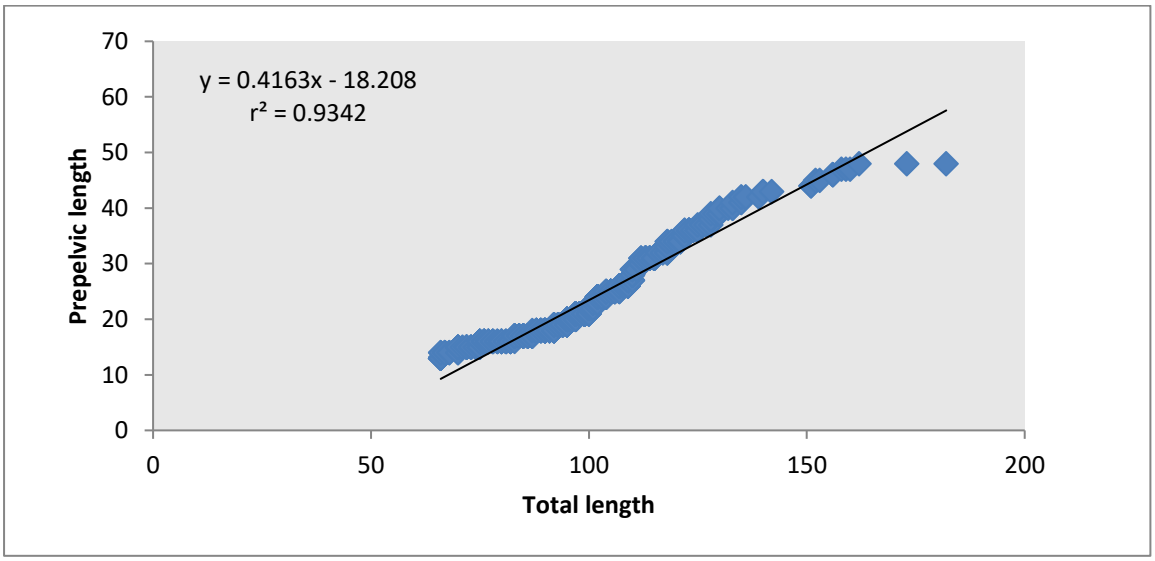
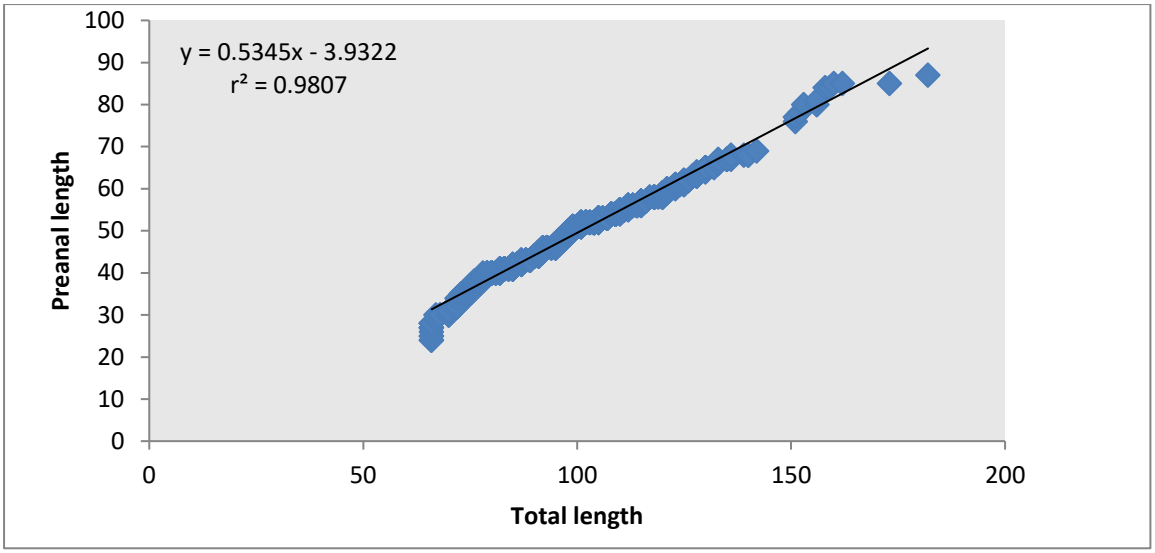
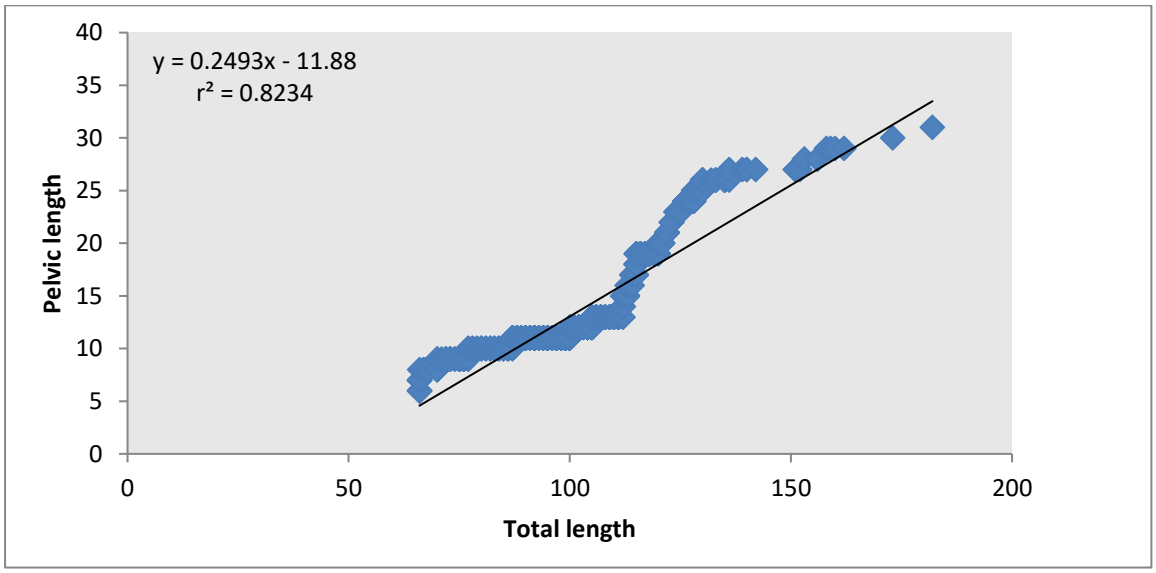


Fig 3.1d: Relationship between various morphometric measurements and total length of *P.ocellatus* male





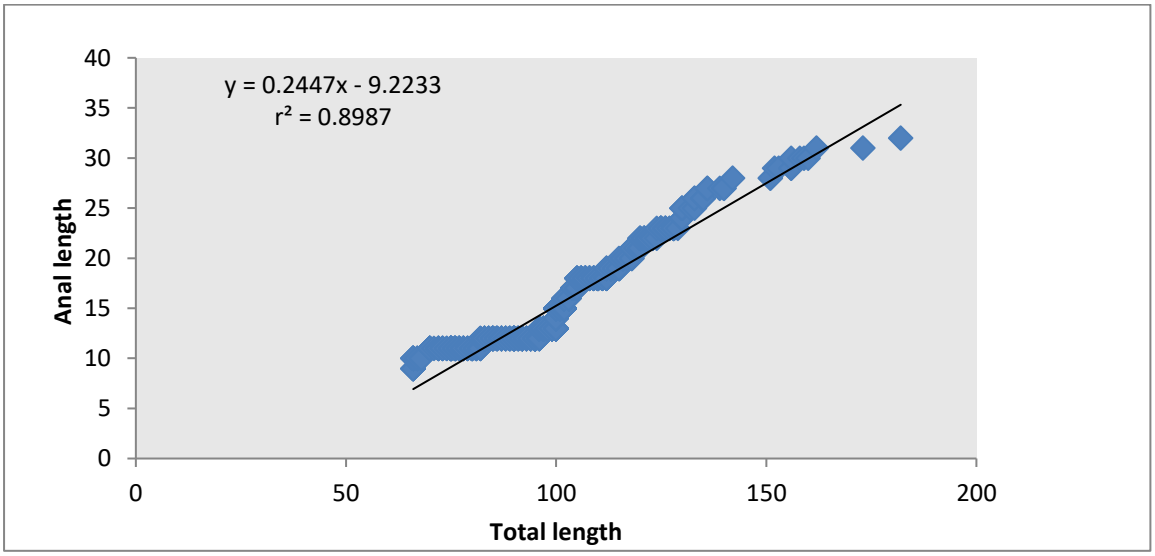


Fig 3.1e: Relationship between various morphometric measurements and total length of *P.ocellatus* male

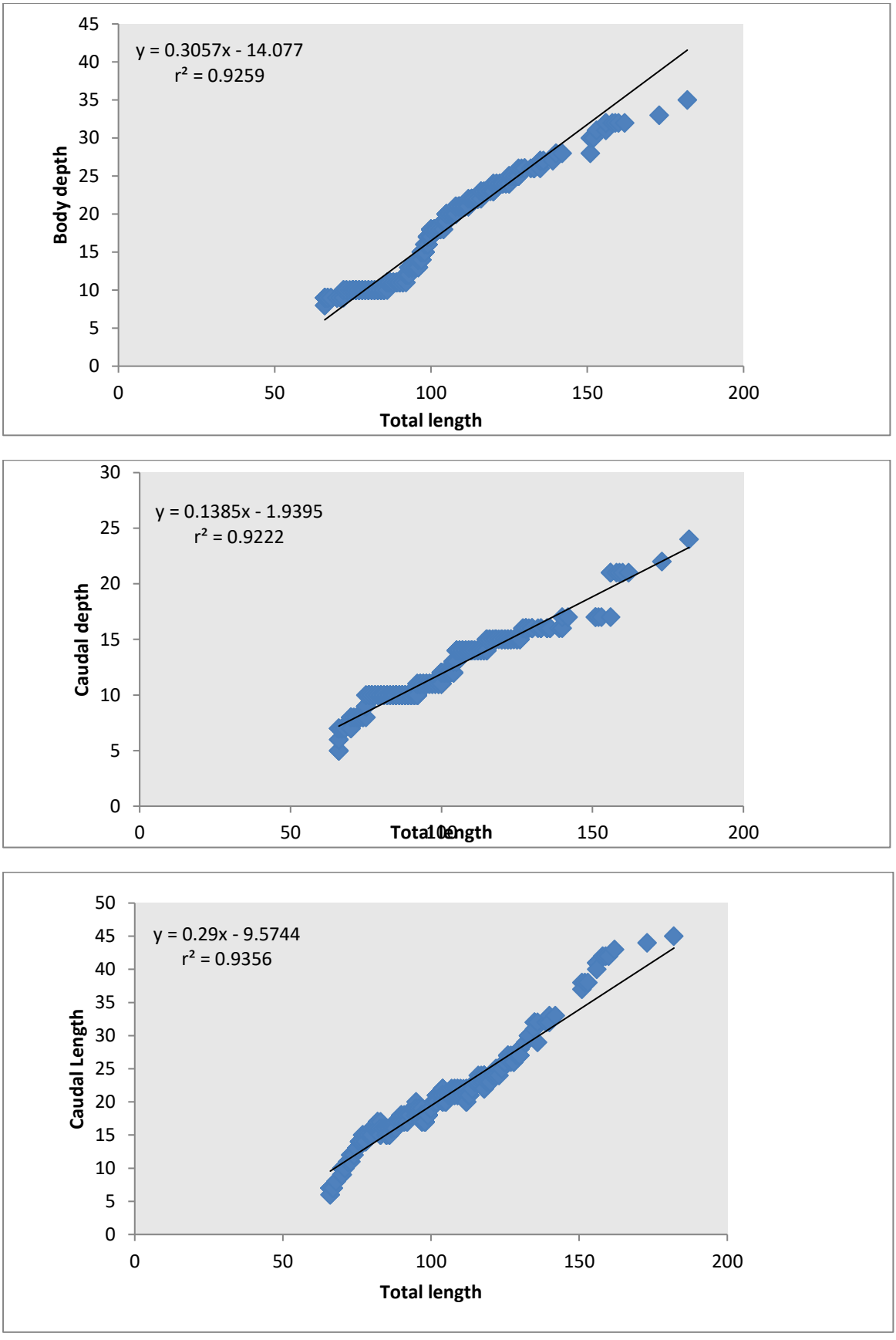
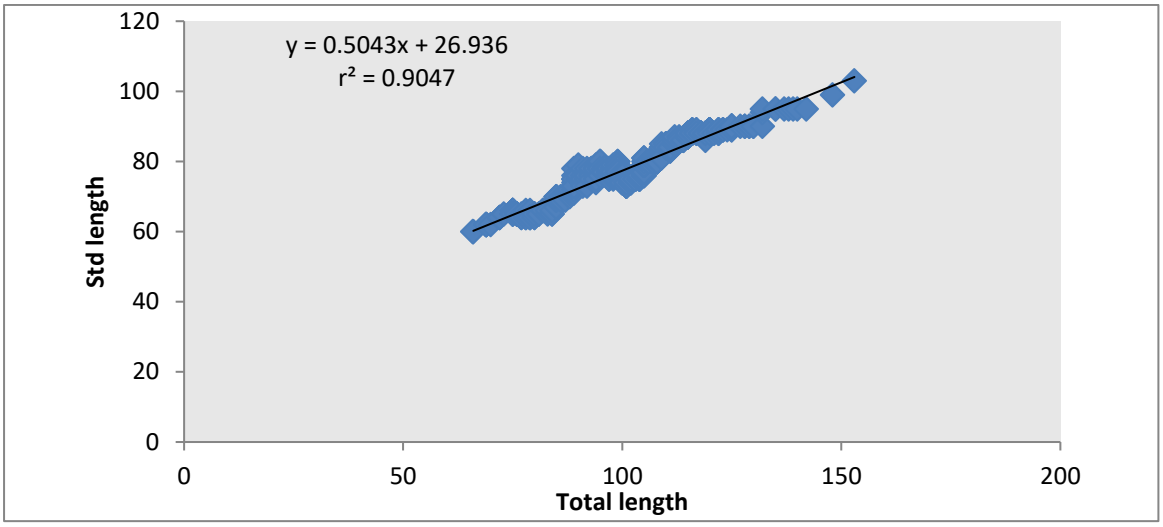
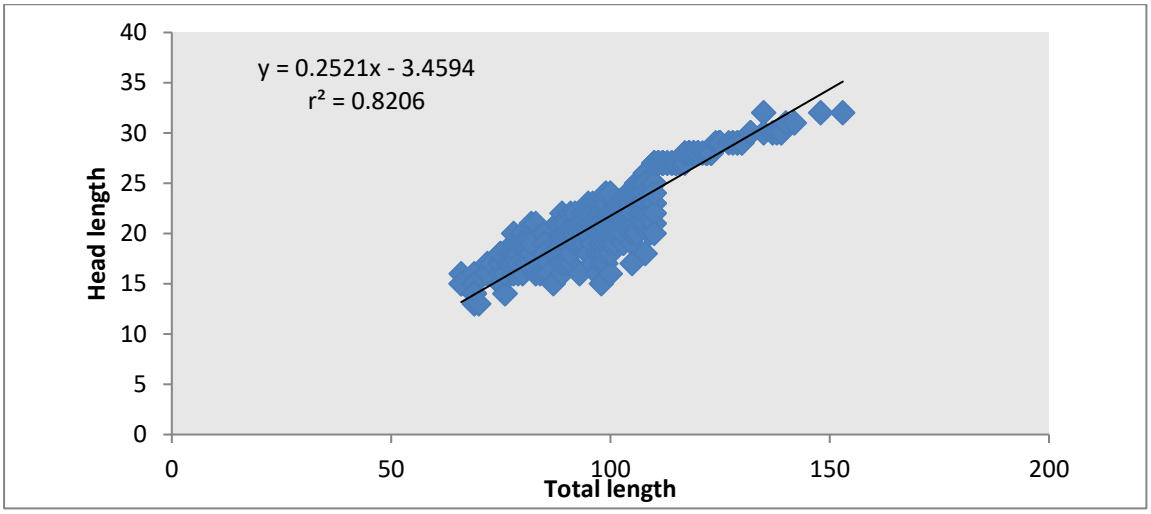


Fig 3.1 f: Relationship between various morphometric measurements and total length of *P.ocellatus* male





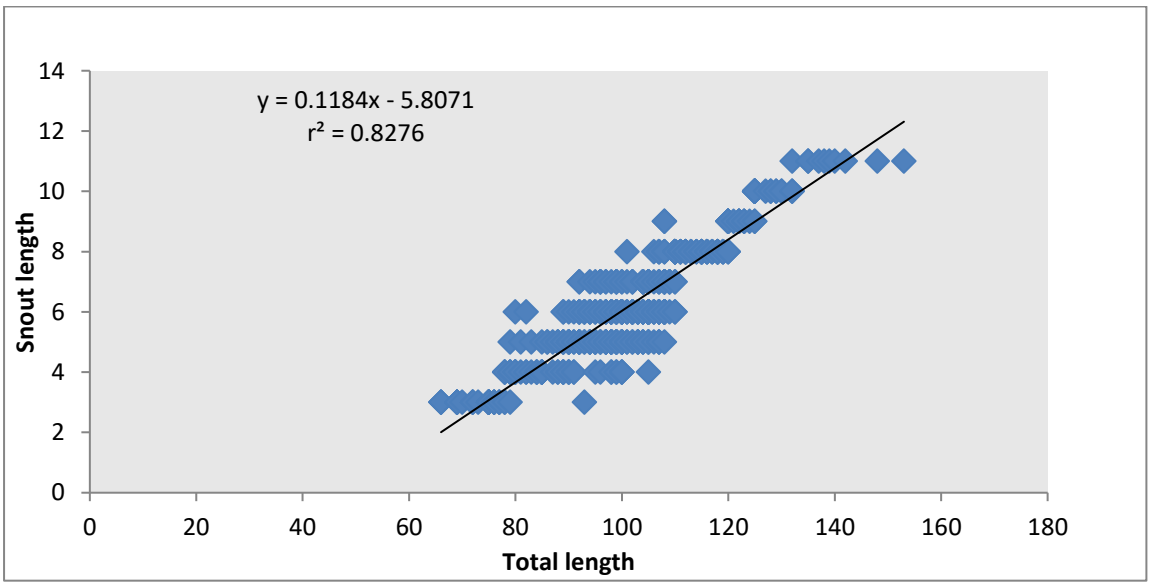


Fig 3.2a: Relationship between various morphometric measurements and total length of *P.ocellatus* female

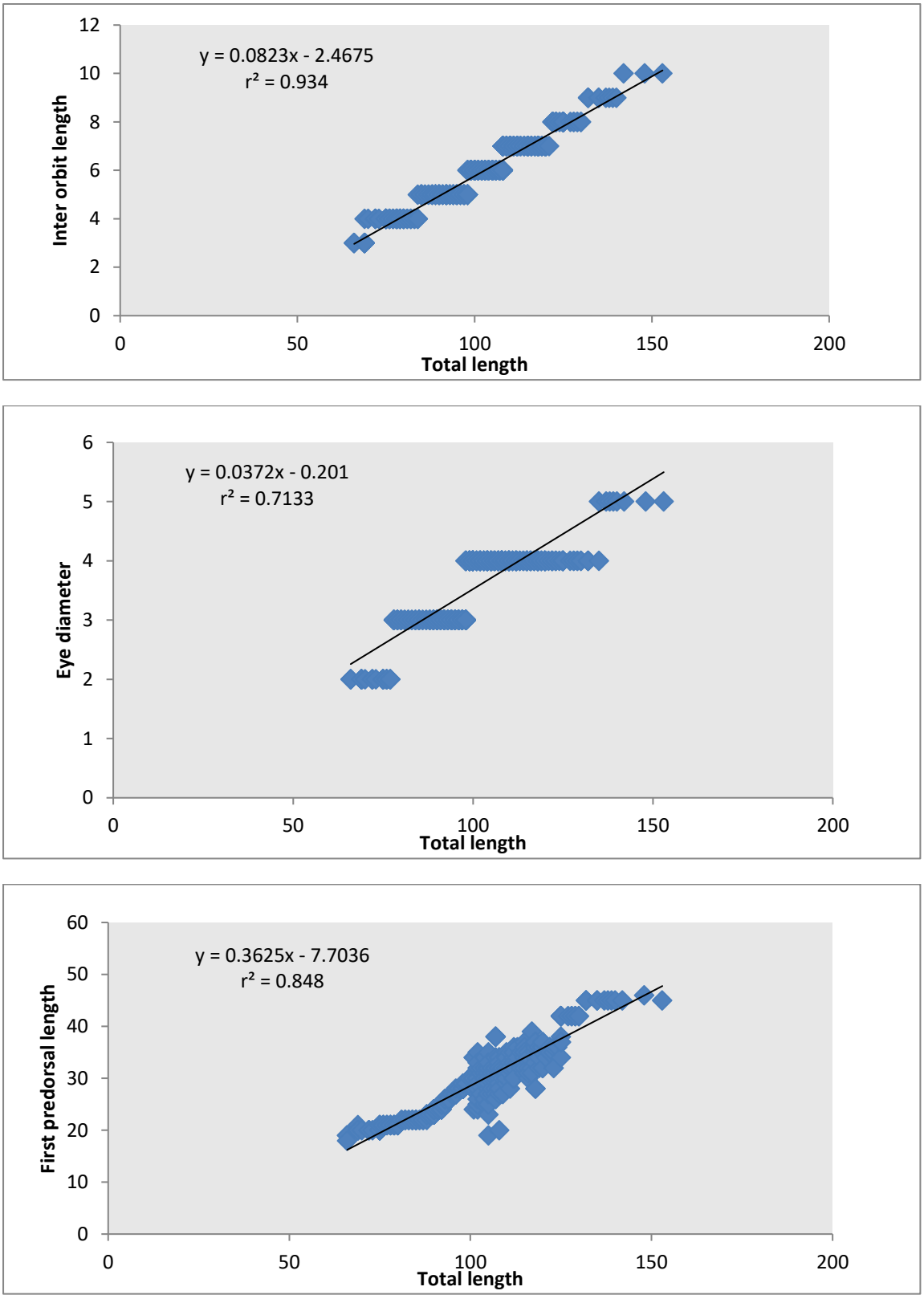


Fig 3.2b.: Relationship between various morphometric measurements and total length of *P.ocellatus* female

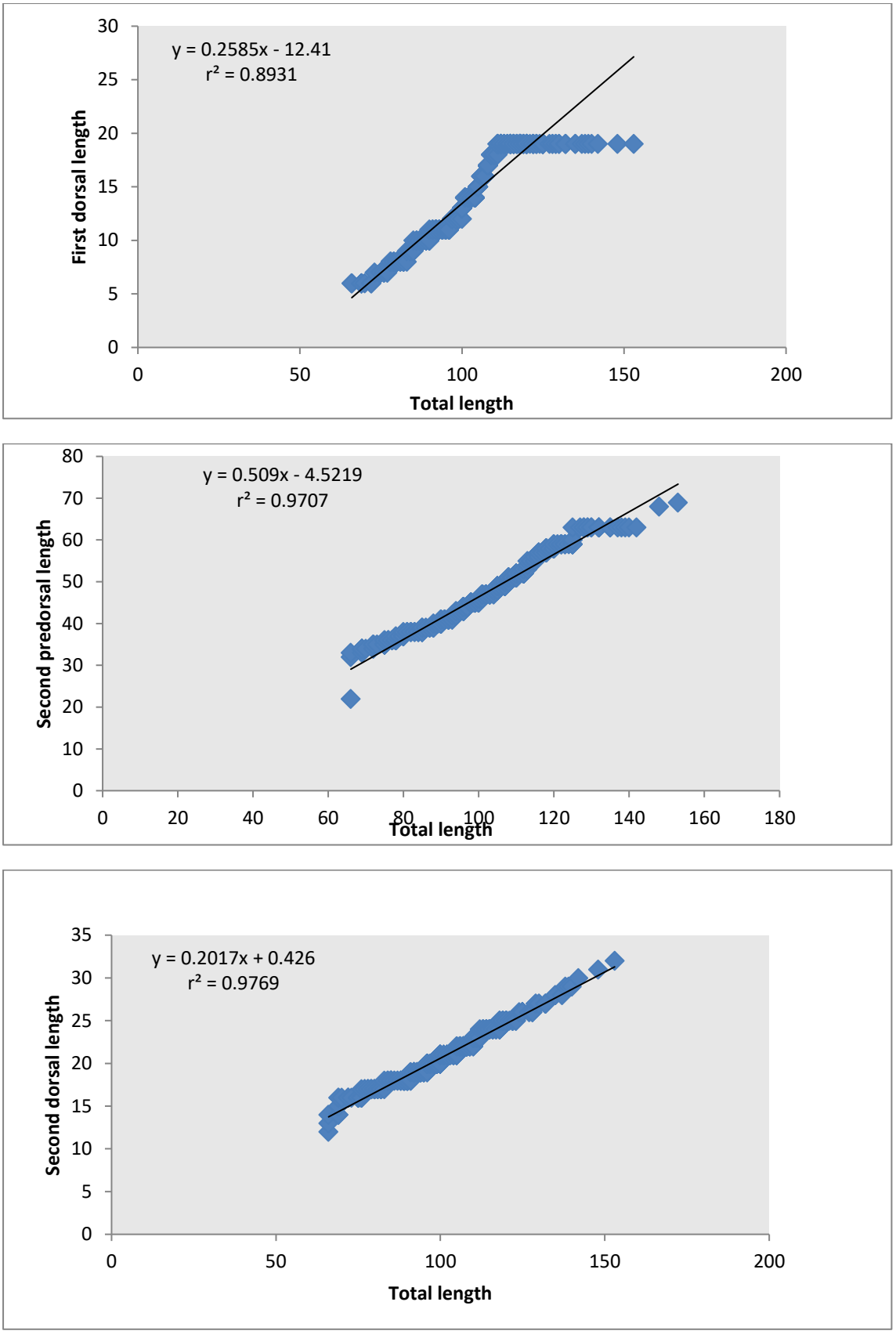


Fig 3.2c: Relationship between various morphometric measurements and total length of *P.ocellatus* female

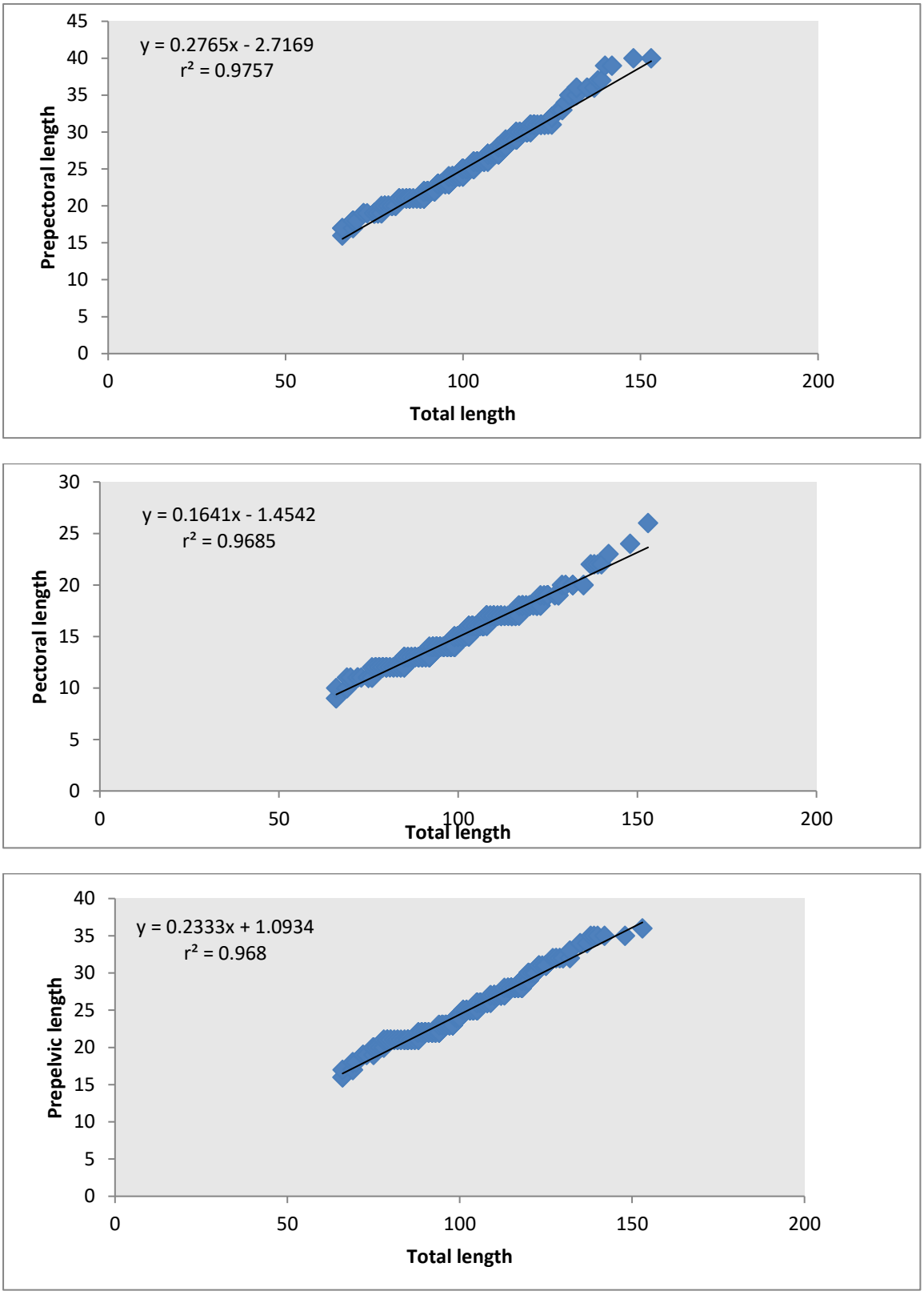
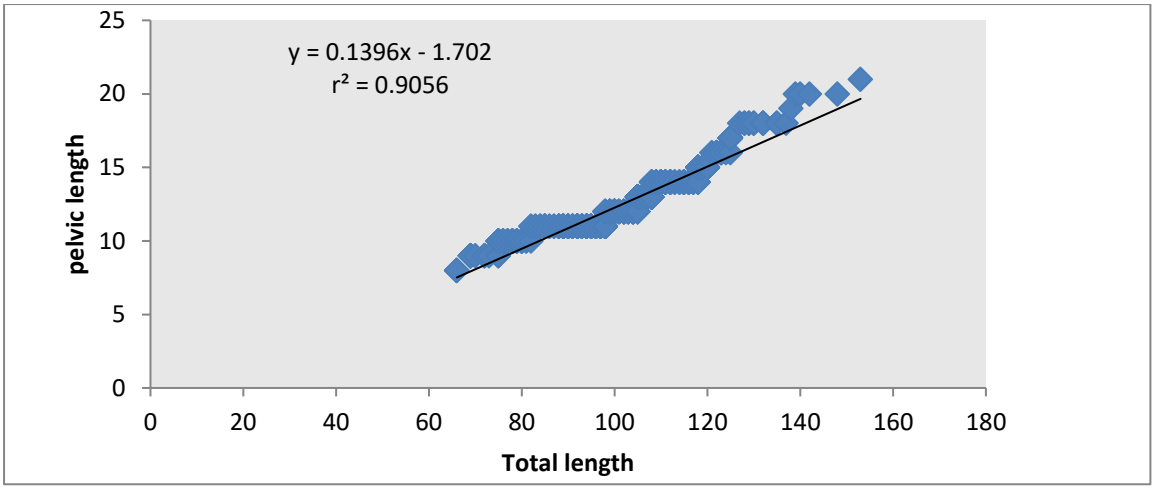
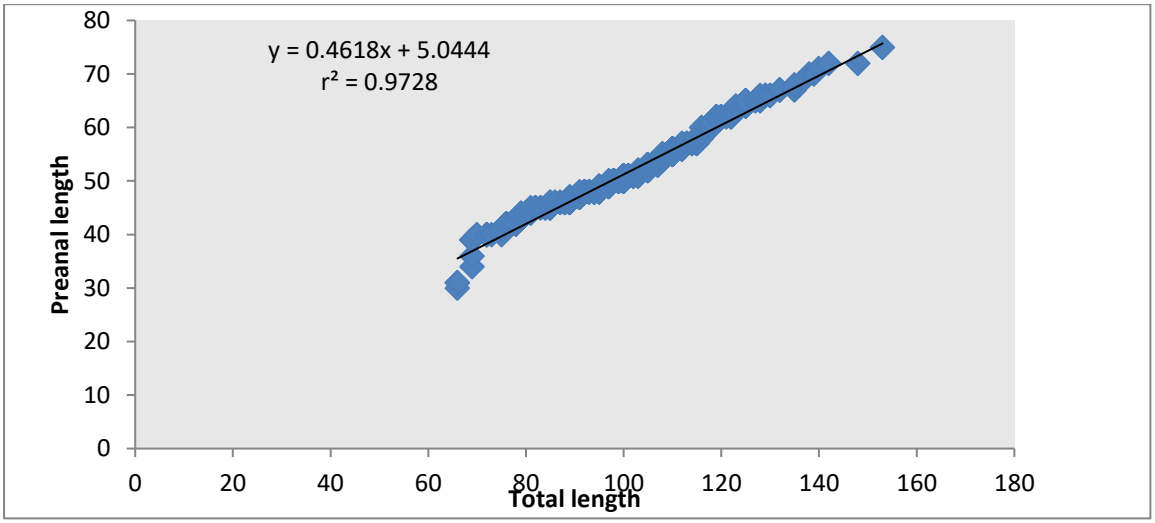


Fig 3.2d: Relationship between various morphometric measurements and total length of *P.ocellatus* female





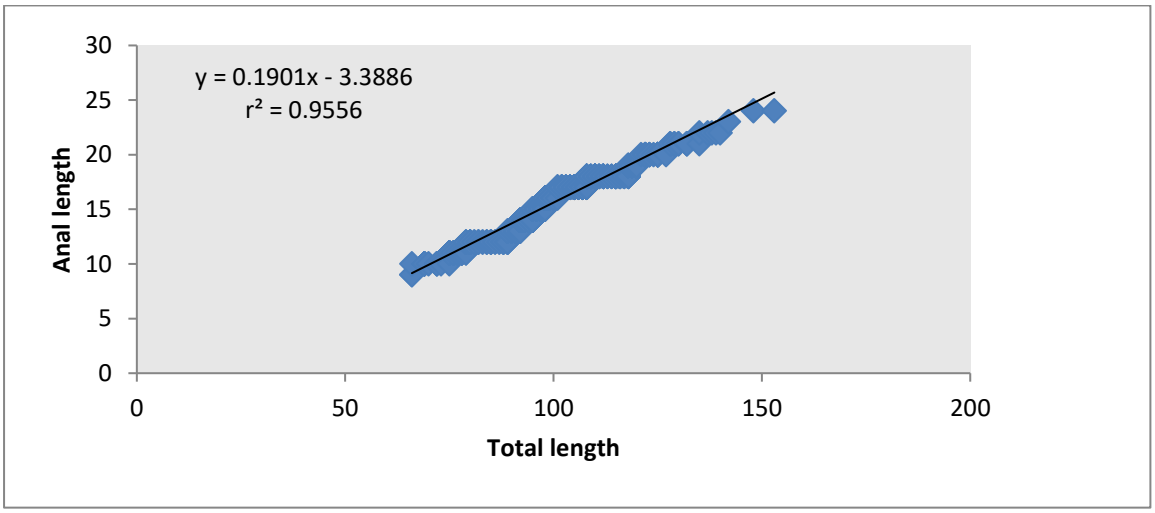


Fig 3.2e: Relationship between various morphometric measurements and total length of *P.ocellatus* female

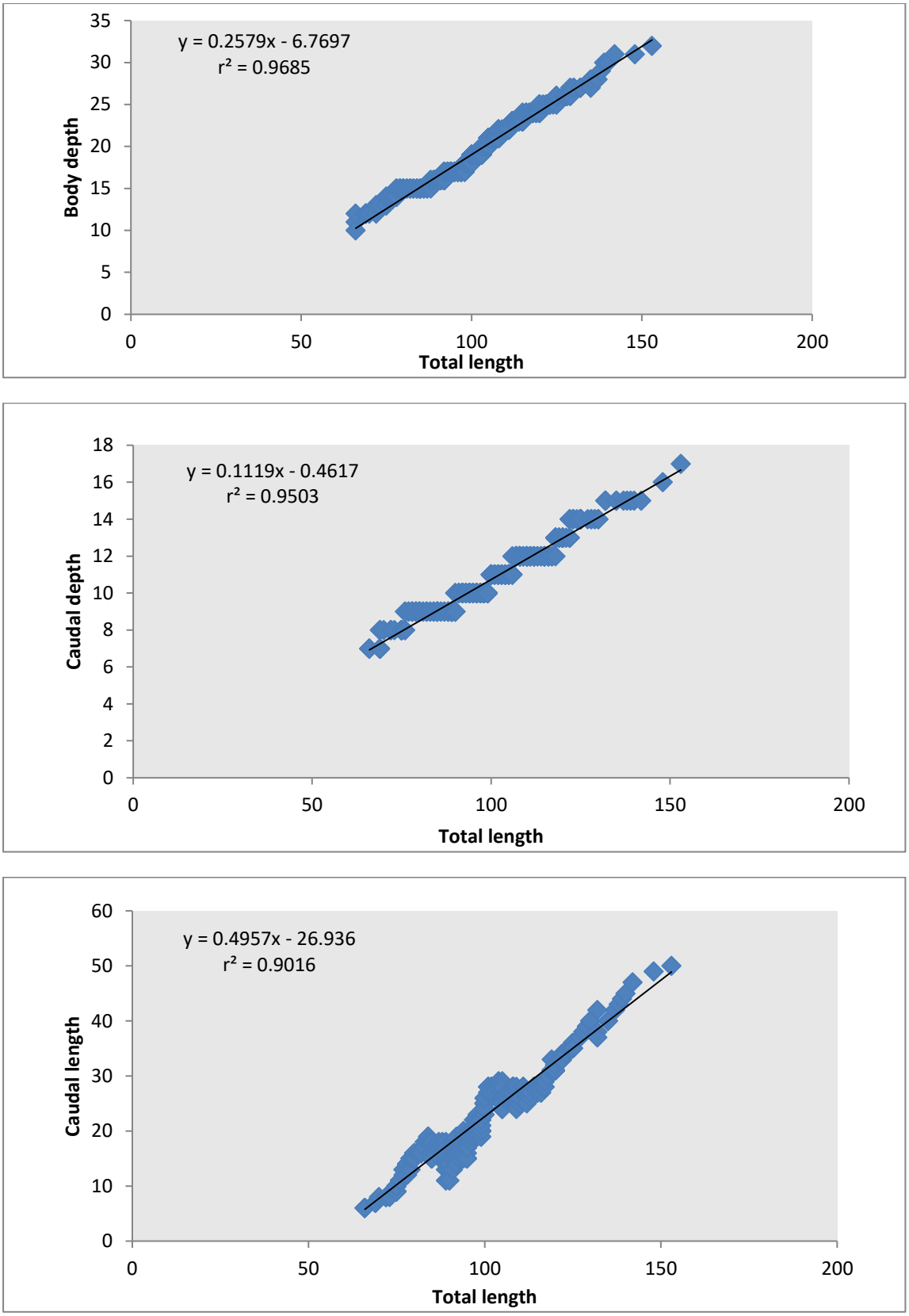


Fig 3.2f: Relationship between various morphometric measurements and total length of *P.ocellatus* female

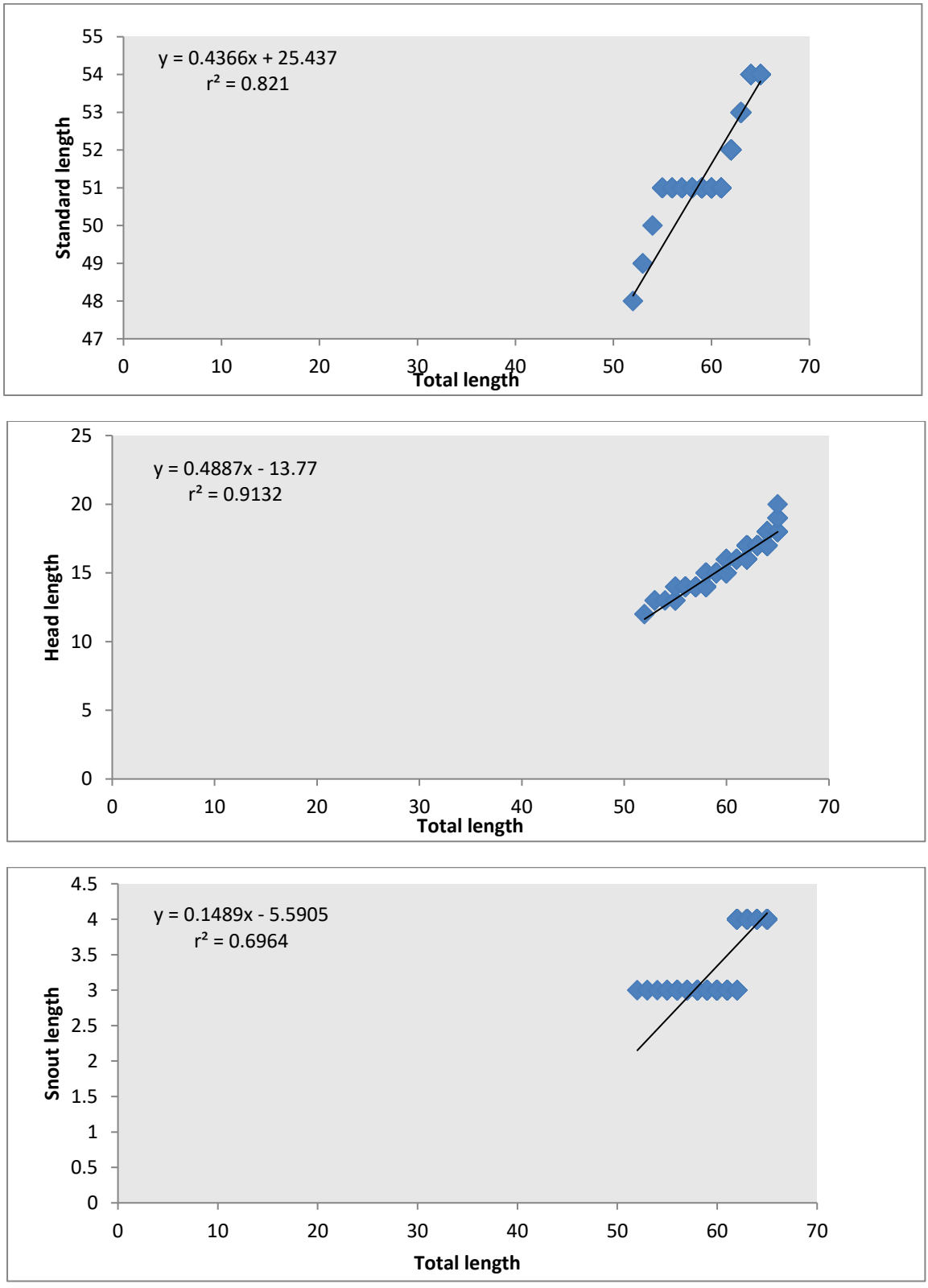


Fig 3.3a: Relationship between various morphometric measurements and total length of *P.ocellatus* juvenile

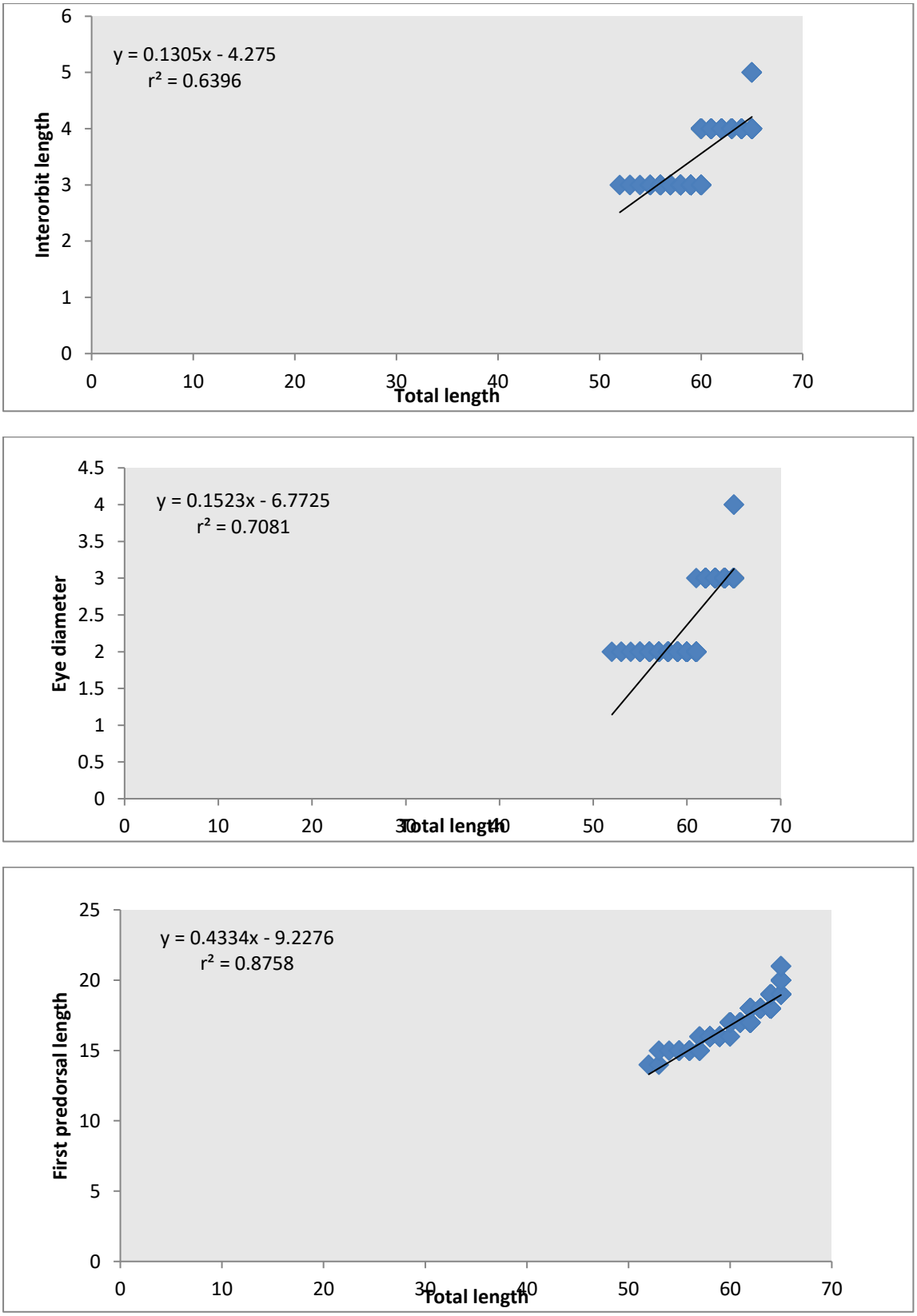


Fig 3.3b: Relationship between various morphometric measurements and total length of *P.ocellatus* juvenile

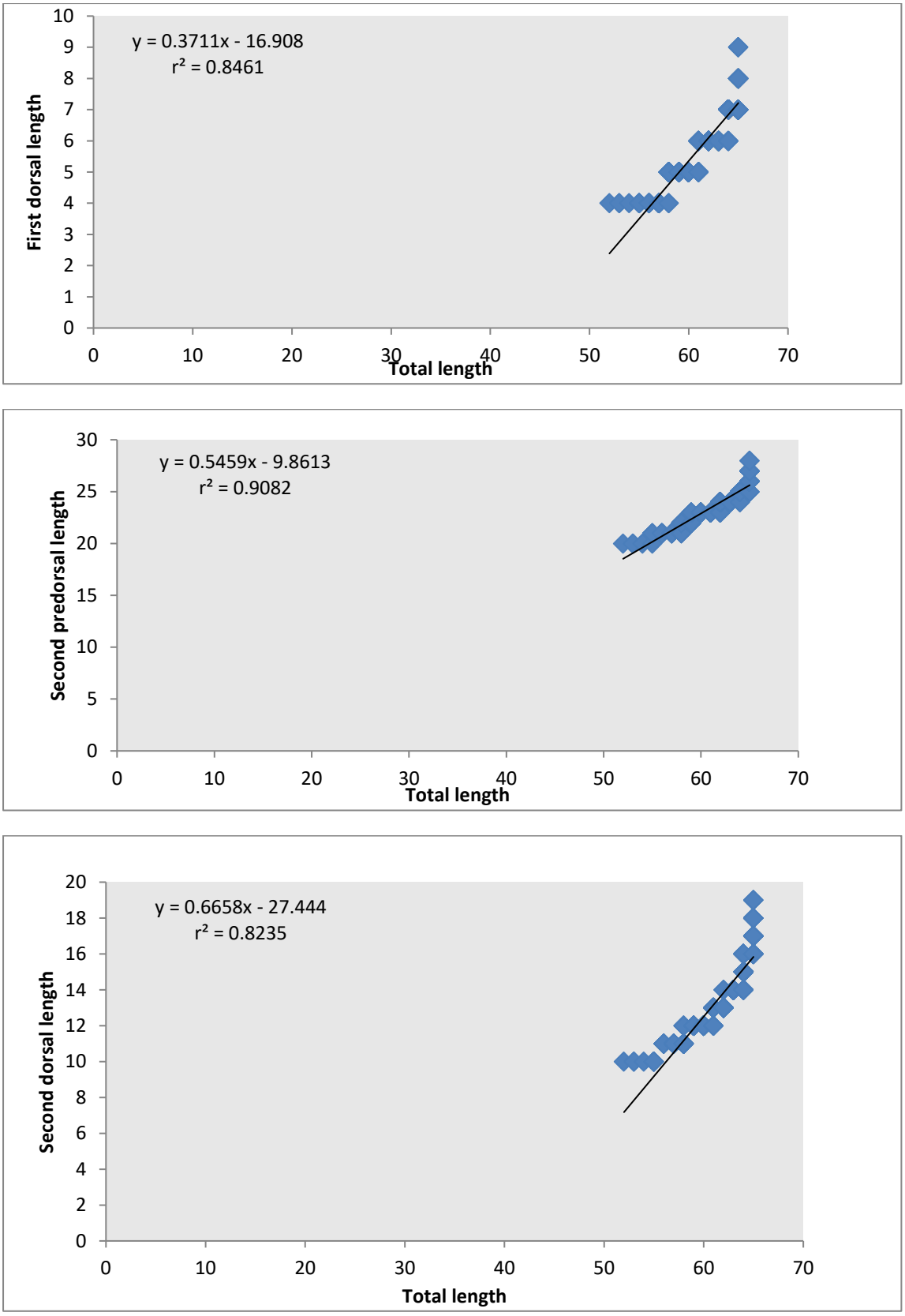
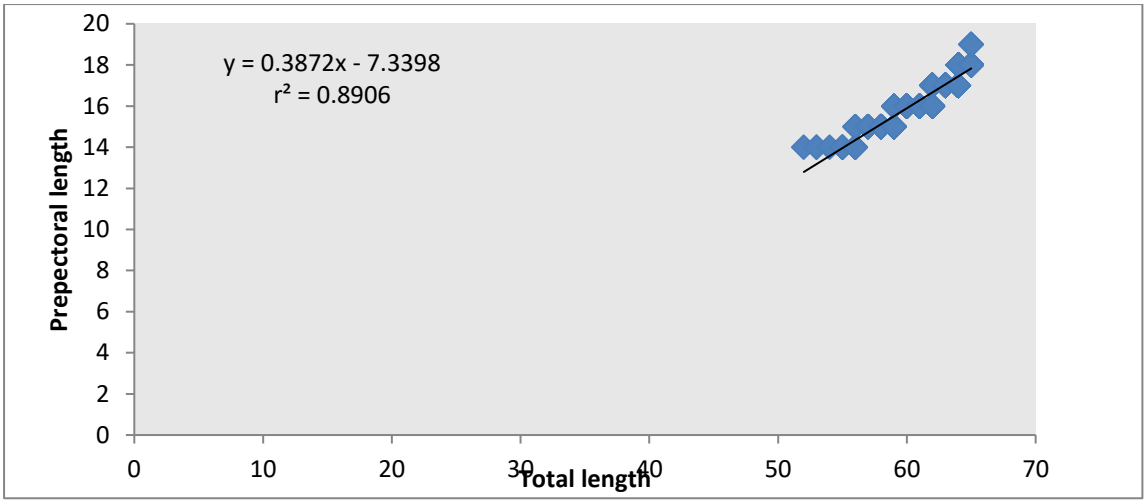
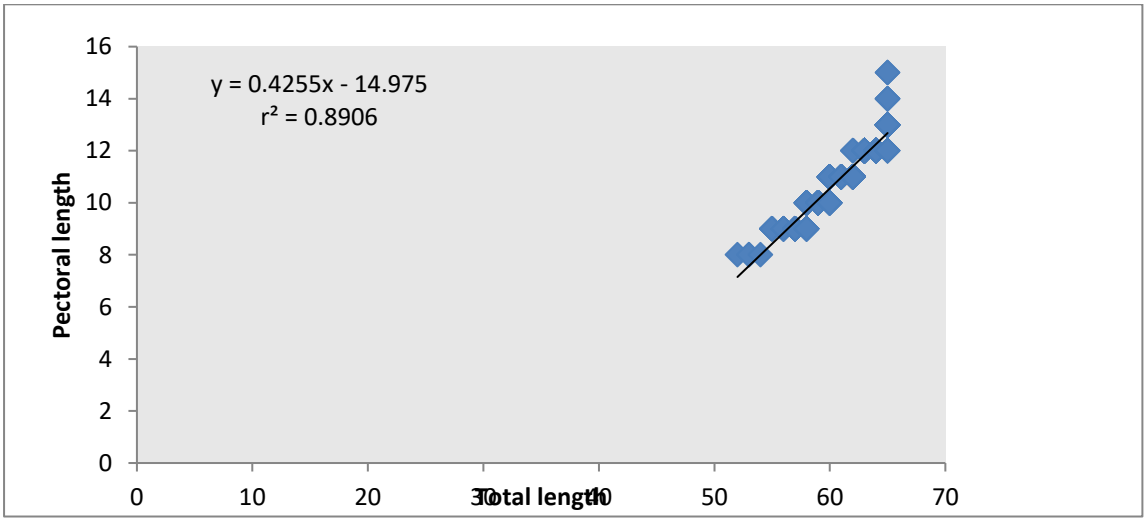


Fig 3.3c: Relationship between various morphometric measurements and total length of *P.ocellatus* juvenile





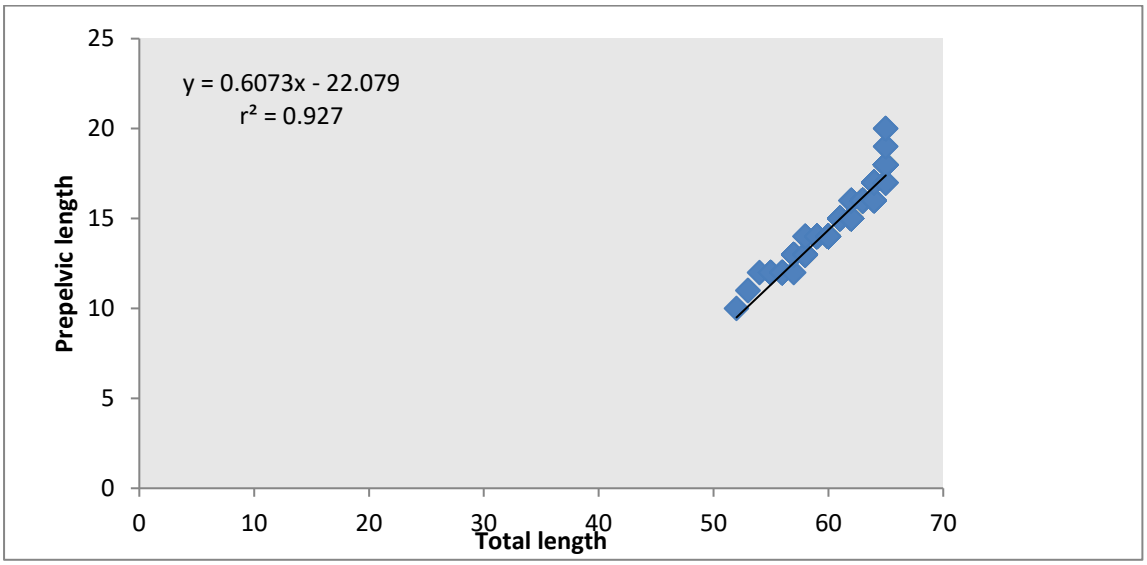


Fig 3.3d: Relationship between various morphometric measurements and total length of *P.ocellatus* juvenile

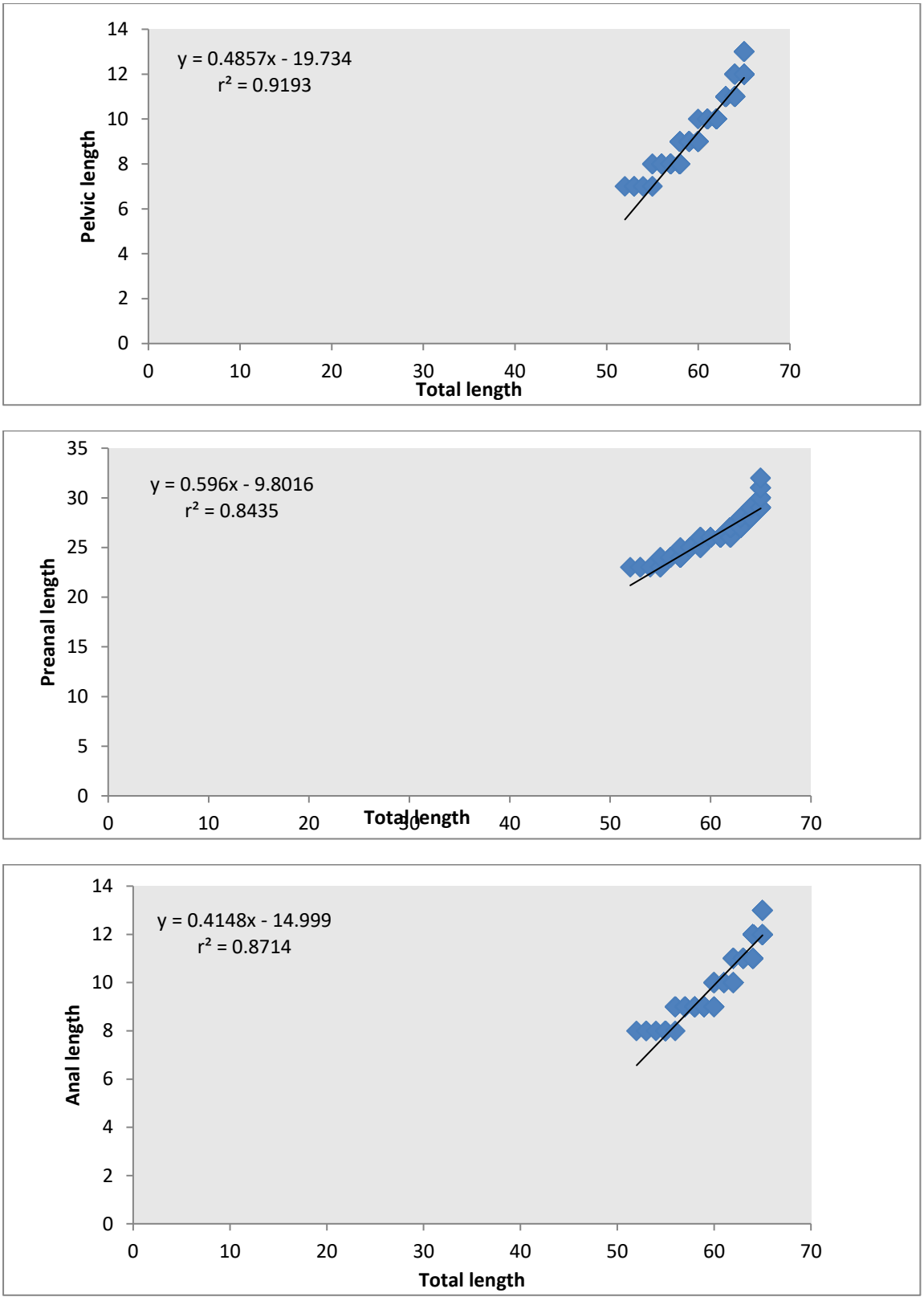
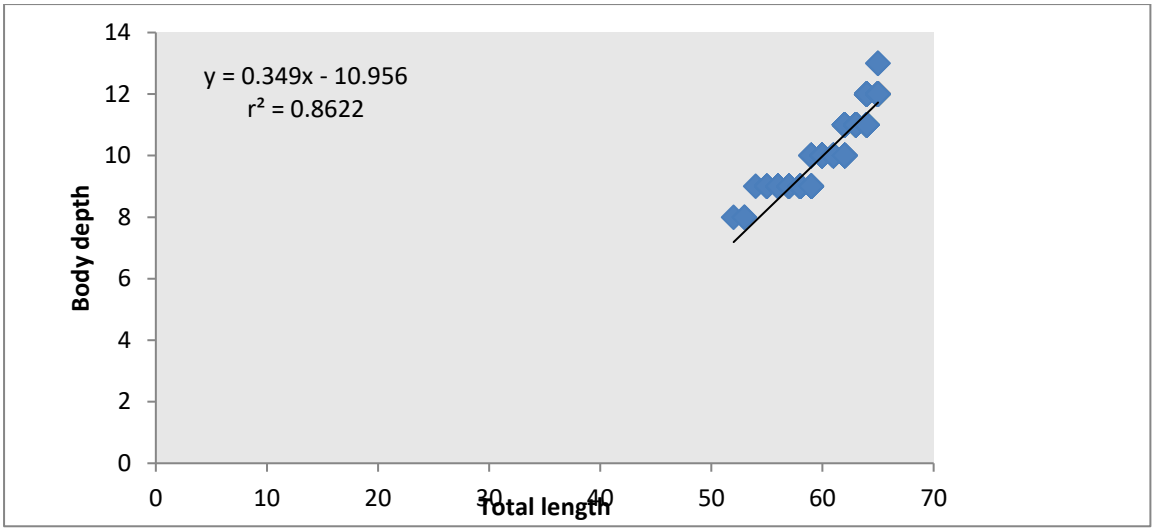


Fig 3.3e: Relationship between various morphometric measurements and total length of *P.ocellatus* juvenile



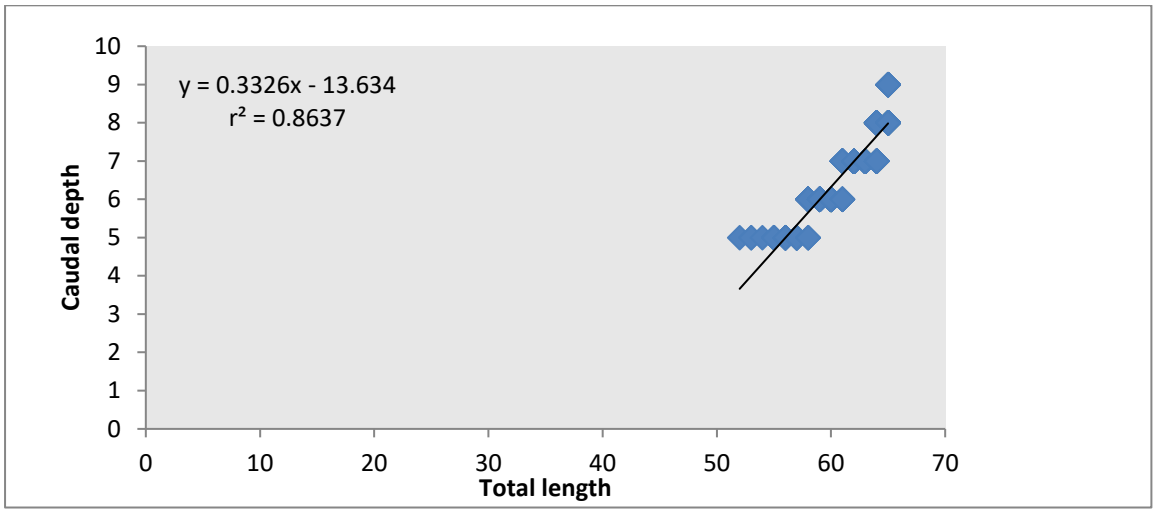


Fig 3.3f: Relationship between various morphometric measurements and total length of *P.ocellatus* juvenile

3.5 Discussion

In the present study various morphometric characters of *P.ocellatus,* in all nineteen have been recorded for specimens collected from the four creeks of Mumbai. The characters have been listed separately for males, females and juveniles. The total length ranged between 66-182mm in males and 66-153 in females. In the immature or unsexed fishes or juveniles, the TL ranged between 52-65mm. Male fishes were found to be longer than the female fishes. Similar observations were recorded in goby *Bathygobius soporator* (Adeboyejo, 2011).

Pillay (1952, 1957) has referred to the usefulness of regression analysis and Godsil (1948) has employed analysis of covariance in the racial study of fishes. Several univariate and multivariate techniques are used to nullify the effect of size and regression analysis is one among them (Sebastian, 2011). The regression analysis of *P.ocellatus* indicated that in males standard length has high growth rate followed by second pre dorsal length while eye diameter has the slowest growth rate. In females the second pre dorsal length has highest growth rate followed by standard length while eye diameter showed the slowest growth rate. Piska (1990) and Shettu (1993) in *Bolephthalmus dentatus* and Gore (2007) in *Boleophthalmus boddaerti* found maximum rate of growth in standard length and minimum in eye diameter in both the sexes.

In juveniles of *P.ocellatus* second dorsal length was the fastest growing parameter followed by pre pelvic, pre anal, caudal length, head length, pelvic length, standard length and eye diameter. The inter orbit length was the slowest growing parameter. Juveniles or unsexed fishes showed such difference in growth pattern compared to mature adults probably because they have to develop and adjust faster to survive in the muddy creeks.

A straight line relationship was observed between total length and each of the other body measurements in *P. ocellatus* as observed in Figure 3.1 to 3.3. Similar observations were recorded in gobies like *Boleopthalmus dentatus* (Shettu, 1993) and *Boleopthalmus boddaerti* (Gore, 2007) from creeks of Mumbai.

The student's t test was used for testing hypothesis of difference in regression coefficient 'b' of male and female population of *P.ocellatus*. It was applied to verify the difference in growth rate of different morphometric characters in male and female. The differences in growth of all morphometric characters of male and female fish were not statistically significant except caudal length at $p<0.05$. This indicates that male and female fishes have similar growth pattern except in caudal length.

The value of correlation coefficient 'r' was highly significant at $P \leq 0.01$ in all the parameters in male, female and juvenile ranging between 0.7-1. Thus there seemed to occur positive correlation between morphometric characters in adults as well as juvenile *P.ocellatus* indicating homogeneity of population. Gore (2007) obtained strong

correlation between total length and other characters in *Boleophthalmus boddaerti* from Bhayander creek

.

The coefficient of determination 'r^2' ranged between 0.773 – 0.9886 in males and between 0.7132- 0.9769 in females and between 0.6395-0.9269 in juveniles indicating that the regression line fits well as the value is closer to 1 for the different morphometric characters with total length. Thus the growth rate of *P.ocellatus* as indicated by coefficient of determination 'r^2' in creeks of Mumbai was quite satisfactory. Hossain *et al.* (2009b) recorded value of 'r^2'> 0.712 ($p<0.001$) in *Glossogobius guiris* from the Ganges of Bangladesh.

In the present study of ontogenic changes based on morphometry, isometric growth was observed between total length and standard length in male, while positive allometry was observed in female and juvenile. All other characters in male showed negative allometry while in female second dorsal length, pre pectoral length and pre anal length showed isometry. Thus sexual dimorphism is exhibited in some of the morphometric characters in *P.ocellatus*.

The correlation coefficient of male and female *P.ocellatus* from all the four sites were analysed by t test at $p<0.05$ and they did not show any statistically significant differences. It may therefore be concluded that the creeks of Mumbai from where the samples of *P.ocellatus* for the present study were collected are not geographically isolated from each other and there is homogeneity in the population of the species from these creeks.

Thus in conclusion it can be stated that in the male P.*ocellatus* the standard length was the fastest growing parameter and the eye diameter the slowest growing one. In females the second pre dorsal length was the fastest growing parameter and the eye diameter was slowest one. In juveniles the second dorsal length was found to be the fastest growing parameter and the inter orbit length the slowest growing one. A linear relationship has been observed between the total length and the other body parameters in males, females and juveniles.

Chapter 4

Meristic characters

4.1 Introduction

4.2 Review of Literature

4.3 Materials and methods

4.4 Result

4.5 Discussion

4.1 Introduction

Meristics is an area of ichthyology which relates to quantitative features which can be counted such as the number of fins, fin rays, scales, vertebrae etc. Meristics can be used to describe a particular species and is useful in identification of fish of an unknown species. Meristic characters are most commonly used for differentiation of species and populations. Environmental factors like temperature can influence meristic characters specially during development. Variations of this nature have been noted in many species (Hubbs, 1922; Taning, 1952; Weisel, 1955; Lindsey, 1958, 1962; Fowler, 1970). Meristic features may also be size dependent within or among species (Strauss, 1985). Meristic characters provide substantial phylogenetic information despite the potential for increased levels of homoplasy and thus remain relevant to empirical systematics (Campbell and Frost, 1993; Wiens, 1995; Wiens and Servedio, 1998).

Variability in the meristic characters was observed in the Salmon, *Oncorhynchus keta* due to temperature changes during development (Murray and Beacham, 1989). In zebra fish *Danio rerio* meristic characters presented a significant differentiation in the extreme temperature where as lower temperature produced higher meristic count in majority of characters (Sfakianakis *et al.,* 2011).The scale counts in salmonids have been most widely used for differentiation of populations within species (http://en.wikipedia.org 16/10/2012). In rainbow and steel hard trout the most notable differences among populations occur in counts of scales (http://en.wikipedia.org 16/10/2012).

Meristic characters share many properties with morphometric characters: they are readily described numerically; they usually vary within and among taxa and often appear to follow similar underlying frequency distributions (Burbnik, 2001; Allsteadt *et al*., 2006). Differences in meristic characters are less pronounced than in morphometric ones, but they can be successfully used to discriminate samples or stocks within wide geographic regions (Hermida *et al.,* 2005). Analysis of meristic features has been widely used by ichthyologists for monitoring ontogenesis (Beacham *et al.,* 1983; Tolan and Newstead, 2004), assessing morphological status of a species (Favaloro and Mazzola, 2000), differentiating populations (Murta 2000) and species (Kullander and Ferreira, 2006), and performing paleontological studies (Carnevale and Bannikov, 2006). Meristic characters are generally lumped with morphometric characters into the broader category of quantitative continuous characters for phylogeny reconstruction (Lawing *et al.,* 2008).

4.2 Review of Literature

Jordan (1891) studied the relationship between the temperature and the number of vertebrae in fishes. Babu Rao (1964) reported that *Stolephorus insularis* collected from three places along the east coast of India exhibited extreme difference in meristic characters due to their different ecological conditions and he indicated that they constitute three distinct populations. Choudhary and Dwivedi (1984) studied meristic characters in *Lactarius lactarius* and reported that the pectoral fin rays and spines of ventral fin, caudal rays and anal spines did not show any variation. Epperly (1989) observed significant differences in meristic characters of the fish *Brevoortia tyrannus* captured from south and north of Long Island waters in New York which he attributed as migratory behaviour of fish and the differences in ecological conditions. Piska *et al.* (1991) reported in *Ambalyphryngodon mola* the pectoral and pelvic fins had fixed number of fin rays, only dorsal, anal and caudal showed some variations. They concluded that these variations in meristic characters were not sufficient to classify them into separate populations since they were temporary variations and were liable to disappear with the changes of the habitat. Ferreri *et al.* (2000) studied the meristic counts in wild and reared zebra fish and reported that the variability of the meristic counts exhibited by the wild populations was higher than reared ones. Different strains

of angel fish *Pterophyllum scalare* were identified using meristic counts as a preliminary step in identification (Koshy and Pillay, 2003).

The meristic characters in family gobiidae were studied by various authors from different parts of the world as follows: *Boleophtalmus dussumeiri* from Mumbai coast (Mutsaddi, 1964); *Callogobius mannarensis,Callogobius liolepis* from Gulf of Mannar (Rangarajan, 1968); *Lubricogobius exiguus* from Taiwan (Chen and Fang, 1997); *Papuligobius uniporus* from north-eastern Laos (Chen and Kottelat, 2003); *Knipowitschia longicaudata* from Lake Manyas (Turan *et al.,* 2005); *Boelophthalmus boddaerti* from Tamil nadu and Mumbai coast(Ravi, 2000; Gore, 2007)and *Glossogobius giuris* from Iran (Coad, 2006). The meristic counts of three species of juvenile *Pseudogobius* from mangrove estuary of Southern Thailand was studied by Yokoo *et al.* (2008).

The gobiid fish *Vanderhorstia opercularis* from red sea was distinguished from 13 valid species of the same genus from its meristic characters (Randall, 2007). The number of fin rays, scales head pores as well as differences in colour and pattern are used to distinguish among species of goby fishes (Sweat, 2009). Scalici and Gibertini (2012) detected significant intra and inter population differences for some meristic traits in *Padogobius nigricans*. A new species of mudskipper *Boleophthalmus poti* was reported from New Guinea based on meristic variations with others of the same genus (Polgar *et al.,* 2013).

The meristic characters in *Parachaeturichthys ocellatus* were noted and fin formula was recorded by Day (1858) and Mutsaddi and Bal (1973). However in the survey of literature carried out by the candidate revealed that not all the meristic counts have been covered by earlier reports. Hence the present study was aimed to provide a comprehensive description of various meristic characters and compare the same with those reported in literature earlier.

4.3 Materials and method

The fishes for the present study were collected every fortnight at regular intervals during the period from June 2010 to September 2011 from Malad, Vasai, Thane and

Mahul creeks along Mumbai coast. The fishes were collected and brought to the laboratory in icebox. They were thoroughly washed and cleaned in the laboratory. In all eleven meristic characters were recorded as follows: brachiostegal rays, first dorsal fin rays, second dorsal fin rays, pectoral rays, pelvic rays, anal rays, caudal rays, longitudinal scales, transverse scales, vertebrae, and gill rakers. The meristic counts were made based on the standard procedure described by Appa Rao (1966), Dwivedi and Menzes (1974). The minimum and maximum counts for the characters were noted and following statistical parameters for the characters were recorded: mean, median, mode, standard deviation, standard error, variance, coefficient of variation. Meristic characters of the fishes from the four creeks of Mumbai were compared and their counts were tested for significance at $p<0.05$

The meristic characters in the present study were compared with those from previous literature of Day (1858) and Mutsaddi and Bal (1973).

4.4 Results

In the present study fish samples were collected from Malad, Vasai, Thane and Mahul creek for meristic counts of eleven characters. Table no. 4.1, 4.2, 4.3 record meristic values in male, female and juvenile *P.ocellatus* respectively. Among the meristic counts the brachiostegal rays numbering 5 and first dorsal fin rays numbering 6 were same in male, female and juvenile. For the remaining 9 meristic characters in male and female fish, the range observed was as follows: second dorsal fin rays 10-12, pectoral fin rays 16-20, pelvic fin rays 8-10, anal fin rays 8-11, caudal fin rays 20-26, vertebrae 22-26, longitudinal scales 32-36 transverse scales 8-11 and gill rakers 11-14. In juveniles the values for the same were as follows: second dorsal fin rays 9-11, pectoral fin rays 14-16, pelvic fin rays 8-10, anal fin rays 8-9, caudal fin rays 16-18, vertebrae 22-24, longitudinal scales 24-26, transverse scales 6-7 and gill rakers 11-14.

In males the highest coefficient of variation was recorded in the number of anal fin rays (10.7195) and lowest in longitudinal scales (5.0406). The females showed highest coefficient of variation in number of pelvic fin rays (10.4404) and lowest in longitudinal scales (3.6561).The juveniles showed highest coefficient of variation in pelvic fin rays

(11.59) and lowest in longitudinal scales (4.02). The juveniles of unsexed individuals also exhibited differences in meristic counts compared to adult fishes.

The range and median meristic counts of male and female *P.ocellatus* from the creeks of Mumbai selected for the present study viz. Malad, Vasai, Thane and Mahul are recorded in Table no. 4.4 and 4.5 respectively. The area wise difference observed in the counts was not significant at $p< 0.05$.

A comparative account of the meristic counts as per Day (1858), Mutsaddi and Bal (1973), and by the candidate during present study is presented in Table no. 4.6. Similarly Table no. 4.7 presents a comparative study of fin formula by Day (locit) and Mutsaddi and Bal (loc.cit).

The meristic counts in the present study revealed variations in counts of second dorsal fin, pectoral fin, pelvic fin, anal fin, vertebrae, longitudinal scales and transverse scales. A greater variability was observed in the number of caudal fin rays which ranged from 22-26 in the present study while the same was 12 according to Day(locit).

Table no.4.1: Profile of meristic characters in male *P. ocellatus*.

Characters	Minimum	Maximum	Mean	Median	mode	Standard deviation	Standard error	Variance	Coefficient of variation
Brachiostegal rays	5	5	5	5	5	0	0	0	0
First dorsal fins	6	6	6	6	6	0	0	0	0
Second dorsal fins	10	12	11.2099	11	11	0.6655	0.0739	0.4429	5.9368
Pectoral fin rays	16	20	17.5062	18	18	1.0262	0.1140	1.05308	5.8619
Pelvic fin rays	8	10	9.6296	10	10	0.7817	0.0868	0.6111	8.1180
Anal fin rays	8	11	9.4444	9	9	1.0124	0.1124	1.025	10.7195
Caudal fin rays	20	26	23.1235	24	24	2.3097	0.2566	5.3345	9.9884
Vertebra	22	26	23.7777	24	22	1.3784	0.1531	1.900	5.7970
Longitudinal Scales	32	36	33.7037	34	32	1.6989	0.1888	2.8861	5.0406
Tranverse Scales	8	11	8.716	9	9	0.8789	0.0977	0.7725	9.8199
Gill rakers	12	14	13.4197	14	14	0.8374	0.0930	0.70123	6.2229

Table no. 4.2: Profile of meristic characters in female *P. ocellatus*.

Characters	Minimum	Maximum	Mean	Median	mode	Standard deviation	Standard error	Variance	Coefficient of variation
Brachiostegal rays	5	5	5	5	5	0	0	0	0
First dorsal fins	6	6	6	6	6	0	0	0	0
Second dorsal fins	11	12	11.5507	12	12	0.501	0.0603	0.2510	4.3379
Pectoral fin rays	16	20	17.7391	18	18	0.8686	0.1046	0.7544	4.8966
Pelvic fin rays	8	10	9.2753	10	10	0.9683	0.1165	0.9377	10.4404
Anal fin rays	8	11	10.2029	10	11	0.9006	0.1084	0.8111	8.8274
Caudal fin rays	20	26	22.8696	23	21	2.2551	0.2715	5.0856	9.8609
Vertebrae`	22	26	23.7971	24	24	1.461	0.17589	2.1346	6.1397
Longitudinal Scales	32	34	33.786	34	34	1.2351	0.1487	1.5255	3.6561
Tranverse Scales	8	11	9.2463	9	9	0.9299	0.1119	0.8648	10.0579
Gill rakers	11	14	13.0579	14	14	0.9231	0.1111	0.8520	6.9081

Table no. 4.3: Profile of meristic characters in juvenile *P. ocellatus.*

Characters	Minimum	Maximum	Mean	Median	mode	Standard deviation	Standard error	Variance	Coefficient of variation
Brachiostegal rays									
First dorsal fins	6	6	6	6	6	0	0	0	0
Second dorsal fins	9	11	9.5714	9.5	9	0.6462	0.1727	0.4175	6.75
Pectoral fin rays	14	16	15.2142	15.5	16	0.8925	0.2385	0.7967	5.86
Pelvic fin rays	8	10	8.8571	8	8	1.0271	0.2745	1.0549	11.59
Anal fin rays	8	9	8.4285	8	8	0.5135	0.1372	0.2637	6.09
Caudal fin rays	16	18	16.8571	17	16	0.8644	0.231	0.7472	5.12
Vertebrae	22	24	22.7142	22	22	0.9944	0.2657	0.989	4.37
Longitudinal Scales	24	26	24.7142	24	24	0.9944	0.2657	0.989	4.02
Transverse Scales	6	7	6.5	6.5	6	0.5188	0.1386	0.2692	7.98
Gill rakers	11	14	12.5	12	14	1.4005	0.3743	1.9615	11.2

Table no. 4.4: Variations in meristic chatacters of male *P.ocellatus* from different stations.

Characters	Malad	Median	Vasai	Median	Thane	Median	Mahul	Median
Brachiostegal rays	5	5	5	5	5	5	5	5
First dorsal fins	6	6	6	6	6	6	6	6
Second dorsal fins	10-11	11	10-12	11	10-12	11	10-11	11
Pectoral fins	18-20	18	18-20	18	18-20	18	18-20	18
Pelvic fins	8-10	10	10	10	8-10	10	8-10	10
Anal fins	8-11	9	8-11	9	8-11	9	8-11	9
Caudal fins	20-26	24	20-26	24	20-26	24	20-26	24
Vertebrae	32-36	34	32-36	34	32-26	34	22-26	34
Longitudinal Scales	28-36	34	28-36	34	24-36	34	24-36	34
Transverse scales	8-11	9	7-11	9	7-10	9	7-10	9
Gill rakers	12-14	14	11-14	14	12-14	14	12-14	14

Table no.4.5: Variations in meristic chatacters of female *P.ocellatus* from different stations.

Characters	Malad	Median	Vasai	Median	Thane	Median	Mahul	Median
Brachiostegal rays	5	5	5	5	5	5	5	5
First dorsal fins	6	6	6	6	6	6	6	6
Second dorsal fins	10-11	11	10-11	11	10-11	11	11-12	11
Pectoral fins	16-20	18	18-20	19	16-20	18	16-20	18
Pelvic fins	8-10	10	9-10	10	9-10	10	8-10	10
Anal fins	8-11	10	9-11	10	8-10	10	8-11	10
Caudal fins	20-26	23	20-26	23	20-26	23	21-226	23
Vertebrae	22-26	24	24-26	24	24-26	24	22-26	24
Lateral line Scales	32-34	34	32-34	34	32-34	34	32-34	34
Transverse line scales	8-11	9	9-11	9	9	9	9-11	9
Gill rakers	12-14	14	12-14	14	12-14	14	12-14	14

Table no. 4.6: Comparative data of Meristic characters of *P.ocellatus* by different authors.

Characters	Day	Mutsaddi and Bal (1973)	Present study(2010-11)
Brachiostegal rays	-	-	5
First dorsal fins	6	6	6
Second dorsal fins	10	10	9-11
Pectoral fin rays	20	20	16-20
Pelvic fin rays	10	-	8-10
Anal fin rays	10	9	8-11
Caudal fin rays	12	-	22-26
Vertebrae	-	-	22-26
L ongitudinal Scales	33	32-33	32-36
Tranverse Scales	8	9	8-11
Gill rakers	-	-	11-14

Table no. 4.7: Comparative study of fin formula of *P.ocellatus* by different authors

Authors	Fin formula
Day (1858)	D6 |1/10, P20, V1/5, A1/10, C12 L1 33, Ltr 8
Mutsaddi and Bal (1973)	D16, D2 1/10, A1/9, P20, L1 32-33, Ltr 9
Present study (2010-2011)	Bv, D1 6, D2 1/ 9-11, P16-20, V8-12, A1/8-11, C22-26, L1 32-36, Ltr 8-11.

4.5 Discussion

In present study meristic counts were recorded in *P.ocellatus* from Malad, Vasai, Thane and Mahul creek over a period from June 2010 to September 2011. Among the eleven meristic characters recorded brachiostegal rays and first dorsal fin rays were the same among males, females and juveniles. The highest value of coefficient was observed in anal fin rays in male, while in female it was found in pelvic fin rays. The

values were not significant at $p<0.05$. Gore (2007) observed highest variation in pelvic fin rays of *Boleophtahlmus boddaerti* from Mumbai coast. The variation in meristic characters of *P.ocellatus* in the present study seems to be a part of natural diversity characteristic of biological characters whether these are dependent on environmental fluctuation is difficult to say since the variations are not statistically significant. Barlow (1961) has suggested that the body shape in fishes is related to genetic cause while meristic characters are dependent on environmental fluctuations.

Morphometric and meristic characters were used to identify possible sexual differentiation in marble goby *Oxyeleotris marmaorata* by Idris *et al.* (2012). In *P.ocellatus* the meristics observed do not vary significantly between male and female hence cannot be used to differentiate between the sexes. The variations between meristic characters of juveniles and adult *P.ocellatus* however are statistically significant. Georgakopoulon *et al.* (2007) has reported that temperature strongly affects both body shape and meristic characters during the development of juveniles whether the lower meristic counts observed in juvenile *P.ocellatus* as compared to that of adult can be attributed to the influence of temperature and other environmental factors or they are simply natural as a part of growth and developmental process would require further studies.

Al-Hassan and Miller (1987) reported that the goby *Rhinogobius brunneus* from Arabian Gulf showed low values of pectoral rays in comparison to the same species from the eastern Asian region in response to higher environmental temperatures during development. Morris (1977) observed in Staghorn sculpin *Leptocottus armantus,* well defined seasonal trends in meristic characters which appeared to be related to the thermal history of their habitat. Babu Rao (1966) reported that *Stoleophorus insularis* collected from three places along the east coast of India exhibited extreme differences in meristic characters due to their different ecological conditions. Similar observations were made in *Escualosa thoracata* (Dutt and Rao, 1981) and in *Brevoortia tyrannus* (Epperly,1989). Scalici and Gibertini (2012) suggested that in *Padogobius nigricans* meristic pattern changes from one population to another even within short geographical distance and similar environmental conditions. During the present study of meristic characters in *P.ocellatus* obtained from Malad, Vasai, Thane and Mahul creek significant variations were not observed in any

of the fishes. These creeks of Mumbai from where the fish samples were collected do not have much difference in environmental conditions there are no geographical barriers and the waters of the creeks intermingle with each other.

The range of meristic characters in the present study showed deviation from those observed by Day (1858), Mutsaddi and Bal (1973). A marked difference was observed in caudal fin rays which were 12 as per the fin formula of Day (1858) while in present study the range of caudal fin rays was 22-26. The pectoral fin rays, pelvic fin rays, anal fin rays longitudinal and transverse scales however showed only slight variation in the present study compared to that of Day (loc.cit.) and Mutsaddi and Bal (loc.cit.).

The meristic characters can be used for differentiating populations (Vidalis *et al*.,1997; Tudela, 1999; Murta, 2000) and assessing morphological status of a species (Beacham *et al.,* 1983; Tolan and Newstead, 2004). According to Hermida *et al.* (2005) meristic traits provide limited evidences for differentiation but it has been widely used by ichthyologists (Waldman, 2005) for differentiating population and species (Murta, 2000; Kullander and Ferreira, 2006). Rangarajan (1968) recorded a new species of goby *Callogobius mannarensis* in Gulf of Mannar based on the meristic variation between other species of the same genus. A new species of the goby *Vanderhorstia bella* was recorded from, Fiji based on the difference in meristic characters from other species by Greenfield and Longenecker (2005). A new species of mudskipper *Boleophthalmus poti* was reported from Gulf of Papua, New Guinea based on variations in morphometric and meristic characters from other *Boleophthalmus spp* prevalent in the area (Polgar *et al*., 2013).

In the present study, the variations observed in the meristic counts of fishes sampled from all the four creeks are slight, statistically without any significance and therefore do not merit their being placed into separate population. It can safely be assumed that the fish from all the four creeks belong to the same stock of population of *P.ocellatus.*

Chapter 5

Length weight relationship

5.1 Introduction

5.2 Review of Literature

5.3 Materials and methods

5.4 Result

5.5 Discussion

5.1 Introduction

Growth is one of the fundamental properties of all living organisms involving progressive increase in size up to a well defined range specific for species. Nikolsky (1963) has stated that growth is a specific adaptive property ensured by the unity of the species and its environment. Measurement of growth is a specific and its environment. Measurement of growth of an organism would be an important factor in any study of biology of the organism. Growth is a multidimensional process leading to increase in the length as well as weight of the organism. The length weight relationship in fact provides a standard index of growth, a mathematical expression between the two variables i.e. length and weight such that if one is measured the other can be reliably computed. The length weight relationship of fishes has significance in both: basic studies on biology of the fish and applied aspects in terms of size of fish in capture fisheries for rational fishing. Length-weight relationships are useful in fishery management for both applied and basic uses (Pitcher and Hart 1982) to convert length distributions into weights for biomass estimates (Gerritsen and McGrath, 2007). A mathematical representation of length-weight relationship derived from study of different sexes and sizes from a particular geographical area is a practical index of the condition of the fish (Petrakis and Stergiou, 1995) and is a very useful tool for the study of biology, physiology, ecology, population dynamics, fisheries assessment and general conditions of the fish (Jaiswar *et al*., 2004). A life history and morphological comparison of populations from different regions can be made from length weight relationship (Goncalves *et al*., 1997). Similarly calculating standing stock biomass and

several other aspects of population dynamics can be determined using length weight relationship (Morato *et al*., 2001).

Schneider *et.al* (2000) has stated that for routine population surveys number of fish sampled need not be high; 5-10 fish per inch group over a wide range are enough to establish a regression line for each important species. The authors have studied the length weight regressions of fish from Great lakes of Michigan and stated that they are useful for: a) calculating total weight of fish from length-frequency data, b) measuring changes in robustness/ health of the population (relative to past or future samples at the same place and season), c) determining the relative condition of small fish compared to large fish (from the slope of regression) and d) comparing condition of this population to the state wide standards.

The principle of the length weight relationship is that the weight of the fish increase in relation to increase in its length. Theoretically, it can be described using a formula in which weight is expressed as proportional to the length raised to the power of 3 and the same can be expressed as $W=aL^3$ where 'a' is a constant and 'W' and 'L' are weight and length of the fish. The actual relationship between the variables, length and weight may depart from this, either due to environmental conditions or condition factor (Le Cren, 1951). In nature, the body proportions of a fish continually change with ageing. The form and specific gravity do not remain constant throughout the life history of the fish. Thus cube law expression does not hold well throughout the life history of the fish (Srivastava, 1999). Hence, a more satisfactory formula to express the length weight relationship has been advocated by LeCren (1951) which is $W=aL^b$, where 'a' is constant and the value of 'b' lies between 2.5 and 4.0.

Fish can attain either isometric growth, negative allometric growth or positive allometric growth. Length-weight relationship for fish was originally used to provide information on the condition of fish and to determine whether somatic growth was isometric or allometric (LeCren, 1951; Ricker, 1975). Sekharan (1968) has observed that in an isometric growth, the value of 'b' equates 3 for a hypothetical ideal fish which maintains shape while Tesch (1968) reported that if the value of 'b' is other than 3 the fish grows allometrically. Most of the fishes change their shape as they grow (Martin, 1949), hence the cube relationship between length and weight would hardly be

expected. He further reported that 'b' may be different for fish of different sexes and localities. The length-weight relationship may thus be a useful character for the differentiation of small taxonomic units. It provides a mathematical relationship between the two variables, length and weight, so that the unknown variable can be easily calculated from the known variable.

5.2 Review of Literature

Length weight relationship (LWR) of Family Gobiidae was carried out by different authors. Khaironizam and Rashid (2002) studied length weight relationship in 10 species of mudskippers along Malaysia coast namely *Periophthalmus chrysospios, P. graciis, P. novemradatus, P. argentilineatus, P. spilotus, Periophthalmodon schlosseri, P. septemradiatus, Boleophthalmus boddaerti Scartelaos histophorus, Pseudapocryptes elongates.* The authors found that b values of ten species ranged between 2.56-3.50. The b values of LWR in *Acanthogobius flavimanus* of Tokyo ranged between 2.57-2.94 (Yoshihara *et al.,* 1999). The b values of Neogobius melanostomus from Turkey ranged between 2.87-3.27 (Tarkan *et al.,* 2006) while that from Croatia ranged between 3.28-3.47 (Piria *et al.,* 2011). The b values of the same ranged from 2.48-3.28 in different localities (www.fishbase.us 15/7/2012). In monkey goby Neogobius fluviatilis from Turkey weight increased allometrically for all sexes as b value was 2.9848 (Sasi and Berber, 2010). Frill fin goby *Bathygobius soporator* from Lagos lagoon, Nigeria showed a positive allometry with value 4.58 for male and 3.99 for female Adeboyejo (2011) while the same species from Badagry creek Nigeria showed negative allometry of value of 1.43 (Lawson *et al.,* 2011).

The length weight relationship of Tank goby *Glossogobius guiris* from Ganges of Bangladesh was 2.95 and 3.29 in male and female respectively (Hossain *et al* 2009b). The same species from Atrai river of Northern part of Bangladesh was 2.76 for male and 2.66 for female (Joadder, 2009), while from Chilika Lagoon Odisha, b value was found to be 3.085 (Karna and Panda, 2012).

Mutsaddi (1964) studied LWR in *Boleophthalmus dussumeiri* from Mumbai coast and found b values were 3.71 in male and 3.44 in female. Hoda (1980) reported that in same species from Karachi the b value was 2.53 for male and 2.07 for female. Soni

and George (1986) reported the b values in *Boleophthalmus dentatus* was 2.75 while the reports of Shettu (1993) differed with a very low value of b which was 1.20 in males and 1.15 in females. Ravi (2000) studied length weight relationship in *Boleophthalmus boddaerti* from south east coast of India and was found b values to be 2.81 in male and 2.76 in females while Gore (2007) studied the same from Mumbai coast and found the b values 1.24 in males and 1.31 in females.

The present work of goby fish *P.ocellatus* from creeks of Mumbai was undertaken to find out comprehensive relationship between length and weight in male, female and juveniles and thus to establish pattern of growth which would contribute to population dynamics of the fish.

5.3 Materials and methods

Fish samples for the present study were collected every fortnight at regular intervals from Vasai, Malad, Thane and Mahul creek during June 2010 to September 2011. Fishes were brought to the laboratory and thoroughly washed and cleaned. Total length was measured from the tip of the snout to the tip of the caudal fin in millimetres and weight was noted to the nearest 0.001 gram on a digital analytical balance. The length weight relation was estimated as per formula $W=aL^b$ advocated by Le Cren (1951). This equation can also be expressed in its logarithmic form as:

Log W= Log a + b.Log L

where W= total weight, L=total length, a=intercept (initial growth coefficient),
b= slope (growth coefficient).

The values of 'a' and 'b' were estimated by linear regression analysis by the method of least square (Snedecor and Cochran, 1967). The log transformed data and the association degree between variables W and L was calculated by coefficient of determination (r^2). The significance of regression was assessed by ANOVA. Variance ratio F was calculated by the following formula

$$F = \frac{\text{Mean square between groups (MS)}}{\text{Mean square within groups (Residual)}}$$

The regression coefficients of the sexes were compared by the analysis of covariance (ANCOVA) to establish the variations in the b values, if any between males and

females. The significance of the difference, in the estimate of b in males, females, juveniles and pooled data of sexes from the expected value of 3 was tested by Bailey's t-test (Snedecor and Cochran, 1967) as given by the formula,

$$t = \frac{b-3}{Sb}$$

where b= regression coefficient of log transformed data and Sb = standard error of b

The t-test on 'r' values reveals whether significant correlation exist between length and weight.

5.4 Results

To understand the length weight relationship the length and weight of a sample of fish were recroded and statistical analysis in terms of correlation coefficient and regression coefficient were computed.

Table no 5.1 represents the statistical details as follows: the number of fish studied, the range of total length, range of total weight, correlation coefficient 'r' and t values for correlation coefficient 'r' , intercept 'log a' , regression coefficient 'b' , std error 'Sb' and t values of 'b' for *P. ocellatus* male, female and juvenile. The pooled values for male and female are also included in the table. The values 'a' and 'b' obtained for the calculation of LWR are as follows:

Male: Log W= -4.8161 + 2.9071. Log L

Female: Log W= -4.3520 + 2.7216. Log L

Juvenile: Log W= -4.5939 + 3.0082. Log L

Pooled(for male and female): Log W= -4.7474 + 2.8919. Log L

The regression lines based on these observations are presented in Figure 5.1, 5.2, 5.3 and 5.4. The correlation coefficient 'r' between log length and log weight was found to be 0.9913 in males, 0.9699 in females, 0.9604 in pooled (males and females) and 0.9913 in juveniles . The regression values were found to be highly significant ($p<0.001$) indicating a strong relationship between length and weight in *P.ocellatus*. The values of coefficient of determination 'r^2' were 0.9818 in the males, 0.9407 in the females and 0.9180 in the juveniles.

Table no.5.2, 5.3 and 5.4 presents the results of ANOVA in male female and juvenile respectively. The length and weight relationship was found to be highly significant at p<0.01 in all the three cases. The results of the analysis of covariance (ANCOVA) are presented in Table no. 5.4. The values of regression coefficient 'b' exhibited significant difference between male and female (F=9.06, df 1, 1173 at 5% level of significance). Table no.5.5 depicts the comparison of LWR between males and females carried out using student's t test. The results indicate that there is significant difference in LWR between male and female *P.ocellatus* at p< 0.01.

The significance of variations in the values of regression coefficient 'b' from '3' was tested by using t test and is presented in Table no.5.6. The results indicate that t value is significant in males, females and pooled observation of male and female, while in juveniles it is not significant at p<0.01. The 'b' values were 2.9071, 2.7216 and 3.0082 in males, females and juveniles respectively. Based on LWR the growth in males and females was negative allometric whereas the same in juveniles was almost isometric.

Table no. 5.1: LWR studies in *P.ocellatus* male, female, and juvenile- statistical analysis.

Individuals sampled	Length range in mm (Y)	Weight range in grams (X)	Sample size (N)	Correlation (r)	t value	P value	Log a	Slope (b)	Std error (Se)	t value	P value
Males	66-182	1.552-54.801	685	0.99139	197.86	p<0.001	-4.81613	2.90706	0.02032	143.04	p<0.001
Females	66-153	2.209-38.383	489	0.96990	87.87	p<0.001	-4.3520	2.7216	0.02125	128.05	p<0.001
Juveniles	52-65	1.175-3.545	338	0.91805	42.44	p<0.001	-4.5939	3.0082	0.00387	77.61	p<0.001
Pooled (males and females)	66-182	1.552-54.801	1174	0.96041	118.01	p<0.001	-4.7474	2.89199	0.01482	195.07	p<0.001

Table no. 5.2: Analysis of Variance (ANOVA) on the regression of the LWR in male *P.ocellatus*

	df	SS	MS	F value	p value
Regression	1	3.600521	3.600521	39162.25	p<0.001
Residual	683	0.062794	9.19E-05		
Total	684	3.663316			

df- degree of freedom, SS Sum of squares, MS Mean square

Table no. 5.3: Analysis of Variance (ANOVA) on the regression of the LWR in female *P.ocellatus*

	df	SS	MS	F value	p value
Regression	1	1.78988	1.78988	7728.129	p<0.001
Residual	487	0.112792	0.000232		
Total	488	1.902672			

df- degree of freedom, SS Sum of squares, MS Mean square

Table no. 5.4: Analysis of Variance (ANOVA) on the regression of the LWR in juvenile *P.ocellatus*

	df	SS	MS	F value	p value
Regression	1	0.11289	0.11289	1801.748	P<0.001
Residual	336	0.021052	6.27E-05		
Total	337	0.133942			

df- degree of freedom, SS Sum of squares, MS Mean square

Table no.5.5: Comparison of regression lines of males and females of *P.ocellatus* by ANCOVA

Source of Variation	Degree of freedon	Regression coefficient	Deviation from regression		
			Degree of freedom	Sum of squares	Mean square
Male	685	2.9070	684	31.49	0.046
Female	489	2.7216	488	14.98	0.030
Total			1172	46.47	0.04
Pooled	1174		1173	50.73	0.043
Comparison of slope F= 9.06, df=1173, significant at 5%					

Table no 5.6: Comparison of regression coefficients of male and female *P.ocellatus* using t- test

Between	df	t value	p
Males- Females	1170	6.401	p<0.01 highly significant

df-degree of freedom

Table no.5.7: Significance of variations in the estimates of regression coefficient value 'b' from '3' using t test

	b	t value	p	Significance
Male	2.90706	-4.57	P<0.01	significant
Female	2.7216	-13.10	P<0.01	significant
Juvenile	3.0082	2.12	p>0.01	Not significant
Pooled	2.89199	-7.29	P<0.01	significant

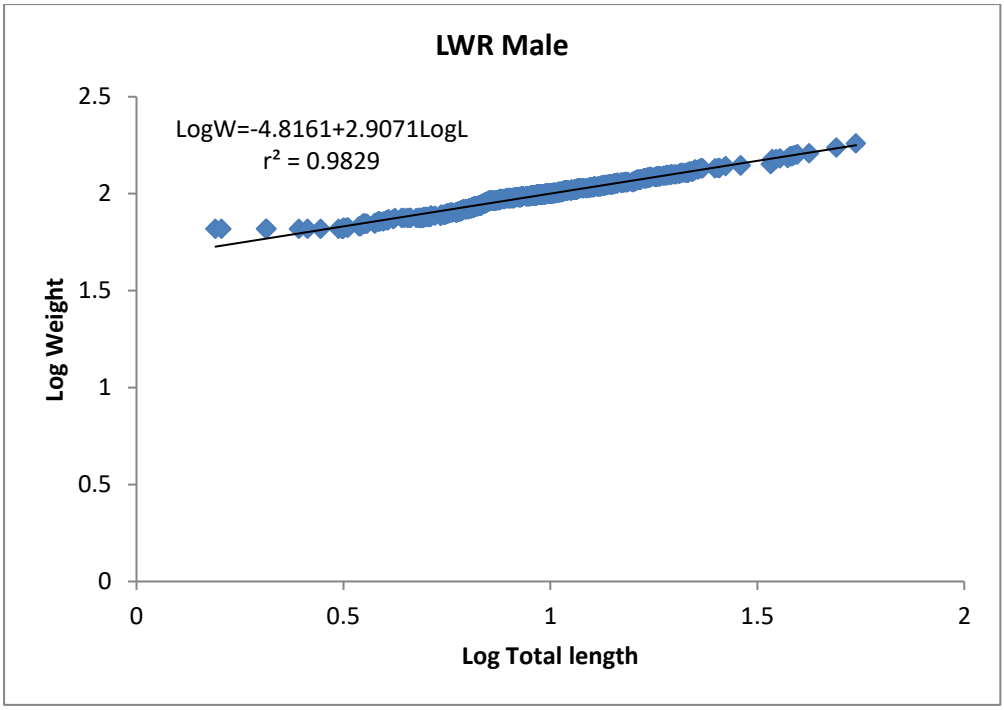


Fig 5.1: LWR between total length and total weight in male *P.ocellatus*

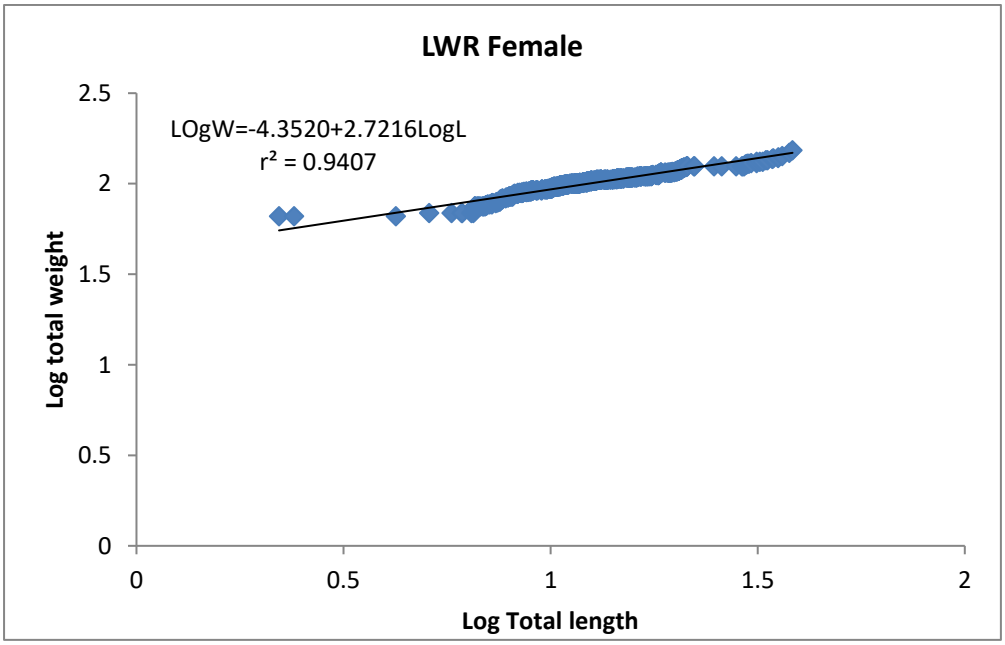


Fig 5.2: LWR between total length and total weight in *P.ocellatus* female

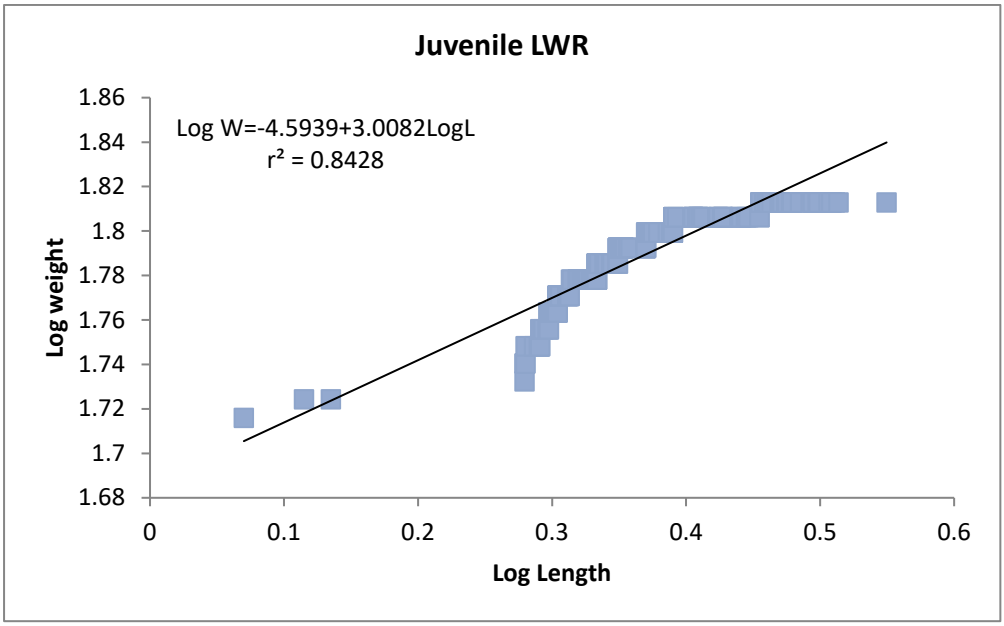


Fig 5.3: LWR between total length and total weight in *P.ocellatus* juvenile

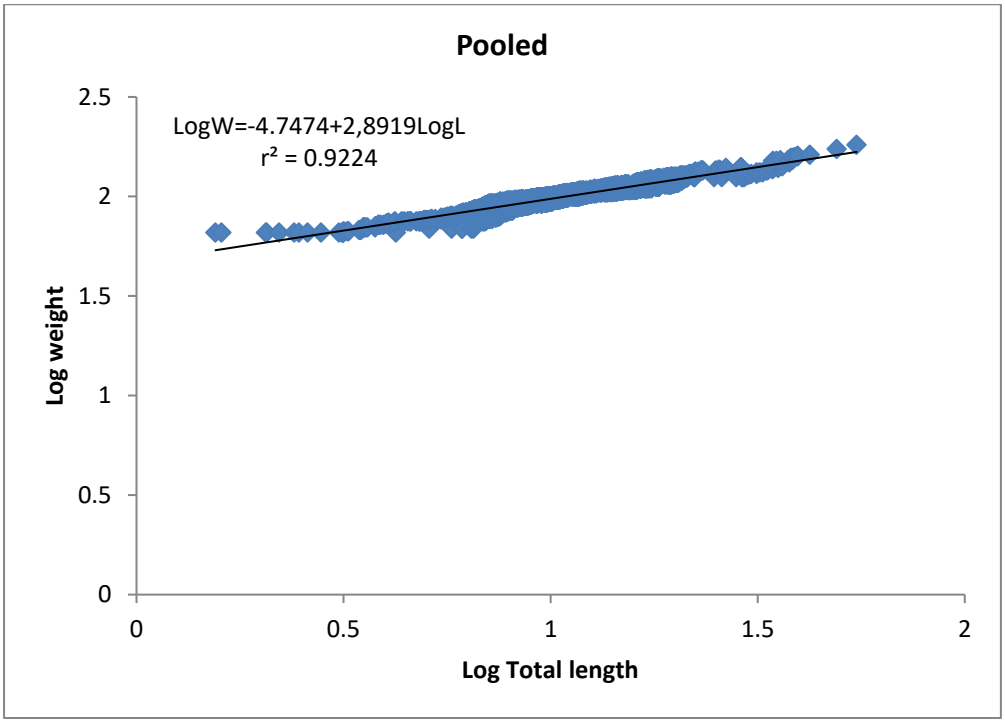


Fig 5.4: LWR between total length and total weight in *P.ocellatus* male and female (pooled)

5.5 Discussion

Length-weight relationship of any fish is dependent upon various environmental factors besides body shape, outline and contour (Ojha *et al*., 2007). The principle of the length-weight relationship is that the weight of the fish increases in relation to increase in its length. To test application of this principle to studies on LWR in *P.ocellatus* the statistical tool like correlation coefficient, regression analysis, ANOVA and ANCOVA are employed.

In the present study the correlation coefficient 'r' was observed to be highly significant in male female and juvenile *P.ocellatus* indicating a strong correlation between length and weight of the fish.

Wooton (1990) has observed that if fish retains the same shape and its specific gravity remains unchanged during the lifetime, it is growing isometrically and the value of exponent 'b' would be exactly 3.0 whereas a value of less than 3.0 shows that the fish becomes lighter (negative allometry) and greater than 3.0 indicate that the fish becomes heavier (positive allometric) for a particular length as it increases in size. According to Jhingran (1968) and Frosta *et al*. (2004) the slope value 'b' indicates the rate of weight gain relative to growth in length and varies among different populations of the same species or within the same species.

In the present study the 'b' value representing LWR was 2.9071 in male and 2.7116 in female. The't' test on b values indicated a significant deviation from cube law in both male and female *P.ocellatus* suggesting that the male and the female had negative allometric growth. The 'b' value in male which is slightly higher than that of female is suggestive of comparatively greater weight gain in male fish than that in the females for the corresponding increase in their length. Similar trend was observed in *Gloossogobius guiris* from North Western Bangladesh which showed b value of 2.768 and 2.667 for males and females respectively (Joadder, 2009) indicating negative allometry. Kalayci *et al*. (2007) reported that the growth was negative allometric for *Gobius niger, Engraulis encrasicolis, Sprattus, sprattus* and *Pomatomus saltatrix*. The authors opined that functional regression 'b' value represents the body form, and it is

directly related to the weight, affected by ecological factors such as sex, age, fishing time area and fishing vessels.

The analysis of covariance and comparison of slopes revealed significant differences between both the sexes of *P.ocellatus* at $p< 0.05$. The observed differences in the males and females in the present study may be attributed to factors like gonad maturity, sex and diet. Tesch (1971) has stated that length weight relationship can be affected by several factors including habitat, area, seasonal effect, degree of stomach fullness, gonad maturity, sex, health, preservation techniques and differences in the observed length ranges of the specimen caught. Moyle and Cech (1988) indicated that the differences in length between the sexes are the most common form of sexual dimorphism among fishes. The males being longer than the female is a distinct sexually dimorphic character in *P.ocellatus* observed during the period of study.
In the present study on LWR in *P.ocellatus* the b value for juveniles was 3.0082 which was highly significant at $p<0.01$. The 't' test clearly indicated that b values did not deviate from 3.0 significantly showing an isometric growth i.e. increase in weight with the corresponding increase in length. The observation of LWR in juveniles and adult *P.ocellatus* are in agreement with Nikolsky (1963) in terms of specific characteristics of growth in different age groups.

All allometric values observed in the present study were within the range of 2.5 to 3.5 indicating that growth of *P.ocellatus* in the creeks of Mumbai was satisfactory. Hile (1936) found that the exponent 'b' usually lies between 2.5 and 4.0 with 3 as the ideal value for 'b' indicating isometric growth while deviation from 3 indicates an allometric growth. The value of coefficient of determination 'r^2' was 0.9828, 0.9407 and 0.8428 for males, females and juveniles respectively. The value being closer to 1 indicates goodness of fit for regression to the observed data.

The present study provides a baseline data on the LWR of *P.ocellatus* from the four creeks of Mumbai. LWR and linear regression was highly significant in males, females and juveniles. The males and females indicated a negative allometric growth pattern while the juveniles exhibited isometric growth pattern. The significant difference between the slopes of regression of male and female reflects a divergence in growth pattern in both the sexes.

Chapter 6

Relative condition factor

6.1 Introduction

6.2 Review of Literature

6.3 Materials and methods

6.4 Result

6.5 Discussion

6.1 Introduction

The Condition Factor is a frequently used index in studies on fish biology, since it furnishes important information related to the physiological state of the fish. The condition factor is an index reflecting interactions between biotic and abiotic factors reflecting on the physiological condition of the fishes. It shows the population's welfare during the various stages of the life cycle (Angelescu *et al*., 1958).Condition factor indicates relative robustness, or degree of well being, of a fish expressed by coefficient of condition denoted by 'K' (also known as Fulton's condition factor or Ponderal Index). It is given by the formula:

$$K = \frac{W}{L^3} \times 100$$

where 'K' is the condition factor, 'W' is the weight of the fish; 'L' is the length of the fish. Fluctuations in 'K' values have been used as a tool to study various biological events of fish life history by many biologists. K values vary in fish with age, season, sex, species and size. If the fish does not undergo the cube law, the 'K' value is directly affected by length, age, maturity, feeding intensity and other factors. In order to eliminate the effect of these factors on the 'K' value, LeCren (1951) suggested the calculation of relative condition factor 'Kn' which is expressed by the formula

$$Kn = \frac{W}{W'}$$

where 'Kn' is the relative condition factor, W is the observed weight of the fish, W´ is the calculated weight of the fish from the LWR. Le Cren (loc.cit.) proposed relative condition (Kn) in preference to condition factor (K) as the former considers all the

variations like those associated with food and feeding, sexual maturity etc while the latter does so only if the exponent value is equal to 3.The difference between ‘K’ and ‘Kn’ is that while the former measures the deviation from a hypothetical ideal fish, the latter measures deviation of an individual fish from the average weight or length. The relative condition factor has an expectation of one and the deviation from one will yield information such as differences in the nutritive level and the effect of physicochemical factors on the life cycle of the fish species and contributed to adequate management of these species and therefore, to the maintenance of equilibrium in the ecosystem (Le Cren, 1951)

.

Anderson and Neumann (1983) reported that the condition factor was a relative indicator of fish health and the degree of sustainable environments, where variations in the relative condition factor is linked to sexual maturity and the degree of nutrient supply within the environment. Changes in Kn may be attributed to sexual maturation and active spawning sizes and seasons (El-Agami, 1988; Hadi, 2008; Shalloof and Salama, 2008). The variation of ‘K’ in the fish may be indicative of food abundance, adaptation to the environment and gonad development (King, 1995). Barnham and Baxter (1998) reported that in some fish species the gonads may weigh up to 15% or more of the total body weight and the K value will decrease rapidly when the eggs are shed.

Suitability of an aquatic habitat for fish growth is determined by the value of relative condition factor with higher values indicating better habitat suitability in terms of food availability and other requirements for optimum fish growth (Samat *et al.,* 2008; Abowei, 2009). The environmental conditions such as rainfall and productivity of the ecosystem can also influence Kn values (Abowei, 2010). The condition factors of threatened species of fishes are the most important biological parameter which provide information on condition of fish species and the entire community and is of high significance for management and conservation of natural populations (Sarkar *et al*., 2009; Muchilisin *et al.,* 2010). Decreasing trends of ‘Kn’ may be attributed to the development of gonadal stages and a resource transfer to the gonads during reproductive periods (Sugilar *et al*., 2012).

6.2 Review of literature

The survey of literature reviewed by the candidate revealed a few reports on the condition factor studies of fish by researchers from various parts of the world. Nash (1982) observed in *Lesuerigobius friesii* that the condition factor continued to fall with the onset of spawning. In goby *Acanthogobius virdipunctatus* maximum relative condition values were observed from February to April suggesting gonadal maturation and spawning (Hoda, 1991). Maximum values of condition factor were observed in smaller sized individuals of *Glossogobius giuris* from Atarai river of Bangledesh (Joadder, 2009). The condition factor of *Neogobius fluviatilis* from Turkey ranged from 1.225-1.458 in males and 1.192-1.283 in females (Sasi and Berber, 2010). Another species of goby *Neogobius melanostomus* had relative condition factor value of 1.071 and 1.103 in downstream and upstream waters respectively (Raby, 2010). In *Bathygobius soporator* from Badgary creek Nigeria the condition factor ranged between 0.01-2.20. In the same species it increased from March to June during the period of increased rate of feeding, followed by increase in accumulated fat (Lawson *et al*., 2011). In sleeper goby *Butis gymnopomus* condition factor ranged between 0.617-1.002 in males and 0.812-0.899 in females (Mat Isa *et al.,* 2012).

Indian fish studies report fluctuation in the condition factor of many fishes in relation to their reproductive cycle (Neelakantan & Pai, 1985; Narejo *et al.,* 2002), feeding rhythms (Pandey and Sharma, 1997) or physico-chemical factors of environment, age and physiological state of fish (Kurup and Samuel, 1987; Kurup, 1990; Kalita and Jayabalan, 1997).

Kader *et al* (1988b) reported in *Gobioides rubicundus* that the condition factor reached its peak in the maturation period and it remained considerably high until the beginning of spawning. A drastic fall in condition factor during and immediately after spawning was observed in *Boleophthalmus dentatus* by Shettu (1993). Ravi (2000) observed that in *Boleophthalmus boddaerti* relative condition factor was not closely associated with feeding but with sexual cycle and weight of gonads. Gore (2007) observed that value of relative condition factor in *Boleophthalmus boddaerti* was 0.9668-1.0543 in males and 0.9550-1.0349 in females.

The present study of relative condition factor ‘Kn’ of *Parachaeturichthys ocellatus* was carried to assess month wise and length wise general condition of the fish to be useful in studies on fish biology management of the fisheries of the fish in the creeks of Mumbai.

6.3 Materials and Methods

The total length and weight of *P.ocellatus* was measured as the method described in this chapter 5 of LWR.

The relative condition factor Kn was calculated using the formula expressed by Le Cren (1951) as follows:

$$Kn = \frac{W}{W'}$$

where W is the observed weight of the fish and W´ is the calculated weight of the fish derived from the length weight relationship.

‘Kn’ was calculated for different months for males, females and juveniles. The average value of each month was calculated and plotted. The length wise average ‘Kn’ values was calculated and plotted using a frequency distribution of length in class interval of 10mm in adults and 5mm in juveniles.

6.4 Results

For determination of relative condition factor the weight was recorded month wise and length wise male, female and juvenile *P.ocellatus*. The weight was also calculated from the length weight relationship.

In the present study a sample of 1512 fish was assessed for relative condition values. The sample consisted of 685 males, 489 females and 338 juveniles. The range of weight in adult fishes was 1.152-54.801g in males, 2.209-38.383g in females, whereas the range of weight in juveniles was 1.775-3-545g. The data was analyzed using a frequency distribution with range of class equal to 10mm in adult fish and 5mm in juvenile fish. Relative condition values were calculated from June 2010 to September 2011 in male, female and juvenile *P.ocellatus* separately.

The month wise values for relative condition factor ‘Kn’ for male, female and juvenile *P.ocellatus* are listed and presented in Table no.6.1 and figure 6.1. The mean value for relative condition factor ’Kn’ obtained was 1.0126, 1.0375 and 1.0013 for male, female and juvenile fishes respectively. The maximum ’Kn’ value equal to 1.0470 was observed in November 2010 in males and of 1.0764 in females in June 2010. In juveniles high value of 1.0059 was observed in August 2010.

Table no. 6.2 and Figure 6.2 presents the ‘Kn’ values of male and female in different length groups. The maximum ‘Kn’ value of 1.0129 was observed in the length group of 106-115mm in males while in female the maximum value of 1.0384 was observed in length group of 66-75mm. Similarly the ‘Kn’ values in different length groups in juveniles are represented in Fig 6.3. The minimum value was observed in lowest length group of 51-55mm and maximum in highest length group of 60-65mm.

Table no. 6.1: Relative condition factor ‘Kn’ values of male, female and juvenile *P.ocellatus* during different months.

Months	Male	Female	Juvenile
Jun-2010	1.0024	1.0764	1.0018
Jul-2010	1.0038	1.0403	1.0023
Aug-2010	1.0052	1.0564	1.0059
Sept-2010	1.0036	1.0548	1.0016
Oct-2010	1.0155	1.0201	1.0020
Nov-2010	1.0470	1.0302	1.0030
Dec-2010	1.0357	1.0333	1.0016
Jan-2011	1.0353	1.0407	1.0010
Feb-2011	1.0341	1.0555	1.0007
Mar-2011	1.0081	1.0411	-
Apr-2011	1.0003	1.0134	-
May-2011	1.0002	1.0003	0.9964
Jun-2011	1.0013	1.0515	1.0006
Jul-2011	1.0031	1.0201	1.0013
Aug-2011	1.0041	1.0235	1.0001
Sept-2011	1.0029	1.0430	1.0003
Average	1.0126	1.0375	1.0013

Table no. 6.2: Relative condition factor'Kn' values in different length groups of male and female *P.ocellatus.*

Length group	Male	Female
66-75	1.0125	1.0394
76-85	1.0126	1.0383
86-95	1.0127	1.0381
96-105	1.0128	1.0380
106-115	1.0129	1.0372
116-125	1.0127	1.0371
126-135	1.0126	1.0373
136-145	1.0125	1.0369
146-155	1.0124	1.0352
156-165	1.0124	-
166-175	1.0123	-
176-185	1.0122	-

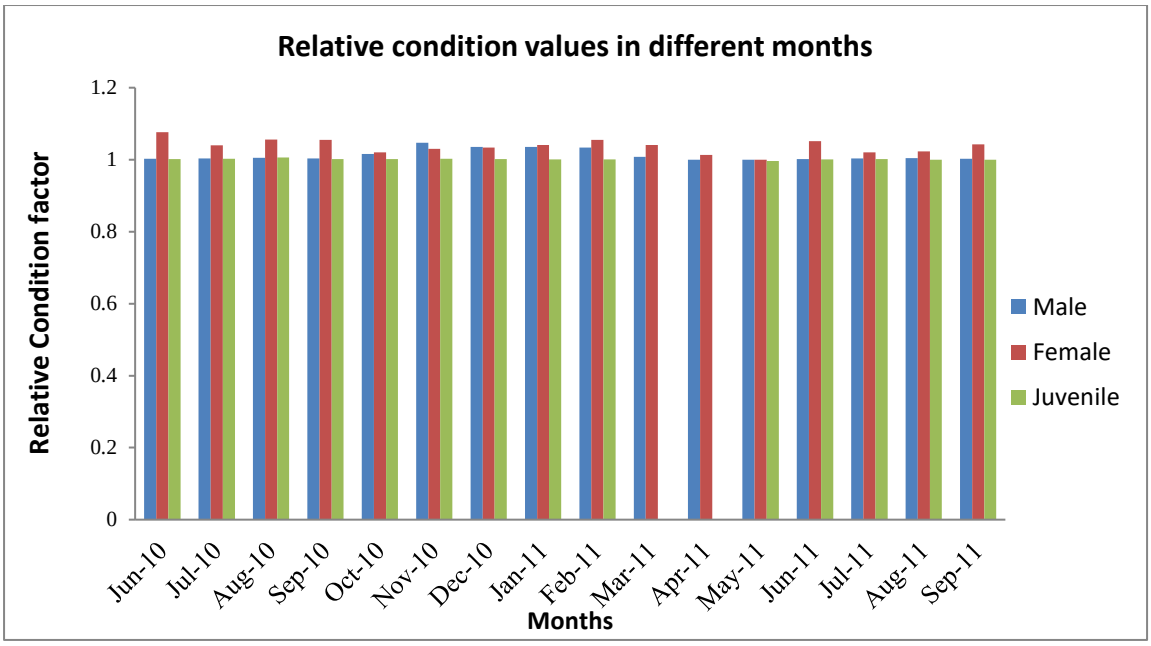


Figure 6.1: Relative condition values of male, female and juvenile *P.ocellatus* during different months.

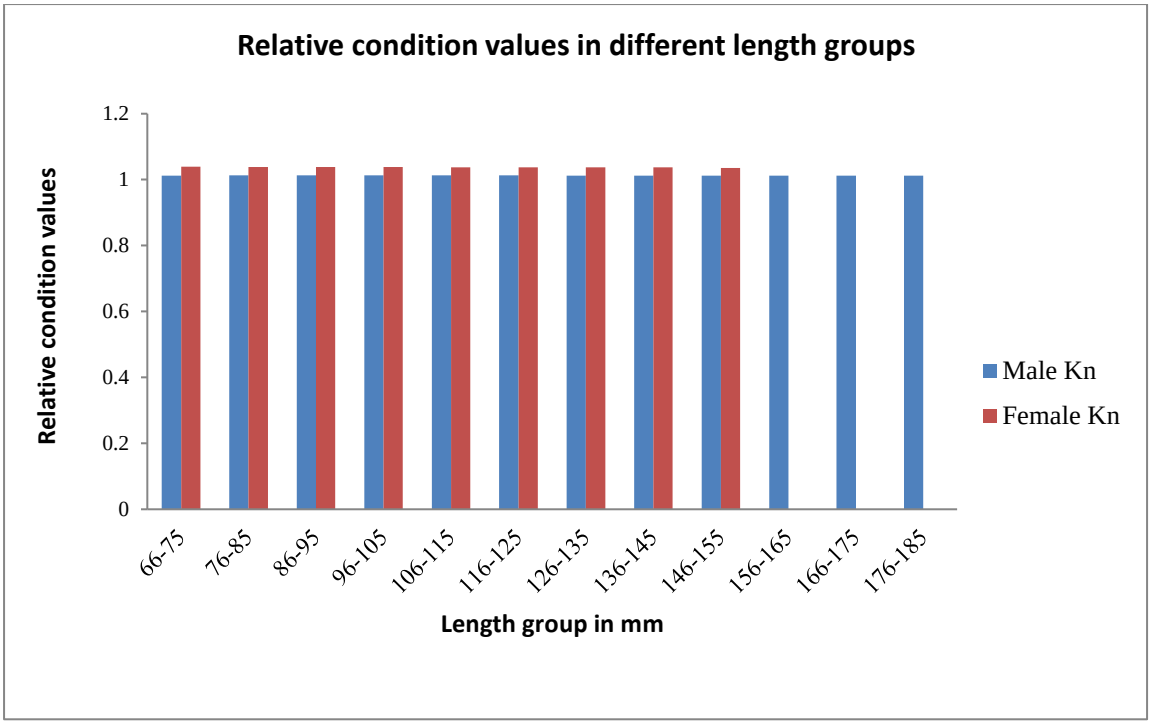


Figure 6.2: Relative condition factor of male and female *P.ocellatus* in different length groups.

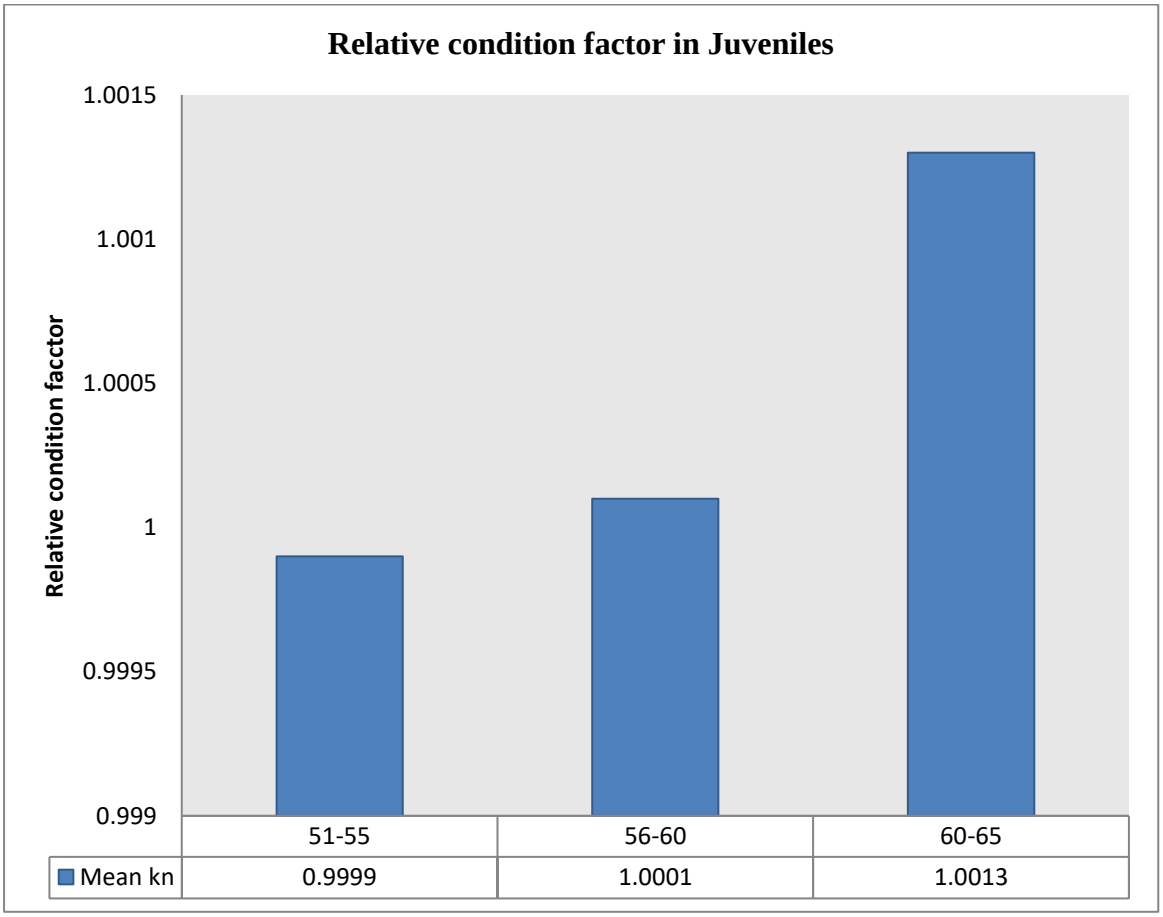


Figure 6.3: Relative condition factor of juvenile *P.ocellatus* in different length groups.

6.5 Discussion

The condition factor as a frequently used index furnishes important information related to physiological state of the fish and its determination is important for any studies on fish biology. According to Le Cren (1951) Kn greater than 1 indicated good general condition of fish. In the present study the mean 'Kn' value which is ratio of W:W´ where W is the recorded weight and W´ is the calculated weight from LWR observed in male female and juvenile was greater than 1 indicating an overall good condition of fish in creeks of Mumbai throughout the year. Sex wise analysis revealed 'Kn' value of 1.0375 and 1.0126 in male and female fish respectively. The female fish thus seem to be heavier than male fish for a given length. LeCren (1951) reported that females are heavier than males of the same length probably because of difference in fattiness and gonadal development. The present observation of comparative value of 'Kn' in male and female *P.ocellatus* was in agreement with the observation of Le Cren (loc.cit.) and the findings of Ravi (2000) and Gore (2007) in *Boleophthalmus boddaerti*.

Sebastian (2011) reported that there was a definite seasonal cycle in the 'Kn' values of both male and female *Colletteichthys dussumieri*. In the present study maximum 'Kn' value was observed in male fish in November 2010 and the value progressively decreased though slightly till February 2011 The values showed a sharp decline from March 2011 to May 2011. The lowest value was recorded in May 2011 There is a gradual increase in 'Kn' value from June 2011 to August 2011 indicating a recovery in the general condition of male fish.

In female *P.ocellatus* maximum 'Kn' value was observed in the month of June 2010 which the decreased gradually from August 2010 to October 2010. There was an increase gradually thereafter till February 2011.The 'Kn' values declined sharply again in April 2011 and continued to decline till May 2011. The 'Kn' value was found to again increase sharply in June 2011. Thus the 'Kn' value in *P.ocellatus* also seems to follow a seasonal cycle. Similar observations were noted in *Lesuerigobius friessi* by Nash (1982) and in *Gobioides rubicundus* by Kader *et al.,* (1988b).

When the condition factor of a fish is determined every month of the year the suitability of the environment of the fish during each month could be better understood (Bagenal, 1979). Seasonal variation of 'Kn' is influenced by gonadal development, feeding activity and several other factors (Gowda 1984, Doddamani *et al.,* 2001). The period in which lower condition value is obtained is also a period in which accumulated fat is in use for spawning (Braga *et al*., 1990). Condition and feeding activity decrease in the spawning time (Maddock and Burton, 1999). Relative condition factor is closely related not only to the feeding intensity but also with sexual cycle and weight of gonads before and after spawning as reported in gobiids of south east cost by Ravi (2000). Lizama and Ambrosio (2002) reported that lowest 'Kn' values during the more developed gonadal stages suggesting resource transfer to the gonads during the reproductive period. According to Da Costa and Araujo (2003), relatively lower 'Kn' values are usually due to the fact that a larger part of the energy is allocated for certain activities such as growth and emptying of ovaries. Sebastain (2011) reported that higher 'Kn' values in *C.dussumieri* may be related to the increase in the feeding intensity of the spent fishes to rebuild their body reserves resulting in sharp increase of 'Kn' at the end of spawning and during post spawning period.

In the present study of *P.ocellatus* the condition value of male was high in pre spawning phase being maximum during November 2010 and declined during the spawning period to reach minimum immediately after the peak spawning to again show a great rise. In female 'Kn' values increased gradually from the pre spawning period of November 2010 to the peak spawning period of February and March 2011 and declined sharply in the post spawning phase to reach minimum during May 2011. The female recovered immediately after spawning with sharp increase in condition value whereas the condition values in males increased gradually as compared to the female.

El-Agami (1988), Hadi (2008) and Shalloof and Salam (2008) reported that the condition factor determines the period of gonad maturation, and can be attributed to sexual and active spawning sizes. Froese (2006) observed that reproduction results in lower value of Condition factor with K<1 coinciding with the post spawning period when the fish tends to lose weight. However in the present study the 'Kn' was never less than 1 throughout the year and it can therefore be assumed that *P.ocellatus* tends

to maintain its overall good condition irrespective of its reproductive phase probably by modulating its feeding intensity. The condition values of juvenile ranged between 0.9964-1.0059 and the juvenile fish were found to be in overall good condition throughout the year except in May 2011.

The ‘Kn’ also varies in different length groups and probably also depends on feeding intensity. The variation of ‘Kn’ values observed in different length groups seems to be due to differences in feeding intensity and reproductive cycle. Sebastian (2011) reported that in *C.dussumeiri* high ‘Kn’ values observed in 131-140 mm TL and 151-160 mm TL size groups of male might be due to the occurrence of large number of maturing and mature individuals within that particular range. The ‘Kn’ values in male *P.ocellatus* gradually increases from the length group of 66-75mm through 96-105mm reaching the maximum value in the length group 106-115mm. This probably correlates with the advancing stages of maturity. The lower ‘Kn’ values in *P.ocellatus* were observed in the large sized individuals with a length of 166-175mm and 175-185mm probably because the male fishes have reached the post spawning stage. However the ‘Kn’ values in male *P.ocellatus* was never less than 1 in the sample of fish analysed.

In female *P.ocellatus* maximum ‘Kn’ value was observed in smallest length group of 66-75mm. The value slightly decreased in the higher length groups. The lowest value was observed in the length group of 146-155mm. Thus be surmised that in male *P.ocellatus* the relative condition factor ‘Kn’ increased till the males attained maturity and then the ‘Kn’ decreased slightly while the females are in good condition at minimum body length and later undergo slight decrease in condition values in the higher length groups reaching the lowest values in the large sized females. According to Palazon-Fernandez *et al.* (2001) males and females of *Halobatrachus didactylus* matured at different length and the authors opined that size at maturity for males was greater than that of females, which may indicate that after first maturation females tend to allocate energy mainly for the production of gamete and then they do not exhibit further growth in terms of length while males, with a small reproductive effort, continue growing to the larger length group.

Juvenile *P.ocellatus* showed lower ‘Kn’ values in lowest length group of 51-55mm and increased with the increase in length of fish as would be expected till they attain adulthood.

During the course of present study, the male, female and juvenile *P.ocellatus* were found to be in a healthy condition in the creeks of Mumbai. The sex wise analysis revealed that females have higher ’Kn’ values and are in a better condition than males. The condition factors may be influenced by number of factors of which feeding and reproductive activity may probably be the important factors.

Chapter 7

Food and feeding habits

7.1 Introduction

7.2 Review of Literature

7.3 Materials and methods

7.4 Result

7.5 Discussion

7.1 Introduction

Fishes, as living organisms, are linked to other life forms in their environment through the food web. Food is one of the most essential prerequisite for survival and growth of all living forms. The diets of the fish species may change with age and growth. The time and extent of changes in food and feeding habits vary from species to species and often with changes in the life style or habitat (Blaber, 2000). The study of food and feeding habits of a fish is of primary importance, since the growth, reproduction, development migration and other physiological activities are dependent on the energy derived from the food (Bal and Rao, 1984). The food and feeding habit of fishes vary from season to season. Seasonal change in temperature not only influence food consumption and rate of digestion but also quality and quantity of available food organisms (Sebatian, 2012).

The feeding behaviour in a fish is a species characteristic formed during its evolutionary history (Nikolsky, 1963). The general nature of a fish's feeding habits can be inferred from the knowledge of its functional morphology (Weatherly, 1972). Saxena (1980) reported that the mouth, buccal cavity and pharynx of fishes are associated with the selection and seizure of the food. The author further states that the position and form of the mouth, dentition on the jaws and the buccopharynx and the gill rakers show a close relation with the mode of feeding and the kind of food. Diets of fishes represent an integration of behaviour, condition, habitat use, energy intake and inter and intra specific interactions. (Zacharia and Abdurahiman, 2004).

Food habits of gobies are very diverse consisting of crabs, shrimps, small crustaceans like copepods, amphipods and ostracods, molluscs and fishes (Jonna, 2004). Darcy (1980) reported that most species of gobies are carnivorous and only few are herbivorous. He further stated that some species of the gobies feed on small benthic invertebrates and algae, some have very specialized food habits, some are semi pelagic and feed on planktonic copepods while those living in freshwater streams and lakes feed on diatoms and other micro algae. Mudskippers of genus *Boleophthalmus*, *Periophthalmus, Periophthalmodon* and *Scartelaos* actively forage over mudflats and mangrove roots for crustaceans and insects. Members of genus *Gobiosoma* act as cleaner fishes, feeding on parasites and dead skin of larger fish (Allen and Robertson, 1994). Gobies of all sizes eat small molluscs and crustaceans, small and medium sized gobies eat polychaetes but only larger individuals eat other fish (Skazkinia and Kostyuchenko,1968 and Kovtun *et al.,* 1974).

A lot of information on the type of food of a fish can be derived from analysis of the gut content with simple observation and microscopic studies. The food encountered in the gut contents of a fish may not always be its natural food. The gut content at times may include accidental, emergency or spurious food items. The food recorded in the gut contents of a fish has to be verified and examined with the help of collateral parameters; the gut contents only indicate what the fish would feed on and hence require additional information to ascertain its natural food (Lagler, 1949). Pillay (1952) made a critical review of different methods of food analysis of fishes and stated that the best way of examination of food and feeding habit of fish is by studying its gut contents.

Hynes (1950) pointed out different methods of food analysis for fishes and stated that if a large number of guts are analyzed for study the results obtained by occurrence, dominance and point's method are approximately the same. Index of preponderance is a definite and measurable basis for grading the various food items. The index of preponderance is an index taking into consideration both frequency of occurrence and volume of food items. It was constructed by Natarajan and Jhingran (1961) and is a desirable tool to study food preference of the fish. The Index of preponderance assumes biological significance when examined against

the state of digestion of food in stomach and rectum. The study of the feeding habits of fish and other animals based upon analysis of stomach content has become a standard practice (Hyslop, 1980). There is no single method available, which could give sufficient accuracy over the quantitative and qualitative aspects of food, and yet be not time consuming and tedious (Qasim, 1972). In an attempt to consolidate the desirable properties of individual diet measures, compound indices were developed that combine two or more measures into a single index (Zacharia and Abdurahiman, 2010).

Feeding intensity is the quantitative index of the bulk of food that a fish would feed on. Feeding intensity of fishes can be assessed based on emptiness percentage and stomach fullness indices (Shanti Prabha and Manjulatha, 2008). The feeding intensity of a fish is related to its stage of maturity, reproductive state and the availability of food items in its environment (Maddock and Burton, 1999; Sivakami, 1996; Kiran and Puttaiah, 2004). Feeding index of the food is calculated based on the percentage of feeding intensity.

Gastro somatic index is the percentage of the amount of food present in the gut of fish in relation to the total weight of fish. Gastrosomatic index is useful in estimating the feeding intensity of fishes (Desai, 1970). According to Venkatramanujam and Ramanathan (1994) gastrosomatic index indicates the spawning period in some teleostan fishes. They further states that rise and fall of gastrosomatic index and relative condition values always show an inverse relationship with the gonadosomatic index and percentage of empty stomachs. Thus the knowledge of food and feeding habits of fish along with feeding intensity and gastrosomatic index will be useful in understanding the biological aspects like condition factor and reproductive status of fish which will be useful in the successful management of fishery.

7.2 Review of Literature

The earliest reports available in the survey of literature undertaken for the present study date back to 1917 (Blegvad) who studied gobies from Denmark and reported that the food of *Gobius niger* was amphipods, mysids, decapods, crustaceans,

polycheates, molluscs, insect larvae, small fishes, algae and that of *Gobiusculus flavescens* was calanoid and harpacticoid copepods, larvae of small crustaceans, small polycheates and small mollusks. Hildebrand and Schroeder (1928) studied gobies from Chesapeake bay and reported that *Gobiosoma bosci* fed on gammarus, small crustaceans, annelids, small fish and fish eggs while *Gobiosoma ginsburgi* fed on gammarus and small crustaceans. *Microgobius gulosus* from Florida was found to feed on copepods, mysids, amphipods (Reid, 1954). The goby *Parioglossus taeniatus* fed on planktonic copepods (Dotu, 1955a), *Gobius poecilichthys* fed on molluscs and crustaceans (Dotu, 1955b), *Zonogobius boreus* fed on small crustaceans (Shiogaki and Dotsu, 1974), *Eutaenichthys gilli* from Japan estuaries fed on organic detritus (Dotu, 1965), *Paleatogobius uchidai* fed on worms, young fish detritus (Dotu, 1958a), *Rhinogobius giurinus* from the estuaries and fresh water of southwest Japan fed on insects, small fishes, molluscs, crustaceans, detritus, fish eggs (Dotu, 1961a),*Chaenogobius scrobiculatus* from Southwest Japan estuaries fed on small crustaceans molluscs, detritus and algae and *Apocryptodon bleekeri* from Ariake Sound Japan fed on mud and diatoms (Dotu,1961c).

Randall (1967) reported that *Gobiosoma spp* from Virgin Islands of Caribbean sea fed on gnathid isopods. Gibson (1970) reported that *Gobius cobitus* from Pallas fed on algae, gammarid amphipods, crabs, isopods, chironomid larvae and adults and small fishes. Odum (1970) reported that *Lophogobius cyprinoids* from north river estuary, Florida fed on amphipods, plant detritus, filamentous algae, mysids, caridean and penaeid shrimps and Darcy (1978) reported that same species from Dade County, Florida fed on algae, crustaceans, molluscs, insects, bryozoans, and polycheates. The smallest goby *Aphia minuta* from Belt sea Denmark fed on harpacticoid copepods, barnacles, mysids, unidentified crustaceans and algae (Hesthagen, 1971). The same species from north western Adriatic sea was found to be planktivorous feeding exclusively on pelagic invertebrates like copepods, decapods, polycheates and bivalves (La Mesa, 2010). Gibson and Ezzi (1978) observed *Lesuerigobius friesii* fed predominantly polycheates although small crustaceans, and mollusc also featured commonly in its diet.

The food of *Porogobius schlegelii* from Elechi creek off Bonny River, Niger delta, Nigeria fed on detritus, diatoms and blue green algae (Ockiya, 2001). The violet goby *Gobioides broussoneti* from estuaries of Tecolutla, Veracruz, Mexico fed on algae and detritus (Cortes *et al.,* 2004). Black goby *Gobius niger* from Aegean sea, Turkey fed on crustaceans, polycheates, foraminiferons and teleosts (Filiz and Togulga, 2009). Frill fin goby *Bathygobius soporator* from Badgary creek, Lagos Nigeria fed on crustaceans, Pisces, insects detritus, bivalves and gastropods (Lawson *et al*., 2011). American fresh water goby *Ctenogobius shufeldti* from Paranagua bay showed that it was a typical omnivorous, generalized benthic predator of low trophic levels feeding on 56 dietary items (Contente *et al.,* 2012).

Bhowmick (1963) made a preliminary study of the feeding biology of *G giuris* from Hoogly estuary and found that crustaceans formed the major food of the juveniles while the most preferred food of the adults was fish. Kumar and Roy (2009) observed that *G.guiris* showed cannibalism but mainly subsisted on zooplankton, aquatic insects and other fishes. *Boleophtlamus boddaerti* mainly subsists on plant biota, feeding exclusively on phytoplankton with a distinct preference for diatoms (Biswas, 1979). Ravi (2000) studied *B.boddaerti* from South east coast and found that it fed exclusively on phytoplankton. Gore (2007) found *B.boddaerti* from Mumbai coast fed on phytoplankton of which diatoms formed the principal component of the food. Kader *et al.* (1988a) observed that *Gobiopterus rubicundus* was mainly carnivorous and even cannibalistic at times in its feeding habits. *Parachaeturichthys polynema* from Gulf of Thailand fed on crustaceans and shrimps (Yamashita *et al.,* 1991).

Literature review revealed hardly any reports on food and feeding of *Parachaeturichthys ocellatus* from around the world and none for the fish from the creeks of Mumbai. The study of food and feeding is of primary importance in any study of its biology. The knowledge of food and feeding is essential also for the fishery management and conservation in different habitats and its commercial exploitation. Thus the present study was carried out to understand the seasonal and length wise variation in food, feeding intensity and gastro somatic index of *P.ocellatus* from the creeks of Mumbai.

7.3 Materials and methods

Fish samples for the present study were collected from Malad, Vasai, Thane and Mahul creek every fortnight from June 2010 to September 2011. The samples were brought to the laboratory in ice-box. Morphological observation of features related to food and feeding habit was observed and noted and the fishes were cleaned and total length for each fish in millimetres and total weight in milligrams were recorded. The fish were then dissected by making an incision from the anus up to the throat and following characters were noted: sex, states of maturity and fullness of stomach. The alimentary canal was then removed from the body to record its length in millimetres and weight in milligrams. The alimentary canal was preserved in 5% formaldehyde; the fish too was preserved separately for other studies.

For understanding food and feeding habits following parameters were determined: 1) Relative gut length 2) Index of preponderance 3) Feeding intensity 4) Gastro somatic index.

Relative gut length

The value of Relative gut length was calculated by the formula:

$$RGL = \frac{\text{Length of the gut} \times 100}{\text{Total body length}}$$

General diet composition in terms of gut contents

The gut contents were obtained by dissecting the stomach and microscopic examination of the contents was carried out. The food items were sorted out and identified up to the species level. The food items which could not be distinguished due to state of digestion were grouped as semi digested food.

Index of preponderance (IoP)

The occurrence method (Hynes 1950) was employed to express the percentage occurrence of each food item in the total number of stomachs examined. The percentage volume of each food item of major groups was estimated by displacement method (Pillay, 1952). The food items were graded by the method of

index of preponderance (Natarajan and Jhingran, 1961) which combines both frequency of occurrence and volumetric estimation by displacement method. It was resolved by the equation

$$IoP = \frac{ViOi \times 100}{\sum ViOi}$$

where

IoP = Index of preponderance of the food item

Vi = percentage of volume index of the food item

Oi = percentage of occurrence index of the food item.

The IoP was determined separately for male, female and juvenile *P.ocellatus.*

Feeding intensity and feeding index

The stomach fullness was visually examined and classified as gorged, full, three-fourth full, half full, one-fourth full, trace and empty depending on the fullness and amount of food contained in it. The average feeding intensity was evaluated by point's method. Points were assigned as 10, 8, 6, 4, 2, 1, 0 for gorged, full, three-fourth, half, one-fourth, trace and empty respectively (Bapat and Bal, 1950). The fish was considered active feeder when stomach was gorged, full and ¾ full, moderate when half full and poor feeder when ¼ full or with traces of food items. Feeding index was determined for all the fishes observed in the sample used for the study. The determination was carries out separately during each month for male, female and juvenile fish and for different length groups of male and female fish. The feeding index was calculated as per the following formula.

$$\text{Feeding index} = \frac{X \times 100}{N \times \text{points assigned (10, 8, 6, 4, 2, 1, 0).}}$$

where

X= the number of particular type of fullness of stomach

N= total number of stomachs examined.

Gastrosomatic index (GaSI)

GaSI was calculated using the method adopted by Desai (1970):

$$GaSI = \frac{\text{weight of the stomach contents}}{\text{total weight of the fish}} \times 100$$

The above analysis were carried out in terms monthly variation in male, female and juvenile fishes separately and in terms of length groups for male and female fishes.

7.4 Results

The feeding behaviour in a fish is a species characteristics formed during its evolutionary history (Nikolsky, 1963). The general nature of the fish's feeding habits can be inferred from the knowledge of its functional morphology (Weatherly 1972). The nature of food can be surmised by analysis of gut contents and other characters.

Morphological features.

Saxena (1980) had reported that form of mouth, dentition on the jaws and the buccopharynx and the gill rakers show a close relation with the mode of feeding and kind of food. The following morphological features which are important for understanding food and feeding of *P.ocellatus* were observed in the fish:

Body elongated and cylindrical, dorsoventrally flattened head, protruding eyes for vision in dark and crescent shaped wide mouth extending below the eye orbit. A protruding lower jaw with many minute barbels for feeding on benthos. There were four rows of teeth on lower jaw with larger teeth in outer row and small villiform teeth in inner rows, the number of teeth decreased from outer to inner rows. Upper jaw too had four rows of teeth, the outer row having larger teeth with the front four teeth being the largest. The size decreased progressively on both the sides. The four teeth in the front were also slightly recurved. The inner teeth on the upper jaw were smaller in size. Ventral and dorsal pharyngeal tooth plates were observed in both jaws. There were four pairs of gill arch which are spaced apart and bear 16-18 tooth-like gill rakers on each. All the observed characters in terms of the position and the form of mouth and the dentition in jaws, all indicate that *P.ocellatus* is carnivorous.

Pelvic fins were united to form a sucking device which extended till the vent thus enabling the fish to adhere to the substratum in water and thereby maintain their position. A large wedge shaped caudal fin would facilitate acceleration in water. All these morphological features indicate that *P ocellatus* seems to be carnivorous predatory fish.

Relative gut length

Relative gut length gives an idea of the nature of food. The range and average of relative gut length of *P.ocellatus* is as presented below:

Male = 0.51 - 0.85 with an average of 0.68
Female = 0.55 - 0.88 with an average of 0.70
Juvenile = 0.78 - 0.84 with an average of 0.79

Fig 7.7 presents the RGL value of male female and juvenile *P.ocellatus* in different months.

General diet composition

Average percentage of various food items in the *P. ocellatus* male, female and juvenile are presented in Table no. 7.1 and figures 7.1 a, b, c .The various food items recorded from the gut of *P.ocellatus* consisted of the following major groups:

Crustaceans formed the major bulk of the food with an average IoP value of 40.71% in male, 38.64% in female and 38.28% in juvenile. The food included zoea larvae of crab, zoea and megalopa of paenid and metapaenid prawns, mysis, acetes, lucifer, crustacean appendages, crustacean eggs and other whole and remanants of arthropods were also obtained from the gut namely amphipod e.g. caprellids, copepods e.g. acartia, paracalanus, eucalanus and cladocerans e.g. daphnia.

Molluscans obtained in the food of *P.ocellatus* consisted of velliger of bivalve, clams, young ones of gastropods e.g *Nassarius spp* and *Thiara spps*, young ones of bivalves. Of the general diet, molluscans formed about 12.80% of the entire gut contents in male, 12.64% in female and 3.37% in juvenile *P.ocellatus*.

The general diet composition also include various adult and juvenile **fishes** e.g *Glossogobius guiris, Boleophthalmus dussumeiri*, fish larvae, fish eggs, scales, fins etc. Of the entire gut contents, fishes consisted of 9.44%, 11.66% and 6.10% in male, female and juvenile respectively.

Of the general diet composition **phytoplanktons** observed in the gut contents of *P.ocellatus* consisted of Phylum Cyanophyta e.g Oscillatoria, Phylum Chlorophyta which included Spirogyra, Zygnema, Cladophora, Ulothrix and Phylum Bacillariophyta (Diatoms) which consisted of Melosira, Pleurosigma, Synedra, Nitzchia, Naviculla, and Pseudonitzchia. Of the entire gut content phytoplanktons formed 4.07% in males, 5.87% in females and 13.16% in juveniles.

The general diet of *P.ocellatus* also consisted of **miscellaneous food** e.g nymphs of May fly, Hymenoptera larvae, Trichoptera larvae, polycheates worms e.g. nereis and glycera spp, Sagitta spp, rotiferons**,** dinoflagellates e.g. noctiluca, medusae, and foraminiferans . Of the entire gut content miscellaneous food formed 2.89% in males, 5.16% in females and 3.01% in juveniles.

Semi digested food in the gut content consisted of fishes, prawns, fish larvae in digested and semi digested state which could not be identified. Of the entire gut content semi digested food formed 10.59% in males, 8.24% in females and 11.96% in juveniles.

The gut contents also revealed presence of **detritus**, **mud** and **sand**. Detritus consisted of organic matter comprising of 9.69%, 8.87% and 12.44% in gut contents of male, female and juvenile respectively. Mud constituted 6.73%, 5.91% and 9.09% in male female and juvenile respectively while sand were 3.08%, 3.02% and 2.17% in male, female and juvenile respectively.

Monthly variation in food composition

Month wise index of preponderance of various food items in the guts of *P.ocellatus* is presented as follows: Males- Table no. 7.2a and Figure 7.2a Females Table no. 7.2b and Figure 7.2b and Juveniles Table no.7.2c and Figure 7.2c.

Crustaceans: Gut contents revealed that crustaceans formed the major bulk of food of males, females and juveniles in all seasons. The maximum IoP values recorded were 52.41 and 48.52 for males and females respectively in August 2011 where as in juveniles IoP was maximum at 45.84 in February 2011. The minimum values recorded were 31.07 and 28.04 in June 2010 and April 2011 in males and females respectively while in juveniles the minimum value of 32.42 was observed in October 2010.

Molluscs: Molluscs were the second most preferred food of males and females in all seasons while in juveniles it was third most preferred food. The maximum IoP values of mollusc were 26.73 and 18.82 in male and female respectively in September 2011 while in juveniles it was 8.12 in August 2011. The molluscs were minimum of values 1.23 and 4.09 in males and females respectively in May 2011 while in juveniles the minimum value was 1.07 in September 2010.

Pisces: Pisces was the third most preferred food of male and female *P.ocellatus* during monsoon months from June to September and the post monsoon months from October to January. However pisces formed the second most preferred food during the pre monsoon months from February to May. The maximum IoP of Pisces in the food composition were found to be 16.87 in male fish during June 2011; 26.63 in female fish during May 2011 and 9.06 in February 2011 in the juvenile fish. The minimum values were 5.05, 6.75 and 2.69 in male, female and juvenile fish; the minimum value was obtained in male in September 2011 whereas in female and juvenile the minimum values were obtained in the month of September 2010.

Phytoplankton: Phytoplankton was observed in the guts of male, female and juvenile in monsoon and post monsoon period. However the contribution of planktons to the diet composition surmised from the gut content was very little during pre monsoon months in male and female *P.ocellatus*. On the contrary phytoplankton contributed a considerable to the diet of juveniles almost throughout the period of study. It was very less in males and females in pre monsoon months. Juvenile gut recorded phytoplankton even in post monsoon months showing a preference for phytoplankton.

Micellaneous food items: Miscellaneous food items like insects, annelids, cheatognaths, rotiferans dinoflagellates and cnidarians were recorded as per their availability in the creeks. The maximum IoP of male, female and juvenile was 7.03, 9.04 and 5.16 in Septerber 2011, March 2011 and May 2011 respectively. The minimum IoP for male was 0.25 in May 2011, female was 2.00 in October 2010 and juvenile was 0.7 in September 2011.

Semi digested: Semi digested food was recorded from the guts of male, female and juvenile *P.ocellatus* in all seasons. The maximum IoP value was 19.74, 12.53 in May 2011 in both male and female while in juvenile it was 15.03 in July 2010. The minimum IoP values recorded were 4.99 and 3.35 in September2011 in both male and female fish while the value in juvenile was 8.45 in February 2011.

Detritus: Detritus was found to be present in gut contents of male, female and juvenile *P.ocellatus* in all seasons. The maximum IoP values recorded were 14.78 in July 2011 in males, 12.72 in December 2010 in female and 17.47 in juvenile fish during June 2010. The minimum values recorded were 5.65 in January 2011 in males, 4.81 in September 2011 and 10.22 in juveniles during June 2011.

Mud and Sand: Mud and Sand occurred in the gut contents of male female and juveniles throughout the period of study.

Thus *P.ocellatus* was found to forage on a variety of food items in different seasons.

Length wise variation in food items:

The values of index of preponderance of various food items in the gut contents of male and female *P.ocellatus* in different length groups are presented in Table no. 7.3a and 7.3b and Figure 7.3a and 7.3b.

Crustaceans: In male and female *P.ocellatus* crustaceans were the dominant food in all length groups. In males the maximum IoP value of 63.33 was recorded in length group of 166-175mm and minimum IoP value of 36.78 was obtained in the length group 66-75mm. In females crustaceans recorded the maximum IoP value

of 48.9 in the length group of 136-145mm and the minimum IoP value of 21.14 in the length group of 66-75mm.

Mollusc: Molluscs were the second most preferred food of the male in all length groups with the maximum IoP at 22.28 in the length group of 156-165mm and the minimum IoP value of 8.37 in the length group 136-145mm. In females, molluscs were the second preferred food in the entire range of length group from 66-125mm while in females of length range from 126-155mm, molluscs formed the third most preferred food. The IoP was maximum at 20.66 in the length group 76-85mm where as minimum at 5.00 was obtained in length group 146-155mm.

Pisces: Pisces consisting of adult fishes, fish larvae, fish scales, and eggs were recorded from the gut contents of male and female *P.ocellatus* in all the length groups with the maximum IoP values in larger length group male and female. In males the maximum IoP value of 12.5 was obtained in the largest length group of 176-185 mm while the minimum IoP of 3.93 was observed in the lowest length group of 66-75mm. In females Pisces formed the second most preferred food in the length group of 126-155mm. The maximum IoP value at 23.57 was obtained in the length group of 146-155mm and minimum IoP at 2.52 was obtained in length group of 76-85mm.

Phytoplankton: Though the phytoplankton forms on a average 4.07% of the gut contents; in *P.ocellatus* males ranging in the length group of 146-175mm phytoplankton were absent. Maximum IoP at 12.19 was obtained in the length group of 106-115mm in male and the minimum value at 0.25 was obtained in longer length group of 136-145mm. In female *P.ocellatus* also phytoplankton was absent in the gut contents in the range of the fish belonging to length range of 136-155mm. The maximum IoP of 17.39 was observed in length group of 66-75mm and minimum IoP at 4.38 in the length range of 126-135mm

Miscellaneous food: Miscellaneous food items were remarkably absent in male *P.ocellatus* in higher length group ranging from 166-185mm. The maximum IoP at 4.67 was obtained in length group of 66-75mm and minimum at 1.57 in length group of 136-145mm. In females also miscellaneous food items were absent in the gut

contents of largest length group of 146-155mm with maximum IoP at 10.14 in length group 66-75mm and minimum value of IoP at 1.57 in length group of 136-145mm.

Semi digested: In male *P.ocellatus* semi digested food was observed in the gut contents in males except in length group of 166-175mm. The maximum IoP was obtained at 13.01 in length group of 136-145mm with minimum value of 6.27 in length group of 116-125mm. In female fish semi digested food was obtained in all length groups and maximum IoP at 14.29 in the length group 146-155mm and minimum IoP at 5.77 in the length group of 106-115mm.

Detritus: Detritus was recorded in the gut content of male and female *P.ocellatus* in all the length groups. The maximum IoP recorded in the male fish was at 12.62 in length group of 136-145mm with the minimum IoP at 6.25 in the length group of 116-125mm. In female the maximum IoP 17.85 was recorded in length group of 146-155mm and minimum at 5.6 in length group of 106-115mm

Mud and Sand: Mud and sand were found to be absent in male and female *P.ocellatus* in the largest length groups. In males the IoP of mud was maximum at 8.96 and minimum at 4.17 in length groups of 126-135mm and 156-165 mm respectively while the IoP value of sand was the maximum at 4.21 in the length group of 76-85mm and the minimum at 0.75 in length group of 156-165mm. In females the maximum IoP of mud was at 9.83 in length group of 76-85mm and minimum IoP at 4.23 in the length group of 116-125mm while the maximum IoP for sand was 7.58 in the length group of 126-135mm and minimum at 2.12 in the length group of 76-85mm.

Thus length wise variation in gut contents indicated that males and females of lower length groups tend to fed on variety of food items dominated by crustaceans while males and females of higher length groups showed preference for larger food items though crustaceans were the dominant and the preferred food.

Monthly variation in feeding index

Percentage variations in feeding index in different months for male, female and juvenile *P.ocellatus* are presented in tabular and graphical form in Table.no.7.4a, 7.4b and 7.4c. and Fig.7.4a, 7.4b and 7.4c

The males are observed to be active feeders as reflected by feeding intensity in June 2010, January, February, May and June 2011 where as the feeding activity was moderate in September and December 2010, January, March, April, July, August and September 2011 and the feeding intensity was poor in July, August, October and November 2010.

The data reveals that females fed actively in September 2010, May, June and September 2011 whereas the feeding intensity appears moderate in June, July, August 2010, January, February, April and July 2011 and females appear poor feeders in October, November, December 2010, March and August 2011.

The juveniles were found to be poor feeders throughout the year with moderate feeding activity in June, August 2010, and September 2011.

Empty guts were observed in all months in male, female and juveniles barring June 2010, July 2010 and October 2010 in male ; October 2010 in female and June 2011 and July 2011 in juveniles.

Length wise variation in feeding index

Percentage variation in feeding index of male and female *P.ocellatus* in different length group based on degree of fullness is presented in Table No.7.5a and 7.5b and in Figure No. 7.5a and 7.5b.

The males in the length group of 106-115mm, 116-125mm and 126-135mm, 146-155mm, 156-165mm and 166-175mm were actively fed while those in length group of 96-105mm, 136-145mm and 176-185mm were found to be moderately fed where as the length group 66-75mm, 76-85mm and 86-95mm were found to be poorly fed.

The females in the length group 96-105mm, 106-115mm and116-125mm were observed to be actively fed and length group of 126-135mm, 136-145mm and 146-155mm were found to moderately fed while the fishes in length group 66-75mm,

76-85mm, 86-95mm were found to be poorly fed. The feeding intensity was thus observed to vary depending upon the size of fish and season.

Gastro somatic index (GaSI)

The gastro somatic index of male, female and juvenile *P.ocellatus* in different months is presented in Figure 7.6. In males Ga.S.I was found to be lowest in November 2010 (2.04) and highest in June 2011 (4.77). In females Ga.S.I was found to be lowest in March 2011 (1.71) and highest in June 2011(3.32). In juvenile the difference in value of Ga.S.I was comparatively less with values of 2.12 in May 2011 and 2.99 in September 2011.

Length wise Ga.S.I in male and female *P.ocellatus* in Fig 7.7. In males Ga.S.I was minimum in length group 176-185mm with a value of 2.01 and maximum of 3.62 in length group 126-135mm. In females Ga.S.I was minimum in length group 146-155mm with a value of 1.91 and maximum with a value of 3.23 in length group 116-125mm.

Table no. 7.1: Average Index of Preponderance of various food items in the gut of *P.ocellatus.*

Sr.no	Food items	Index value		
		Male	Female	Juvenile
1	Crustaceans	40.71	38.64	38.28
2	Mollusca	12.80	12.64	3.37
3	Pisces	9.44	11.66	6.10
4	Miscellaneous	2.89	5.16	3.01
5	Phytoplanktons	4.07	5.87	13.16
6	Semidigested	10.59	8.24	11.96
7	Detritus	9.69	8.87	12.87
8	Mud	6.73	5.91	9.09
9	Sand	3.08	3.01	2.17

Table no.7.2 a: Index of preponderance of various food items in the guts of male *P.ocellatus* duringS different months.

Food items	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	Feb-11	Mar-11	Apr-11	May-11	Jun-11	Jul-11	Aug-11	Sep-11
crustaceans	31.07	39.12	37.36	46.28	35.59	45.95	44.09	45.03	40.01	49.15	34.94	37.43	40	36.22	52.41	36.69
Mollusca	4.33	7.74	9.52	21.69	13.32	14	13.45	17.37	19.52	13.42	13.51	1.23	8.24	9.71	11.09	26.73
Pisces	9.15	10.6	5.23	5.53	5.46	10.31	8.32	10.5	8.61	8.64	15.11	16.41	16.87	9.23	6.06	5.05
Miscellaneous	5.54	2.49	3.16	4.8	2.82	1.3	1.12	4.08	2.29	3.26	1.55	0.25	2.91	0.5	3.13	7.03
Phytoplanktons	9.31	10.56	10.49	0.31	11.19	0	4.16	3.23	0.51	0.53	0	0	0.52	6.65	3.14	4.59
Semi digested	14.82	10.43	10.74	9.2	10	11.76	8.97	8.35	8	10.48	11.18	19.74	10.59	11.29	8.91	4.99
Detritus	13.6	8.78	12.76	6.87	10.53	6.44	9.32	5.65	10.55	7.61	11.52	12.53	10.96	14.78	7.32	5.75
Mud	7.85	7.89	7.27	3.4	7.36	5.88	7.51	4.23	6.56	4.72	8.24	8.55	7.65	8.42	6.19	5.95
Sand	4.33	2.39	3.47	1.92	3.73	4.36	3.06	1.56	3.95	2.19	3.95	3.86	2.26	3.2	1.75	3.22

Table no. 7.2 b: Index of preponderance of various food items in the guts of female *P.ocellatus* during different months.

Food items	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	Feb-11	Mar-11	Apr-11	May-11	Jun-11	Jul-11	Aug-11	Sep-11
crustaceans	28.43	43.48	41.83	41.47	37.76	35.45	36.81	38.38	42.37	40.07	28.04	29.89	39.48	41.08	48.52	45.10
Mollusca	6.97	6.25	8.26	18.51	4.7	14.02	18.49	15.08	18.51	14.92	17.27	4.09	11.98	13.16	11.2	18.81
Pisces	11.7	7.41	11.7	6.75	9.54	8.83	6.93	9.68	10.7	7.75	20.11	26.63	18.76	10.09	9.11	10.93
Miscellaneous	8.26	2.82	3.07	3.33	2.00	6.18	4.56	6.34	5.14	9.04	4.68	5.56	3.66	5.92	6.46	5.53
Phytoplanktons	13.34	11.62	9.35	6.38	13.74	3.43	6.31	5.39	2.03	2.59	0	1.65	2.09	4.4	6.03	5.62
Semidigested	10.11	8.53	8.61	8.06	11.47	6.58	10.34	8.31	7.52	6.73	10.25	12.53	6.59	7.98	4.92	3.35
Detritus	10.72	9.8	8.96	7.67	12.28	12.72	10.77	8.07	5.91	9.22	9.33	7.49	8.29	8.84	7	4.81
Mud	5.89	6.67	5.12	5.42	7.17	9.76	4.25	4.15	5.55	5.95	6.4	9.06	6.49	5.11	3.84	3.69
Sand	4.58	3.42	3.1	2.41	1.34	3.03	1.54	4.6	2.27	3.73	3.92	3.1	2.66	3.42	2.92	2.16

Table no. 7.2c: Index of preponderance of various food items in the guts of juvenile *P.ocellatus* during different months.

Food items	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	Feb-11	May-11	Jun-11	Jul-11	Aug-11	Sep-11
crustaceans	35.2	32.56	37.72	34.91	32.42	35.79	42.95	40.49	45.84	33.12	43.62	37.52	40.23	43.5
Mollusca	2.28	0	0	1.07	1.12	2.82	4.34	2.25	5.94	5.67	2.75	6.37	8.12	4.41
Pisces	4.96	5.71	4.68	2.69	6.39	6.31	7.85	9	9.06	7.25	8.98	4.55	3.41	4.57
Miscellaneous food items	1.92	2.61	3.89	2.09	1.8	3.67	3.05	4.35	3.39	5.16	3.27	2.58	3.64	0.7
Phytoplanktons	10.6	22.2	20.56	19.66	15.77	14.04	5.79	10.77	2.58	12.48	12.54	14.11	13.02	10.08
Semidigested	15	15.03	12.4	12.1	11.81	10.61	13.72	13.03	8.45	11.3	11.26	11.07	9.71	11.92
Detritus	17.47	13.19	11.89	13.44	16.55	13.6	10.41	11.84	11.98	14.47	10.22	12.8	10.48	11.81
Mud	7.57	7.39	7.31	11.33	13.53	12.9	9.57	7.52	10.91	6.35	7.36	7.78	8.43	9.35
Sand	5	1.31	1.55	2.71	0.61	0.26	2.32	0.75	1.85	4.2	0	3.22	2.96	3.66

Table no.7.3a: Index of preponderance of various food items in the guts of male *P.ocellatus* in different length groups.

Food items	66-75 mm	76-85 mm	86-95 mm	96-105 mm	106-115 mm	116-125 mm	126-135 mm	136-145 mm	146-155 mm	156-165 mm	166-175 mm	176-185 mm
Crustaceans	36.78	41.99	47.21	47.65	41.49	38.93	38.92	50.43	46.67	42.28	63.33	50.63
Mollusc	18.73	10.6	10.2	14.53	15.35	19.18	8.46	8.37	19.87	22.28	13.33	15.63
Pisces	3.93	4.5	6.56	5.99	5.83	7.68	7.58	8.57	8.13	11.42	10.02	12.5
Miscellaneous	3.83	4.67	3.29	3.24	4.15	4.2	2.45	0.74	2.41	2.62	0	0
Phytoplankton	8.41	4.79	9.28	7.65	12.19	9.38	9.17	0.25	0	0	0	5.63
Semidigested	11.69	11.11	7.82	6.54	6.43	6.27	11.09	13.01	7.83	7.5	0	9.36
Detritus	8.42	10.31	6.93	6.49	6.5	6.25	10.33	12.62	10.84	8.98	6.67	6.25
Mud	4.74	7.82	4.9	4.31	5.23	5.1	8.96	6.01	4.25	4.17	6.65	0
Sand	3.47	4.21	3.81	3.6	2.83	3.01	3.04	0	0	0.75	0	0

Table no.7.3b: Index of preponderance of various food items in the guts of female *P.ocellatus* in different length groups.

Food items	66-75 mm	76-85 mm	86-95 mm	96-105 mm	106-115 mm	116-125 mm	126-135 mm	136-145 mm	146-155 mm
crustaceans	21.14	30.24	39.71	44.23	39.02	38.75	26.73	48.9	39.29
Mollusc	15.81	20.66	12.45	12.15	17.42	18.26	7.7	11.13	5
Pisces	8.54	2.52	8.99	8.52	8.37	8.35	13.88	11.72	23.57
Miscellaneous	10.14	2.43	3.91	2.05	5.37	2.41	2.16	1.57	0.00
Phytoplanktons	17.39	8.07	10.4	7.17	10.99	11.52	4.38	0	0
Semidigested	7.51	11.77	8.5	7.26	5.77	6.46	13.99	10.52	14.29
Detritus	6.32	12.36	7.79	8.62	5.6	6.47	14.05	6.4	17.85
Mud	8.7	9.83	4.95	6.18	4.33	4.23	9.53	7.42	0
Sand	4.45	2.12	3.3	3.82	3.13	3.55	7.58	2.34	0

Table no.7.4a: Feeding index in *P.ocellatus*, male during different months

Months	No. of fish	Poor feeding			Moderate feeding	Active feeding		
		Empty (%)	Traces (%)	1\4 (%)	1\2 (%)	3\4 (%)	Full (%)	Gorged (%)
Jun-10	40	4.62	2.22	15.01	26.99	4.17	37.90	9.09
Jul-10	36	2.76	15.74	26.93	36.91	17.68	0.00	0.00
Aug-10	40	0.00	2.38	40.10	35.89	15.68	5.95	0.00
Sep-10	23	0.00	1.25	36.44	42.35	19.96	0.00	0.00
Oct-10	80	0.34	5.44	57.13	37.08	0.00	0.00	0.00
Nov-10	39	0.00	8.02	56.16	30.27	5.55	0.00	0.00
Dec-10	70	0.00	2.57	42.71	49.93	4.80	0.00	0.00
Jan-11	50	0.00	0.00	24.00	40.41	25.04	6.54	4.00
Feb-11	34	0.00	0.00	10.92	36.22	44.14	8.72	0.00

Mar-11	35	0.00	0.00	18.55	51.37	30.08	0.00	0.00
Apr-11	17	0.00	0.00	24.76	52.50	13.81	8.93	0.00
May-11	8	0.00	0.00	10.00	31.67	33.33	25.00	0.00
Jun-11	17	0.00	0.00	17.16	8.82	55.58	9.62	8.82
Jul-11	90	0.00	0.00	44.93	50.56	4.51	0.00	0.00
Aug-11	81	0.00	0.65	30.99	55.53	12.84	0.00	0.00
Sep-11	25	0.00	0.00	19.68	47.02	16.03	17.26	0.00

Table no.7.4b: Feeding index in *P.ocellatus*, female during different months.

Months	**No. of fish**	**Poor feeding**			**Moderate feeding**	**Active feeding**		
		Empty (%)	**Traces (%)**	**1\4 (%)**	**1\2 (%)**	**3\4 (%)**	**Full (%)**	**Gorged (%)**
Jun-10	24	0.00	7.48	24.36	37.50	19.09	11.58	0.00
Jul-10	17	0.00	0.00	49.17	50.83	0.00	0.00	0.00
Aug-10	33	0.00	4.25	31.00	49.87	14.89	0.00	0.00
Sep-10	25	0.00	0.00	3.13	41.71	55.17	0.00	0.00
Oct-10	49	0.93	16.18	49.35	33.54	0.00	0.00	0.00
Nov-10	22	0.00	8.12	43.18	48.71	0.00	0.00	0.00
Dec-10	52	0.00	9.35	49.03	41.62	0.00	0.00	0.00
Jan-11	26	0.00	3.67	34.51	44.05	17.78	0.00	0.00
Feb-11	26	0.00	0.00	8.40	57.10	34.50	0.00	0.00
Mar-11	34	0.00	21.33	18.92	35.95	23.9	0.00	0.00
Apr-11	24	0.00	2.27	23.81	30.33	43.59	0.00	0.00
May-11	9	0.00	0.00	0.00	32.17	67.83	0.00	0.00
Jun-11	24	0.00	1.43	28.10	40.48	22.86	7.14	0.00
Jul-11	50	0.00	2.21	26.20	51.88	19.72	0.00	0.00
Aug-11	54	0.00	8.89	31.55	31.36	24.53	3.68	0.00
Sep-11	20	0.00	2.78	31.07	29.78	36.38	0.00	0.00

Table no. 7.4c: Feeding index *P.ocellatus*, juvenile, during different months

Months	No. of fish	Poor feeding			Moderate feeding	Active feeding		
		Empty (%)	Traces (%)	1\4 (%)	1\2 (%)	3\4 (%)	Full (%)	Gorged (%)
Jun-10	20	0.00	1.92	30.39	34.05	33.64	0.00	0.00
Jul-10	27	0.00	26.24	31.76	42.00	0.00	0.00	0.00
Aug-10	21	0.00	2.94	43.82	53.24	0.00	0.00	0.00
Sep-10	30	0.00	6.34	41.79	24.09	27.78	0.00	0.00
Oct-10	37	0.00	36.50	47.40	16.09	0.00	0.00	0.00
Nov-10	26	0.00	58.04	35.71	6.25	0.00	0.00	0.00
Dec-10	25	0.00	9.36	71.16	19.49	0.00	0.00	0.00
Jan-11	25	0.00	21.65	46.58	23.44	8.33	0.00	0.00
Feb-11	7	0.00	27.78	52.22	20.00	0.00	0.00	0.00
May-11	9	0.00	58.33	33.34	8.33	0.00	0.00	0.00
Jun-11	21	2.27	10.10	54.43	33.20	0.00	0.00	0.00
Jul-11	31	2.27	16.02	26.35	51.79	3.57	0.00	0.00
Aug-11	35	0.00	9.26	33.15	52.60	5.00	0.00	0.00
Sep-11	24	0.00	4.01	37.98	44.08	13.94	0.00	0.00

Table no.7.5a: Feeding index in male *P.ocellatus*, in different length groups.

Length group in mm	No. of fish	Poor feeding			Moderate feeding	Active feeding		
		Empty (%)	Traces (%)	1\4 (%)	1\2 (%)	3\4 (%)	Full (%)	Gorged (%)
66-75	47	1.19	5.14	52.47	41.2	0	0	0
76-85	72	0	1.25	50.25	42.35	6.15	0	0
86-95	138	0	1.28	46.27	47.11	5.34	0	0
96-105	201	0.07	1.66	45.67	43.32	6.75	2.53	0
106-115	92	0	0	17.63	57.28	21.68	2.02	1.39
116-125	71	0	0	15.29	38.39	38.99	3.33	4
126-135	27	0	0	14.68	33.98	30.51	8.93	11.9
136-145	13	0	0	13.33	47.92	31.17	7.58	0
146-155	15	0	0	30	20	22.22	27.78	0
156-165	7	0	0	30.15	31.7	38.15	0	0
166-175	1	0	0	0	0	100	0	0
175-185	1	0	0	0	100	0	0	0

Table no.7.5b: Feeding index in *P.ocellatus*, female in different length groups.

Length	No.	Poor feeding			Moderate	Active feeding		
		Empty	Traces	1\4 (%)	1\2 (%)	3\4 (%)	Full (%)	Gorged
66-75	21	0	13.67	72.04	14.29	0	0	0
76-85	42	0	7.07	51.94	36.23	4.76	0	0
86-95	81	0	1.28	51.17	34.06	13.49	0	0
96-105	140	3.42	1.3	15.64	37.2	35.65	6.79	0
106-115	97	2.16	0.2	9.87	40.81	32.28	12.26	2.42
116-125	51	0	0	7.47	24.18	40.52	21.24	6.59
126-135	34	0	0	0	62.3	23.34	0	0
136-145	15	0	0	0	63.59	17.85	0	0
146-155	8	0	0	0	60.81	14.44	0	0

Table no.7.6 a: Gastro somatic index in *P.ocellatus* male, female and juvenile during different months.

Months	Male	Female	Juvenile
Jun-10	3.66	3.12	2.43
Jul-10	2.44	2.47	2.64
Aug-10	2.65	2.44	2.74
Sep-10	2.83	3.24	2.85
Oct-10	2.15	2.01	2.15
Nov-10	2.04	1.92	2.19
Dec-10	2.35	2.49	2.29
Jan-11	2.83	2.79	2.48
Feb-11	3.45	2.89	0
Mar-11	2.55	1.71	0
Apr-11	2.43	1.82	2.18
May-11	3.13	2.95	2.12
Jun-11	4.77	3.32	2.27
Jul-11	2.15	2.55	2.91
Aug-11	2.23	2.47	2.94
Sep-11	2.43	2.78	2.99

Table no.7.6 b: Gastro somatic index in *P.ocellatus* male, female and juvenile in different length groups.

Length group (mm)	Male	Female
66-75	2.15	2.26
76-85	2.62	2.51
86-95	2.79	2.63
96-105	2.93	2.95
106-115	3.11	3.02
116-125	3.32	3.23
126-135	3.62	2.31
136-145	3.15	2.24
146-155	2.32	1.91
156-165	2.23	-
166-175	2.11	-
176-185	2.01	

Table no. 7.7: Monthly variation in general diet composition of *P.ocellatus* male, female and juvenile

Food items	Male				Female				Juvenile			
	month	Min	month	Max	month	Min	month	Max	month	Min	month	Max
Crustaceans	Jun-10	31.07	Aug-11	52.41	Apr-11	28.04	Aug-11	48.52	Oct-10	**32.42**	Feb-11	45.84
Mollusc	May-11	1.23	Sep-11	26.73	May-11	4.09	Sept-11	18.81	Sep-10	**1.07**	Aug-11	8.12
Pisces	Sep-11	5.05	Jun-11	16.87	Sep-10	6.75	May-11	26.63	Sep-10	**2.69**	Feb-11	9.06
Phytoplankton	Sep-10	0.31	Oct-10	11.19	May-11	1.65	Oct-10	13.74	Feb-11	**2.58**	Jul-10	22.2
Miscellaneous	May-11	0.25	Sep-11	7.03	Oct-10	2.00	Mar-11	9.04	Sep-11	**0.7**	May-11	5.16
Semidigested	Sep-11	4.99	May-11	19.74	Sept-11	3.35	May-11	12.53	Feb-11	**8.45**	Jul-10	15.03
Detritus	Jan-10	5.65	Jul-11	14.78	Sept-11	4.81	Dec-10	12.72	Jun-11	**10.22**	Jun-10	17.47
Mud	Sep-10	3.4	May-11	8.55	Sept-11	3.69	Nov-10	9.76	May-11	**6.35**	Oct-10	13.53
Sand	Jan-10	1.56	Nov-10	4.36	Oct-10	1.34	Jan-11	4.6	Nov-10	**0.26**	Jun-10	5

Table no. 7.8: Length wise variation in general diet composition of *P.ocellatus*

Food items		Male			Female			
	Length group in mm	Min	Length group in mm	Max	Length group	Min	Length group	Max
Crustaceans	66-75	36.78	166-175	63.33	66-75	21.14	136-145	48.9
Mollusc	136-145	8.37	156-165	22.28	146-155	5	76-85	20.66
Pisces	66-75	3.93	176-185	12.5	76-85	2.52	146-155	23.57
Phytoplankton	136-145	0.25	106-115	12.19	126-136	4.38	66-75	17.39
Miscellaneous	136-145	1.57	66-75	10.14	136-145	1.57	66-75	10.14
Semi digested	116-125	6.27	136-145	13.01	106-115	5.77	146-155	14.29
Detritus	176-185	6.25	136-145	12.62	106-115	5.6	146-155	17.85
Mud	156-165	4.17	126-135	8.96	116-125	4.23	76-85	9.83
Sand	156-165	0.75	76-85	4.21	76-85	2.12	126-135	7.58

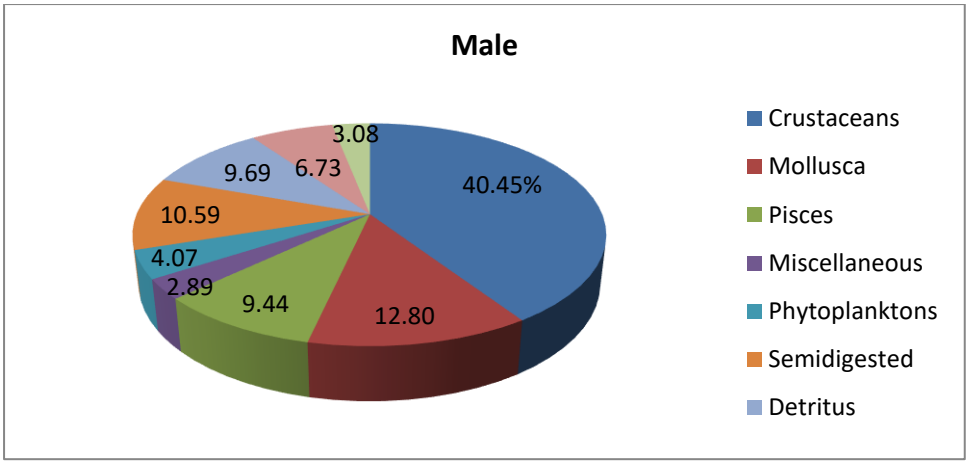


Fig 7.1a: Diet of male *P.ocellatus*, composition of food item in the gut.

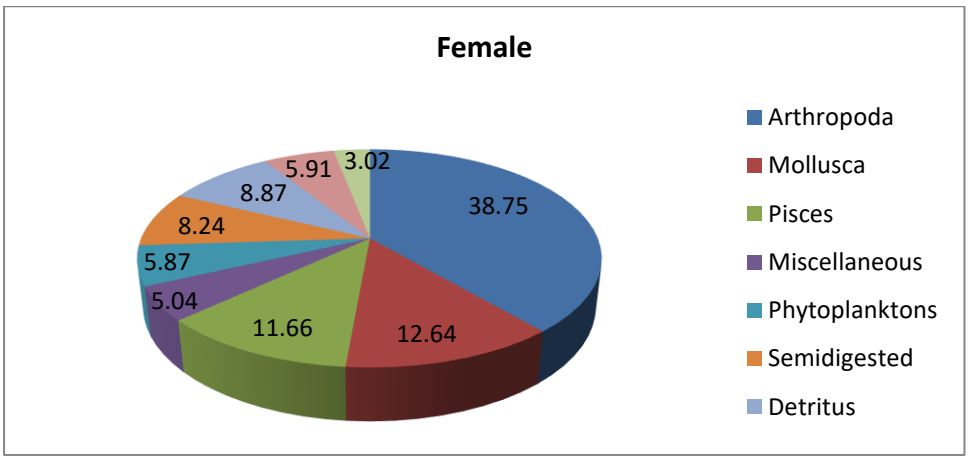


Fig 7.1b: Diet of female *P.ocellatus*, composition of food item in the gut.

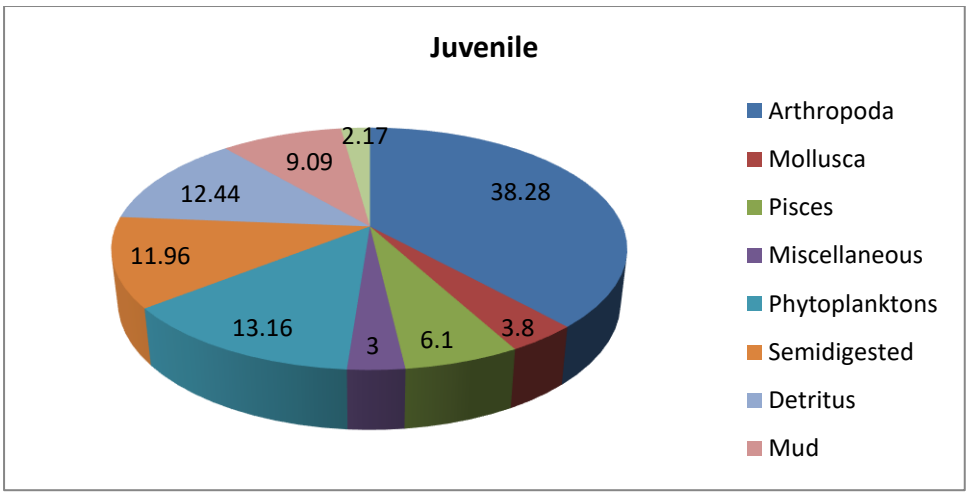


Fig 7.1c: Diet of juvenile *P.ocellatus*, composition of food item in the gut.

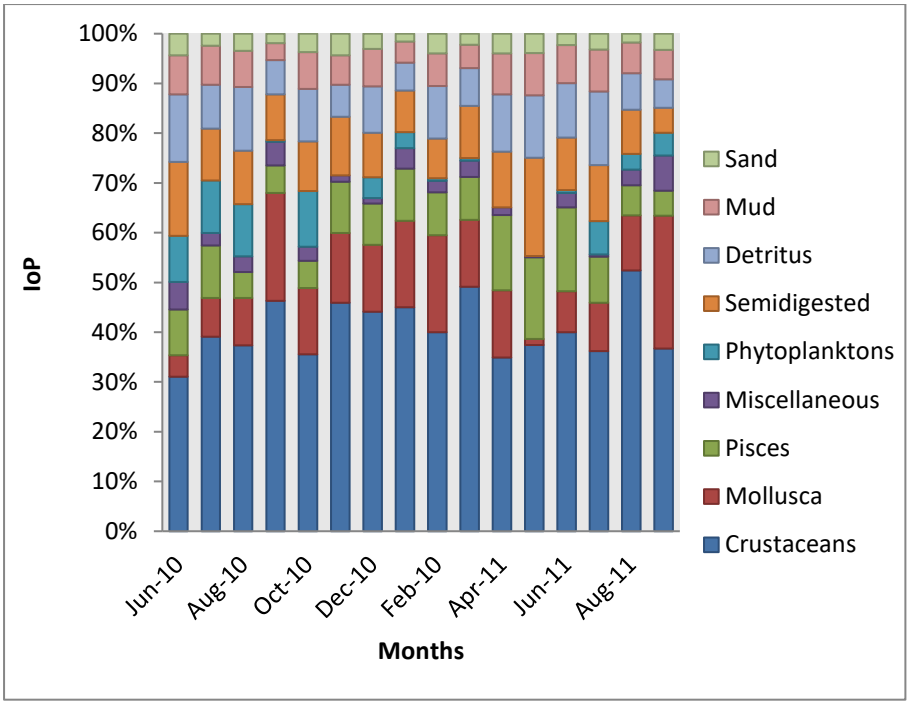


Fig 7.2a: Index of preponderance of various food items in the gut of male *P.ocellatus* during different months.

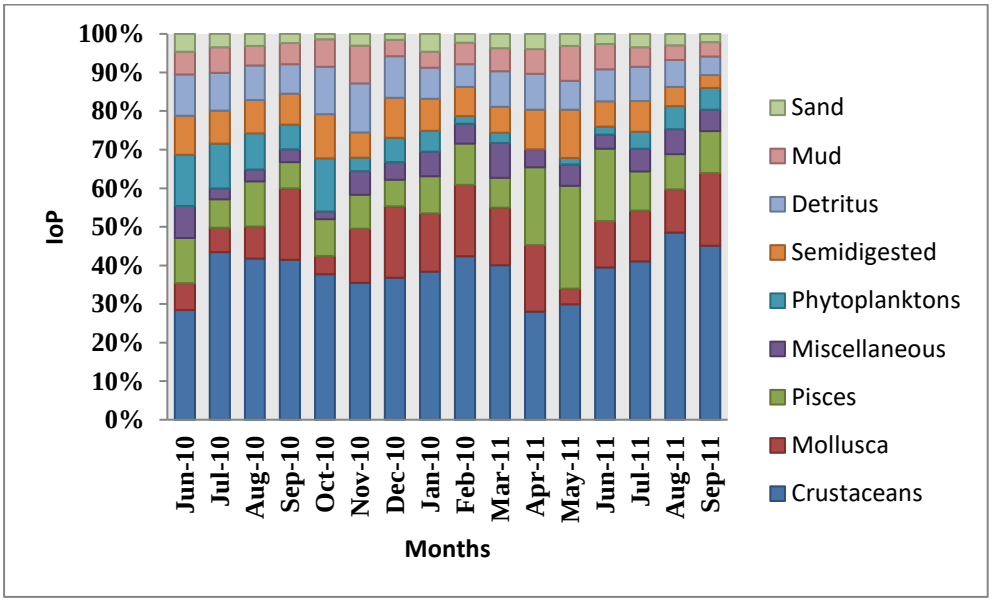


Fig 7.2b: Index of preponderance of various food items in the gut of female *P.ocellatus* during different months.

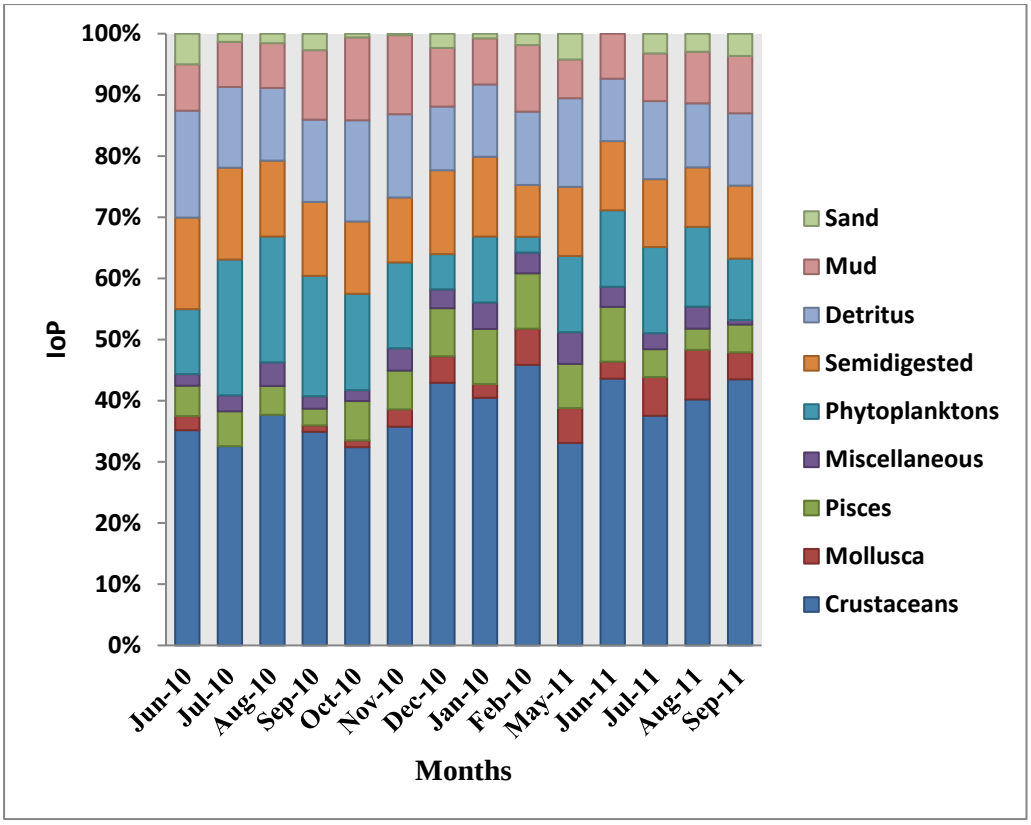


Fig 7.2c: Index of preponderance of various food items in the gut of juvenile *P.ocellatus* during different months.

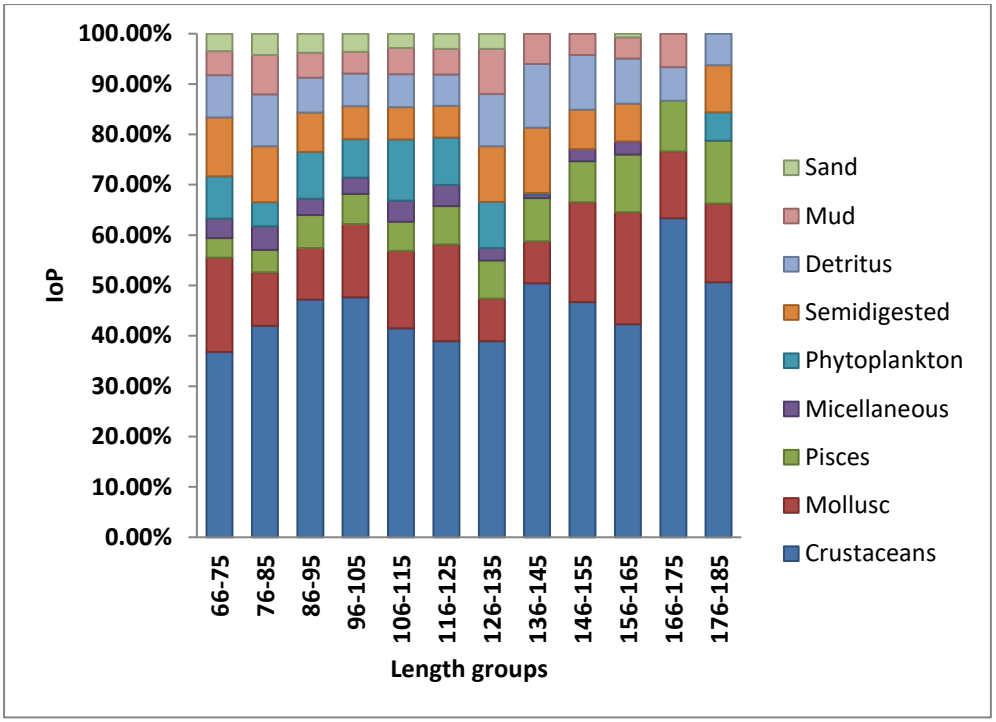


Fig 7.3a: Index of preponderance of various food items in the guts of male *P.ocellatus* in different length groups.

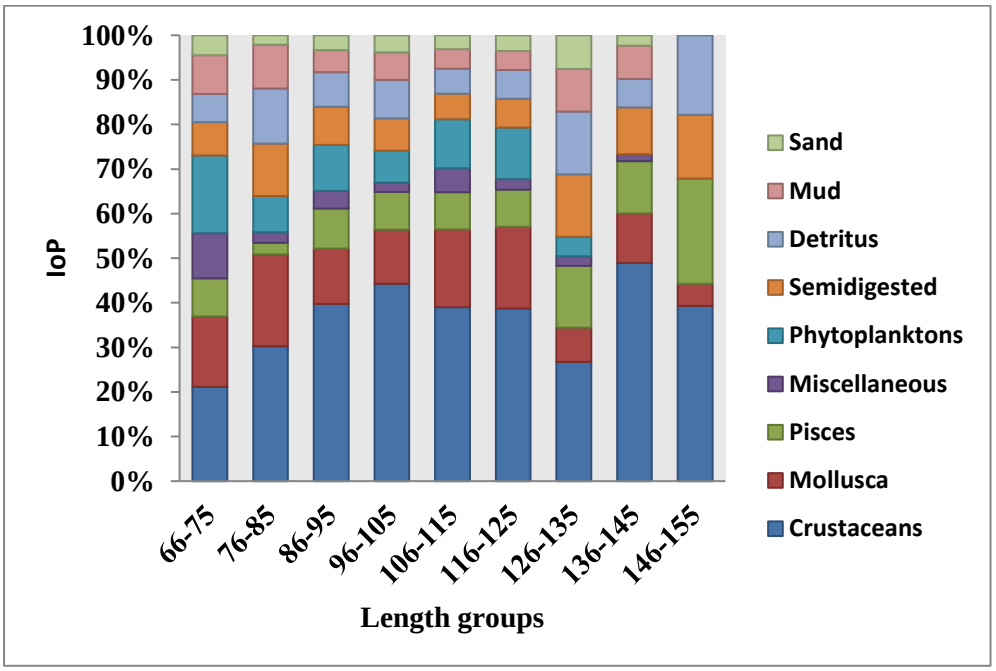


Fig 7.3b: Index of preponderance of various food items in the guts of female *P.ocellatus* in different length groups.

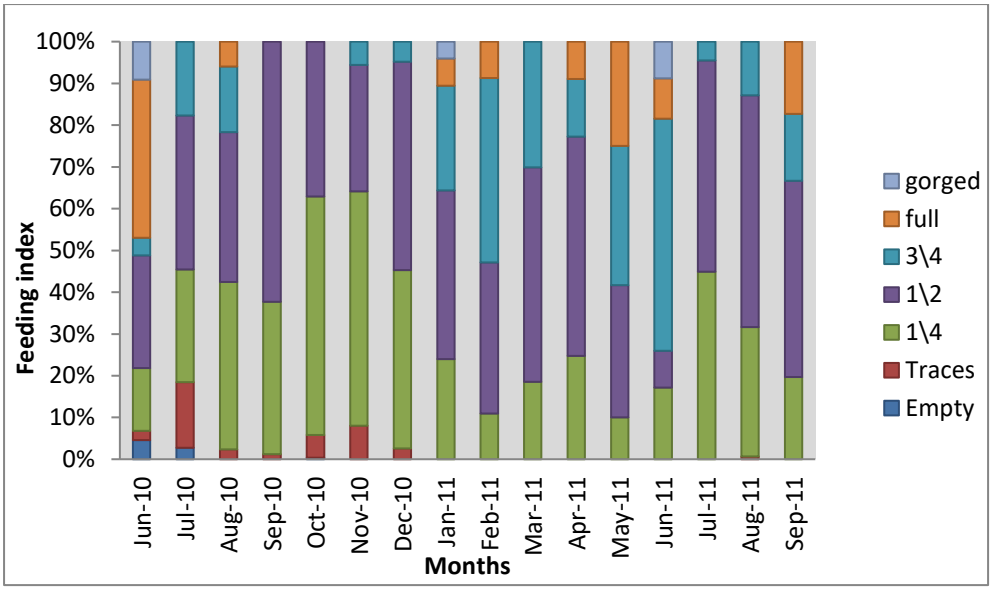


Fig 7.4a: Feeding index of male *P.ocellatus* during different months.

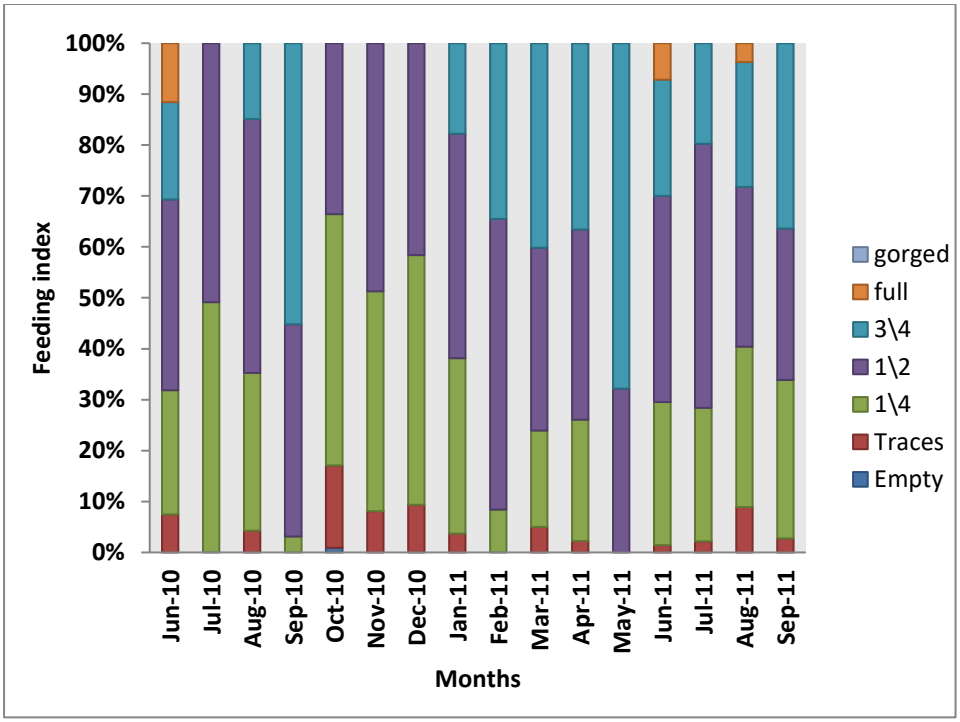


Fig 7.4b: Feeding index of female *P.ocellatus* during different months.

.

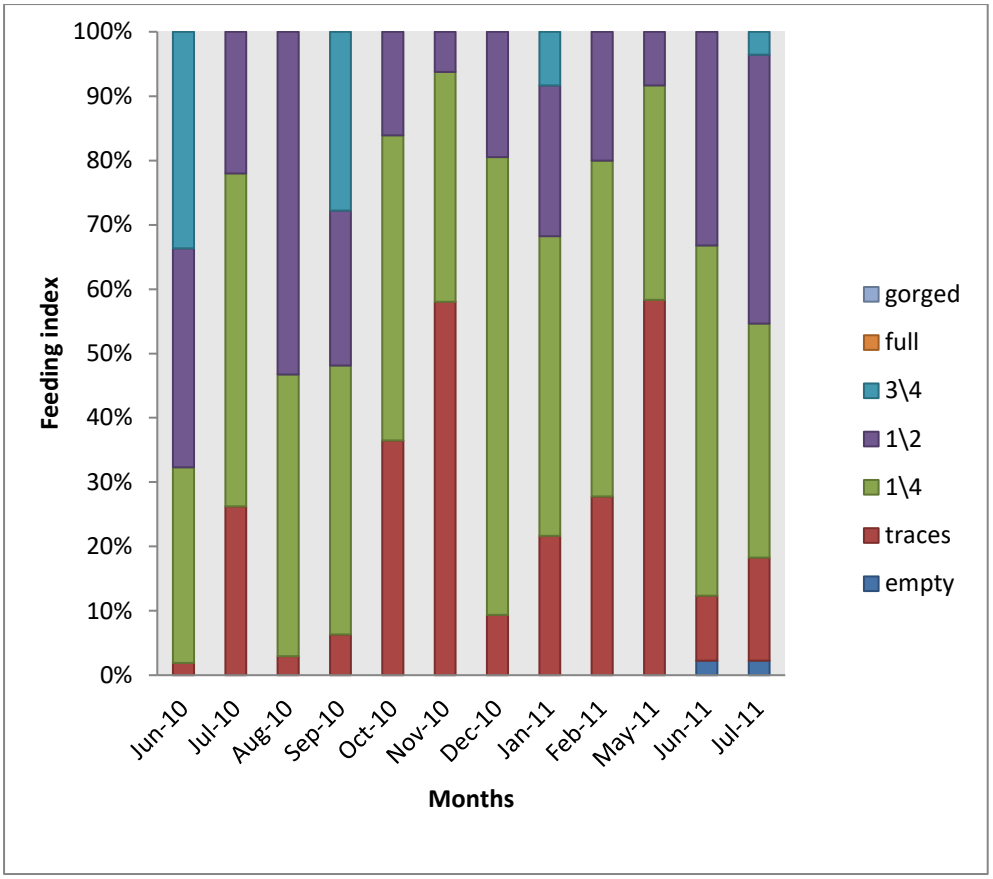


Fig 7.4c: Feeding index of juvenile *P.ocellatus* during different months.

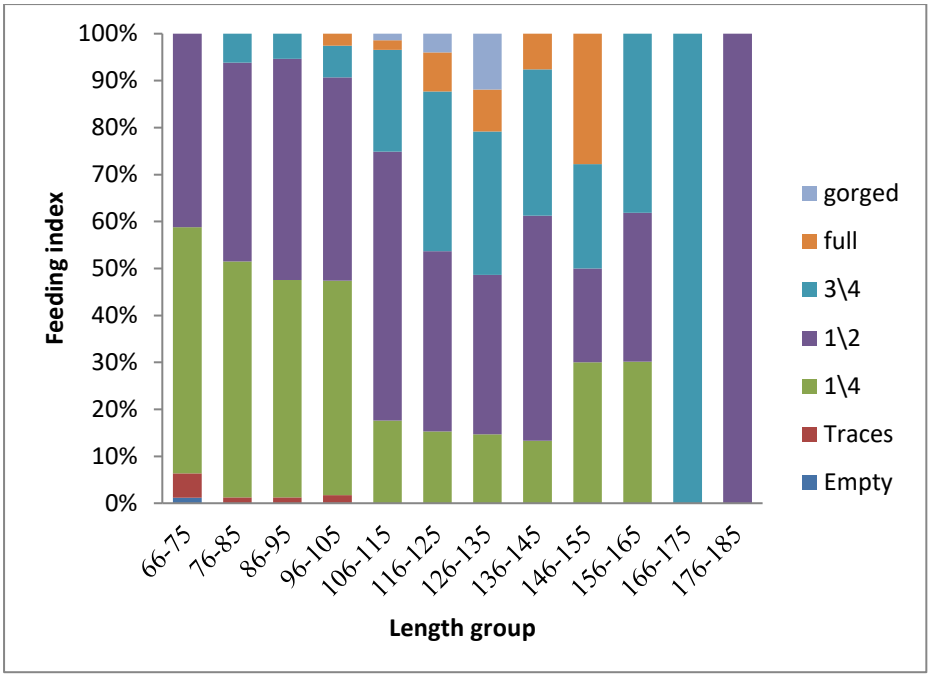


Fig 7.5a: Feeding index of male *P.ocellatus* in different length groups.

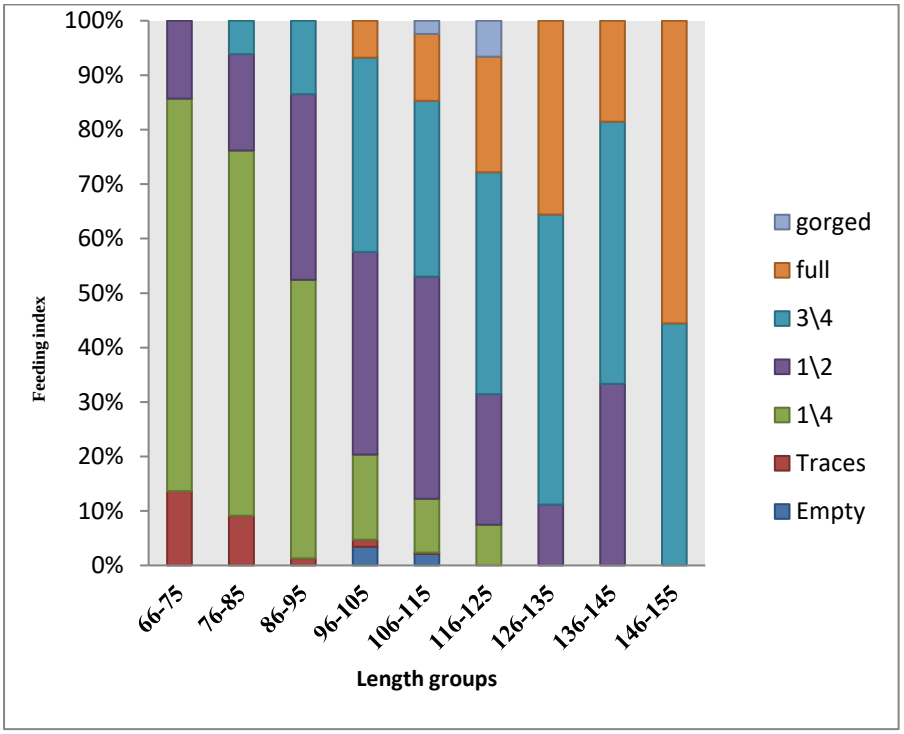


Fig 7.5b: Feeding index of female *P.ocellatus* in different length groups.

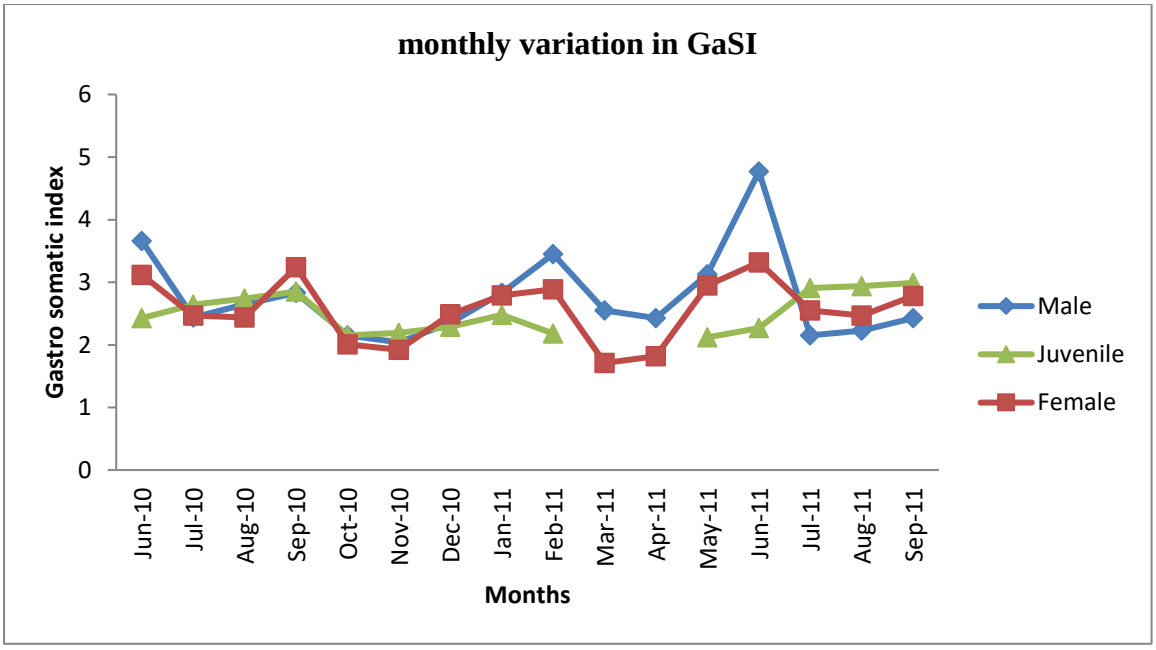


Fig 7.6: Gastrosomatic index of male, female and juvenile *P.ocellatus* in different months.

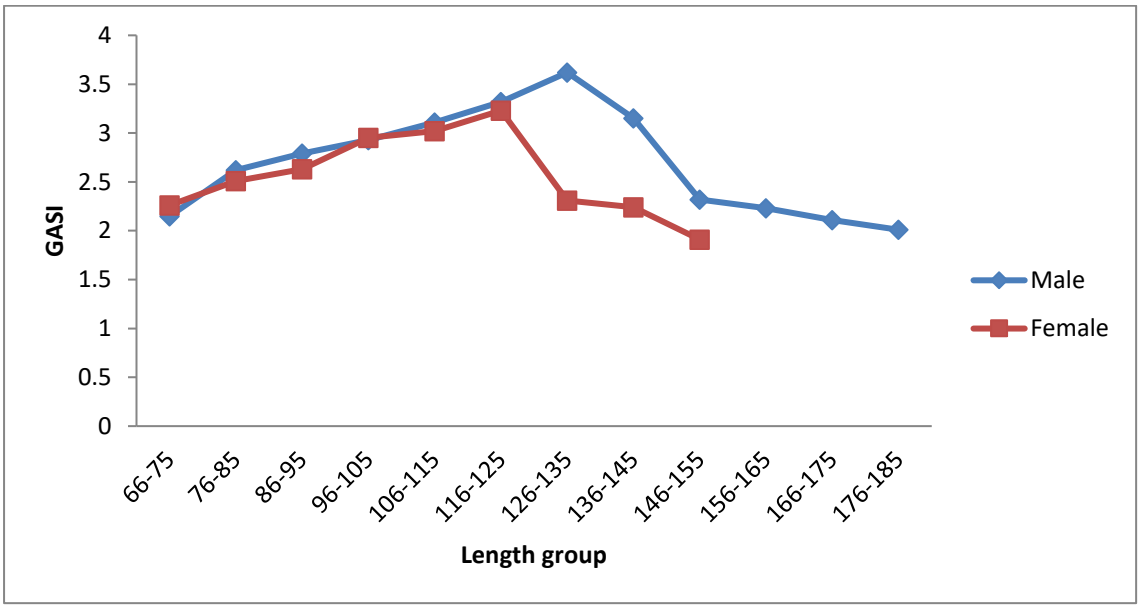
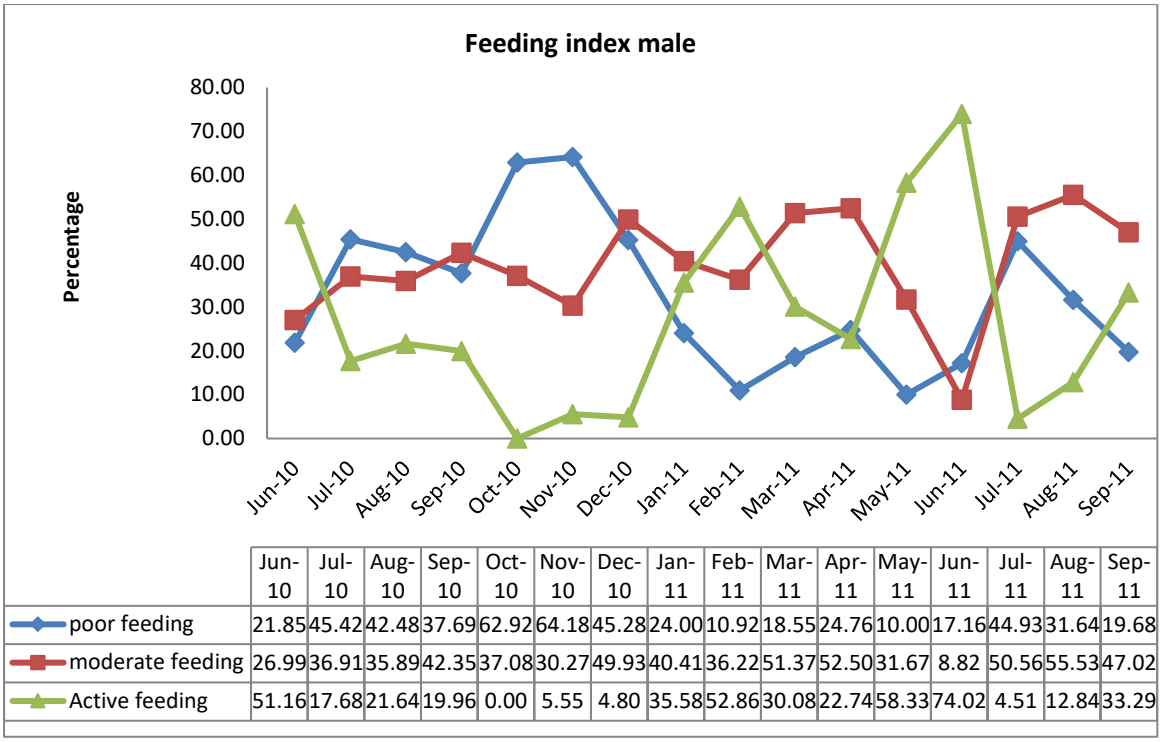
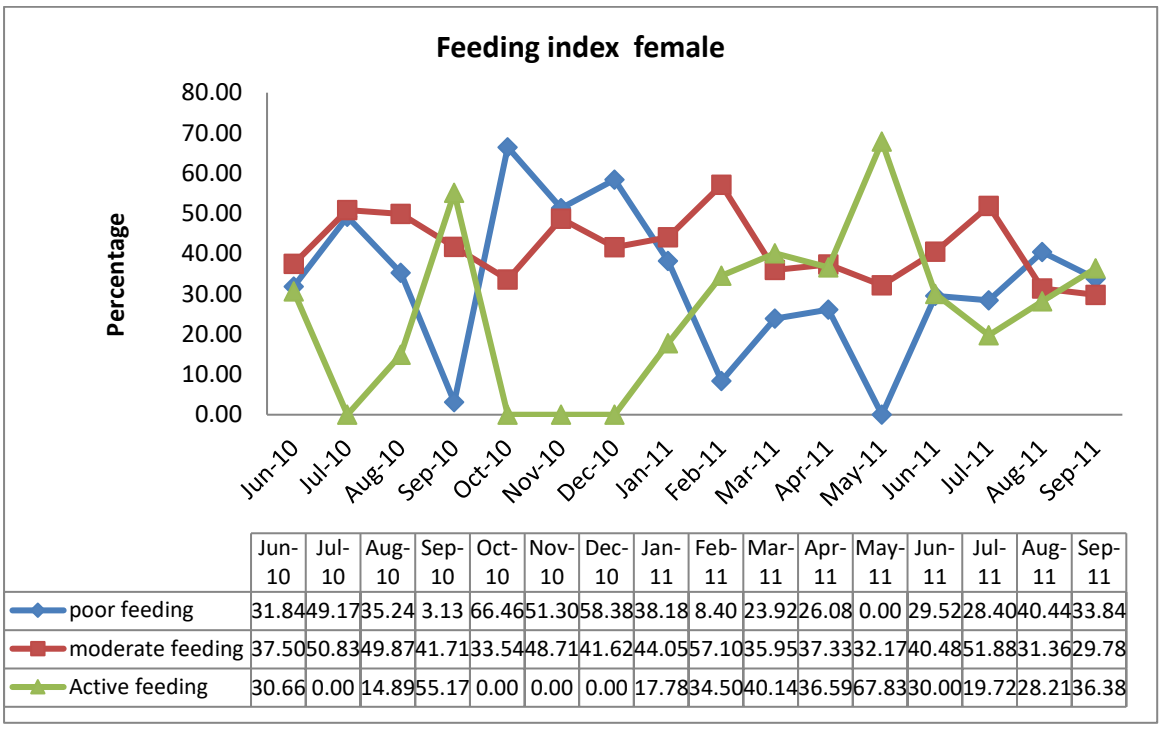


Fig 7.7: Gastrosomatic index in male and female *P.ocellatus* of different length groups.



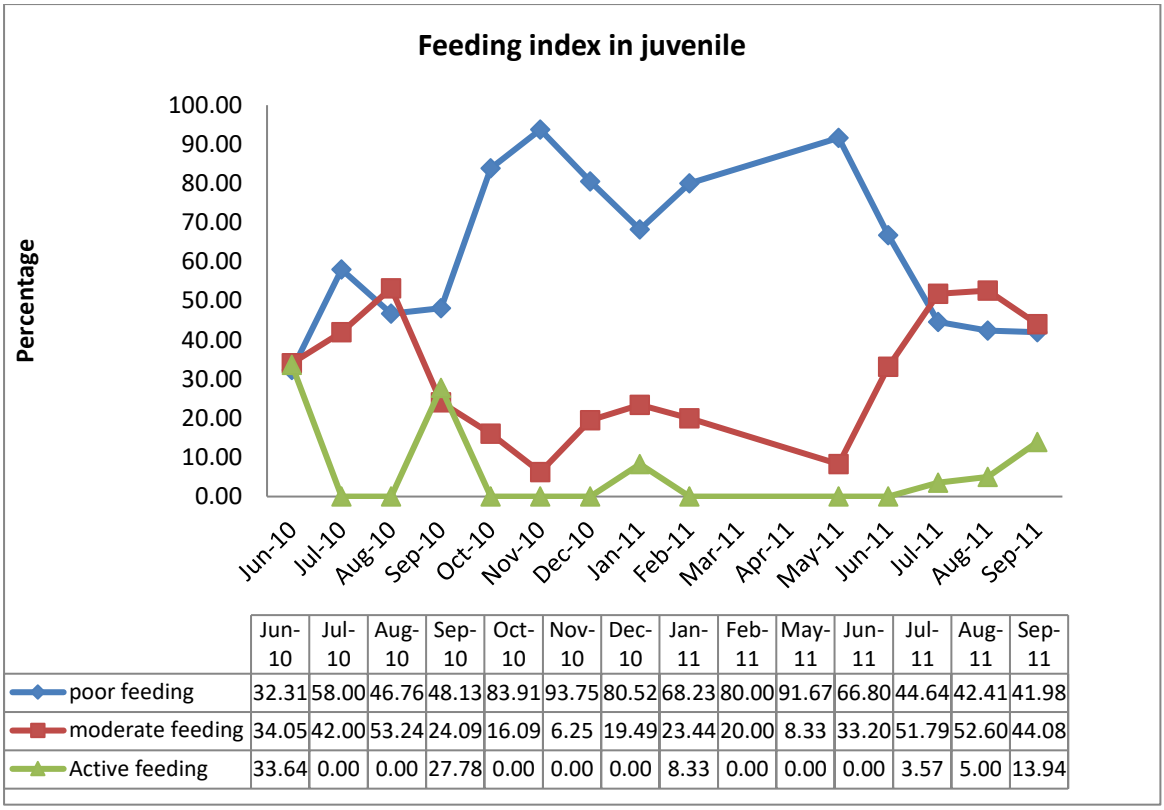
	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	Feb-11	Mar-11	Apr-11	May-11	Jun-11	Jul-11	Aug-11	Sep-11
poor feeding	21.85	45.42	42.48	37.69	62.92	64.18	45.28	24.00	10.92	18.55	24.76	10.00	17.16	44.93	31.64	19.68
moderate feeding	26.99	36.91	35.89	42.35	37.08	30.27	49.93	40.41	36.22	51.37	52.50	31.67	8.82	50.56	55.53	47.02
Active feeding	51.16	17.68	21.64	19.96	0.00	5.55	4.80	35.58	52.86	30.08	22.74	58.33	74.02	4.51	12.84	33.29

Fig 7.8a: Feeding intensity of *P.ocellatus* male during different months



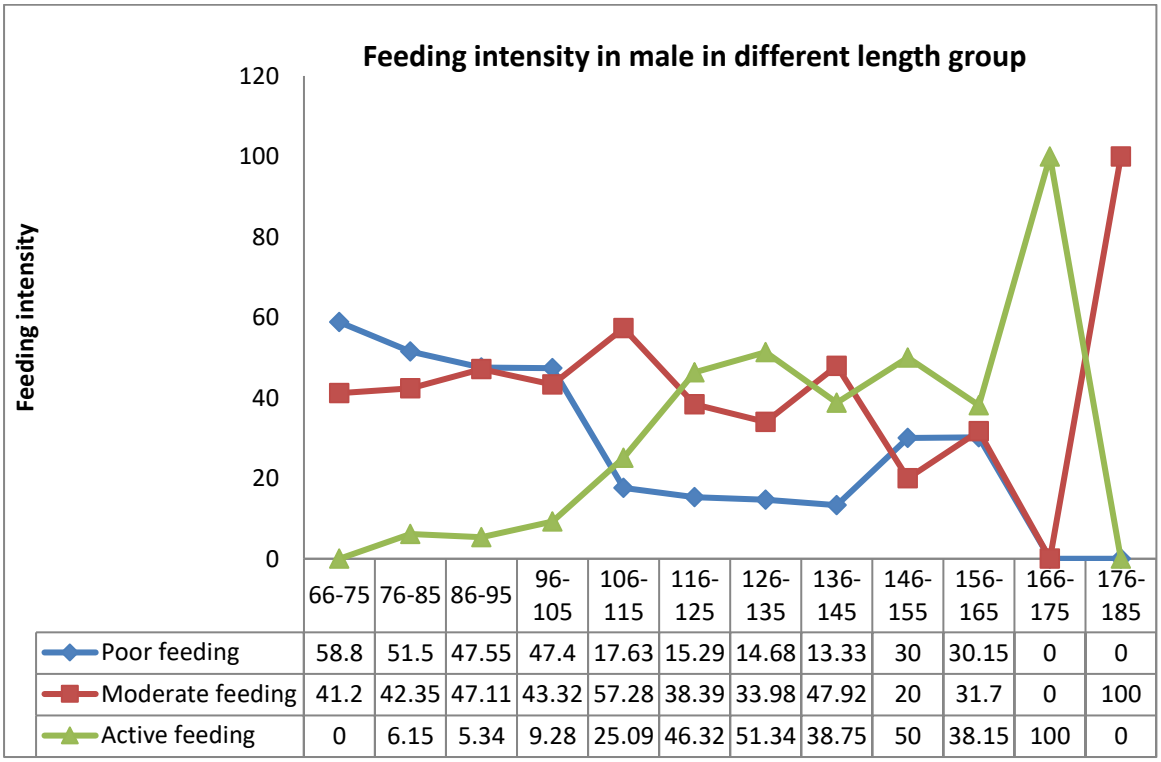
	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	Feb-11	Mar-11	Apr-11	May-11	Jun-11	Jul-11	Aug-11	Sep-11
poor feeding	31.84	49.17	35.24	3.13	66.46	51.30	58.38	38.18	8.40	23.92	26.08	0.00	29.52	28.40	40.44	33.84
moderate feeding	37.50	50.83	49.87	41.71	33.54	48.71	41.62	44.05	57.10	35.95	37.33	32.17	40.48	51.88	31.36	29.78
Active feeding	30.66	0.00	14.89	55.17	0.00	0.00	0.00	17.78	34.50	40.14	36.59	67.83	30.00	19.72	28.21	36.38

Fig 7.8b: Feeding index of *P.ocellatus* female during different months.



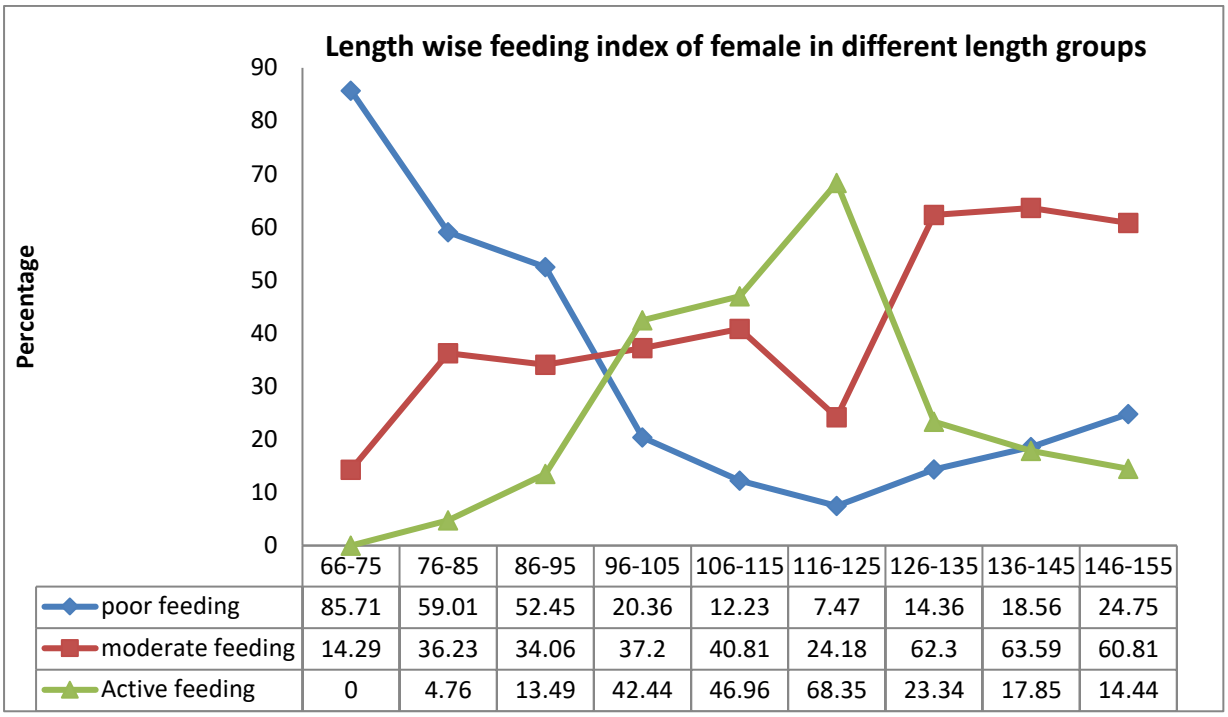
	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	Feb-11	May-11	Jun-11	Jul-11	Aug-11	Sep-11
poor feeding	32.31	58.00	46.76	48.13	83.91	93.75	80.52	68.23	80.00	91.67	66.80	44.64	42.41	41.98
moderate feeding	34.05	42.00	53.24	24.09	16.09	6.25	19.49	23.44	20.00	8.33	33.20	51.79	52.60	44.08
Active feeding	33.64	0.00	0.00	27.78	0.00	0.00	0.00	8.33	0.00	0.00	0.00	3.57	5.00	13.94

Fig 7.8c: Feeding index of *P.ocellatus* juvenile during different months.



	66-75	76-85	86-95	96-105	106-115	116-125	126-135	136-145	146-155	156-165	166-175	176-185
Poor feeding	58.8	51.5	47.55	47.4	17.63	15.29	14.68	13.33	30	30.15	0	0
Moderate feeding	41.2	42.35	47.11	43.32	57.28	38.39	33.98	47.92	20	31.7	0	100
Active feeding	0	6.15	5.34	9.28	25.09	46.32	51.34	38.75	50	38.15	100	0

Fig 7.9a: Feeding index of *P.ocellatus* male in different length groups.



	66-75	76-85	86-95	96-105	106-115	116-125	126-135	136-145	146-155
poor feeding	85.71	59.01	52.45	20.36	12.23	7.47	14.36	18.56	24.75
moderate feeding	14.29	36.23	34.06	37.2	40.81	24.18	62.3	63.59	60.81
Active feeding	0	4.76	13.49	42.44	46.96	68.35	23.34	17.85	14.44

Fig 7.9b: Feeding index of *P.ocellatus female* in different length groups.

7.5 Discussion

In fishes, both external (shape, size, position of mouth, shape of caudal fin) and internal morphology (stomach shape and size, gut length) provide important information on a species' feeding ecology (Keast and Webb, 1966; Hart, 1997; Wootton, 1998). For a given species of fish, the overall morphology is chiefly related to the nature of food, feeding habits, body size, shape and sex (Kapoor *et al.,* 1975; Smith, 1989). *P.ocellatus* has a elongated and cylindrical body and dorsoventrally flattened head with protruding eyes for vision in dark. The fused pelvic fins form a sucking device which enables it to cling to rocks, stones and substratum in water. The large wedge shaped caudal fin of the fish may help for swift acceleration in water for capturing the prey and escaping from the predators. The mouth is wide and terminal with many pointed teeth well suited for carnivorous feeding. Moyle and Cech (1982) have observed that an elongate fusiform body, large terminal mouth, large caudal fin with anal and dorsal fins placed near it enable a swift attack on

passing prey by the fishes. The characters of P.ocellatus mentioned above are in agreement with Moyle and Cech (1982).

P.ocellatus has a protruding lower jaw probably helping in benthic feeding. It has been reported by Alexander (1967) and Osse (1985) that the ability to protrude the jaw confers an advantage in specific circumstances such as obtaining benthic prey or food from otherwise inaccessible places. In *P.ocellatus* lower jaw is provided with minute barbels which may also help in benthic feeding. Barbels are sensory structures which carry tactile and chemical receptors and are used to locate prey. In *P.ocellatus* pharyngeal teeth are present in both dorsal and ventral jaw and the fish seems to be well adapted for mastication of food. Gasoline (1996) had opined that pharyngeal teeth are adapted to perform mastication.

Abuzinadah (1995) noticed that carnivorous fishes are characterized with few and limited number of gill rakers. Sebastian (2011) studied the gill rakers in *Colletteichthys dussumieri* which that they are short stubby and spaced apart, characteristics which according to him seems to prevent the escape of prey from the mouth of fish. The gill rakers in *P.ocellatus* too are short, stubby and spaced apart to prevent escape of prey as suggested by Sebastian (loc.cit.).

The stomach in *P.ocellatus* was observed to be highly muscular which is believed to be characteristic for carnivorous feeding as reported by Sebastian (loc.cit). The intestine in *P.ocellatus* was short and relatively straight. Carnivorous fishes normally have short and more or less straight intestine because the meat gets digested more easily (Pandey and Shukla, 2005; Serajuddin and Ali, 2005). *P.ocellatus* was observed to have a relatively short intestine with RGL having a range of 0.51-0.88 in adults and 0.78-0.84 in juveniles. Thus RGL which is less than 1 indicates that *P.ocellatus* is a carnivorous fish. It is generally accepted that RGL<1 indicates carnivorous diet, 1<RGL<3 indicates omnivorous diet and RGL>3 indicates herbivorous diet (Ward-Campbell *et al* 2005). Thus the morphological characters of *P. ocellatus* like shape of the body, shape of mouth, dentition, occurrence of pharyngeal teeth, muscular stomach, short and straight intestine, all the characters together confirm the carnivorous nature of the fish.

Most species of gobiidae are carnivorous (Coad, 2006). There are numerous studies reporting that most members of family gobiidae feed on benthic organisms such as molluscs, crustaceans and worms etc. (Simonoviv *et al.,* 2001, Fitzsimous *et al.,* 2006, Lederer *et al.,* 2006). Geevarghese (1976) observed that *Glossogobius guiris* from Lake Veli in Kerala was carnivorous and fed on fishes and crustaceans whereas Marquez (1960) found *G guiris* from Phillippines to be predominantly herbivorous. On the contrary Tandon (1962) found *G.guiris* from Varanasi (India) to be carnivorous feeding on fishes and insects. Many species of gobiids in the mudflats of coastal Mumbai like *Beleophthalmus dentatus*, *B. boddaerti* , *B dussumieri* were found to forage on phytoplanktons (Shettu,1993; Gore, 2007; Rathod and Patil, 2009). The adult *P.ocellatus* was found to feed on crustaceans, molluscs, fishes, miscellaneous groups of organisms and phytoplanktons. Thus *P.ocellatus* can be said to be predominantly carnivorous, though phytoplankton was comparatively predominant in gut contents of juveniles.

Based on the extent of variation in the selection of food, Nikolsky (1963) classified fishes as (a) euryphagic: feeding on a variety of food (b) stenophagic: feeding on few selected types of food and (c) monophagic: feeding only on a single type of food. *P.ocellatus* has a wide variety of organism mainly animals in the gut content and it can be presumed that the fish is a euryphagus feeder as it feeds on wide variety of food like crustaceans, copepods, smaller invertebrates, molluscs, fishes and small quantity of algae and diatoms. The semi digested food containing fish larvae, mollusc, prawns etc were found in large quantity often in a state in which it was difficult to identify. Barring a few months, the guts were found to be empty in male, female and juvenile *P.ocellatus*. According to Lawson and Ajibola (2010) the occurrence of empty guts is a characteristic feature of predatory fishes which is associated with rapid rate of digestion. The empty guts of *P.ocellatus* thus seem to indicate predatory mode of feeding in *P.ocellatus*. The presence of detritus, mud and sand in the gut contents of male, female and juvenile P.ocellatus collectively indicate benthic feeding.

The material food of fishes was classified by Schaperclaus (1933) into 3 groups' i.e. main food, occasional food and emergency food. Nikolsky (1963) classified the food of fishes based on feeding habits into 4 group's i.e. basic food, secondary food,

incidental food and obligatory food. The most preferred food of *P.ocellatus* throughout the year was crustaceans. Mollusc ranked second followed by Pisces and detritus. Phytoplankton was also recorded from the guts of male, female and juveniles but juveniles were found to prefer phytoplanktons in contrast to adults. Miscellanous food items like insects, rotiferans, foraminiferans, cnidarians, medusae, annelids and chaetognaths were often found in the gut contents of *P.ocellatus* though in smaller proportions. Detritus was found in the gut contents of male, female and juvenile *P.ocellatus* in considerable amount. Thus it can be concluded that in adult *P.ocellatus*, crustaceans formed the basic food while mollusc and Pisces formed the secondary food. Detritus formed the obligatory content and phytoplankton and miscellaneous food items were incidental food. On the contrary in juveniles crustaceans molluscs formed basic food while Pisces and phytoplankton formed secondary food, detritus obligatory and miscellaneous were incidental food. Seasonal variations are observed in gut contents of *P.ocellatus* especially in the different types of crustaceans in the diet depending on their availability, though crustaceans formed predominant food in *P.ocellatus*.

The juveniles of *P.ocellatus* were found to feed on smaller crustaceans, phytoplanktons, copepods, crustacean eggs and fish eggs. The smaller crustaceans like mysis, shrimps and lucifer formed the most favoured food for juveniles whereas the second preferred food for the juvenile *P.ocellatus* was phytoplankton dominated by bacillariophyta. Detritus, mud and sand were also found in the gut of juvenile *P.ocellatus*. The quantity of detritus was higher in gut content of juveniles in the month of May probably due to scarcity of food.

Kader *et al* (1988a) concluded on the basis of the analysis of the stomach contents of *Gobioides rubicundus* that it was mainly carnivorous and even cannibalistic at times in its feeding habits. Rao and Rao (2002) reported that in *Glossogobius guiris* from Gosthani estuary cannibalism was noticed during peak spawning season due to abundant availability of fry of its own species. In *P.ocellatus* though cannibalism could be observed its occurrence was not regular in the general diet.

The food and feeding intensity of the fishes vary from month to month due to the changes in the composition of food occurring at different seasons of the year

(Bhuiyan *et al.,* 1997, 1998, 1999). In the gut contents thus crustaceans consisted of crab larvae, prawn larvae and at times large paenid prawns. *P.ocellatus* was also found to feed on mysis, acetes, lucifer, eggs and appendages of crustaceans. The second most prefered food in *P.ocellatus* consists of Mollusc e.g bivalves, gastropods, velliger, clams and slug. Pisces were the next preferred food of *P.ocellatus* with its IoP exhibiting a sharp increase in pre monsoon months from February to May. The fish was found to swallow large preys like fish, fish larvae and prawns. The fish was found to exhibit cannibalism since the gut contents also revealed presence of adult *P.ocellatus* ingested as food. *P.ocellatus* can thus be said to be hyperphagic and cannibalistic.

The *P.ocellatus* was found to show seasonal variation in food. The intake of variety of food depends on the availability and the preference of the fish to feed on a particular type of food. The ultimate objective of dietary changes is to maximize the energy intake, enhance growth rate and minimize the risk of predation in competing for food with bigger predators (Bradstreet and Brown 1985). The *P.ocellatus* was found to forage on a variety of food items in different season. However, there seems to be definite niche segregation between adults and juveniles in terms of preferred food especially related to the seasons during the period of study.

In terms of feeding intensity, the fish can be categorised as active feeders, moderate feeders and poor feeders. Data on feeding intensity revealed male *P.ocellatus* to be actively fed than females. The percentage of emptiness and stomach fullness indices are very important to assess feeding intensity (Shanti Prabha and Manjunalatha, 2008). Feeding intensity is negatively related to the percentage of empty stomachs (Bowman and Bowman, 1980).

The males exhibited high feeding intensity in June, February 2010, May and June 2011 Females were actively fed in September 2010, May, June and September 2011. The high feeding in males occurred during peak spawning and also after immediately spawning while in female high feeding intensity was observed after spawning probably to recover the spent stage. Moderate feeding was observed in males in September, December 2010, January, March, April, July, August and September 2011 while in female it was from June- August 2010, January, February, April and June 2011. Poor feeding was observed in July, August, October and

November 2010 in males and October, November, December 2010, March and August 2011 in females. The poor feeding of November 2010 in male and November December 2010 in female coincides with the resting period in *P.ocellatus*. The juvenile were moderate feeders in June, August 2010, and September 2011 and poor feeders in all other months of study.

The feeding intensity of a fish is related to its stage of maturity, reproductive state and availability of food items in its environment (Maddock and Burton, 1999; Sivakami,1996; Kiran and Puttaiah, 2004). The occurrence of poor feeding coincide with peak breeding in other fishes has been reported by Desai (1970), Khan *et al.* (1988), Rao and Rao (1991), Piska *et al.* (1991), Serajuddin *et al.* (1998), Bhuiyan *et al.* (2006).

The length wise analysis of adult *P.ocellatus* revealed greater proportion of larger sized food in their diet consisting of large prawns, molluscs and fishes in higher length groups. The smaller invertebrates, phytoplankton except diatoms and detritus were found to be considerably low in higher length group organisms. Detritus occurred in all length groups in male and female whereas the mud and sand were absent in the largest length group of male and female. This pattern of change in the diet of *P.ocellatus* adults may probably help to reduce intra specific competition among the fish and offer vast spectrum of the food. The length wise analysis of gut content revealed not only a change in pattern of diet but also characteristics pattern of feeding intensity.

The data on length wise feeding intensity reveals active feeding in *P.ocellatus* in the length group of 106-115mm, 116-125mm and 126-135mm, 146-155mm, 156-165mm and 166-175mm in males and 96-105mm, 106-115mm and116-125mm in females. Moderate feeding intensity was observed in males of length 96-105mm, 136-145mm and 176-185mm and 126-135mm, 136-145mm and 146-155mm in females while poor feeding was observed in length group of 66-75mm, 76-85mm and 86-95mm in male and 66-75mm, 76-85mm, 86-95mm in females. The poor feeding observed in fishes of smaller length group may be due to the fact that the developing individuals of lower length groups fed on smaller crustaceans and planktons while the maturing adults fed on larger crustaceans and fishes.

The gastro somatic index in male and female was found to be highest during June 2010 and 2011 which agrees well with the feeding intensity. Length wise gastro somatic index revealed higher value in length group 116-125mm in both male and female. Gastro somatic index was found to decrease in the larger individuals as can be seen from Figure 7.6b. Minimum GSI was observed in the largest length group of 176-185mmin males and 146-155mm in females. Lower GSI in adult *P.ocellatus* of larger length group may probably be due to increased body weight, though few of them were actively fed or moderately fed.

In conclusion *P.ocellatus* from the coast of Mumbai was found to be carnivorous, euryphagus and predatory fish. It also fed on phytoplankton. It also at times showed cannibalism although it was not a common occurrence observed but only in summer when food was scarce. It was found to be detritus feeder, feeding on the benthos and among complex network of mangrove roots. *P.ocellatus* can also be classified as hyperphagic fish consuming large sized prey. Thus they occupy the position of secondary and tertiary consumers in the food chain determined by the size and type of the food consumed by the fish. The diet composition of the fish was mainly crustaceans, molluscs, Pisces, phytoplankton and traces of other food items which varied as per their availability. An analysis of seasonal variation in food preference, length wise analysis of feeding intensity reveal that the male and female *P.ocellatus* had the same preference throughout the seasons which was different for the juvenile. In this case preference seems to be function of the size/maturity of the fish rather than the sex, niche segregation in terms of preferred food could probably be a strategy for ensuring survival and growth of the juvenile *P.ocellatus*.

Chapter 8

Reproductive biology

8.1 Introduction

8.2 Review of literature

8.3 Materials and methods

8.4 Results

8.5 Discussion

8.1 Introduction

Reproduction is the sole method through which an organism endeavours to propagate and the evolutionary strategy is to have maximum number of viable offsprings for perpetuation of the species. Therefore for studies on biology of an organism, studies on its reproduction are imperative. Moyle and Cech (1988) stated that success of any fish species is ultimately determined by the ability of its members to reproduce successfully in a fluctuating environment and thereby maintain the viable population. The establishment of extensive data on reproduction with corresponding data on abiotic factors enables the study of causal relationships between reproductive potential and environmental variations (Kraus *et al.,* 2002).

In nature, reproduction is closely related with environmental conditions (Sundararaj and Vasal, 1976; Davies *et al.,* 1999) such as temperature and food supply. The temperature of water plays an important role in the reproductive process of fishes and most species have their own favourable range of temperature for spawning (Pawar, 1989). Reproduction is dependent on the consumption of food; the more the fish feeds, the faster is its growth and higher is the fraction of acquired nutrition spent on gonad production (Chiu, 1987). The predation pressure, food availability, habitat and competition within the species for mates are some of the factors which will influence the organism's capacity to produce viable offspring. Thus anatomical, behavioural and physiological adaptation would reflect on reproductive strategies.

Studies on reproductive biology like the sexual dimorphism, sex ratio, spawning periodicity, size at first maturity, assessment of maturation cycle, gonado somatic index, fecundity and histology of gonads of a fish are necessary for quantifying the reproductive potential of individual fish. Some of the aspects of reproductive biology selected for the present study in *P.ocellatus* are as follows: sexual dimorphism and sex ratio, spawning periodicity, gonadosomatic index, fecundity, morphology and histology of gonads.

Sexual dimorphism is a phenomenon in which sexes can be differentiated from each other due to the presence of certain morphological and especially external characteristics. These differences may be seen throughout the life span in some species of fish while in others the differences may be apparent only during the breeding season. The secondary sexual characters are the external characters that specially develop during spawning season and/or at maturity and may help identify the sexes by observation of morphology. These secondary sexual characters serve several functions in fishes such as recognition of opposite sex by the members of the same species, help in copulation, transfer of spermatozoa from male to female, facilitate parental care and play significant role in seed production programme (Idris *et al.,* 2012). Identification of sexes by some morphological studies alone becomes very difficult in most of the fishes that do not exhibit sexual dimorphism. Gore (2007) stated that the sex determination by the observation of secondary sexual characteristics often fails in such cases and hence the sex of a fish can accurately be determined by macroscopic and microscopic examination of the gonads.

Sex ratio is the proportion of number of males to the females in a natural population and is an indicator of population behaviour and fecundity (Panthulu, 1961). According to the sex ratio model of Fisher (1930), animals should produce off springs of a balanced ratio of males and females. An understanding of the sex ratio in a fish population in different months, seasons and length groups is essential for obtaining information on seasonal segregation of the sexes and their relative abundance in pre spawning, spawning and post spawning seasons. The optimum sex ratio may vary drastically being affected by numerous factors (Nikolsky, 1980) which are genetic as well as by environmental (Devlin & Nagahama, 2002).

Venkataramanujam and Ramanathan (1994) stated that “In studies of fisheries biology, it is important to determine the cycle of maturation and depletion of gonads. Determination of maturity stages find primary application in providing basic knowledge on the reproductive biology of a stock. Information derived from these analyses is useful in ascertaining the age and size at which a fish attains sexual maturity, the time and place of spawning and duration of the cycle from the beginning of development of the ovary to actual release of the eggs”. The spawning period is closely connected with the development of intra ovarian eggs in batches (Gore, 2007)

.

The information on the minimum size at maturity of fishes is an important tool in fishery management as it can suggest methods for the conservation of fish and to maintain constant yield by imposing regulation on mesh size.

Mein (1927) introduced gonadosomatic index (GSI) and since then GSI has been widely used as an indicator of relative gonadal development or activity. Gonads represent a significant proportion of the body weight and therefore it is easy to determine the GSI as the ratio of gonad weight to body weight. Saksena (1987) has suggested the use of GSI and volume of gonads as indicators of gonadal state. The significant changes may occur in the size of the gonads throughout the year which may reflect the reproductive cycle of the fish. Gonads undergo regular seasonal cyclic changes in weight; particularly in females indicating the spawning season (Dadzie *et al.,* 2000b). Determination of maturity by GSI has proved significant in the life of fishes which is helpful in fish breeding (Belsare, 1962; Lehri,1968; Shashi and Akela, 1996). GSI is one of the parameters of the fish biology which gives the detailed idea regarding the fish reproduction and reproductive status of the species and helps in ascertaining breeding period in fish (Rao *et al.,* 1999; Mohan and Jhajhria, 2001, Gupta and Shrivastava, 2001, Shankar and Kulkarni, 2005). GSI with histological analysis enhances the ability to determine if fish are spawning in the immediate area (Fox, 2007). The study of GSI thus has a large number of applications such as determining the number and duration of spawning seasons in a year, the size at maturity, the reproductive status of a species etc. These application are of considerable practical significance in the effective management of fishery. The high correlation of gonado somatic index with number of matured females and males could be utilised to

extrapolate peak spawning season and provide good population level information of reproductive performance (Durham and Wilde, 2008).

The fecundity of a fish is defined as the number of eggs that are likely to be laid during a spawning season (Bagenal, 1957). The fecundity varies among the species and individual, and has been known to be dependent on brood conditions such as size (length, weight and age), genetics, food availability and environmental factors (Muchlisin *et a*l., 2011). Estimation of fecundity is important for acquiring knowledge about different races as different races have characteristic fecundities and egg diameter, which in turn is helpful in recognizing the population whether it is homogenous or heterogeneous type (Shafi, 2012). Thus in the study of reproductive biology, fecundity is one of the important aspect, from which the reproductive potential of the fish can be estimated and can be used in the proper management of the fishery.

The knowledge of fecundity or the egg laying capacity of a fish is an essential requisite in fishery science. Fecundity is of central interest in several aspects of fish biology e.g. in recruitment related studies in order to replace spawning stock biomass with total egg production and in studies on life history evolution (Witthames and Marshall, 2008). Fecundity is also considered to be an essential factor to understand variations in population size, recruitment and population growth rate and hence is a life history trait very relevant to fisheries management (Kraus *et al,* 2002; Lambert, 2008; Alonso-Fernandez *et al*., 2009).

The study of gonad morphology at the gross anatomical, histological and fine structural levels has become increasingly important in identifying annual reproductive cycles, the length of breeding seasons, the onset of reproductive maturity, spawning rhythms, fecundity and various other aspects of reproductive biology (Parenti and Grier, 2004). Knowledge of the gonad maturation stages of fishes is helpful for the determination of stocks that are mature and the age and size at first maturity (Bagenal, 1978); to determine the pattern of oogenesis, the spawning pattern and the methods necessary for estimation of annual fecundity (Morrison, 1990); identifying stages of development, documenting presence of intersex tumours, parasites, abnormalities and quantifying atresia (Blazer, 2002); establishing the reproduction period and the length of gonad maturation (Goncalves *et al.*, 2006); determination of reproductive potential of fish

populations and monitoring of changes in biological characteristics of exploited stocks (Williams, 2007).

The use of macroscopic characteristics to classify gonads based on external examination cannot reliably identify reproductive states of those fishes that do not exhibit active spawning (Hunter and Macewicz, 2001). The validation of gonad maturation stages with histology permits better determination and understanding of the process of gonad maturation by revealing the details of oocyte and sperm development, which present less ambiguity in assigning maturity status (Mendonca *et al.*, 2006). Gonad histology is also a fundamental tool in the study of gonochorism, sexual inversion in fish, correct determination of sequence, timing and duration of sex and sex inversion (Al-Masoodi, 2012). The study of histology of gonads is therefore necessary in the studies of reproductive biology. A survey of literature was then undertaken to understand various aspects of reproductive biology of fishes in general and *P.ocellatus* in particular.

8.2 Review of Literature

The literature survey carried out by the candidate on various aspects of reproductive biology such as sexual dimorphism, sex ratio, spawning periodicity, gonadosomatic index, fecundity, morphology and histology of gonads in some teleost fishes in general and goby fishes in particular revealed that the literature is replete with reports on these aspects.

Sexual dimorphism

The sexual dimorphism was observed in many gobiid fishes by various authors. Hora (1923) in *Gobipterus chuno* reported that the ripe female has conical teeth considerably larger than the minute ones found in males. Pillay and Sarojini (1950) for the same species of *G.chuno* stated that the genital papilla, present in both sexes are stouter and prominent in the female than the male. Gibson and Ezzi (1978) reported that in *Lesueurigobius friesii*, the sexes may be distinguished externally by the shape of the genital papillae once the fish attained more than 35 cm standard length; the male papillae was slender, conical and reaching back as far as the first anal fin ray, where as in the female shorter, broader papillae ends approximately half way between

the anus and the first anal fin ray. The sexes can be distinguished externally in the case of *Gobius paganellus* by the shape of the well developed urinogenital papilla (Miller, 1961). Mutsaddi (1964) reported that the sexes in *Boleopthalmus dussumieri* can be differentiated chiefly by means of the urinogenital papilla and the dorsal fins. Doha (1974) observed in *Glossogobius giuris* that the males have straight, thin and pointed genital papilla while the females have short fleshy and circular genital papilla. Unito-Ceniza *et al.,* (2012) observed that in the *G.guiris* the females had deeper body with broader abdomen compared to the males while males had broader caudal peduncle compared to females. In *Gobioides broussonneti* the urogenital papilla in female is short blunt and yellow while in males it is thin, pointed and has a smooth appearance (Mata Cortes *et al.,* 2004). Ravi (2000) and Gore (2007) observed in *Boleophthalmus boddaerti* that the urinogenital papillae in males are conical flat and short, while in females they are round and bulged. The authors further reported that the first, the second, the third and the fourth dorsal fin are longer with soft filamentous extension in male. Idris *et al.* (2012) reported that in *Oxyeleotris marmorata* the females have longer urinogenital papilla, whereas the males had longer caudal fin and caudal peduncle.

Sex ratio

The literature review on sex ratio revealed study of sex ratio in large number of goby fishes across the world. Gibson and Ezzi (1978) elucidated the sex ratio of goby *Lesueurigobius friesii* as 1.12: 1.00 in favour of females. In *Gobioides rubicundus* the male-female ratio was found to be 1: 1.19 (Kader *et al*. 1988b). Miller (1961) observed the sex ratio of the rock goby *Gobius paganellus* to be 1: 1.326 in favour of males. Dotu (1961c) explained that in gobiid fish *Apocryptodon bleekeri* the preponderance of females might be due to burrowing and nest building habit of mudskipper. Keenleyside (1979) and Nash (1982) envisaged that in fry's goby *Lesueurigobius friesii* the unequal sex ratio was probably due to the burrow oriented reproductive behaviour; males were less vulnerable to capture since greater time was spent in the burrow for guarding the eggs. Hoda (1986a) observed the sex ratio of *Boleophthalmus dussumieri* occurring at coastal Karachi and found it to be 1.42 female: 1male. Borek and Sapota (2005) reported that in *Pomatochistus minutus* the females dominated the population during April, with nine fold more numbers than the males. Rao and Rao

(2007) observed that *Glossogobius giuris* from Gosthany estuary showed 1 male: 0.59 female. Goby *Pseudopocryptes elongates* showed female-male ratio of 1:0.96 which was not significantly different (Dinh *et al.,* 2007). Kovacic (2007) reported that in *Gobius vittatus* sex ratio did not differ significantly except during spawning season, when it was strongly biased in favour of females. In *Pomatochistus marmoratus* female to male ratio was 1.54: 1 and was statistically different from unity in females (Koutrakis and Tsikliras, 2009). In *Gobius niger* the sex ratio was 3.3: 1 in favour of males as they were dominant in all ages, in all months and seasons. (Filiz and Togulga, 2009). *Bathygobius soporator* from Badgary creek Nigeria showed sex ratio of 1: 0.0106 in favour of males and were significantly different from the expected value (Lawson and Thomas, 2010). Lekshmi *et al.,* (2010) reported that in a lesser known goby *Stenogobius gymnopomus* the male to female ratio was 1.62:1.00 indicating the dominance of males while from November to February females dominated over males.

Spawning periodicity

A single spawning has been observed and reported in many gobiid species by many workers. *Gobiopterus chuno* breed between October and December (Pillay and Sarojini, 1950), *Gobius paganellus* between April and June (Miller, 1961), *Boleophthalmus dussumieri* in June (Mutsaddi, 1964). Majority of the gobies posses a long breeding season with several spawnings per individual after which they usually die (Miller, 1984). Tandon (1962), Marquez (1960), Saksena (1976a, b) and Geevarghese (1976) reported that *Glossogobius giuris* has an extended breeding season and breeds throughout the year. *Gobius niger* undergoes sequential individual spawning which stretches over a long six month period (Joyeux *et al.,* 1991b, 1992).

Round goby *Neogobius melanostomus* has high fecundity; high frequency of spawning up to six times per year compared to other native gobies of Caspian Sea (Charlebois *et al*., 2001). *Lesueurogobius sanzoi* showed a breeding season that extended from May to October with a minimal gonadal activity during June (Paulo-Matins *et al.,* 2004).

Minimum size of sexual maturity has been reported by many authors in gobiid fishes like *Boleophthalmus dussumeiri* (Mutsaddi, 1964), *B.dentatus* (Hoda and Akhtar, 1985 and Shettu,1993) *B.boddaerti* (Ravi, 2000 and Gore, 2007).

Ova diameter studies were employed in a number of gobiids to determine their spawning season by many workers like on *Gobius paganellus* (Miller, 1961), *Gobius cobitis* (Gibson, 1970), *Lesueurigobius triesii* (Gibson and Ezzi, 1978), *Boleophthalmus dussumieri*, (Mutsaddi, 1964) and *Boleophthalmus boddaerti* (Ravi, 2000 and Gore, 2007).It has been suggested by Hoda (1986a) that the frequency polygon of ova diameter indicated that spawning occurs twice in *Boleophthalmus dussumieri* of Karachi coast whereas Rao and Rao (2007) suggested that Gonadosomatic Index values and ova diameter polygons indicated a prolonged breeding season in *G. giuris* from August to January with its peak in the month of September.

Gonado somatic index (GSI)

The GSI has been successfully used to determine the reproductive season in many gobiid fishes (Kanabashira *et al.,* 1980, Arruda *et al.,* 1993). Geevarghese and John (1983) found the GSI values of the gobiid fish *Oligolepis acutipennis* to be high during spawning. Kader *et al.* (1988b) found that in *Gobioides rubicundus* during the pre-spawning period there is a gradual increase of GSI, reaching a peak during the spawning period and there after undergoing a gradual decrease in the post spawning period. In goby *Awous guamensis* GSI values ranged between 0.2-14.5 in females and 0.01-4.00 in males (Ha & Kinzie, 1996). Ambak *et al.,* (2007) reported that in goby *Pseudocryptes lanceolatus* GSI values ranged between 0.008-0.024 in males and 0.02-2-5 in females. In the frill fin goby, *Bathygobius sorporator* GSI varied between 0.00-2.89 (Lawson and Ajibola, 2010). In goby *Deltentosteus quadrimaculatus* the maximum value of GSI for females was 7.45 and for male was 1.48 (Metin *et al.,* 2011). In *Gobius paganellus* from Tunisian coast the GSI values ranged between 1.10- 7.60 in females and 0.42-0.64 in males (Hajji *et al*., 2012).

Fecundity

The fecundity in gobiids varies widely among and within species ranging from less than 100 eggs in *Eviota lacrimae* to over 500000 eggs in *Awous guamensis* (Ha and Kinzie, 1996). Fecundity of similar sized gobies may differ between different species. In *Sicyopterus japonicus* of 105mm, the fecundity was reported as 2,24,960 eggs

where as in *Neogobius melanostomus* of the same length, the number of eggs produced was 1600 (Miller, 1984).

The habitat of the fish is found to influence fecundity. Many studies have reported that fish fecundity increases with increasing brood size for both fresh water and marine water, for instance in rainbow trout (Bromage *et al* 1990), winter flounder (Buckely *et al.,* 1991), salmonoids (Jonsson& Jonsson, 1999), cardinal fish (Kume *et al.,* 2000), African bony tongue (Adite *et al.,* 2006), Mugilids (Kendall &Gray, 2008) and *Cichla kelberi* (Lawson and Jimoh, 2010).

Morphology and Histology of Gonads

Based on macroscopic and histological examination of gonads in various fish species, different numbers of gonad maturation stages, ranging from five to nine were reported by various authors. These include Ritukumari and Padmanabhan (1976), Pathak and Jhingran (1977), Otobo (1978), Toor *et al*. (1979), Parvathi (1980), Shanbag and Nadkarni (1981), Susan and Nair (1983), Geevarghese (1984), Hunter and Macewicz (1985), Mayer *et al*.(1988), Morrison (1990), White *et al*.(1998), Dos-Santos *et al.* (2004), Seoka *et al*. (2007), Williams (2007), Mahmud (2009) and Shinkafi *et al*. (2011).

The gonad histology of many species of gobies was studied by several authors like *Boleophthalmus dussumeiri* (Mutsaddi and Bal, 1970; Soni and George, 1986), *Gillichthys mirabilis* (De Vlaming, 1972), *Eucyclogobius newberryi* (Goldberg, 1977), *Pomatochistus minutus* (Riehl, 1978), *Gobius niger* and *Gobius paganellus* (Stanley *et al.,* 1965; Miller, 1984; Colombo and Burighel, 1974), *Glossogobius olivaceus* (Asahina *et al*., 1985), *Padogobius martensi* (Cinquetti and Rinaldi, 2009), *Pomatochistus marmoratus* (Bouchereau *et al.,*1991; Mazzoldi and Rosotto, 2001), *Aphia minuta* (Caputo *et al.,* 2000), *Glossogobius giuris* (Zutschi and Murthy, 2001), *Gobiodon okinawae* (Cole and Hoese, 2001), *Gobioides broussoneti* (Mata Cotes *et al.,* 2004), *Sicyopterus japanicus*, *Odontanblyopus lacerpedii*, *Acanthogobius flavimanus* (Hara, 2004), *Schindleria praematura* (Thacker and Grier, 2005), *Oxyeleotris marmoratus* (Boonyoung *et.al.,* 2003; Sawanjarat *et al.,* 2005; Idris *et al.,* 2012), *Trimma okinawae* (Sunobe *et al.,* 2005), *Gobius vittatus* (Kovacic, 2007),

Boleophthalmus boddaerti (Gore, 2007), *Coryphopterus* species (Kramer and Patzner, 2008) *Periophthalmus papilio* (Lawson, 2010, 2011), *Scartelaos gigas* (Kim *et al.,* 2011), *Butis gymnopomus* (Mat Isa *et al*., 2012). Comparative cytology of seminal vesicles of male gobiid fish was studied by Fishelson (1991). The synthesis of steroids in seminal vesicles of *Neogobius melanostomus* was studied by Jasra *et al.* (2007).

The gobies are the largest family of fishes, but there is comapratively very little knowledge of the reproduction of most species (Blaber, 2000). A thorough review of literature revealed that there is hardly any information on the reproductive biology of *Parachaeturichthys ocellatus*. Therefore the present study was carried out to evaluate various aspects of reproductive biology of *P.ocellatus* from the creeks of Mumbai. The aspects of reproductive biology studied were as follows: sexual dimorphism and sex ratio, spawning periodicity, gonadosomatic index, fecundity, morphology and histology of gonads.

8.3 Materials and methods

Samples of *P. ocellatus* were collected from the creeks of Malad, Vasai, Thane and Mahul creek every fortnight during the period from June 2010 to September 2011. The specimens were cleaned and wiped to remove surface moisture. The total length to nearest millimetre and total weight of the fish to the nearest milligram was noted. The following aspects of the reproductive biology were studied in the samples:

Sexual dimorphism

The morphology of the fish was carefully examined to identify sexually dimorphic characters if any and record was maintained during different months in each fish. The fishes were then dissected and the nature and position of the gonads were recorded.

Sex ratio

The numbers of male and female fish were determined during different months and in different length groups. The Chi-square test was employed to find out the goodness

of fit of the observed sex ratio to that of theoretical sex ratio of 1:1 (1male: 1female). The following formula of Bhatnagar (1972) was used for Chi-square test.

$$\chi^2 = \frac{(F-S)^2}{S} + \frac{(M-S)^2}{S}$$

Where χ^2 is the symbol for Chi-Square, F is the observed number of females, M is the observed number of males and S is the expected number of each sex (the hypothetical 1:1 ratio).

Pooled Chi-square (K) was calculated by using the formula of Bhatnagar (1972)

$$K = \frac{(F-M)^2}{F-M}$$

After calculating individual and pooled Chi-square values, the data were tested for heterogeneity.

Spawning periodicity

The gonads from the dissected fish were excised. The length and weight of the gonads were noted and gonad development stage was determined by visual examination. The stage of maturity and colour of the gonads were recorded. The gonads and fish were then preserved in 5% formaldehyde separately for further studies.

Maturation and Spawning habits were studied by the methods by Clark (1934), Hickling and Rutenberg (1936) Prabhu (1956a) and Karekar and Bal (1960). The stages of maturity in fish were determined based on the observation of the gonads. The spawning season was inferred from the observation of matured and ripe gonads in the fish.

In all five maturity stages in ovary and testis were considered following the standard laid down by International council for exploration of sea (Lovern and Wood, 1937) and Jayashankar (1991b).The fishes belonging to maturity stage II onwards have been considered as maturing fishes and are used for the purpose of calculating the size at first maturity. A graph was plotted using the percentage of the maturing and mature fish in both sexes in the length group from 66-185mm in males and 66-155mm in

females. The size at which 50% fishes were mature was considered as the minimum size for maturity.

Ova diameter

Ova from the preserved ovaries were used for the measurement of ova diameter. An ocular micrometre with capacity of magnification of 0.01mm was used to measure ova diameter. Samples from anterior, middle and posterior region of the ovary were used in all measurements. 500 ova from each ovary were selected as per the methods of June (1953) and Jhingran (1961) for the studies of ova diameter. Spawning frequency was determined based on the peaks in frequency polygon of ova diameter in the mature ovaries.

Gonadosomatic index (GSI)

The Gonadosomatic index (GSI) was computed by formula based on June (1953) and Yuen (1955) which is as follows

$$GSI = \frac{\text{Gonad weight}}{\text{Total Body weight}} \times 100$$

Fecundity

To study the fecundity of the fish a small portion of the preserved ovary was excised from the anterior, middle and posterior portion and was weighed to the nearest 0.1g. The sample of the ovary was then teased out in water with the help of lancet. The matured opaque eggs in each of the three sections of the ovary were counted and the mean numbers of eggs were calculated using the formula:

$$F = \frac{\text{Total weight of ovary}}{\text{Weight of the sub sample}} \times \text{Number of mature ova in the sub sample}$$

A mathematical relationship of fecundity was worked out by the formula proposed by Snedecor (1961) which is as follows:

$F = aX^b$

where F is the fecundity, X represents various parameters like total length, total body weight, ovary weight and ovary length, ‘a’ is the point of intercept and ‘b’ the regression coefficient.

The exponential relationship was transformed into a straight line from the following equation Log F = Log a +b Log X where F is the fecundity, X is the variable and ‘a’ and ‘b’ are the two constants.

Morphology and Histology of gametes

Developmental stages of gonads were determined from gross visual examination of preserved gonads.

Macroscopic and microscopic observation were used following the standard laid down by International council for exploration of sea (Lovern and Wood, 1937) and described by Jayashankar (1991b).

Macroscopic determination of maturity stages: All gonads were assigned to their developmental stages, based on size, colour, shape, consistency, vascularisation, tunic transparency, and degree of swelling of gonads.

Histological and staining methods: The gonads fixed in 10% formalin were washed in water to remove excess fixative from the tissues. Processing of the tissues was carried out according to the method suggested by Epple (1967).The tissues were cleaned by tetrahydrofurane. And were pre-embedded with xylene- paraffin and then later fully embedded in pure paraffin wax. This was then poured into a mould and cooled in a freezer. The cooled wax block with the gonads was sliced into very thin ribbons at 4-5 micrometer thickness using a microtome. The sections were mounted on a slide and were processed further following the procedure suggested by Humason (1967) and Morrison (1990). Two staining methods were used: Haemotoxylin Eosin and Toulidine blue. The sections were deparaffinised in xylene and hydrated through graded series of alcohol. Fifty percent of the slides were stained in aqueous Dalafield’s haemotoxylin for 10 minutes. Following dehydration through alcohol series, the

sections were counterstained with alcoholic eosin (90%) and then subjected to changes for clearing alcohol by xylene.

The remaining fifty percent of deparaffinized slides were rehydrated with deionised water and stained with 0.04% Toluidine blue solution for 10minutes. The slides were rinsed with three changes of deionised water and dehydrated with 95% absolute alcohol.

All the slides were finally mounted in DPX mountant and observed under a microscope. Pictomicrographs of the different maturity stages were taken using a digital camera.

8.4 Results

Various aspects of reproductive biology like sexual dimorphism, sex ratio, spawning periodicity, gonado somatic index, fecundity, morphology and histology of gonads were studied. Various observations were recorded and analysed using appropriate statistical tools. Results are expressed in tables, graphs and photographs/plates.

Sexual dimorphism

The plate 8.1 and 8.2 show the male and female *P.ocellatus*. The plates show characters with which the male and female fish could be distinguished by observation of external characters as follows: The males were longer than the females. The ventral side of the body of males was reddish around the pelvic fin and anal fin. The depth of the body at the abdomen was more in females. The female abdomen was large and protruding during February, March, April, August and September months. The second dorsal fin ray of male was longer than that of female of the same length. The fused pelvic fins of male exhibited bifurcation at the anterior end while in female the anterior end was somewhat rounded. The urinogenital papillae in male were straight, thin, long and pointed while in female the papillae were rounded, short, fleshy and prominent compared to male. The determination of the sex from the external characters was confirmed by dissecting the fish and checking the nature of gonads. The colour and appearance of the gonads was different in male and female. The testes in mature male were creamy white in colour whereas ovaries were deep orange in ripe females. Thus it can be concluded that *P.ocellatus* exhibited sexual dimorphism during February,

March, April, August and September months and in general male *P.ocellatus* were slender as compared to female in the same length groups.

Sex ratio

The variation in sex ratio of *P.ocellatus* is presented in Table no.8.1 and Figure no. 8.1. A total of 1174 individuals comprising of 685 males and 489 females were collected in different months during the study period. The overall sex ratio was 1: 0.71, M: F indicating the dominance of males. The monthly sex ratio showed that females were dominant during September 2010 and April, May and June 2011, while the males dominated in all the remaining months during the period of study from June 2010 to September 2011. The highest number of females in the samples was obtained in the month of April 2011 when the ratio was 1:1.41, M: F and the lowest ratio was at 1: 0.47, M: F was obtained in July 2010. The sex ratio in August, September, December 2010, February, March, April, May, June and September 2011 did not statistically deviate from the theoretical ratio of 1:1 at $p \leq 0.05$.

The variations in sex ratio in different length group are presented in Table no. 8.2 and Figure 8.2. The range of length in the males observed was 66-185mm whereas the range of length in females was 66-155mm. No uniform pattern of ratio was observed in the sexes of various length groups. The highest ratio of 1:1.25, M: F was observed in the length group of 126-135mm. The lowest ratio of 1: 0.44, M: F was observed in the length group of 66-75mm. The sex ratio deviated significantly at $p<0.05$ in length groups of 66-75mm, 76-85mm, 86-95mm and 96-105mm.

Spawning periodicity

The spawning periodicity was ascertained by studying the following aspects: Stages of maturity in male and female gonads in different months and length groups, ova diameter, frequency polygon based on ova diameter in different stages of maturity and different months and by determining length at which fifty percent of fish attain maturity.

The visual examination of the gonads of *P.ocellatus* revealed the following:
In all five stages of maturity have been observed during present study for both male and female *P.ocellatus*

Stages of maturity of testes in *P.ocellatus* from visual examination

Stage	Nature of Maturity	Appearance of gonads
I	Immature	Thread like small and thin testes
II	Developing	Greyish white testes extend over half the length of the body cavity
III	Mature	Large, opaque, well developed and white testes occupying 2/3rd to ¾th of the body cavity
IV	Ripe	Thick, milky white testes extending throughout the body cavity
V	Spent	Shrunk, flat and strap like testes occupying 2/3rd of the body cavity

Stages of maturity of ovaries in *P.ocellatus* from visual examination

Stages	Nature of Maturity	Appearance of gonads
I	Immature	Small transparent light ovaries having inconspicuous blood capillaries and occupying ½ of the body cavity
II	Developing	Yellow ovaries occupying ½ of the body cavity
III	Mature	Yellowish orange ovaries with conspicuous blood capillaries occupying ¾th of the body cavity
IV	Ripe	Large bulky orange ovaries with prominent blood capillaries occupying entire body cavity
V	Spent	Flaccid reddish yellow ovaries with prominent dark blood vessels occupying 2/3rd of the body cavity

Maturity stages and season

The percentage occurrence of males and females in various stages of maturity during different months is presented in Tables and figures 8.3a and 8.3b. Based on the concept of minimum size at maturity, immature males were found in the sample from June 2010 to September 2011 except from February 2011 to April 2011. Maximum number of immature males was present in July and then in again in November 2010. Developing males were present throughout the period of study except in May 2011. Mature males in stage III were present during following months: August to October 2010, January to April 2011 and again from July to September 2011. Ripe males were

observed from July to September 2010, predominantly from February to May 2011 and again from July to September 2011. Spent males were observed in the following months: June 2010, September 2010 October 2010, and April 2011 to July 2011. Maximum percentage (56) of ripe males was found in February 2011.

Immature females were found in sample from July 2010 to August 2010, November 2010 to January 2011 and again from June 2011 to August 2011. Maximum percentage (73%) of immature females was observed in November 2011. Developing females occurred in the sample from July 2010 to January 2011 and again from June 2011 to September 2011. Mature females in Stage III were observed from June 2010 to October 2010 and then from December 2010 to April 2011 and again from June 2011 to September 2011. Mature females with ripe ovaries were found in June 2010, from August 2010 to October 2010, from February 2011 to June 2011 and again in August 2011 to September 2011. Maximum percentage (77%) of females with ripe ovaries was found in February 2011.

Maturity stages and length group

Variation in the testicular and ovarian cycles in different length groups are presented in Table no.8.4a and 8.4b and Figure 8.4a and 8.4b. The range of length of males observed was 66-185mm while in females was 66-155mm. All males below 75mm were immature. The developing individuals occurred in length groups from 76-85mm to 136-145mm. Mature males were found to occur in length group 96-105mm to 146-155mm. Ripe males occurred in length group 106-115mm to 176-185mm. All males in the larger size from 156-185mm were ripe and mature. The spent males observed in the present study were in the length group of 86-95mm to 146-155mm.

All the females with length below the range of 75mm were immature. Developing females occurred from length groups in the range of 76-85mm to 116-125mm. Mature females at stage III of maturity occurred from length group 76-85mm to 146-155mm. Ripe female at stage IV of maturity occurred from length range of 86-95mm to 146-155mm. Spent females also occurred from length group 86-95mm to 146-155mm.

In *P.ocellatus* with total length less than 66mm fishes were found to be immature and gonads were minute and translucent hence sex of such fish could not be determined.

Ova diameter

The study of ova in *P.ocellatus* revealed the following ova diameter in various stages of maturity.

Stage	Nature of maturity	Size of the ovum
Stage I	Immature	0.01-0.25mm
Stage II	Developing	0.06-0.35mm
Stage III	Mature	0.11-0.55mm
Stage IV	Ripe	0.5-0.70mm
Stage V	Spent	0.06-0.35mm

The oocytes measuring 0.01-0.25mm were immature. The oocytes measuring 0.06-035mm were the developing batch of eggs. The maturing oocytes showed increase in size in the range of 0.11-0.55mm. The further increase in oocyte to become large ripe eggs with the range of 0.50-0.70mm represented the eggs to be spawned immediately. The unspawned eggs in the ovaries of spent females were in the range of 0.06-0.35mm. The pattern of progression of ova during different months showed predominance of immature oocytes in November and December 2010 and again in May 2011. The progression of immature ova to the developing stages occurred in all the months except February 2011 to May 2011 during the period of study. The maturing oocytes occurred throughout the year in the ovaries except in November to December 2010 and May 2011. The progression of ova to ripening oocytes was observed in June 2010, August to October 2010, February 2011 to June 2011. The unspawned ova in the spent females were observed in June 2010, October 2010 and from March 2011 to June 2011.

Ova diameter frequency polygons of different stages were plotted by measuring the diameter of ova of all stages of maturity. Ova diameter frequency polygon at different stages of maturity and months are presented in Figures 8.6 and 8.7.

Length at which fifty percent of the fish attain maturity

The percentage of mature fishes at each length group was plotted for both male and female. This is shown in Figure 8.5a and 8.5b. It is evident that size at which 50% of fish attain sexual maturity was in the range of 85-96mm for male and female respectively. L_{50} for male was 91mm while in female L_{50} was 94mm. All males and females below 85mm were immature. All males and females above the length 106mm were found to be mature.

Gonadosomatic index (GSI)

The GSI for both male and female *P.ocellatus* in different months are presented in Table No. 8.6a and Figure 8.8a and 8.8b. The monthly GSI value varied from 0.18-0.91 in males and 1.58-12.67 in females. The highest value was recorded in February 2011 and lowest in November 2010 in both the sexes. The GSI value in both male and female was high in August 2010 and then increased from December 2010 to February 2011, then fell sharply in April and May 2011 and increased slightly again in August 2011. The GSI indicated that the spawning period extends from June 2010 to October 2010 and again from January 2011 to September 2011 with peak spawning from February 2011 to April 2011. The fish were found to be in resting phase in the month of November 2010 and December 2010. Female GSI was found to be consistently higher than in males.

The length group analysis of GSI in male and female is represented in Table no.8.6b and Figure 8.9a and 8.9b. The peak of GSI occurred in length group 136-145mm in male and female *P.ocellatus*. The lowest value was recorded from length group 76-85mm in male and 66-75mm in female. In both male and female it was found to increase with increase in length till it attained full maturity in length group 136-145mm, but it decreased in the higher length group of 146-155mm to 176-185mm in male, 146-155mm in female.

Fecundity

A total of 33 mature females were examined to determine fecundity. The length of the female fishes ranged between 100-153mm and their weight ranged between 10.072-38.383g. The fecundity for the sample of 33 matured female *P.ocellatus* ranged between 21,635-1,79,334 eggs with a mean of 48,973. Table no. 8.7 records the

observed and calculated fecundity based on regression equation Y=a+bX where Y is the fecundity, X is the variable i.e. total length/ total weight/ ovary length/ovary weight of the fish. The factors ‘a’ and ‘b’ stand for the intercept and the regression coefficient respectively. The maximum fecundity at 179334 was observed in a fish measuring 153mm in total length and weighing 38.383 grams. The lowest fecundity at 21635 was observed in total length103mm of weight 10.279gm.

The logarithmic relationship between fecundity and total length of fish was linear and is presented in figure 8.10a. The calculated relationship was:

Log F = -4.3523+ 4.3671 log total length.
The correlation ‘r’ at 0.9628 indicated a significant relationship at $p< 0.01$
The fecundity and body weight also showed a linear relationship and is presented in fig 8.10b. The regression equation of fecundity on body weight is expressed as:

Log F = 2.7859 + 1.5195 log total weight.
The correlation ‘r’ at 0.9756 indicated a significant relationship between two variable at $p<0.01$.

Relationship between fecundity and ovary length and ovary weight were linear and is presented in figure 8.10c and 8.10d. The equations that relate fecundity to length and weight of the ovary are:
Log F = -1.7967 + 4.3385 log ovarian weight
Log F = 4.2452 + 1.5182 log ovarian length

The correlation ‘r’ was 0.9705 for the relationships between fecundity and ovary length while it was and 0.9633 for fecundity and ovary weight indicating a high significance at $p<0.01$.

The deviations of ‘b’ values were analyzed against 3 in the case of total length and ovary length and against unit or 1 in case of total weight and ovary weight as adopted by Sebastian (2011). The t values obtained were as follows:

Parameters	t=b-3/Sb	p<0.05	Parameters	t=b-1/Sb	p<0.05
F vs TL	189.99	significant	**F vs TL**	24.85	significant
F vs OL	183.34	significant	**F vs OW**	25.03	significant

The t values thus indicates that the regression coefficient 'b' deviates significantly from the value 3 in case of total length and ovary length while it deviates from unity or 1 in case of total weight and ovary weight.

Morphology and histology of gonads

The testes:

The testes of *P.ocellatus* were paired and elongated structures located dorsal to the body cavity, attached to the coelomic cavity by the mesorchia ligaments. Testes were united at the posterior end into a common spermatic duct which opened at the other terminal end of the genital papillae. The accessory sexual organ, seminal vesicles appeared at the base of the testes and these too opened into the spermatic duct. The seminal vesicles were elongated during the breeding season. According to the stages of sexual maturity, the testis varied in size, shape, colour, weight and location in the coelomic cavity. The ripe mature testes are as shown in plate no. 8.3

The different maturity stages observed as depicted in Plate no. 8.4 were as follows:

Maturity stage	Macroscopic Observation
Stage I Immature	Small thin thread like white testes occupying 1/10th of the body cavity and weighing 0.010-0.025g. No seminal vesicles seen.
Stage II Developing	Elongated, thickened and white testes occupying 1/6th of the body cavity and Weighing 0.035-0.070g. Seminal vesicles were visible in the posterior end of the testes.
Stage III Mature	Large, elongated, thickened and creamy white testes with crenulated edges occupying 1/5th to 1/4th of the body cavity. And weighing 0.120-0.250g. Seminal vesicles were longer than the length of the testes.

Stage IV Ripe	Thick, swollen, mature and creamy white testes occupying 1/3th of the body cavity and weighing 0.250-0.275g. Milt expulsion took place on slight pressure. The seminal vesicles grew past the testes.
Stage V Spent	Shrunken, flat, opaque, compact and white testes reduced to 1/5-1/8 of the body cavity and weighting 0.050-0.010g. No milt expulsion on pressure. The seminal vesicles decreased in size and were not visible in the late spent stage.

The histological study of the testis showed that it was made of two layered wall, outer peritoneum and inner tunica albuginea. The walls were thick in immature testis and were thin in matured one. The testis was mainly composed of numerous lobules which were separated from each other by a thin connective tissue having dispersed interstitial cells or Leydig cells and blood capillaries. The lobules extended from periphery towards the centre. Each lobule was characterized by the presence of seminiferous tubules which contained spermatogenic cells. Various stages of spermatogenic cells were observed such as spermatogonia, primary spermatocytes, secondary spermatocytes, spermatids, and spermatozoa. The seminiferous tubules opened into the lumen of the lobule which showed presence of mature sperms. The inner margins of the seminiferous tubules showed sertoli cells.

The seminal vesicles are accessory organ of male reproductive system. Seminal vesicles are glandular structures lined by cuboidal epithelium, muscles fibres and blood capillaries. The vesicles contain vesicular fluid.

The histological observation of the different stages of testis was as follows:

Stage I: Immature	Plate no.8.5a, 8.5b & 8.5c
The lobules contain numerous seminiferous tubules of different sizes. The seminiferous tubule contains primary and secondary spermatogonia. Narrow and clear lumen observed. No spermatogenic activity observed.	
Stage II: Developing	Plate no. 8.6a, 8.6b & 8.6c

The lobules contain many seminiferous tubules. Some of the tubules shows primary and secondary spermatogonia while some germinal cysts along with spermatogonia have primary and secondary spermatocytes. The lumen is prominent. Dispersed Leydig cells are seen.	
Stage III: Mature	Plate no. 8.7a, 8.7b & 8.7c
Few spermatogonia are observed. Spermatocytes and spermatids are observed on the walls of the seminiferous tubule. Large number of spermatozoa are observed in the lumen. The spermatids are attached to sertoli cells. Leydig cells are observed.	
Stage IV: Ripe	Plate no. 8.8a, 8.8b, 8.8c & 8.8d
The lumen appears large and is completely filled with spermatozoa. Few spermatocytes are observed. Leydig cells are distinct.	
Stage V: Spent	Plate no.8.9a & 8.9b,
The spermatozoa are shed. There is lot of empty spaces in the lumen. Few spermatogonia are seen in the empty tubules . The lobules decrease in size.	

The Ovaries: The ovaries of *P.ocellatus* were paired elongated organs present in the posterior abdominal cavity with blunt anterior and tapering posterior ends, while the middle portion was bulged. They were attached to the body wall by a mesovarium ligament. The ovaries were often found to be unequal in size with the regression in the right ovary. A thin oviduct arose from the posterior side of each of the ovaries and two fused to form a common oviduct which opened into the urogenital papilla or gonopore. In females the gonopore was swollen during the breeding season. During the mature and ripe stage, the abdomen bulge out in female fish due to bulk of the ovaries. The matured and ripe ovary is shown in figure 8.10.

The macroscopic observation of different maturity stages of development of ovary as in Plate no. 8.11 are as follows:

Maturity stage	**Macroscopic description**.
Stage I Immature	Small, slender, thin, light yellow ovaries occupying 1/8 to 1/6 of the body cavity and weighing 0.015-0.295g.
Stage II Developing	Thickened, elongated and clear yellow ovaries occupying ¼ to ½ of the body cavity and weighing 0.2-1.005 g. Network of blood capillaries are seen on the surface of the ovary.
Stage III Mature	Highly thickened, swollen, orange ovaries occupying 2/3rd of the body cavity and weighing 0.824-1.590g. A heavy network of blood capillaries appeared on the ovarian surface.
Stage IV Ripe	Large, swollen and orange ovaries occupying the entire space of the body cavity and weighing 1.620-3.580g. The gonopore was swollen and on gentle application of pressure the eggs flowed out. Dense network of blood vessels are seen on the ovaries.
Stage V Spent	Flaccid hard yellow ovaries occupying 1/3rd of the body cavity and weighing 0.195-0.575g. The blood vessels were prominent and dark.

Each ovary was sheathed by a thin peritoneal membrane. The ovarian wall was thin in early stages and thickened progressively in the later stages of development. The second layer enveloping ovary the tunica albuginea consisted of connective tissue, smooth muscle fibres and blood vessels. The inner most layer, the germinal epithelium project into the lumen of the ovary in the form of lamellae. The ovary contain oocytes of various stages of proliferation from germinal epithelium. The oogonia or germ cells occur as clusters or nests in the lamellae. The younger germ cells were found towards the main matrix while the advanced stages were located towards distal end of the lamellae. The ovaries were asynchronous since they showed ova of different stages of development.

The histological observations of different stages of ovary are as follows:

Stage I: Immature, Pre- vitellogenic and Perinuclear stage	Plate no. 8.12a, 8.12b
The oocytes of different sizes are seen in the ovary. The cytoplasm is homogenous and is stained. Oocytes are surrounded by rows of follicular cells. The diameter of oocyte varies between 0.01-0.25mm	
Stage II: Developing, early vitellogenic, yolk vesicles stage	Plate no.8.13a, 8.13b and 8.13c
The oocytes are spherical, oval or polygonal in shape. They show moderate amount of chromophobic cytoplasm, medium in size nucleus with many nucleoli near the nuclear membrane. Numerous yolk vesicles were seen in the cytoplasm surrounding the nucleus of larger oocytes. Smaller yolk vesicles are seen surrounding the nuclear membrane. Larger vesicles are seen towards the periphery which fills the major part of the cytoplasm towards the later stages. The size of the oocyte varies between 0.06-0.35mm	
Stage III: Mature, late vitellogenic stage	Plate no. 8.14a, 8.14b, 8.14c & 8.14d
Large mature oocytes seen. The nucleus contains many nucleoli. The nuclear membrane is indistinct. Yolk granules, lipid globules and cortical alveoli are present in the ooplasm. The follicular layers and zona pellucida are well differentiated. The size of the oocyte varies between 0.11-0.55mm.	
Stage IV: Ripe, yolk globule stage	Plate no. 8.15a ,8.15b, 8.15c & 8.15d
The large numbers of mature oocytes with maximum diameter are seen. They are spherical or polygonal in shape. The yolk globules and lipid droplets fill the entire ooplasm as the intra vesicular and inter vesicular yolk deposition takes place. The vacuolated large yolk globules are found in the centre. Peripheral	

nucleus with disintegrated nuclear membrane and dispersed nuclear material can be observed. The size of the oocyte varies between 0.5-0.70mm.
Stage V: Spent — Plate no. 8E. 12a, 8E.12b & 8E.12c
The ovarian wall is thick and shows empty follicles. Post ovulatory follicles, immature oocytes and unspawned oocytes are observed. They appear in the active state of reabsorption. Follicles are contracted and tunica wall appears folded. The size of decreased ooyte ranges from 0.06-0.35mm. Atretic oocytes observed in this stage.

Table no. 8.1: Sex ratio of *P. ocellatus* in different months

Months	Males		Females		Total No. of fishes	Expected no. of fishes	Sex ratio	Chi – square (χ^2)	Significance at $p \leq 0.05$
	No. of male	%	No. of female	%					
Jun-10	40	63.00	24	37.00	64	32	1:0.60	4	S
Jul-10	36	68.00	17	32.00	53	26.5	1:0.47	6.811321	S
Aug-10	40	55.00	33	45.00	73	36.5	1:0.83	0.671233	NS
Sep-10	23	48.00	25	52.00	48	24	1:1.09	0.083333	NS
Oct-10	80	62.00	49	38.00	129	64.5	1:0.61	7.449612	S
Nov-10	39	64.00	22	36.00	61	30.5	1:0.56	4.737705	S
Dec-10	70	57.00	52	43.00	122	61	1:0.74	2.655738	NS
Jan-11	50	66.00	26	34.00	76	38	1:0.52	7.578947	S
Feb-11	34	57.00	26	43.00	60	30	1:0.76	1.066667	NS
Mar-11	35	51.00	34	49.00	69	34.5	1:0.97	0.014493	NS
Apr-11	17	41.00	24	59.00	41	20.5	1:1.41	1.195122	NS
May-11	8	47.00	9	53.00	17	8.5	1:1.13	0.058824	NS
Jun-11	17	41.00	24	59.00	41	20.5	1:1.41	1.195122	NS
Jul-11	90	64.00	50	36.00	140	70	1:0.56	11.42857	S
Aug-11	81	60.00	54	40.00	135	67.5	1:0.67	5.4	S
Sep-11	25	55.00	20	45.00	45	22.5	1:0.8	0.555556	NS

Critical value of χ^2 at 1 df = 3.84 at $p \leq 0.05$

Pooled $\chi^2 = \frac{(F-M)^2}{F+M} = \frac{(489-685)^2}{489+685} = \frac{38416}{1174} = 32.72$ χ^2 at 31df = 44.98

Ratio 1: 0.71, M:F, Not significant

S- Significant, NS- Not Significant, F- female and M- male

Table no. 8.2: Sex ratio of *P ocellatus* in different length groups

Length groups	Male		Female		Total no. of fish	Sex ratio	Expected no. of each sex	Chi square (X^2)	Significance at p≤0.05
	No. of males	%	No. of females	%					
66-75	47	69	21	31	68	1: 0.44	34	9.9411	S
76-85	72	63	42	37	114	1: 0.58	57	7.8947	S
86-95	138	63	81	37	219	1: 0.58	109.5	14.8356	S
96-105	201	59	140	41	341	1: 0.69	170.5	10.9120	S
106-115	92	49	97	51	189	1: 1.05	94.5	0.1322	NS
116-125	71	58	51	42	122	1: 0.71	61	3.2786	NS
126-135	27	44	34	56	61	1: 1.25	30.5	0.8032	NS
136-145	13	46	15	54	28	1: 1.15	14	0.1428	NS
146-155	15	65	8	35	23	1: 0.53	11.5	2.1304	NS
156-165	7	100	0	0	7	1: 0	3.5	-	-
166-175	1	100	0	0	1	1: 0	0.5	-	-
!76-185	1	100	0	0	1	1:0	0.5	-	-

Critical value of χ^2 at 1 df = 3.84 at p≤0.05

S- Significant, NS- Not Significant

Table no. 8.3a: Maturity stages of testes in *P.ocellatus* male during different months

Months	Stage-I	Stage II	Stage III	Stage IV	Stage V
Jun-10	30	25	0	0	45
Jul-10	83	14	0	3	0
Aug-10	55	25	5	15	0
Sep-10	21	35	13	9	22
Oct-10	26	56	6	0	12
Nov-10	77	23	0	0	0
Dec-10	46	54	0	0	0
Jan-11	20	24	56	0	0
Feb-11	0	21	23	56	0
Mar-11	0	49	20	31	0
Apr-11	0	12	47	23	18
May-11	25	0	0	25	50
Jun-11	47	12	0	0	41
Jul-11	25	56	4	3	12
Aug-11	43	31	22	4	0
Sep-11	12	48	16	24	0

Table no. 8.3b: Maturity stages of ovaries in *P.ocellatus* female during different months

Months	Stage-I	Stage-II	Stage-III	Stage-IV	Stage-V
Jun-10	0	0	12	21	67
Jul-10	29	59	12	0	0
Aug-10	6	27	40	27	0
Sep-10	0	16	28	56	0
Oct-10	0	4	6	41	49
Nov-10	73	27	0	0	0
Dec-10	15	46	39	0	0
Jan-11	15	19	66	0	0
Feb-11	0	0	23	77	0
Mar-11	0	0	35	41	24
Apr-11	0	0	29	50	21
May-11	0	0	0	33	67
Jun-11	8	17	25	29	21
Jul-11	32	50	18	0	0
Aug-11	35	33	19	13	0
Sep-11	0	15	65	20	0

Table no.8.4a: Maturity stages of testes in *P.ocellatus* male in different length groups

Length groups	Stage-I	Stage II	Stage III	Stage IV	Stage V
66-75	100	0	0	0	0
76-85	75	25	0	0	0
86-95	52	47	0	0	1
96-105	29	35	31	0	5
106-115	27	32	14	14	13
116-125	4	17	26	39	14
126-135	0	7	41	30	22
136-145	0	23	8	54	15
146-155	0	0	47	20	33
156-165	0	0	0	100	0
166-175	0	0	0	100	0
176-185	0	0	0	100	0

Table no. 8.4b: Maturity stages of ovaries *P.ocellatus* female in different length groups

Length groups	Stage-I	Stage II	Stage III	Stage IV	Stage V
66-75	100	0	0	0	0
76-85	38	57	5	0	0
86-95	16	38	15	29	2
96-105	23	24	23	9	21
106-115	0	18	33	32	17
116-125	0	14	29	43	14
126-135	0	0	20	47	33
136-145	0	0	20	46	34
146-155	0	0	13	37	50

Table no. 8.5: Ova diameter in different stages of maturity of *P. ocellatus.*

Ova diameter	Immature	Developing	Maturing	Ripe	Spent
0.01-0.05	44		-	-	-
0.06-0.10	25	32	-	-	5
0.11-0.15	16	38	1	-	17
0.16-0.20	8	7	1	-	23
0.21-0.25	7	5	4	-	35
0.26-0.30	-	11	10	-	11
0.31-0.35	-	7	46	-	9
0.36-0.40	-	-	25	-	-
0.41-0.45	-	-	4	-	-
0.46-0.5	-	-	4	-	-
0.51-0.55	-	-	5	19	-
0.56-0.60	-	-	-	22	-
0.61-0.65	-	-	-	39	-
0.66-0.70	-	-	-	20	-

Table no. 8.6a: Gonadosomatic index of *P.ocellatus* during different months

Month	Male	Female
June-10	0.59	7.63
July-10	0.47	3.53
August-10	0.63	8.56
September-10	0.51	6.72
October-10	0.39	7.95
November-10	0.18	1.58
December-10	0.47	2.14
January-11	0.50	5.81
February-11	0.91	12.67
March-11	0.61	10.86
April-11	0.57	9.79
May-11	0.39	8.83
June-11	0.53	9.18
July-11	0.47	3.7
August-11	0.55	8.16
September-11	0.54	7.01
Average	0.51	7.1

Table no. 8.6b: Gonadosomatic index of *P. ocellatus* in different length groups

length group	male	female
66-75	0.31	1.9
76-85	0.23	3.33
86-95	0.55	4.81
96-105	0.47	5.77
106-115	0.55	7.81
116-125	0.56	8.99
126-135	0.69	10.22
136-145	0.73	12.16
146-155	0.65	9.2
156-165	0.57	-
166-175	0.40	-
175-185	0.38	

Table no. 8.7: Observed and calculated fecundity in *P.ocellatus*

Sr. no	Total length (mm)	Total weight (g)	Ovary length (mm)	Ovary Weight (g)	Observed Fecundity	Calculated fecundity			
						$F=aL^b$	$F=aW^b$	$F=aOL^b$	$F=aOW^b$
1	100	10.072	27	1.225	29547	24094	20424	25898	23934
2	103	10.279	26	1.110	21635	27413	21065	21987	20607
3	103	12.372	27	1.238	23664	27413	27917	25898	24320
4	104	12.626	27	1.250	24616	28595	28792	25898	24679
5	105	12.739	27	1.330	26130	29815	29185	25898	27116
6	106	12.807	28	1.380	27972	31075	29421	30325	28679
7	107	13.250	28	1.390	29833	32376	30982	30325	28995
8	107	13.290	28	1.467	31401	32376	31124	30325	31468
9	108	14.259	29	1.550	32930	33718	34637	35311	34211
10	108	14.478	29	1.616	34020	33718	35448	35311	36446
11	108	14.532	29	1.620	35763	33718	35650	35311	36584
12	108	14.822	29	1.690	37600	33718	36736	35311	39010
13	109	15.198	29	1.693	38304	35103	38161	35311	39115
14	110	15.501	30	1.742	40782	36531	39323	40906	40847
15	110	15.676	30	1.754	41749	36531	40000	40906	41275
16	111	16.091	30	1.766	43002	38004	41620	40906	41704
17	111	16.213	30	1.810	43447	38004	42101	40906	43292
18	112	16.452	31	1.880	44000	39522	43047	47160	45859
19	112	16.457	31	1.907	46880	39522	43067	47160	46863
20	112	16.990	32	1.909	47538	39522	45204	54124	46937
21	117	18.120	32	1.921	48871	47827	49851	54124	47386
22	118	18.342	32	1.921	49765	49638	50782	54124	47386
23	122	18.438	32	1.981	53050	57417	51186	54124	49651
24	123	18.774	32	2.032	54374	59501	52610	54124	51605
25	124	20.063	32	2.122	55180	61643	58196	54124	55114
26	125	20.625	32	2.202	55709	63843	60691	54124	58300
27	125	20.902	32	2.230	57122	63843	61933	54124	59429
28	125	20.939	33	2.460	57715	63843	62100	61855	68979
29	125	20.955	33	2.502	59792	63843	62172	61855	70775
30	127	21.304	33	2.739	68554	68426	63752	61855	81199
31	132	26.501	33	2.983	81939	80995	88827	61855	92431
32	137	26.523	39	3.006	93906	95274	88939	127683	93515
33	153	38.383	40	3.321	179334	154335	155954	142507	108790
Avg	115.36	17.39	30.66	1.901	48973	48521	48512	48535	48075

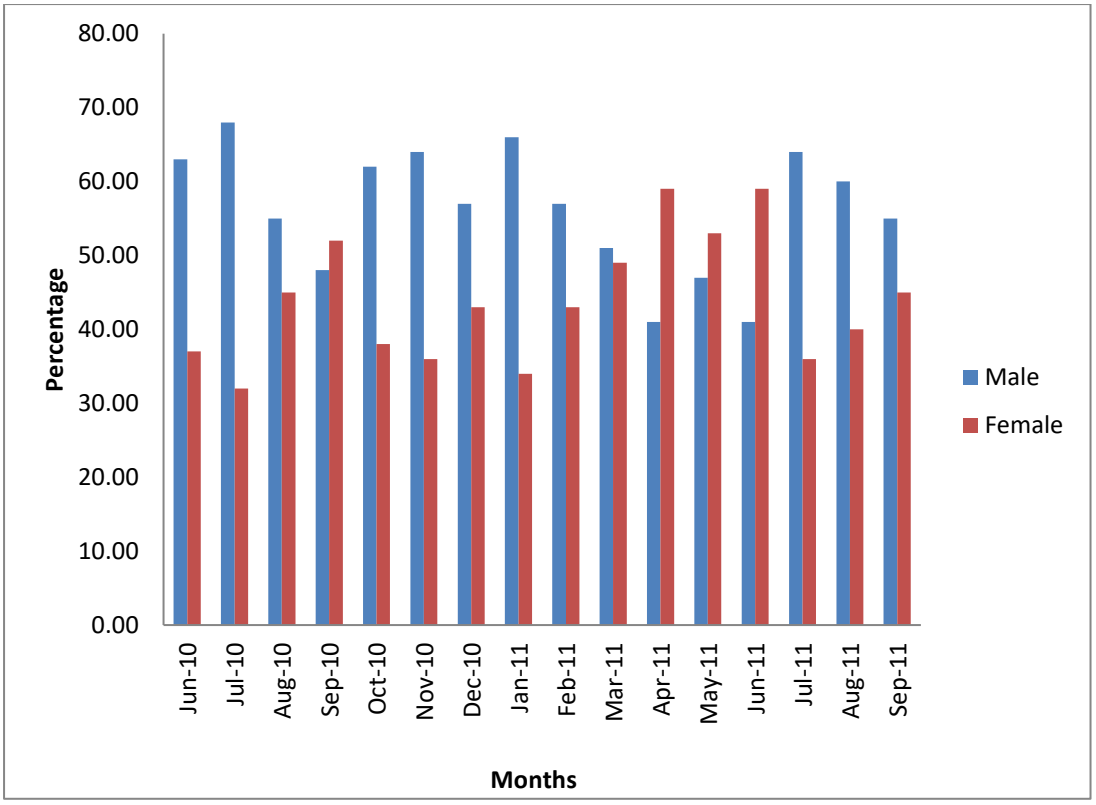


Fig 8.1: Variation in sex ratio of *P.ocellatus* during different months.

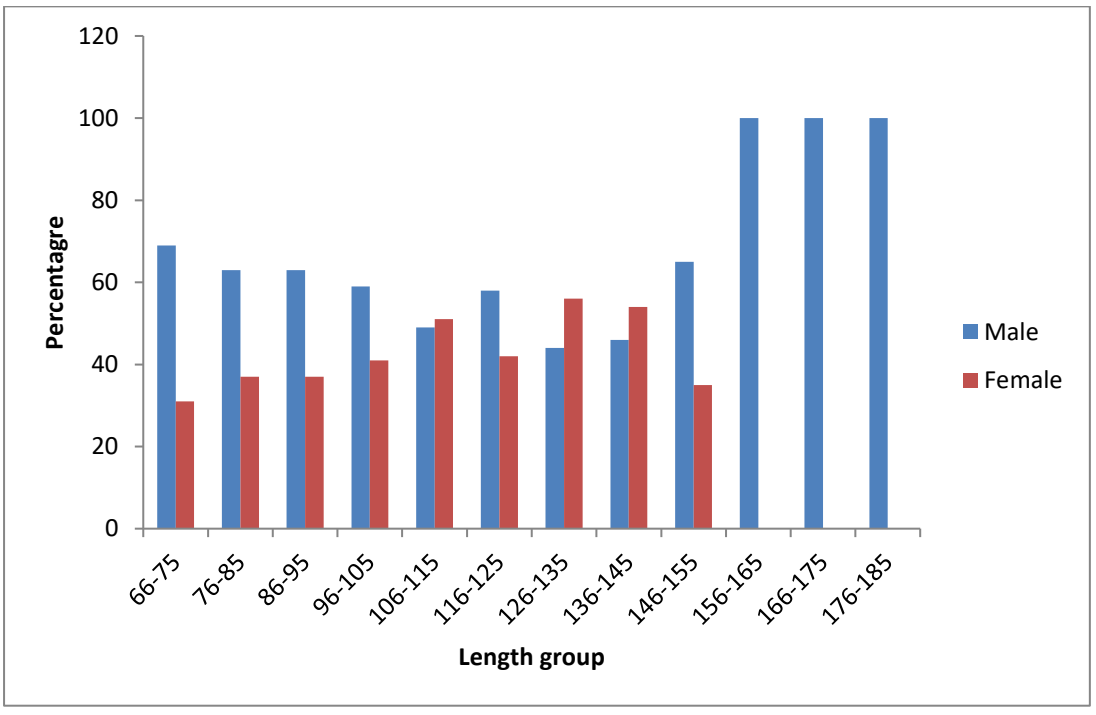


Fig 8.2: Variation in sex ratio of *P.ocellatus* in different length groups.

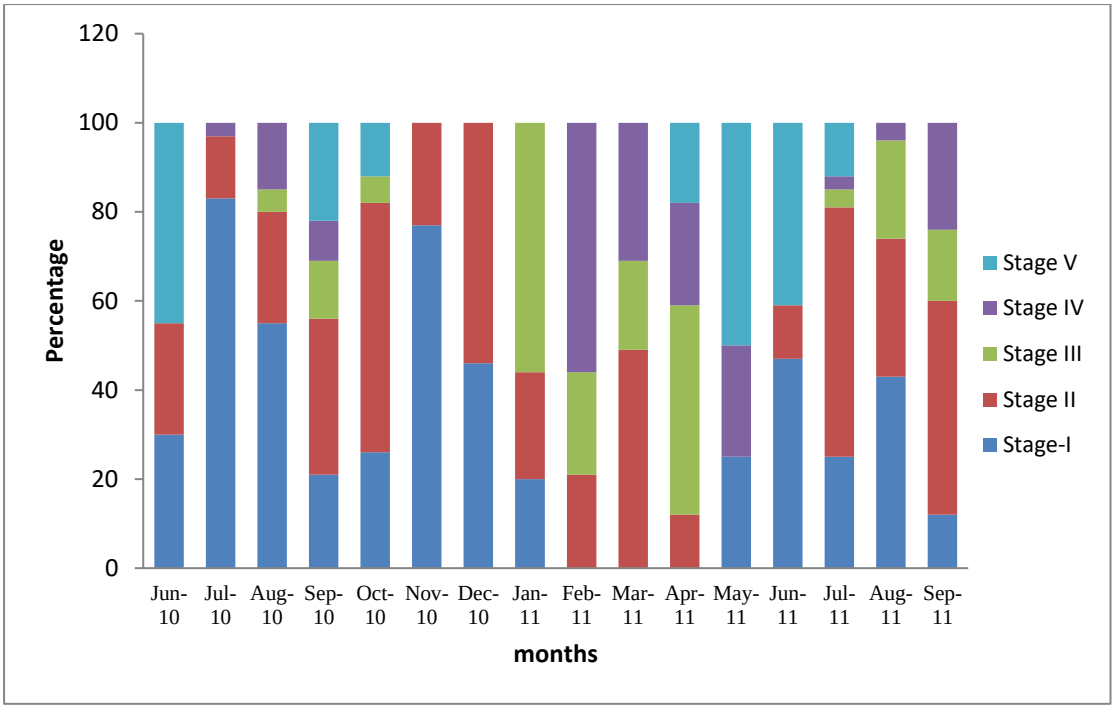


Fig 8.3a: Maturity stages of testes of male *P.ocellatus* during different months expressed as percentage.

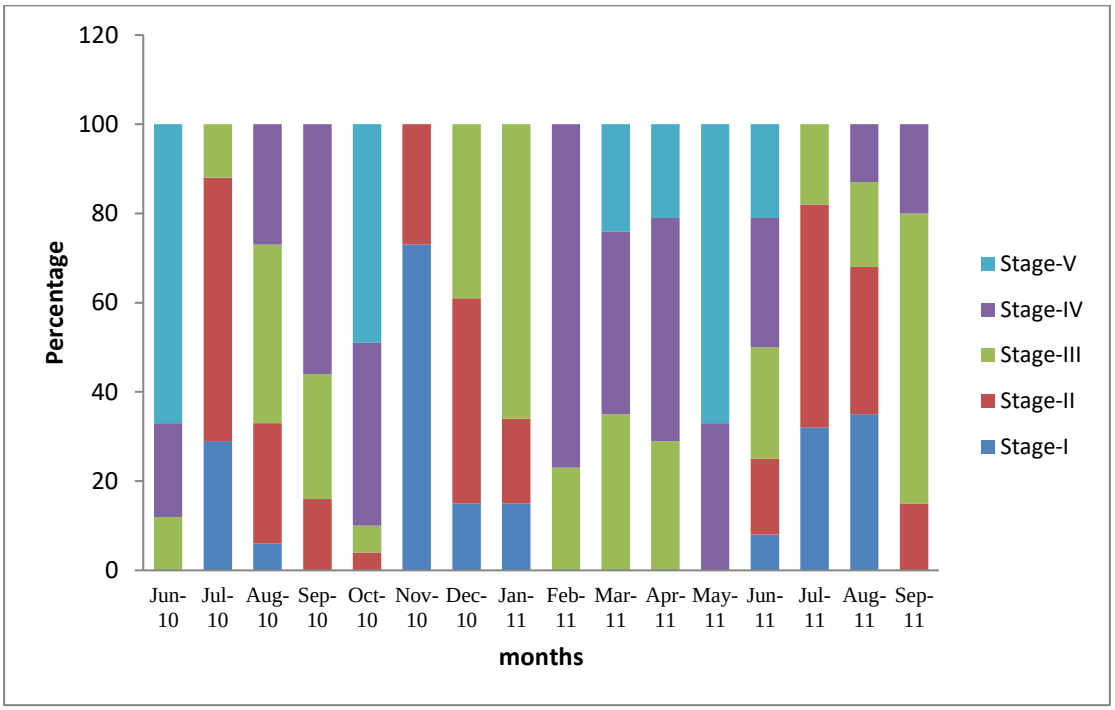


Fig 8.3b: Maturity stages in ovaries of female *P. ocellatus* during different months expressed as percentage.

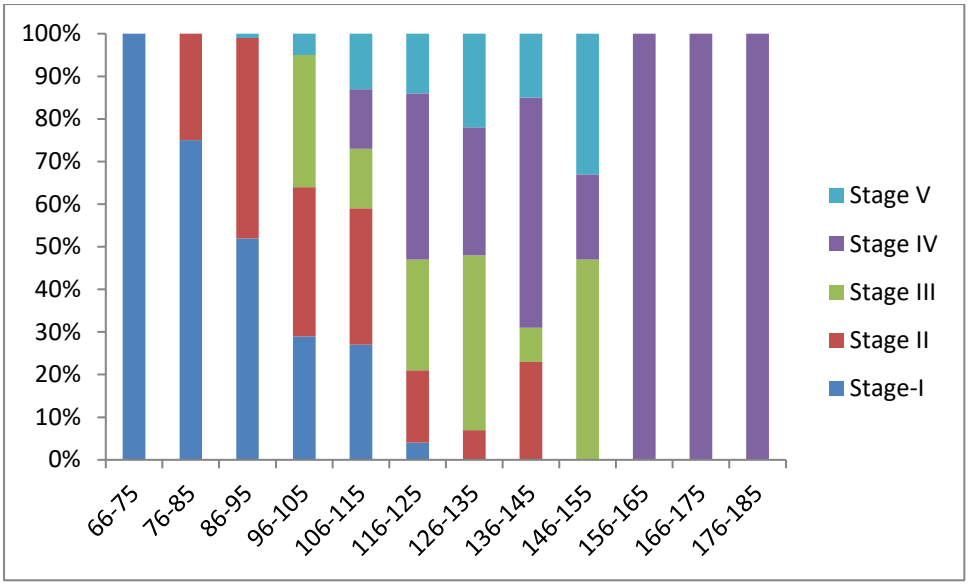


Fig 8.4a: Maturity stages of testes of male *P.ocellatus* in different length groups.

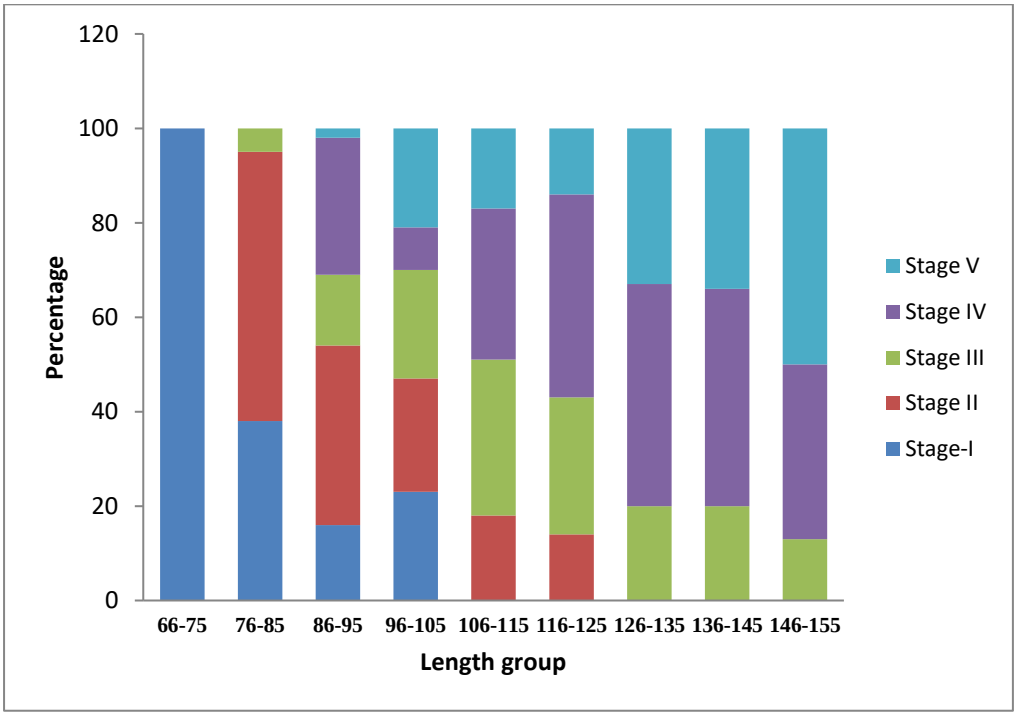


Fig 8.4b: Maturity stages of ovary of female *P.ocellatus* in different length groups.

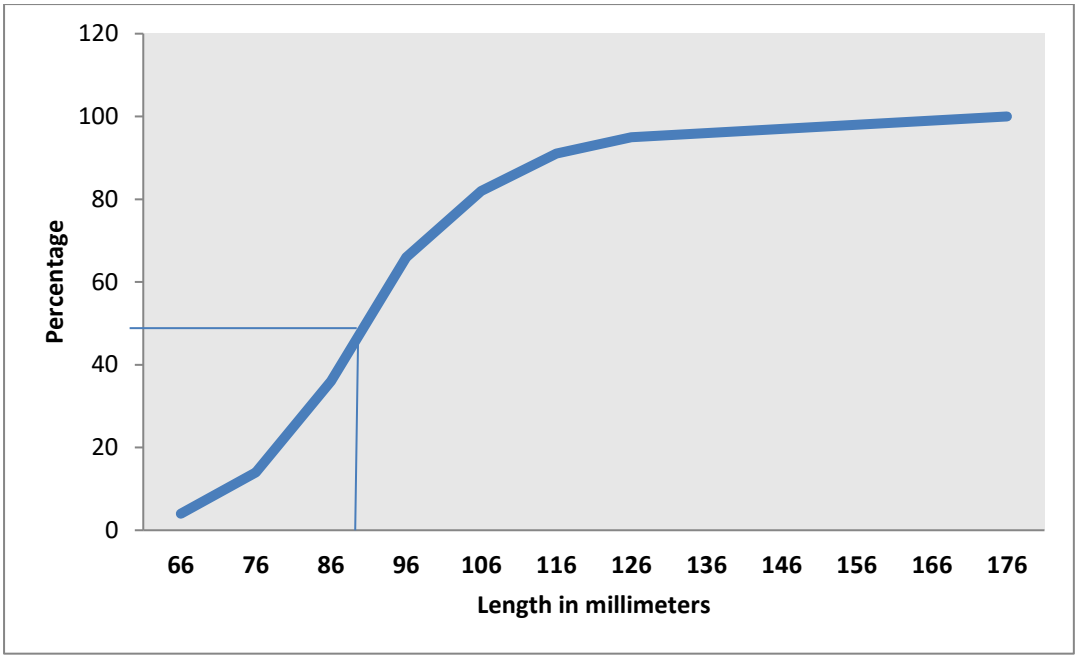


Fig8.5a: Minimum size at which 50% of male *P.ocellatus* attain maturity.

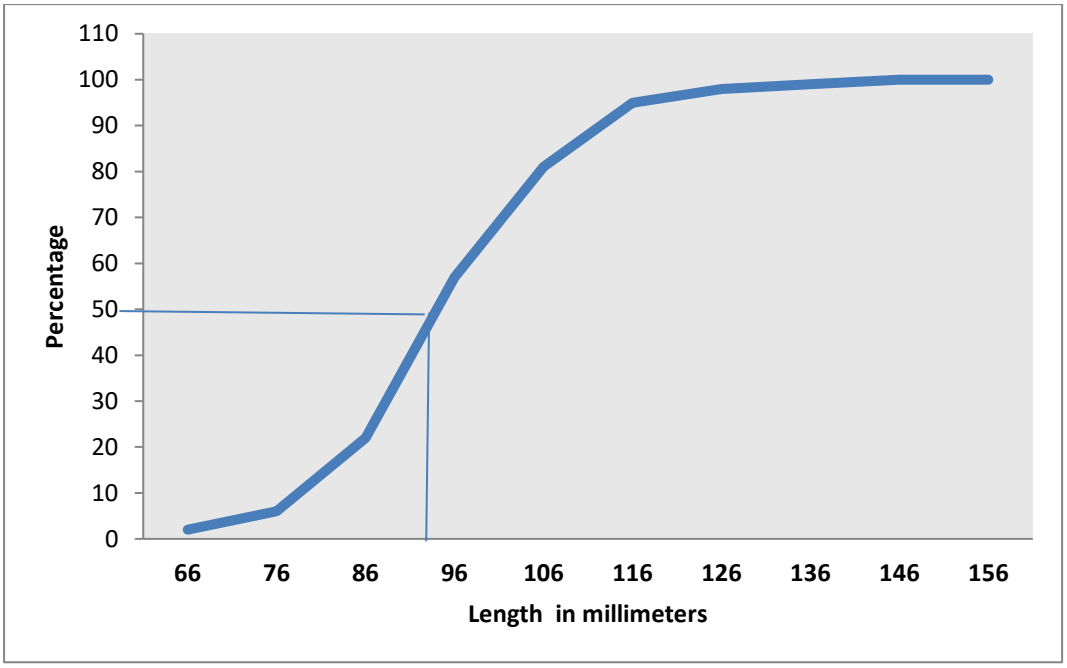


Fig 8.5b: Minimum size at which 50% of female *P.ocellatus* attain maturity.

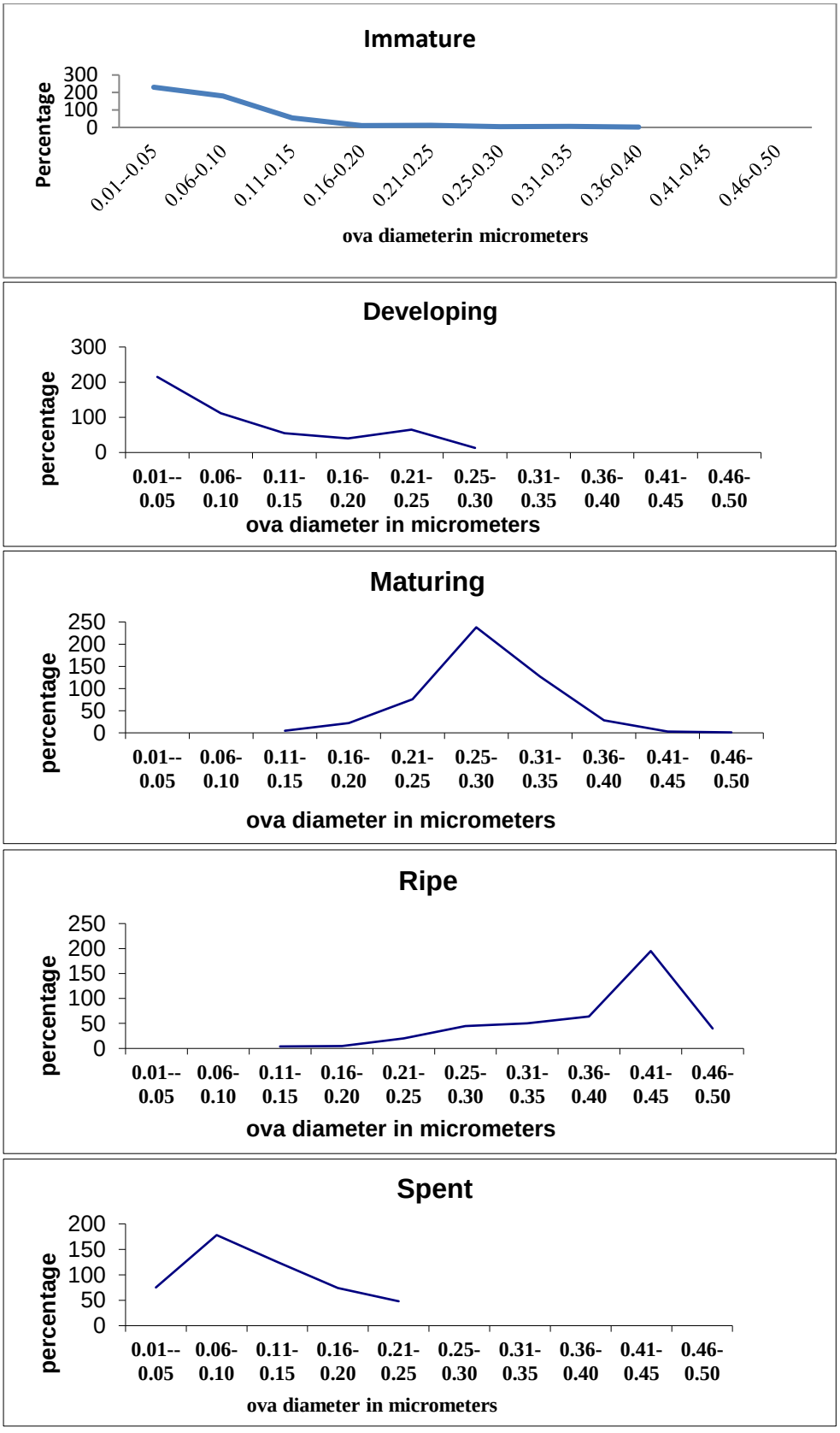


Fig 8.6: Ova diameter frequency polygon of *P.ocellatus* in different stages of maturity

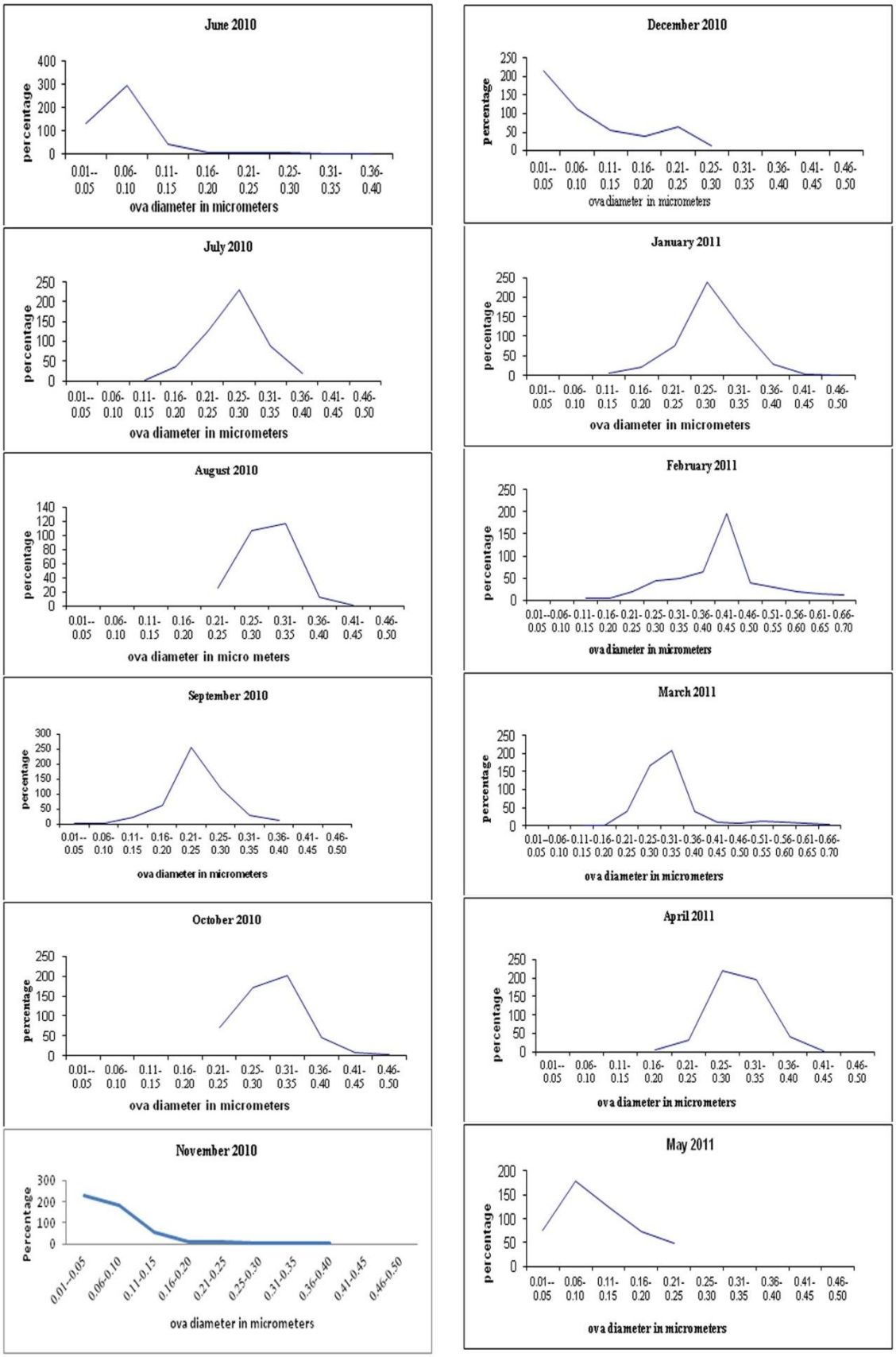


Fig 8.7: Ova diameter frequency polygon during different months

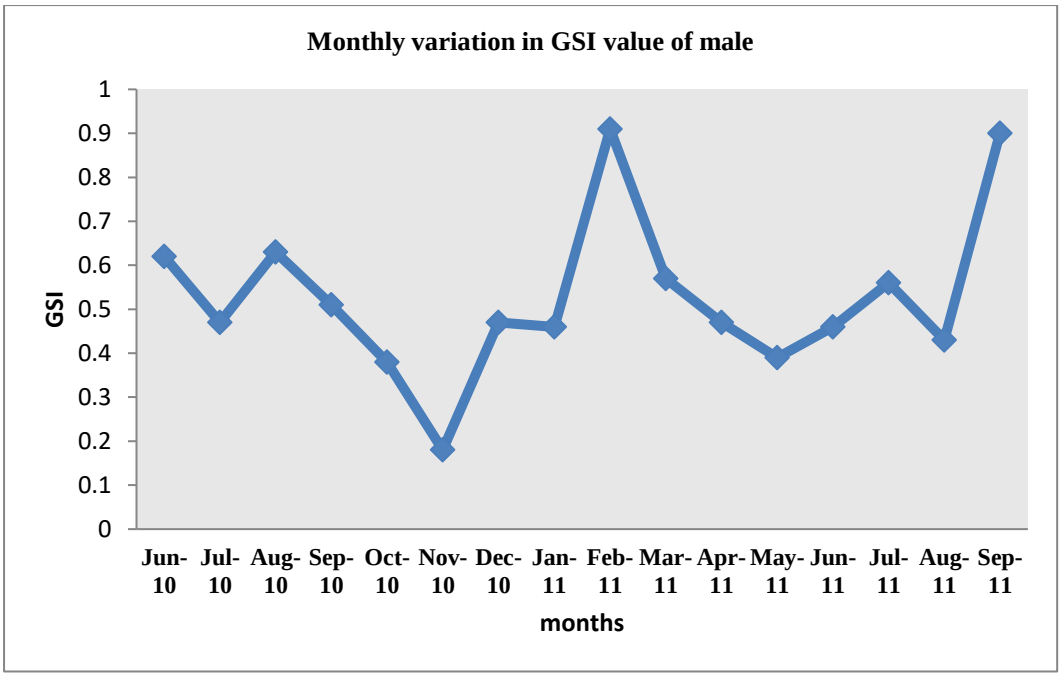


Fig8.8a: Variations in gonadosomatic index of male *P.ocellatus* during different months

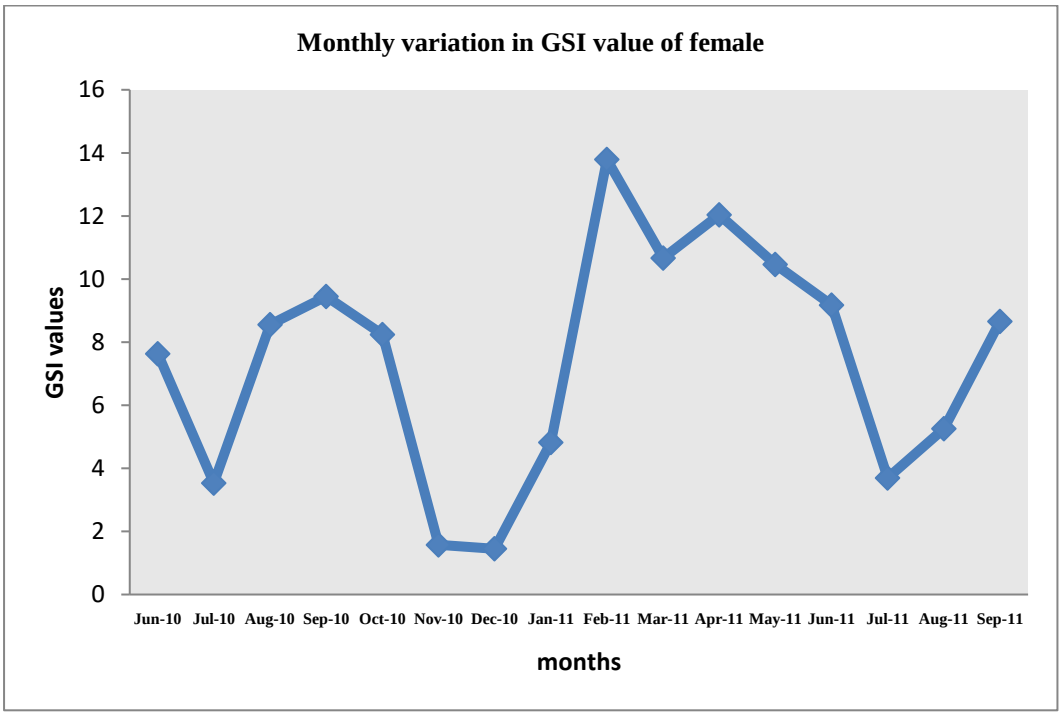


Fig 8.8b: Variation in gonadosomatic index of female *P.ocellatus* during different months

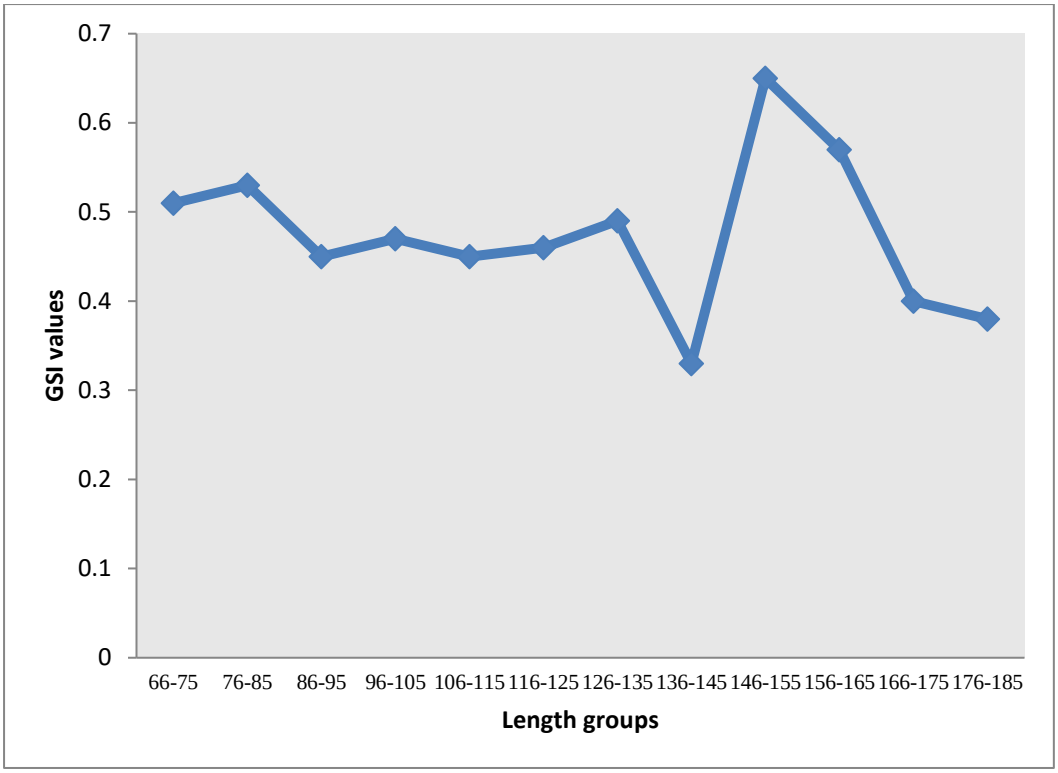


Fig 8.9a: Variation in gonadosomatic index of male *P.ocellatus* in different length groups

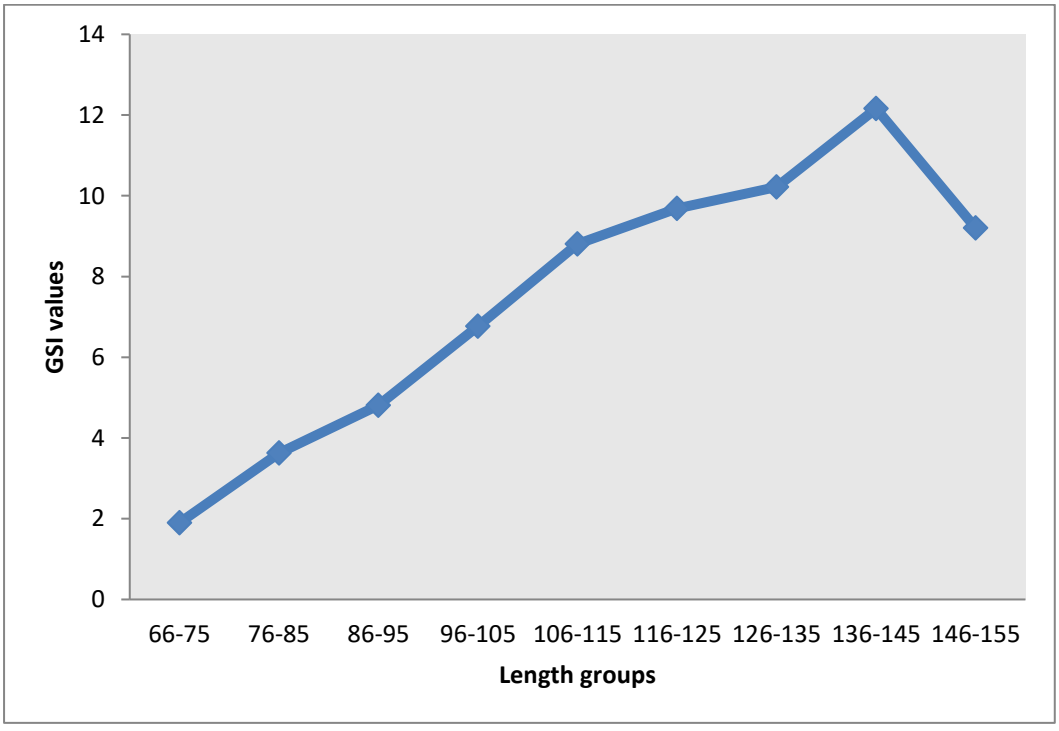


Fig 8.9b: Variation in gonadosomatic index of female *P.ocellatus* in different length groups

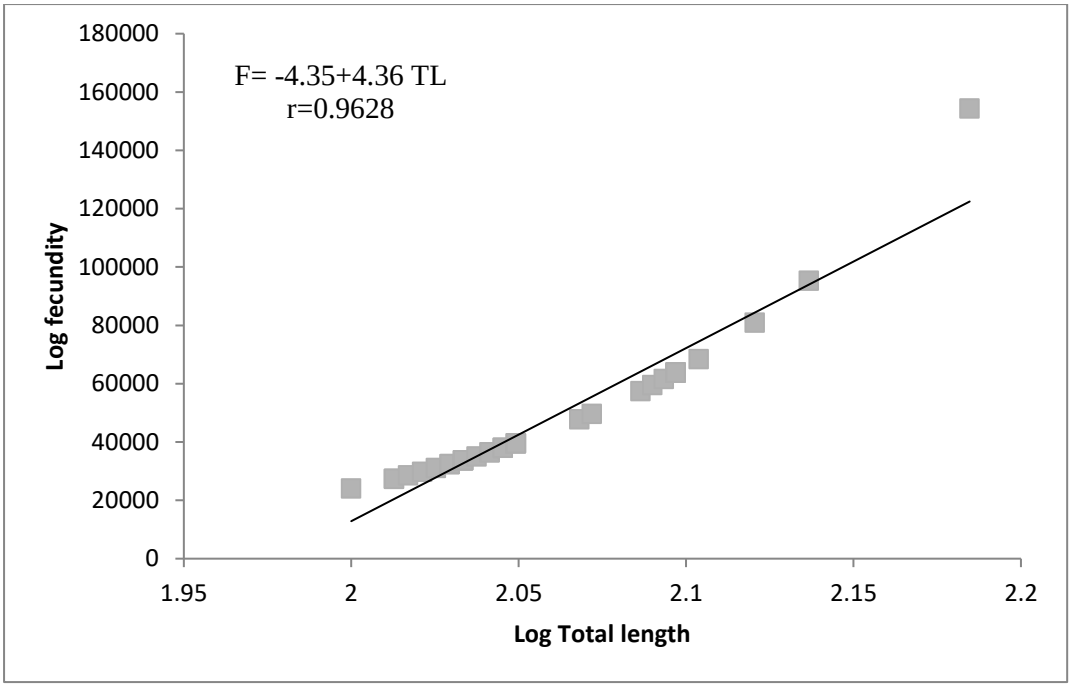


Fig8.10a: Fecundity in relation to total length in *P.ocellatus*

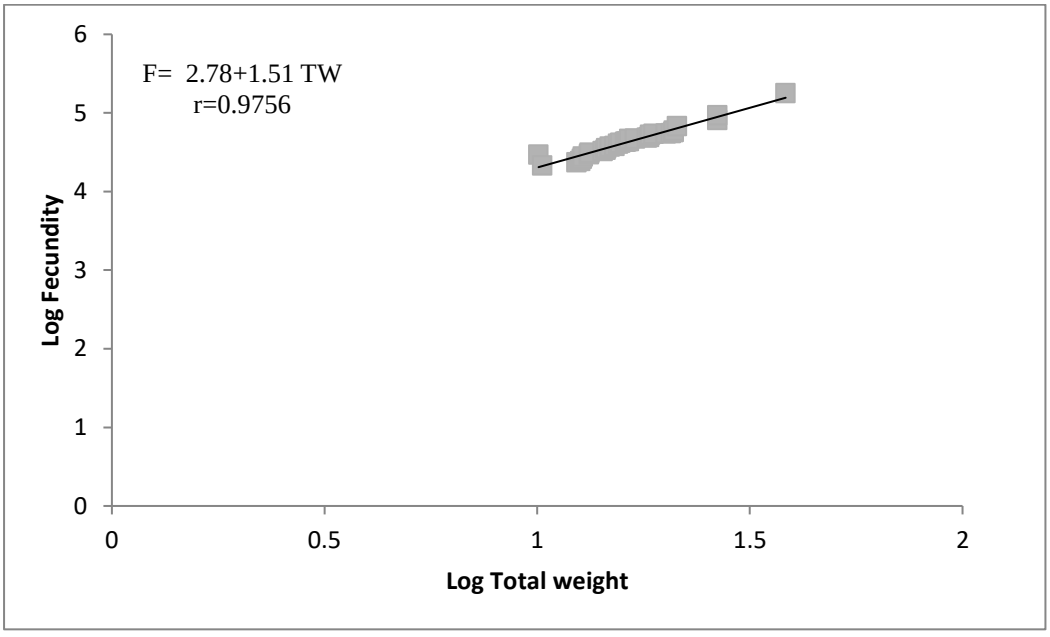


Fig 8.10b: Fecundity in relation to total weight in *P.ocellatus*

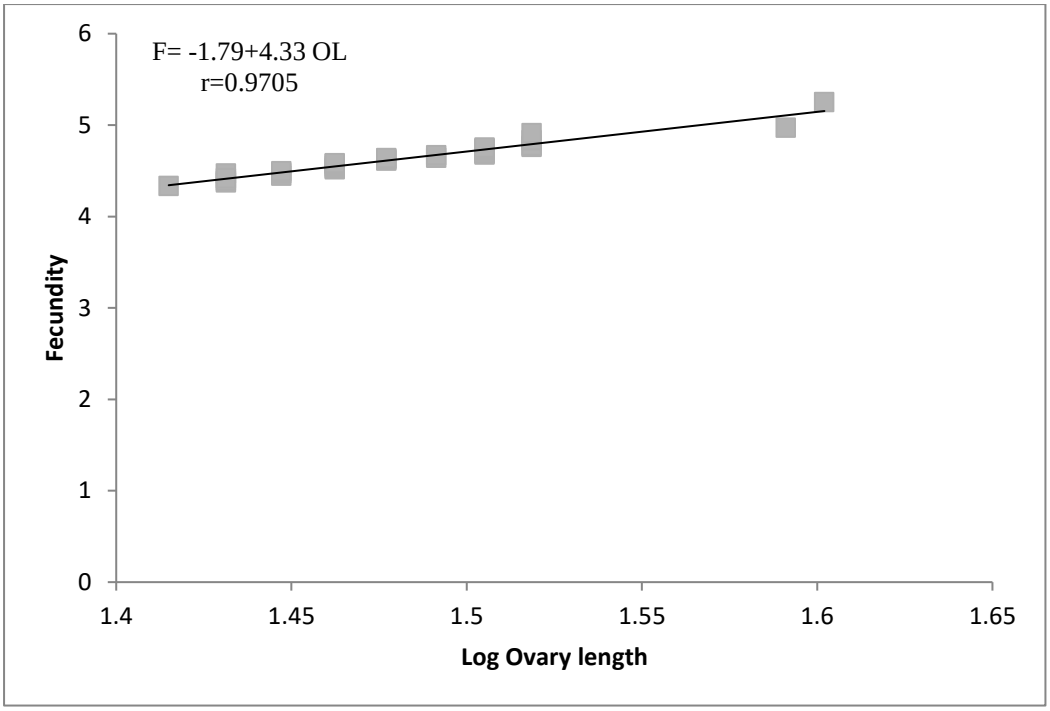


Fig 8.10c: Fecundity in relation to ovarian length in *P.ocellatus*

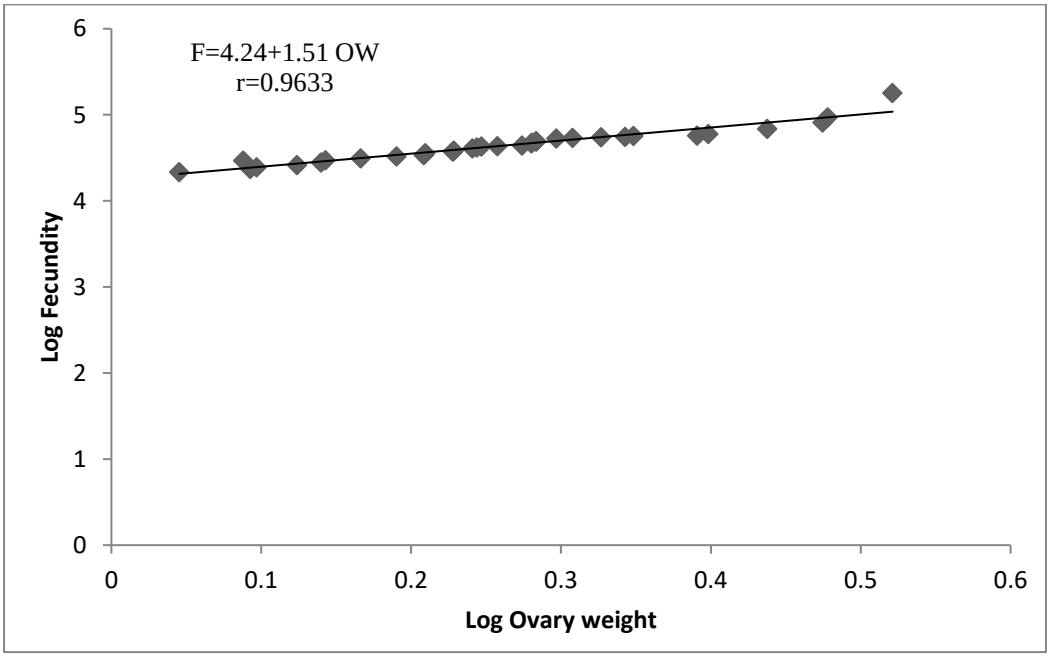


Fig 8.10d: Fecundity in relation to ovarian weight of *P.ocellatus*

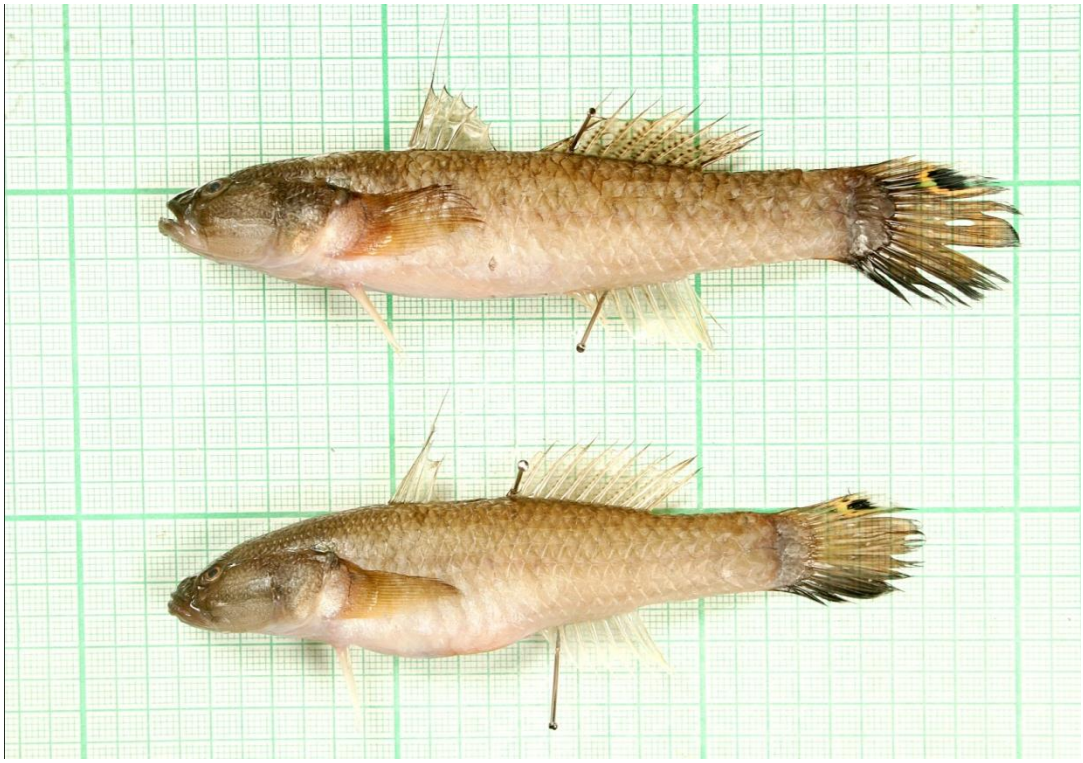


Plate 8.1: Male and female *Parachaeturichthys ocellatus*

Plate no.8.2: Male and female *Parachaeturichthys ocellatus* (ventral view)

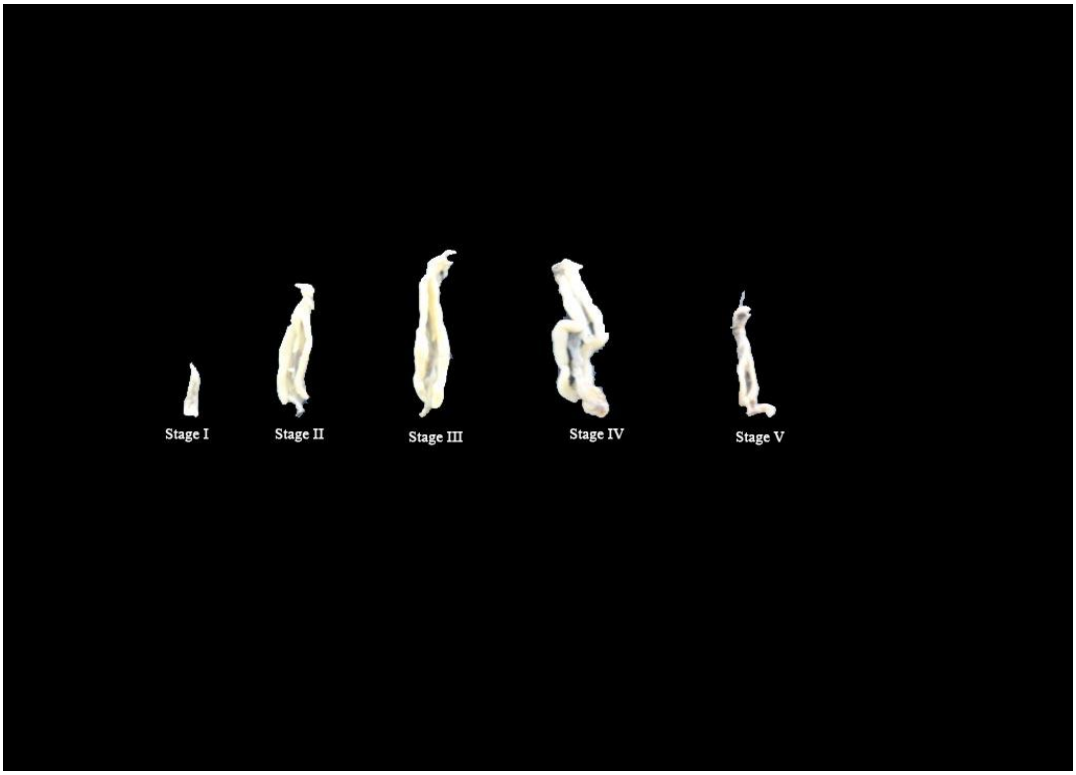


Plate 8.3: Male *P.ocellatus,* testes in different stages of maturity: StageI-Immature, Stage II-developing, Stage III-Mature, Stage IV-Ripe, StageV-Spent.

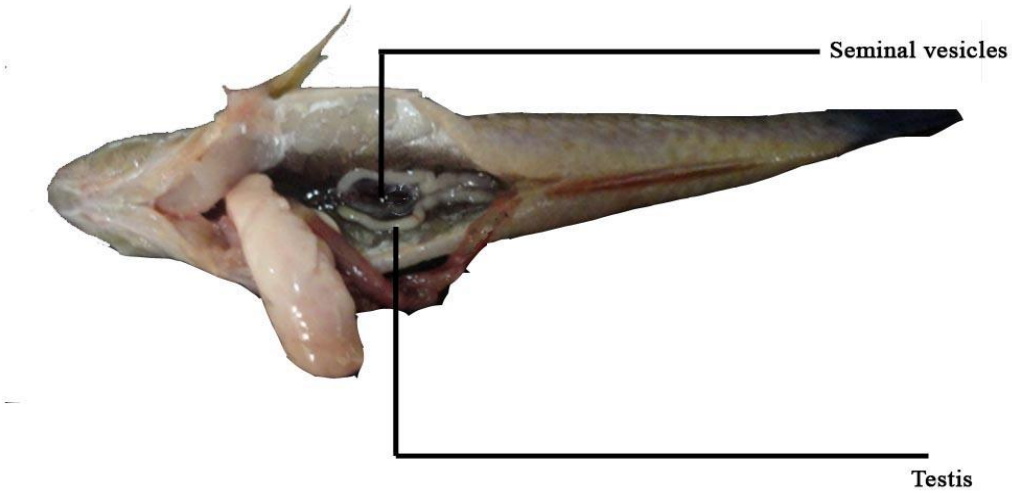


Plate 8.4: Male *P.ocellatus,* Testes in situ.

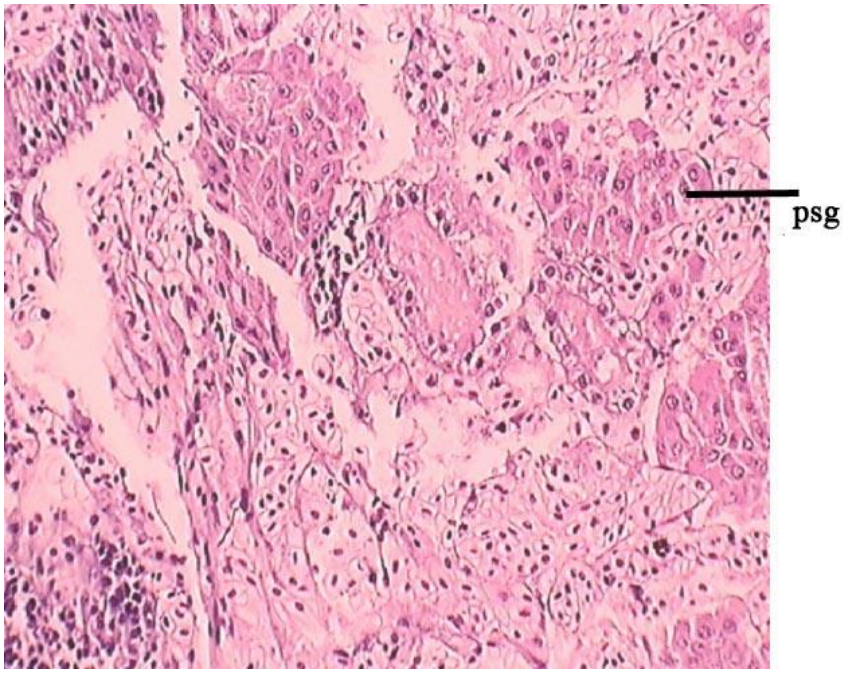


Plate 8.5a: Male *P.ocellatus*, C.S of testis showing stage I-Immature stage , H&E 10X

(Psg-Primary spermatogonia)

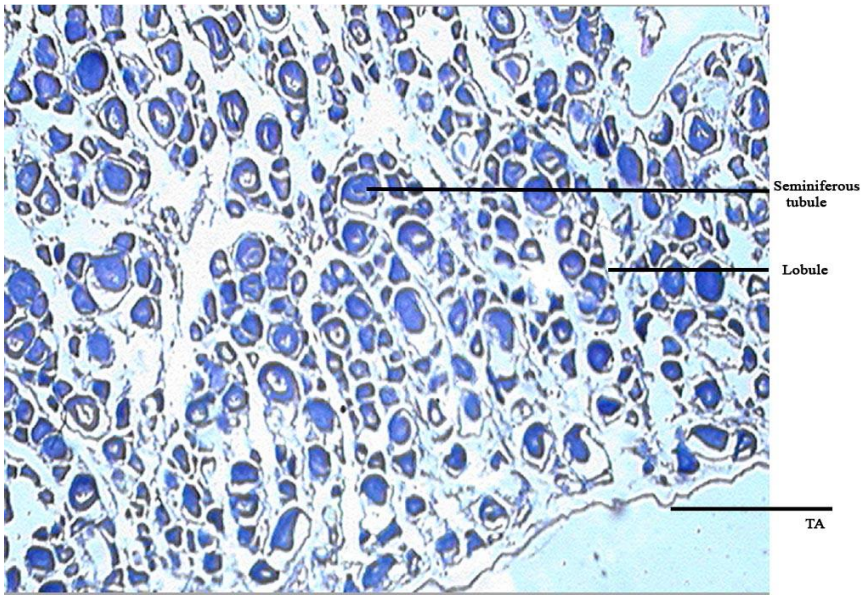


Plate 8.5b: Male *P.ocellatus*, C.S of Testis showing stage I-Immature stage , TB 10X

(TA-Tunica albuginea)

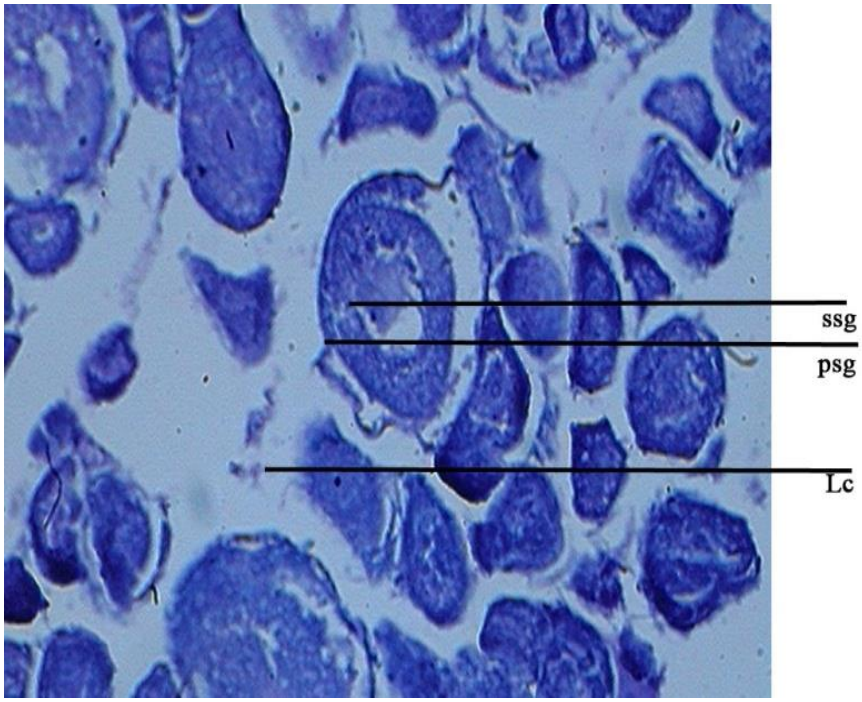


Plate 8.5c: Male *P.ocellatus*, C.S of Testis showing stageI-Immature stage , TB 40X

(ssg- secondary spermatogonia, psg- primary spermatogonia, Lc-Leydig cells)

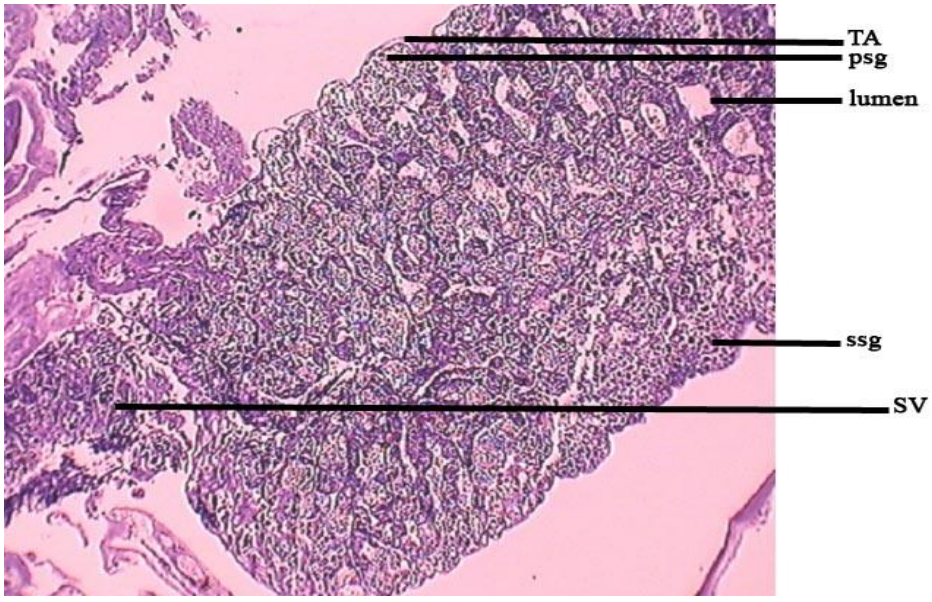


Plate 8.6a: Male *P.ocellatus*, C.S of Testis showing stage II-Developing stage, H&E 10X

(TA- Tunica albuginea, psg-primary spermatogonia, ssg-secondary spermatogonia, SV- seminal vesicles)

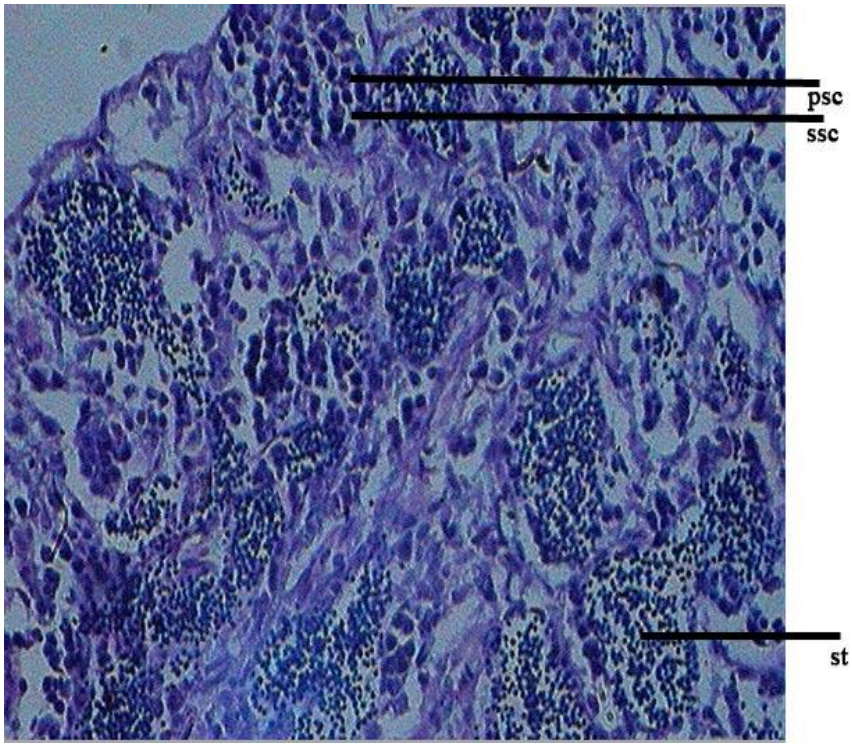


Plate 8.6b: Male *P.ocellatus*, C.S of Testis showing stage II-Developing stage, TB 10X (psc-primary spermatocyte, ssc- secondary spermatocyte, st-spermatids)

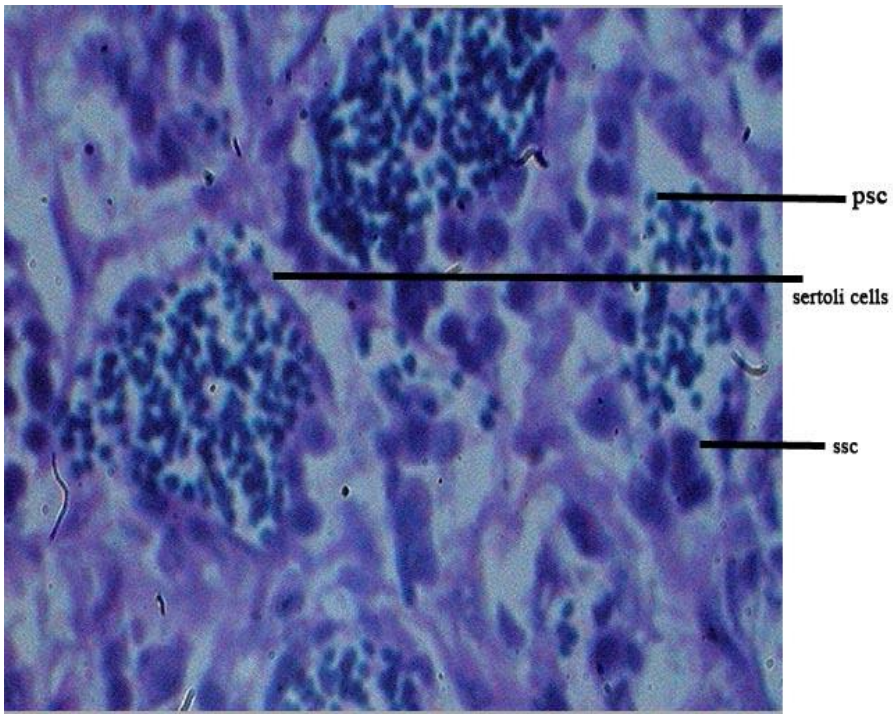


Plate 8.6c: Male *P.ocellatus*, C.S of Testis showing stage II-Developing stage, TB 40X (psc-primary spermatocyte, ssc-secondary spermatocyte)

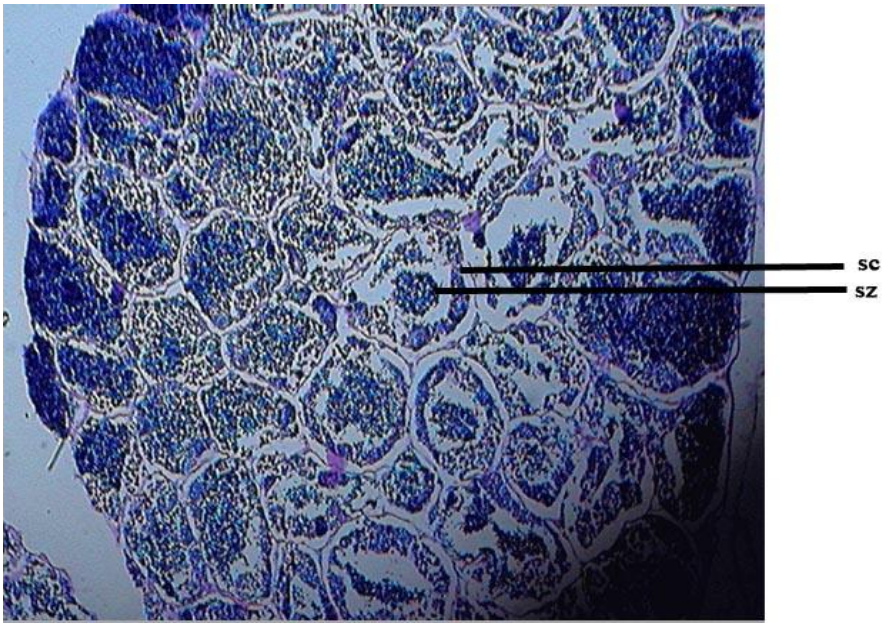


Plate no.8.7a: Male *P.ocellatus*, C.S of Testis showing stage III-Mature stage, TB 10X

(sc-spermatocyte, sz-spermatozoa)

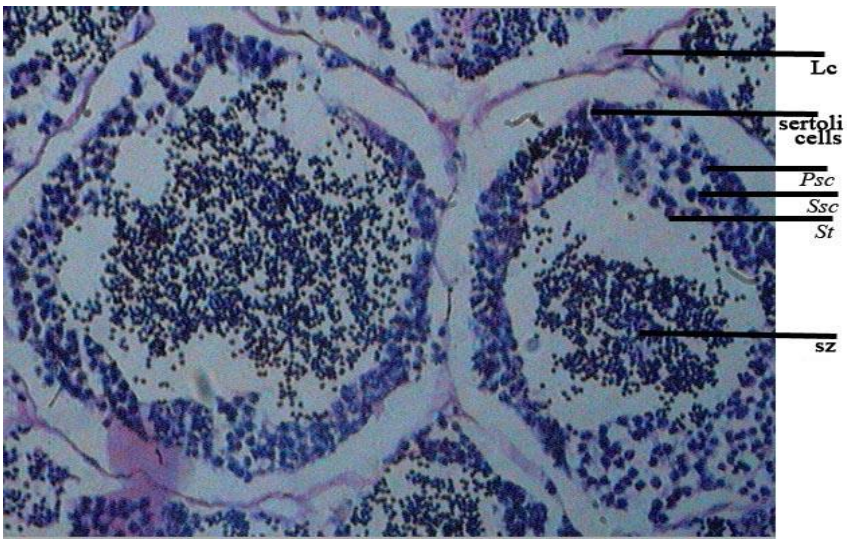


Plate 8.7b: Male *P.ocellatus*, C.S of Testis showing stageIII-Mature stage, TB 40X

(Lc-Leydig cell, psc-primary spermatocyte, ssc-secondaryspermatocyte, st-spermatids, sz-spermatozoa)

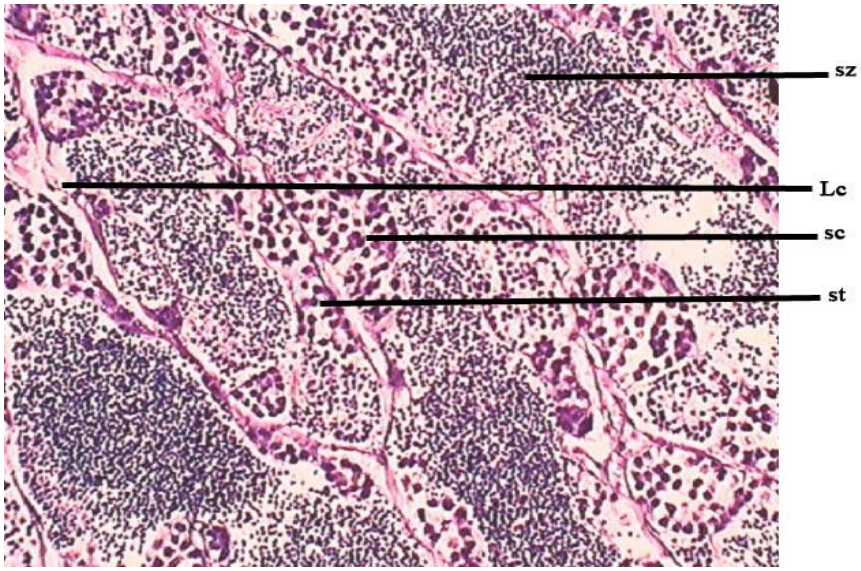


Plate 8.7c: Male *P.ocellatus*, C.S of Testis showing stageIII-Mature stage, H&E 40X

(sz-spermatozoa, Lc-Leydig cell, sc-spermatocyte, st-spermatids)

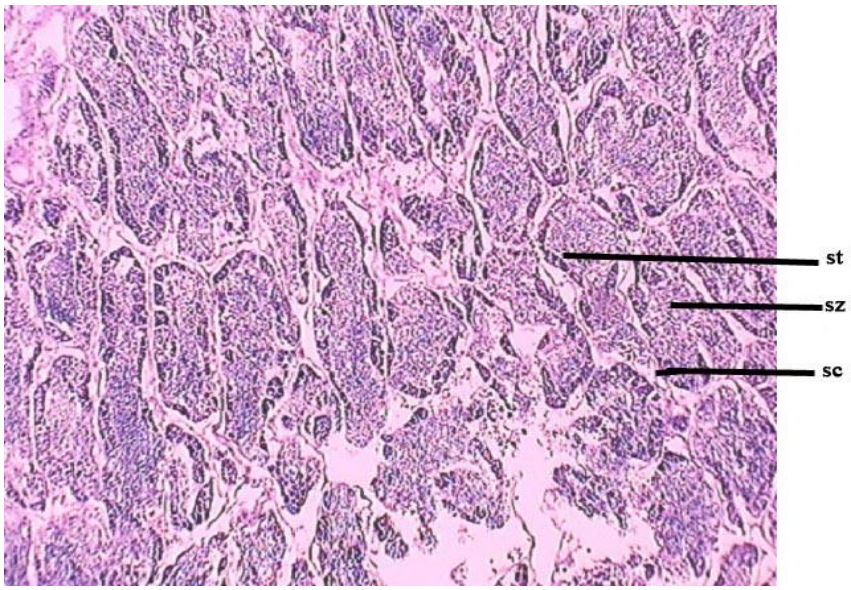


Plate 8.8a: Male *P.ocellatus*, C.S of Testis showing stageIV-Ripe stage, H&E 10X

(st-spermatids, sz-spermatozoa, sc-spermatocyte)

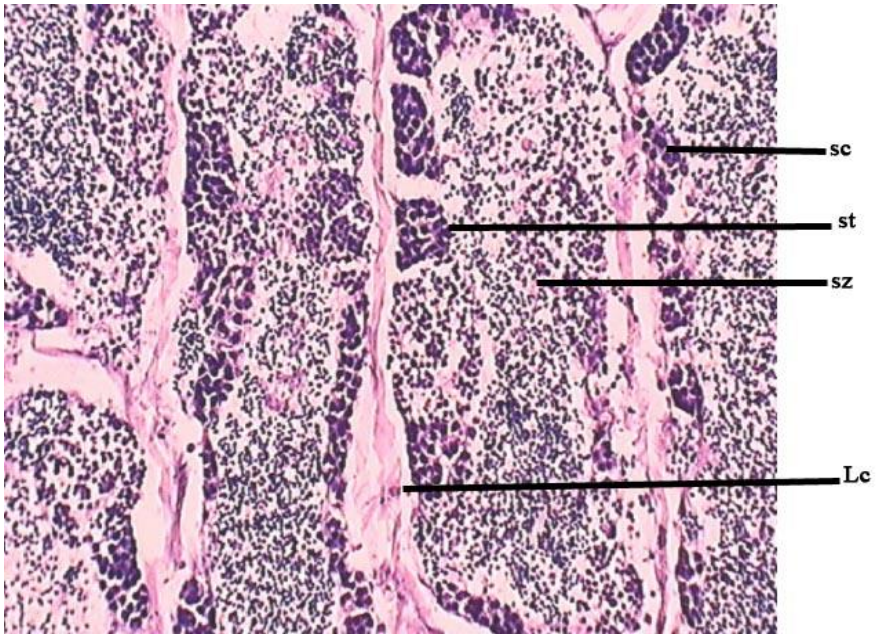


Plate 8.8b: Male *P.ocellatus*, C.S of Testis showing stageIV-Ripe stage, H&E 40X

(sc-spermatocytes, st-spermatids. sz-spermatozoa, Lc-Leydig cells)

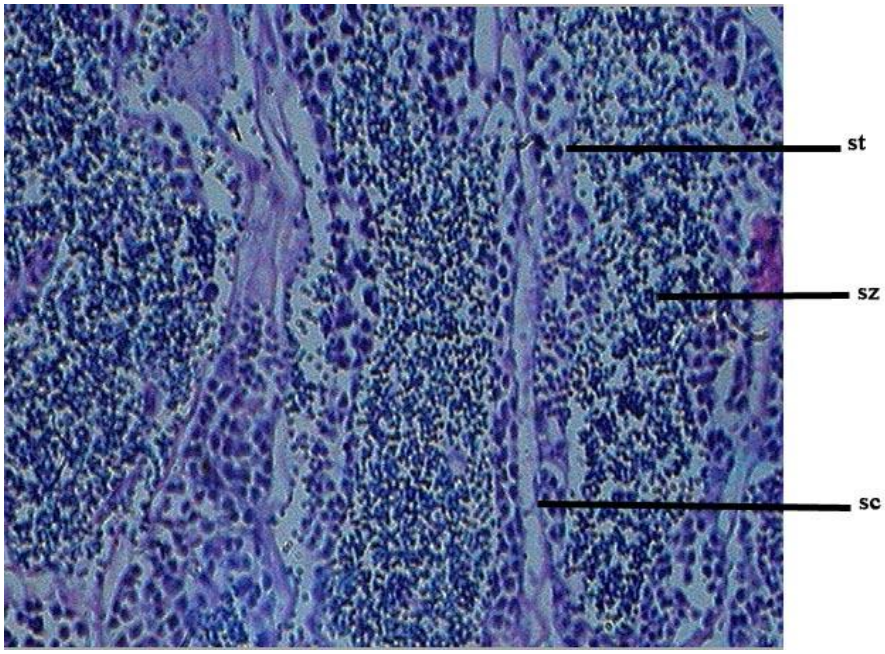


Plate 8.8c: Male *P.ocellatus*, C.S of Testis showing stageIV-Ripe stage, TB 40X

(st-spermatids, sz-spermatozoa, sc-spermatocyte)

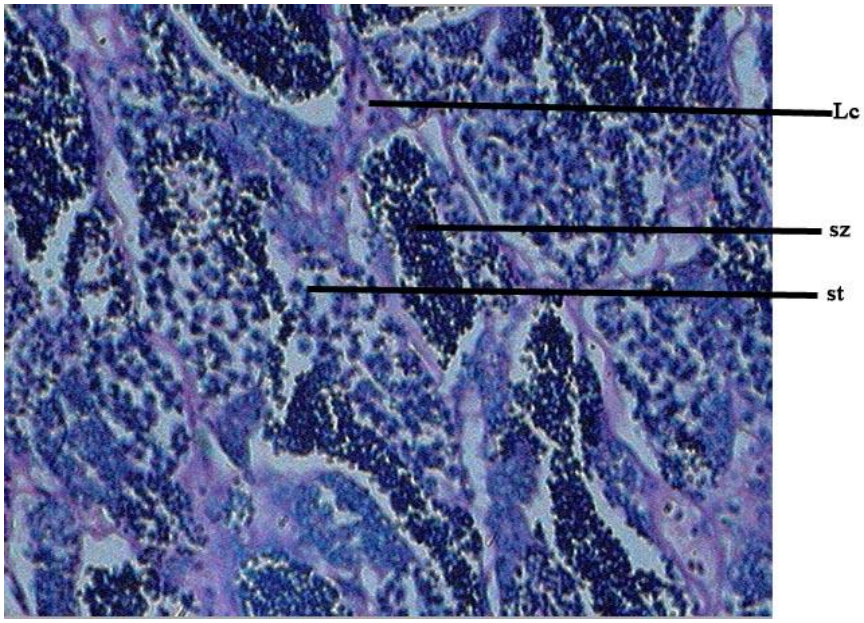


Plate 8.8d: Male *P.ocellatus*, C.S of Testis showing stageIV-Ripe stage, TB 40X

(Lc-Leydigcells, sz-spermatozoa, st-spermatids)

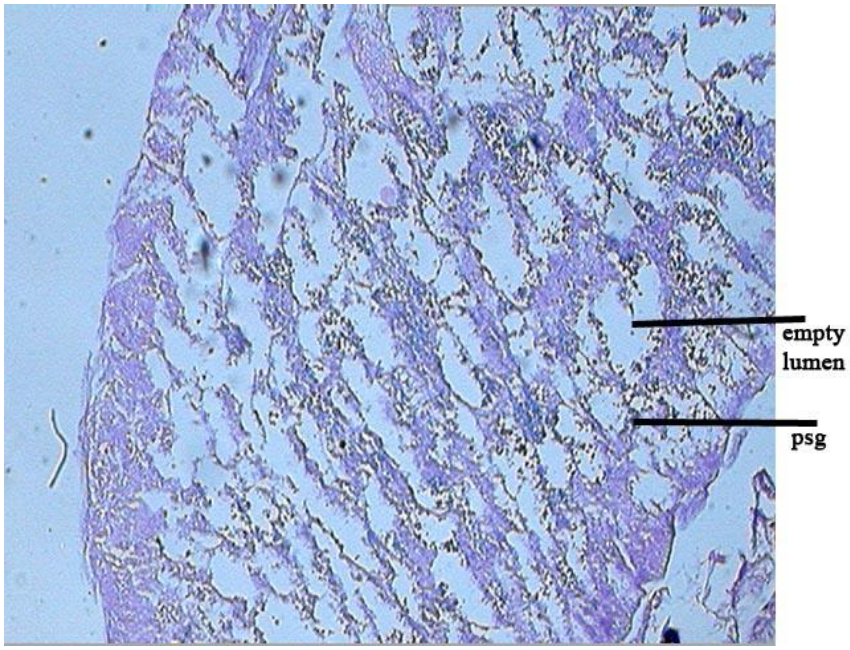


Plate 8.9a: Male *P.ocellatus*, C.S of testis showing stageV-Spent stage, TB 10X

(psg-primary spermatogonia)

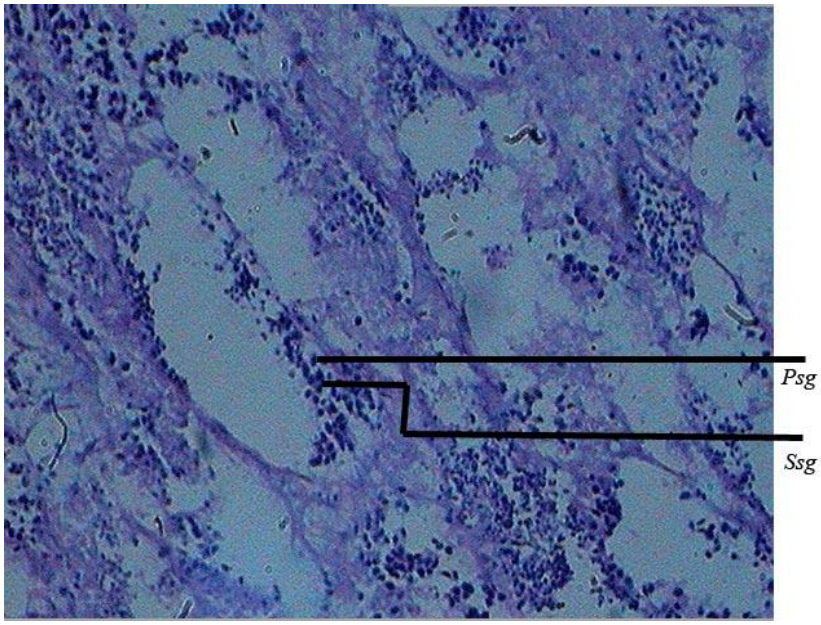


Plate 8.9b: Male *P.ocellatus*, C.S of testis showing stageV-Spent stage, TB 40X

(psg-primary spermatogonia, ssg-secondary spermatogonia)

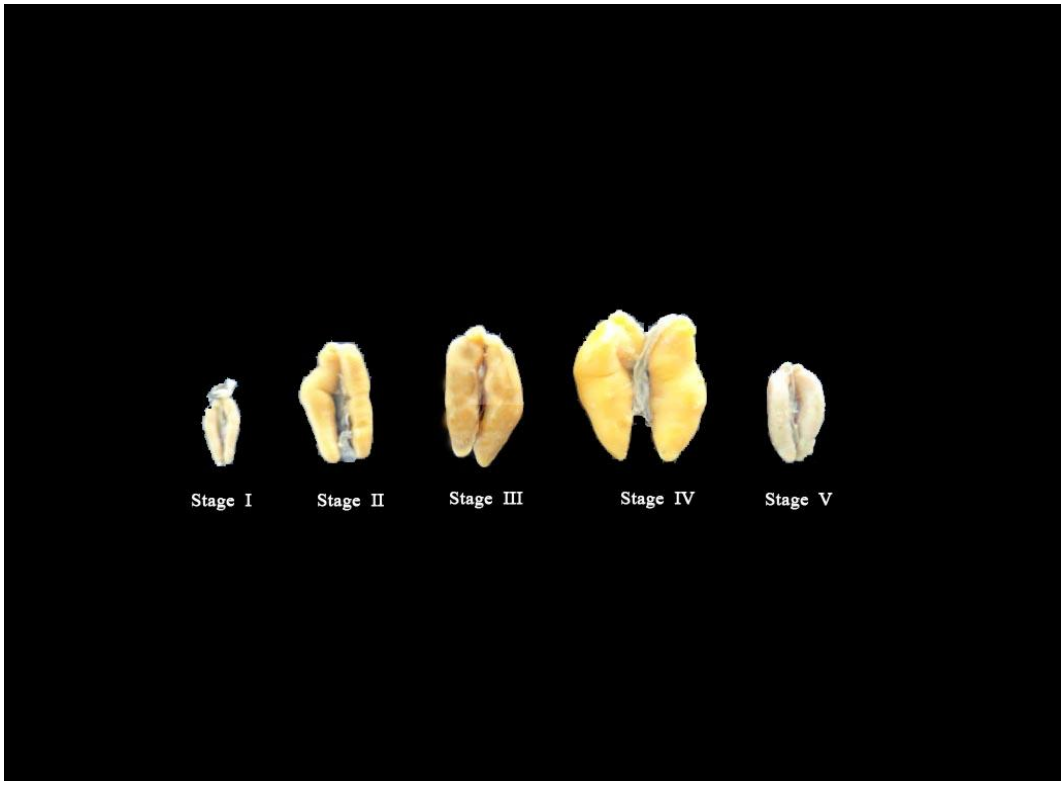


Plate 8.10: Female *P.ocellatus*, ovaries in different stages of maturity.

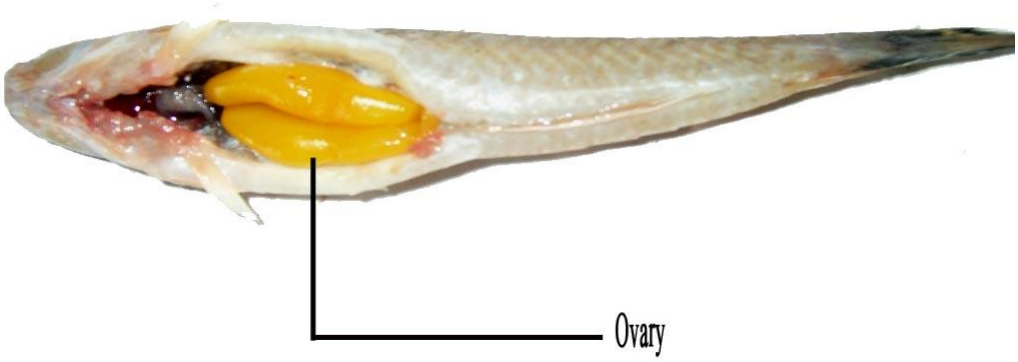


Plate 8.11: Female *P.ocellatus*, Mature ovaries in situ.

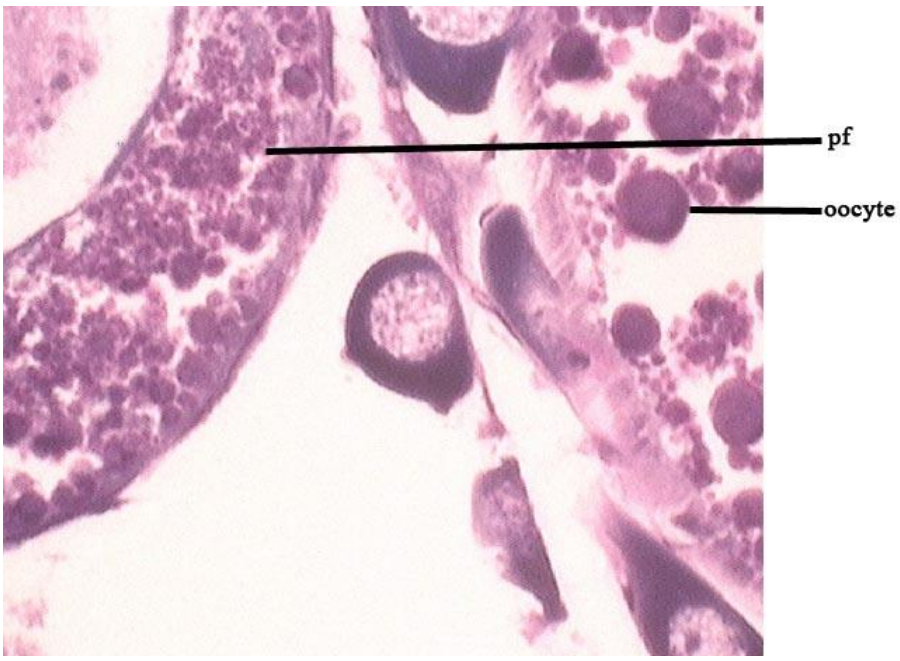


Plate 8.12a: Female *P.ocellatus*, C.S of ovary showing stage I, Immature stage, H&E 10X

(Pf-primary follicle)

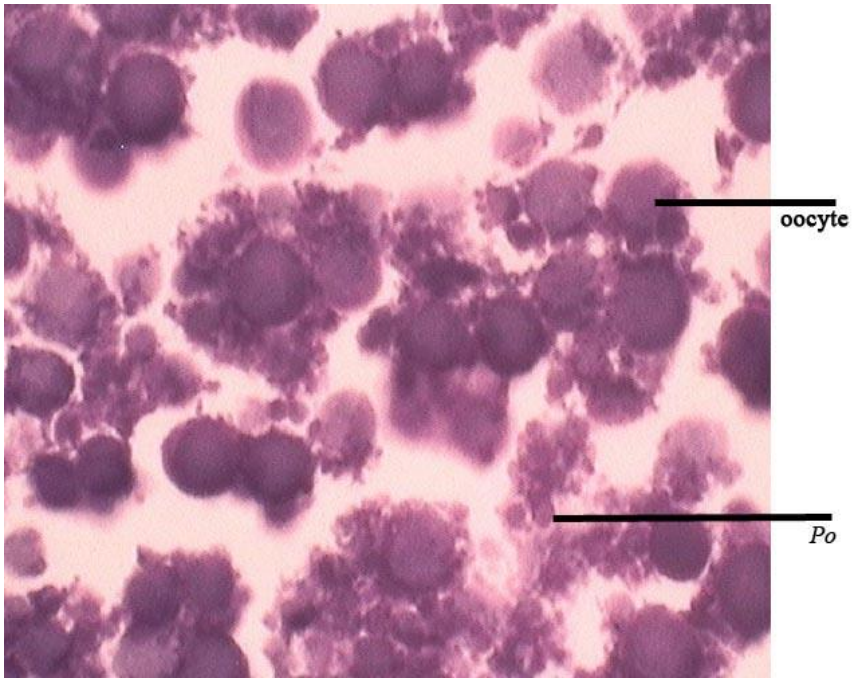


Plate 8.12b: Female *P.ocellatus*, C.S of ovary showing stage I, Immature stage, H&E 40X

(Po-primary oocyte)

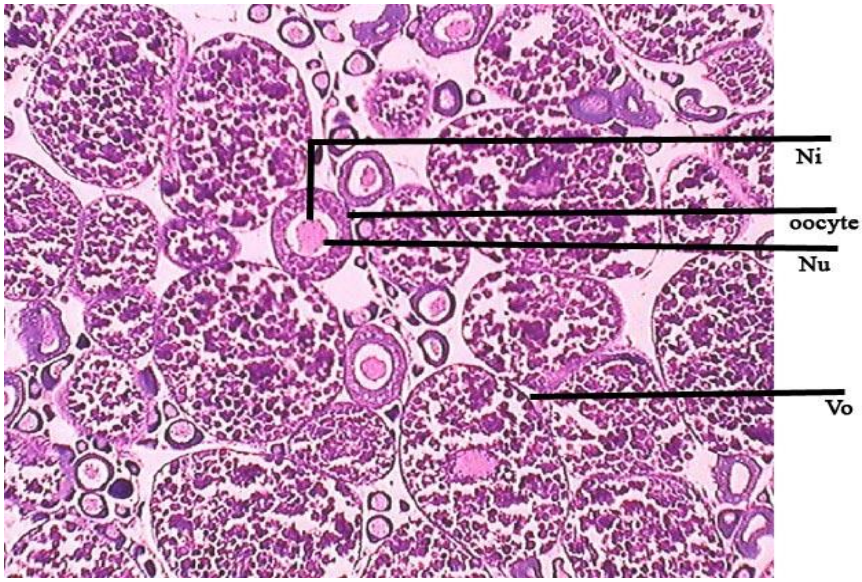


Plate 8.13a: Female *P.ocellatus*, C.S of ovary showing stage II, Developing stage, H&E 10X

(Ni-nucleoli, Nu-nucleus, Vo- Vitelline oocyte)

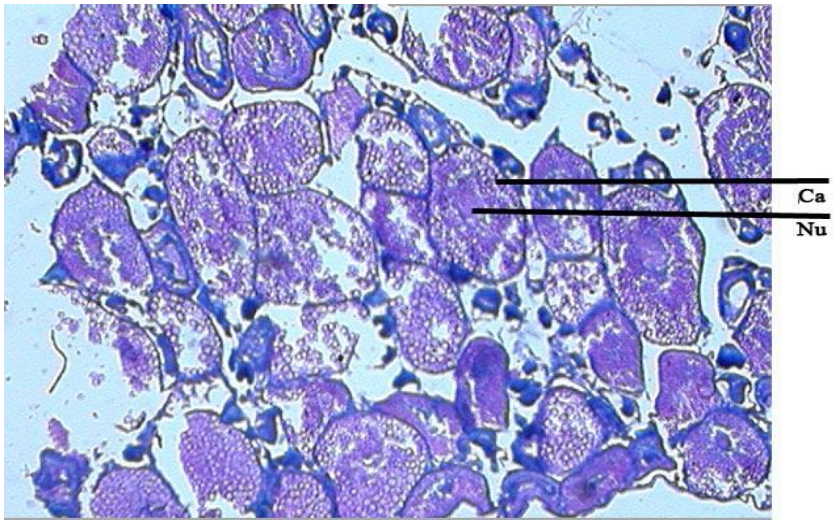


Plate 8.13b: Female *P.ocellatus*, C.S of ovary showing stage II, Developing stage, TB 10X

(Ca- Cortical alveoli, Nu-Nucleus)

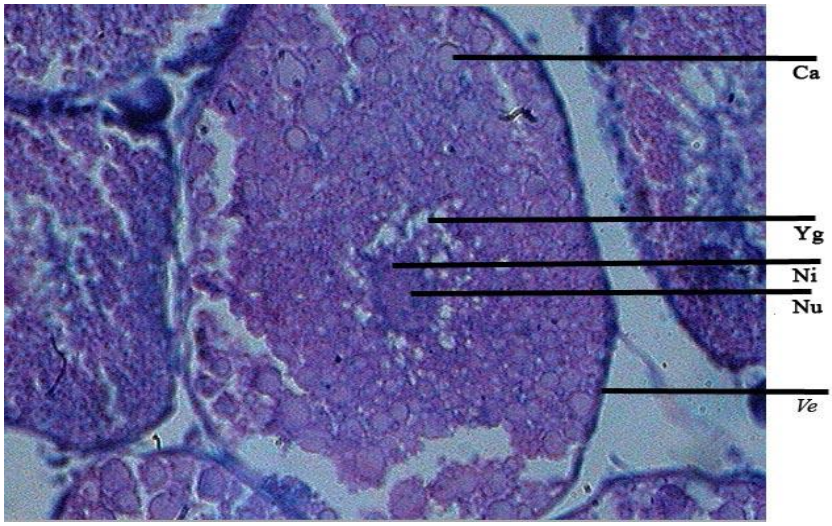


Plate 8.13c: Female *P.ocellatus*, C.S of ovary showing stage II, Developing stage, TB 10X

(Ca-Cortical alveoli, Yg-Yolk globules, Ni-Nucleoli, Nu-Nucleus, Ve- Vitelline envelope)

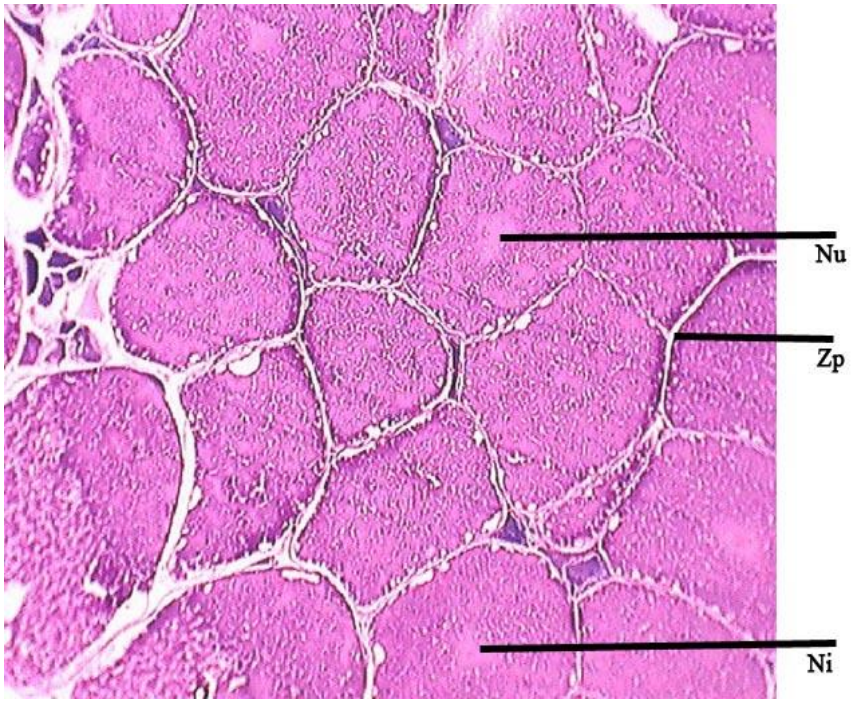


Plate 8.14a: Female *P.ocellatus*, C.S of ovary showing stage III, Mature stage H&E 10X

(Nu-Nuclues, Zp-Zona pellucida, Ni-Nucleoli)

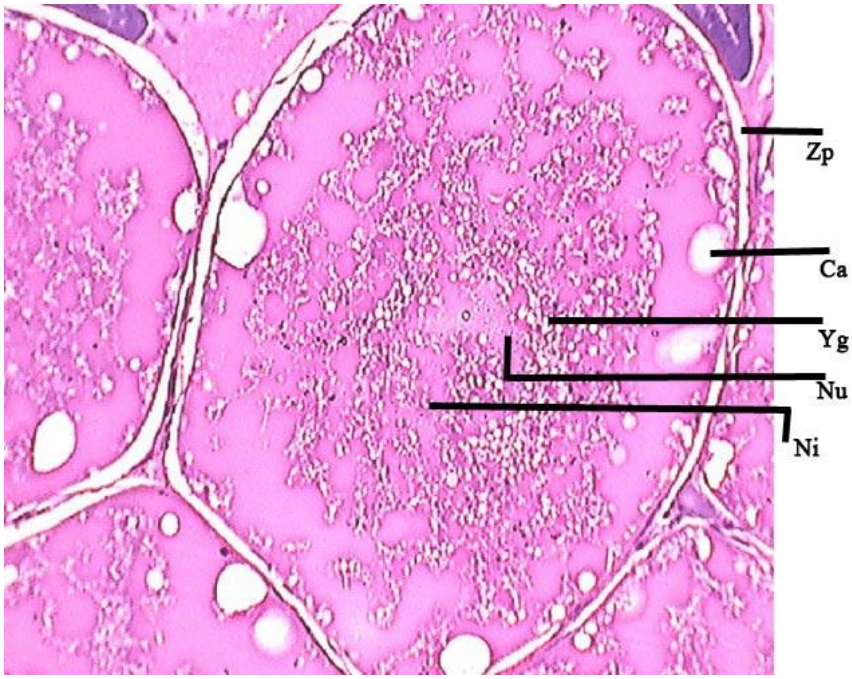


Plate 8.14b: Female *P.ocellatus*, C.S of ovary showing stage III, Mature stage H&E 40X

(Zp-Zona pellucida, Ca- Cortical alveoli, Yg- Yolk globules, Nu- Nucleus, Ni- Nucleoli)

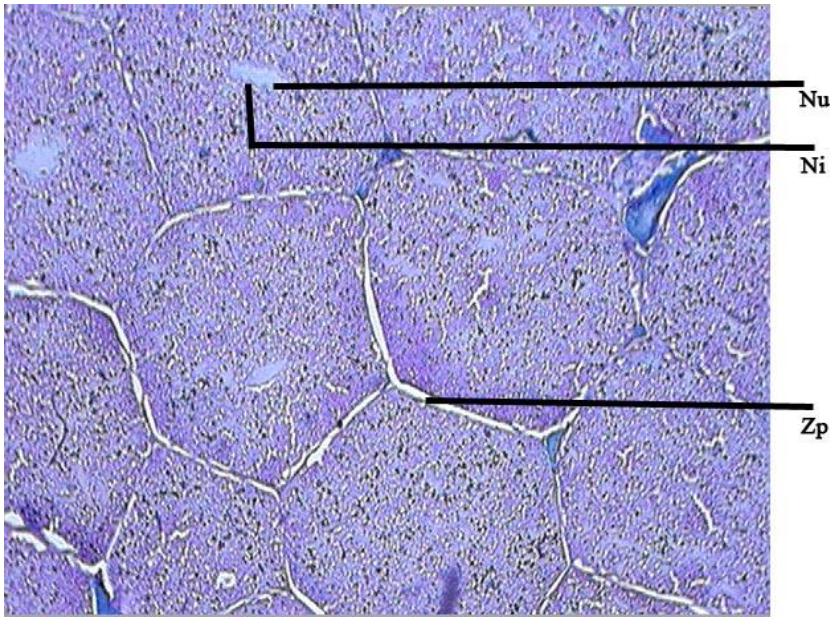


Plate 8.14c: Female *P.ocellatus*, C.S of ovary showing stage III, Mature stage TB 10X

(Nu-Nucleus, Ni-Nucleoli, Zp- Zona pellucida)

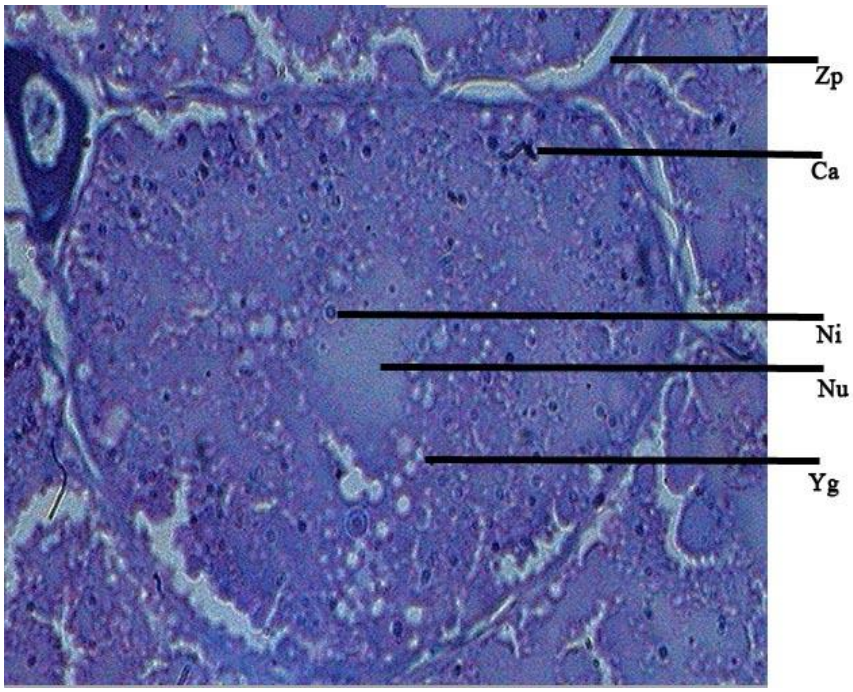


Plate 8.14d: Female *P.ocellatus*, C.S of ovary showing stage III, Mature stage TB 40X

(Zp- Zona pellucida, Ca- Cortical alveoli, Ni-Nucleoli, Nu- Nucleus, Yg- Yolk globule)

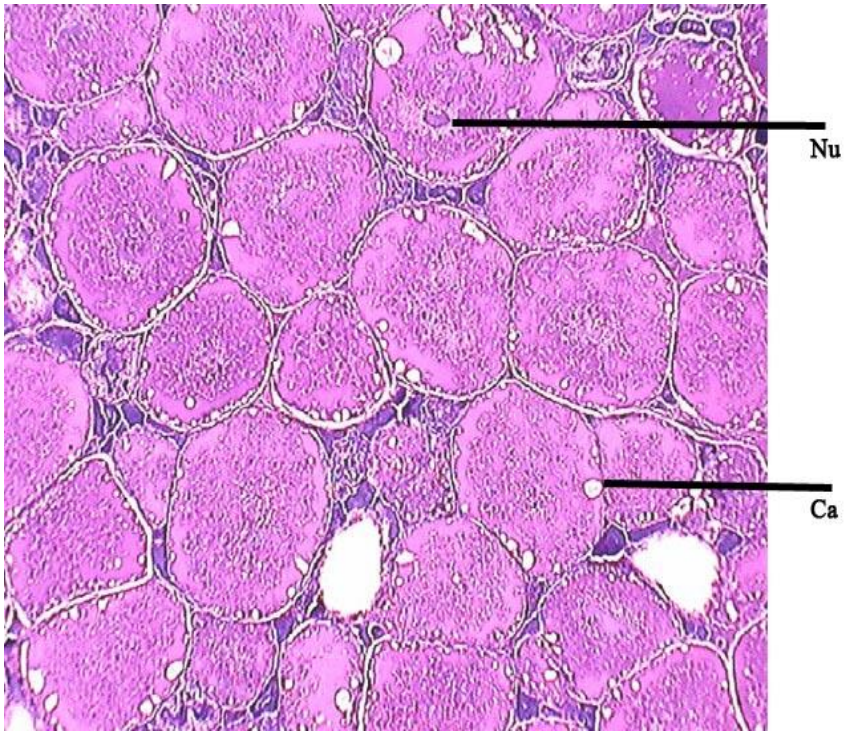


Plate 8.15a: Female *P.ocellatus*, C.S of ovary showing stage IV, Ripe stage H&E 10X

(Nu- Nucleus, Ca-Cortical alveoli)

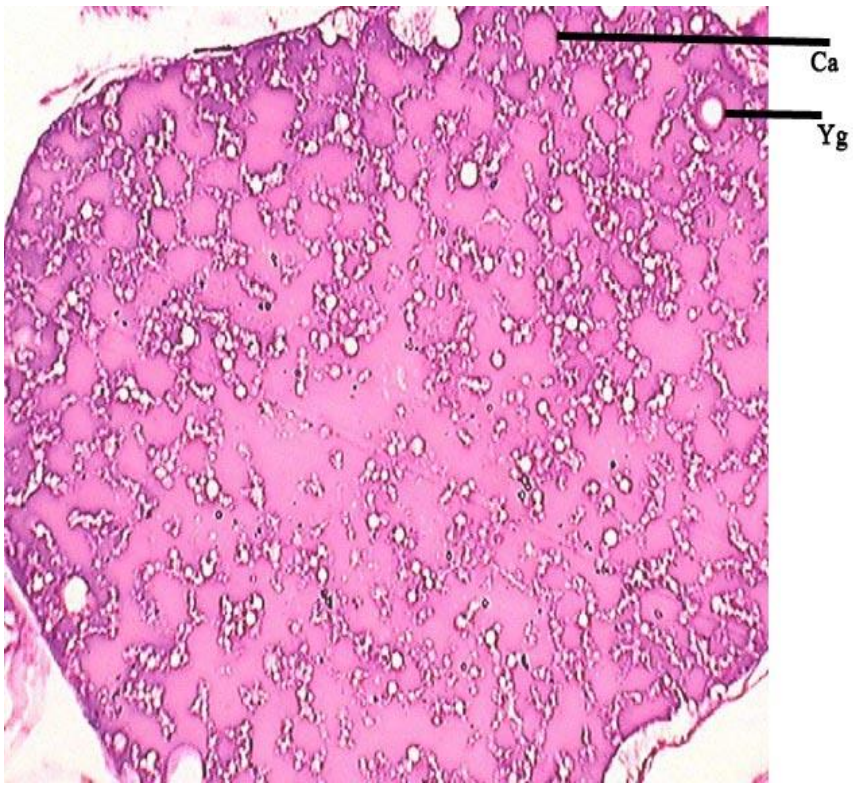


Plate 8.15b: Female *P.ocellatus*, C.S of ovary showing stage IV, Ripe stage H&E 40X

(Yg- Yolk globule)

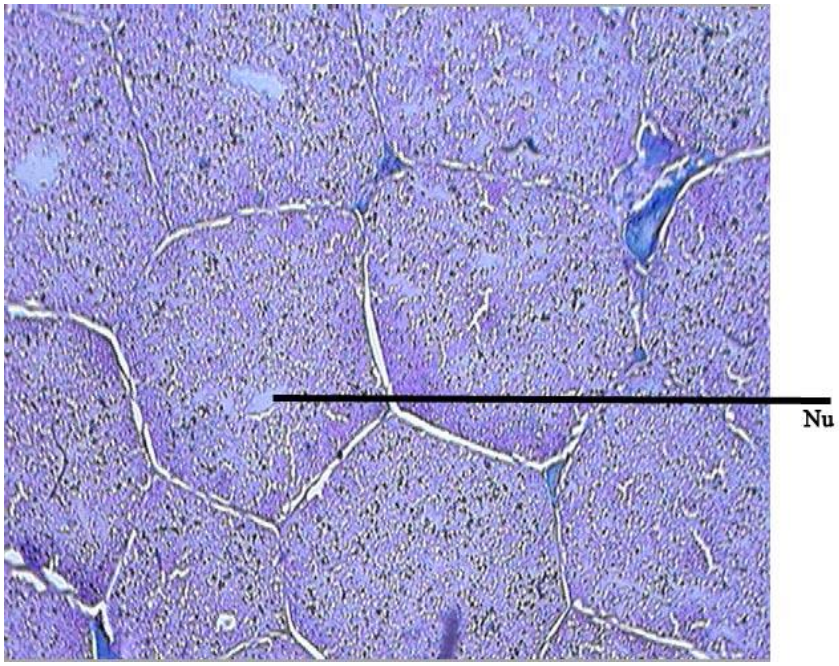


Plate 8.15c: Female *P.ocellatus*, C.S of ovary showing stage IV, Ripe stage TB 10X

(Nu-Nucleus)

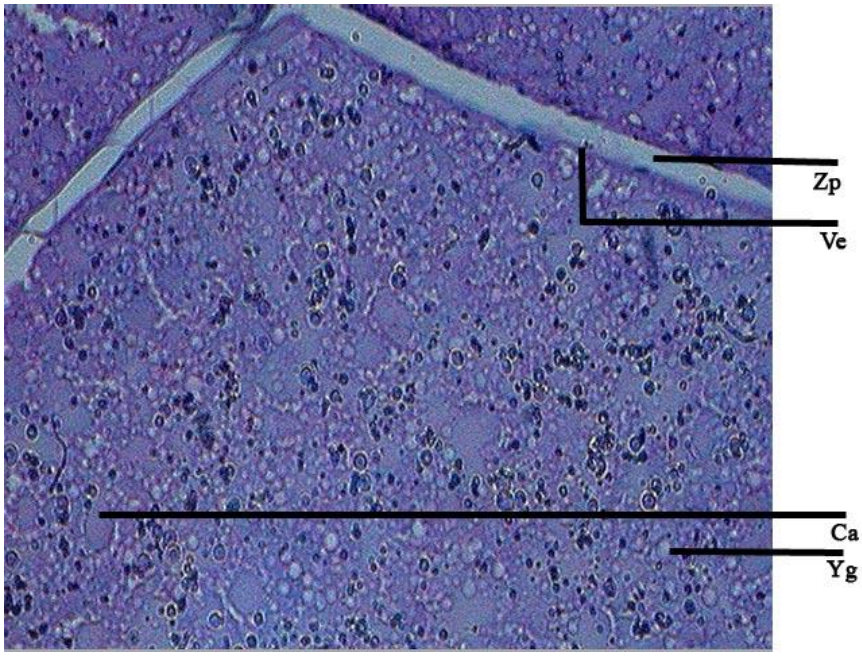


Plate 8.15d: Female *P.ocellatus*, C.S of ovary showing stage IV, Ripe stage TB 40X

(Zp-zona pellucida, Ve-vitelline envelope, ca- cortical alveoli, Yg- Yolk globule)

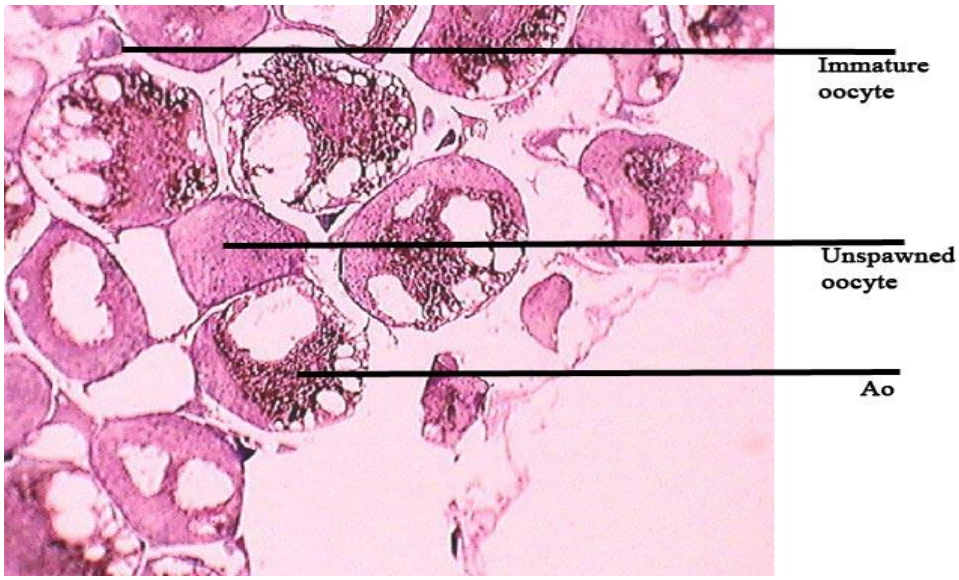


Plate 8.16a: Female *P.ocellatus*, C.S of ovary showing stage V, Spent stage H&E 10X

(Ao- Atretic oocyte)

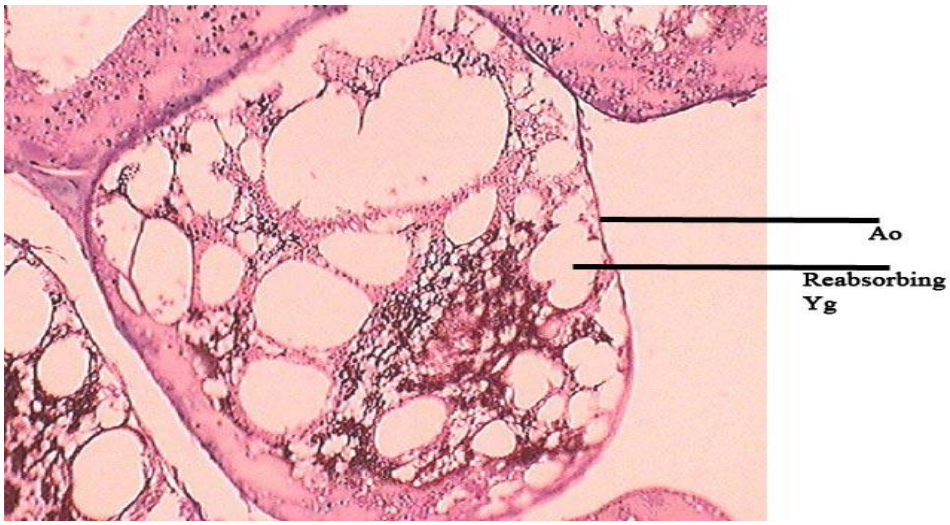


Plate 8.16b: Female *P.ocellatus*, C.S of ovary showing stage IV, Ripe stage H&E 40X

(Ao-Atretic oocyte, Yg- Yolk globule)

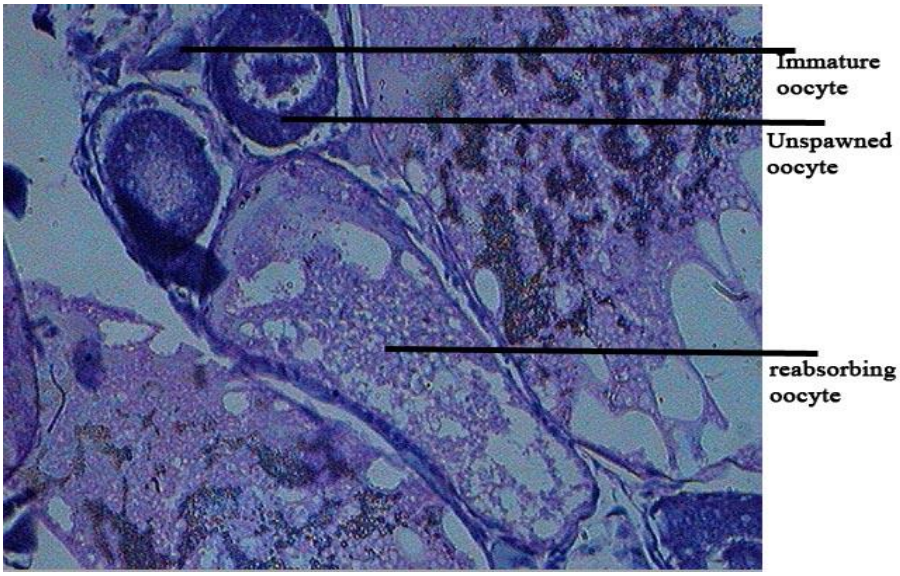


Plate 8.16c: Female *P.ocellatus,* C.S of ovary showing stage IV, Ripe stage TB 10X

8.5 Discussion

The reproductive aspects of biology studied in *P.ocellatus* like sexual dimorphism, sex ratio, stages of gonad maturity, spawning periodicity, length at first maturity, gonadosomatic index, fecundity, morphology and histology of gonads revealed that the reproduction was similar to that observed in most species of gobies by various researchers as reflected in the review of literature. Some aspects of reproduction are discussed below.

Sexual dimorphism

Sexual dimorphism has been observed in P.ocellatus which was prominent during the breeding season. Sexually dimorphic characters noted in *P.ocellatus* during the breeding season were colouration around the pelvic and anal fin, length of the body, depth of the abdomen, length of the second dorsal fin, shape and sturdiness of pectoral fin and pelvic fin, length and shape of urinogenital papillae. The characters like length of the second dorsal fin ray and sturdiness of the pectoral fin were observed throughout the period of study. In *P.ocellatus* males during the breeding season the region around pelvic and anal fins turned reddish in comparison to females. The body of male fish was longer and slender than that of female while the female body was deeper especially the abdomen than that of male. Dorado (2010) and Unito-Ceniza *et al.,* (2012) observed similar body shape in male and female *G. Giuris*.

The second dorsal fin ray of the male *P.ocellatus* was longer than that of the female. Gore (2007) observed in *Boleophthalmus boddaerti* that the first, the second, the third and the fourth dorsal fin rays of the male were longer than those of the female. In male *P.ocellatus* the fin rays of second dorsal fin had \ spots which were darker compared to those on the fin rays of the female fish. The pectoral fins of male *P.ocellatus* were larger and stronger than those of the females. In general the males appeared sturdier than the females. The urinogenital papillae of male *P.ocellatus* were straight, thin, long and pointed while in female they were rounded, short, and fleshy. Similar observations were recorded in urinogenital papillae of *Gobioides broussoneti* (Mata Cortes *et al* 2004), *Glossogobius giuris* (Doha, 1974; Rao and Rao, 2007) and *Boleophthalmus boddaerti* (Gore, 2007) while Gibson and Ezzi (1978) reported that in *Lesueurigobius triesii* the male papilla was slender and conical and reached back as far as the first anal fin ray whereas in females it was shorter broader and ended halfway between anus and first anal fin ray. The pelvic fins of male and female are fused together but the anterior end of joint fin in male fish exhibited bifurcation while in female the same was rounded. However the fish were not sexually dimorphic throughout the life span and prominent dimorphic characters were observed during February, March, April, August and September. During the remaining period the sexes had to be determined by observation of gonads. During maturation the testes were white in colour whereas of mature they were creamy white. The ovaries in female *P.ocellatus* were initially yellow in the maturing females and they turned deep orange in the mature state.

Sex ratio

Sex ratio indicates the proportion of male and female in the population and is expected to be 1:1. Any deviation from equilibrium may be considered to indicate the dominance of one sex over other in the population. The range of sex ratio recorded in the survey of literature carried out by the candidate was: 3.3M:1F in *Gobius niger* reported by Filiz and Togulga (2009) and 1:1.54, M:F in *Pomatochistus marmoratus* reported by Koutrakis and Tsikliras (2009). In the former the ratio was in favour of male dominance and the male fish were dominant in all ages, all months and all seasons (Filiz and Togulga, loc.cit.). Kader *et al*., (1988b), Miller (1961) and Wiley (1973) observed disproportionality in the number of males and females of *Gobiodes rubicundus*, *Gobius paganellus* and *Coryphopterus nicholsli* respectively. Male dominance was recorded

in *Glossogobius giuris* from Gosthani estuary (Rao and Rao, 2007) and *Bathygobius soporator* from Badagry creek (Lawson and Thomas, 2010). Female dominance in the spawning season has been reported in many gobiid fishes like Gobius niger (Nash, 1984), Gobius roulei (Kovacic, 2001), *Gobius vittatus* (Kovacic, 2007), *Gobius paganellus* (Engin and Seyhan, 2009), *Gobius rubicundus* (Kader *et al.,* 1988b), *Periophalmus papilion* (Lawson, 2010).

Deviation from the 1:1 occurrence of the number of male and female *P.ocellatus* during different months was observed. During the present study, the dominance of male or female in the overall sex ratio was evident depending upon season. The females dominated males in September, April, May and June 2011 while the males dominated in all the other months from June 2010 to September 2011.

In *P.ocellatus* the sex ratio fluctuated around 1:1 and did not deviate significantly at $p \leq 0.05$ during the months of August 2010 at 1:0.83, M: F; September 2010 at 1:1.09,M: F; December 2010 at 1:0.74, M: F; February 2011 at 1:0.76, M: F; March 2011 at 1:0.97, M: F and September 2011 at 1 :0.8, M: F. In February and March 2011 most of the fishes are reproductively mature. In all the remaining months the sex ratio seemed to deviate significantly from the expected ratio 1:1. In fish sex ratio varies considerably from species to species, from one population to another of the same species and from year to year in the same population (Nikolsky, 1963). The deviation from the normal 1:1 sex ratio might be due to differential fishing (Kesteven, 1942), differences in age and size at maturity (Reynolds, 1974), differential behaviour of sexes, differences in morphology and physiological activity (Baglin, 1982), through environmental conditions, (Bal and Rao, 1984) and partial segregation of mature fish through their habitat preference (Parrish *et al.,* 1986). In *P.ocellatus* the average sex ratio was 1:0.71, M: F which was a very narrow range and did not deviate significantly at $p \leq 0.05$. It would be interesting to study the reasons for the fluctuations in sex ratio vis a vis the male and female dominance which varied during different months of the year.

The length wise analysis showed near equilibrium in sex ratio in the length group 106-115mm at 1M:1.05F though a slight female dominance was observed. Female dominance was observed in the length groups of 126-135mm and 136-145mm. Males

dominated in all the other length groups whereas in the length group 156-185mm only males were prevalent. The occurrence of males among larger length group in *P.ocellatus* agrees with that of Nash (1982) in *Leseueurigobius frierii* and Kader *et al.,* (1988b) in *Gobioides rubicundus.* Differences in size specific sex ratio have been related to sexual differences in growth, mortality, energetic cost of reproduction and differential migration or spatial segregation (Sadovy and Shipro, 1987; Said *et al.,* 1994 Stergiou *et al.,* 1996) or even sex reversal (Said *et al* 1994). In present study the disparity in sex ratio was observed in various length groups and in general the male *P.ocellatus* tended to be longer and slender while females were shorter and broader.

Thus to conclude in the present study sexual dimorphism was observed prominently during months of August and September 2010, February, March, April, August and September 2011 especially with characters like colouration in male around the pelvic fin and anal fins, length of the second dorsal fin rays, shape and sturdiness of pectoral and pelvic fin length and shape of urinogenital papillae. In general *P.ocellatus* male tended to be longer and slender while females were shorterand had deeper abdomen. Though the near equilibrium of sex ratio was observed during the months from August, September, December 2010, February to June and September 2011 and in the length groups 106-115mm and 136-145mm, the females were slightly dominant in the population of *P.ocellatus* in the terms of sex ratio during the months of September 2010, April, May and June 2011 whereas the males dominated in the population in all the other months. In the length group 156-185 only male *P.ocellatus* were prevalent.

Spawning periodicity

Miller (1984) and Blaber (2000) stated that all gobies are multiple spawners, they breed for most of the year often in wet season. Spawning occurs at a time when environmental conditions are most favourable for larval survival and development.

In the present study of gonad maturity in *P.ocellatus*, the following stages were observed in each month of the study period: In the month of June 2010 mainly immature, developing and spent stages were observed; in July 2010 immature, developing and ripe stages were observed; in August 2010 all the four stages except spent stages were observed; in September 2010 all the five stages were observed; in

October 2010 except ripe all other stages were observed; in November and December 2010 only stage I and stage II were observed; in January 2011 immature, developing and mature stages were observed whereas in February and March 2011 developing, mature and ripe stages were predominantly observed; in April 2011 developing, mature, ripe and spent stages were observed; May 2011 was predominant with spent stages along with few immature and ripe stages; June 2011 also showed predominance of spent stages with immature and developing stages; from July 2011 to September 2011 all four stages like immature, developing, mature, ripe were observed with few spent stages in July 2011. Thus in *P.ocellatus* ripe males occurred in July, to September 2010 and from February to April 2011 and again from July to September 2011.

In females in June 2010 mature, ripe and spent stages were observed; in July 2010, immature, developing and mature stages were observed; in August 2010 immature, developing, mature and ripe stages were observed; in September 2010 developing, mature and ripe stages were observed; in October excepting immature all the other four stages were prevalent with maximum ripe stages; in November and December 2010 immature and developing stages were prevalent with few mature stages in December 2010; in January 2011 immature, developing and mature females were observed; in February 2011 mature and ripe stages were predominantly observed; in March and April 2011 mature, ripe and spent stages were predominant; in May 2011 only few ripe and maximum numbers of spent females were observed; in June 2011 all five stages were observed; in July 2011 immature, developing and ripe females were observed while in August and September 2011, developing, mature and ripe females were observed. Thus in females ripe stages occurred in June 2010, August to October 2010, February to June 2011 and again in August and September 2011.

This study suggests that spawning in *P.ocellatus* extends from June to October 2010 and again from January to September 2011 with the peak spawning occurring from February to April 2011. Report on the spawning periodicities in *P.ocellatus* could not be found during the survey of literature carried out by the candidate.

In the present study following stages of gonad maturity were observed in both male and female *P.ocellatus*: pre spawning stage consisting of immature and developing

gonads, spawning stage consisting of mature and ripe gonads and post spawning stage consisting of spent gonads. Pre spawning stages were observed in males from June 2010 and January 2011 and again from May to September 2011, Spawning stages in August and September 2010, February to May 2011 and again in August and September 2011. Post spawning stages were observed in June 2010, September and October 2010 and from April 2011 to July 2011. In females pre spawning was observed in July 2010, November 2010 to January 2010 and from June to August 2011, spawning stages in June 2010, August 2010 to October 2010, January 2011 to June 2011 and again in August 2011 and September 2011. Post spawning was observed in June and October 2010 and again from March to June 2011.

Pre spawning was predominantly observed from November 2010 to December 2010 in both male and female *P.ocellatus*. Spawning stages were predominant from February to April in both male and female while post spawning was predominantly observed from April to June 2011 while many of them were found in various stages of maturity in different months indicating that this species had a prolonged breeding season from June 2010 to September 2010 and again from January 2011 to September 2011. Thus it can be concluded that *P.ocellatus* breeds throughout the year except during November and December 2010 which appears to be a resting phase during reproductive cycle.

The ova diameter of *P.ocellatus* ranged in size from 0.01mm to 0.70mm. The range from 0.31-0.35mm included ova from developing, mature, and spent stages. The ova with diameter ranging from 0.50-0.70mm included only ripe ones. The maturing ova were found throughout the period of study except November and December 2010 whereas ripe ova ready to spawn occurred in maximum number during February and March 2011 and few occurred in August and September 2010.

The frequency polygon of ova diameter in different stages of maturity in *P.ocellatus* showed only one peak. A single peak in frequency polygon was also observed in all months except November and December. Hickling and Rutenberg (1936) propounded the theory that vital information regarding the spawning habits of fish may be obtained by the investigation of a mature ovary. According to them the number of peaks of ova in a frequency polygon in a mature ovary gives a clue to the number of spawning per

year. Measurement of ova diameter and their frequency polygon distribution at different times of the months in a year was a common method in determining the maturity cycle of the fish (Macer 1974). During the present study the frequency polygons of ova diameter showed a single peak in each stage suggesting that in *P.ocellatus* individual fish spawns once in the year. Similarly a single peak was obtained in the frequency polygon of ova diameter from June 2010 to May 2011. The frequency polygons in terms of monthwise stages of maturity indicate that in *P.ocellatus*, the individual fish may probably spawn only once in a year whereas the population as a whole may spawn throughout the year.

The size at first maturity primarily depends on environmental and genetic factors (Wootton, 1990) but can be influenced by other biological condition like parental care and predation (Abrams and Rowe, 1996). The size at which 50 percent i.e. L_{50} of the population of *P.ocellatus* mature in male was 91mm whereas in female was 94mm. Thus it can be observed that in *P.ocellatus* males attain sexual maturity at a smaller length group than the females Similar observation have been reported in few other species of gobies by Hoda (1986) in *Gobius pagnellus* L_{50} was 52mm for males and L_{50} for females was 55mm, Engin and Seyha (2009) in goby *Pseudocryptes elongates* L_{50} was 154mm in males and 163mm in females. This may indicate that after attaining maturation females allocate more energy for the production of gametes while males with smaller reproductive effort continue growing (Palazon Fernandz *et al.,* 2001). Bowering (1976) pointed out that differences in growth between sexes are the result of genetics that determine the physiology and behaviour of the fish.

Thus the spawning periodicity of *P.ocellatus* during the present study was found to extend from June 2010 to October 2010 and again from January 2011 to September 2011 with peak spawning from February to April while November and December appear to be resting period for reproductive activities. The frequency polygons had a single peak in each stage of maturity and as well as in each month indicating that for the population as a whole the breeding season extends throughout the year (except November and December) though an individual fish spawns only once during the breeding season. The data on maturity stages of male and female *P.ocellatus* and the size at which the population attains sexual maturity will be useful in fishery and aquaculture.

Gonadosomatic index (GSI)

GSI is the ratio of gonad weight to the body weight. The cycle of maturation and monthly variation of GSI are good indicators of the extent of development of gonad with respect to the time of year (Sebastian 2011). The GSI has been widely used as an indicator of the fish spawning period, but its use in reproductive biology is suitable when associated with other reproductive indicators such as macroscopic and histological studies especially in males, since differences in size and weight are less conspicuous than in females (Chaves, 1991).

In *P.ocellatus* in August 2010 high value of GSI was observed in both male and female fish. The lowest GSI was observed in November 2010 in both male and female fish. The GSI increased progressively from December 2010 to February 2011 with a maximum value in February 2011 in both male and female *P.ocellatus*. The GSI then decreased progressively till May 2011 in both male and female and then the GSI showed an upward trend in June 2011 and again in August 2011 with a dip in July 2011 in both the sexes. Low GSI values in November 2010 and May 2011 are concomitant with a period of early development of gonads when the fish are in a resting period during the gonadal cycle. Thus it can be concluded from the GSI values that *P.ocellatus* may probably breed thought out the year except November and December. The high GSI value from February to April indicates peak spawning which is in agreement with the maturity stages.

The female GSI was consistently higher than males. The consistently high GSI in female *P.ocellatus* probably point to the fact that most of the body reserves may be allocated for the development of ovary. Similar aspects are recorded in many gobiid fishes like *Gobius paganellus* (Miller, 1961), *Gobioides rubicundus* (Kader *et al.,* 1988b), *Boleopthalmus boddaerti* (Ravi, 2000; Gore, 2007), *Stenogobius gymnopomus* (Lekshmi *et al.,* 2010) and *Gobius paganellus* (Hajji *et al.,* 2012). Buxton (1990) pointed out that low value of GSI in case of male is due to low energy investment in gamete production as compared to the female.

The length group analysis of *P.ocellatus* showed that in the length group 136-145mm the GSI was maximum in both male and female indicating that the fishes in this length

groups may probably be in peak spawning stages. The decrease in GSI value of males in length group of 146-155mm could be corollary to the highest percentage (33%) of gonads in the spent stage. GSI value decreased in length groups of 156-165mm, 165-175mm and 175-185mm though the males in these length groups were reproductively ripe and mature. The females of length group 146-155mm also showed lower GSI which could be attributed to the spent stage observed in the ovaries of *P.ocellatus*.

It is interesting to note that the GSI values in both male and female *P.ocellatus* follow the same trend in different months. The minimum value of GSI in November 2010 and December 2010 agrees with the stages of gonad maturity that the fishes are in resting phase. Maximum GSI value for both male and female was observed in February 2011 which is in agreement with the stages of maturity indicating that maximum numbers of fishes were in peak spawning period. The drop in values of GSI in May 2011 indicates the termination of spawning season. The length wise analysis of GSI correlates well with the stages of maturity in female fish while in larger males the correlation between GSI and maturity stages is not so clearly observed. Thus the male *P.ocellatus* showed lower GSI values though they were in spawning stages. Thus it can be concluded in general that though high GSI is an indicator of spawning period, for predicting spawning period in *P.ocellatus*, GSI alone is not enough.

Fecundity

Fecundity is the most common measure of reproductive potential in fishes. Fecundity of the individual fish is determined from the total number of mature ova that are destined to be shed at the ensuing spawning season. Marked differences in fecundity among species reflect different reproductive strategies (Pitcher and Hart, 1982; Wootton, 1984; Murua and Saborido-Rey, 2003). Within a given species fecundity may vary as a result of different adaptation to environmental habitat (Witthames *et al,* 1995). Fecundity of any species of fish depends not only upon the size and age of the fish but also on the size of the egg. Fishes that produce larger eggs are generally less fecund than those producing smaller eggs (Tyler and Sumpter, 1996).

The fecundity of gobiids varies widely among and within species ranging from less than 100 eggs in *Eviota lacrimae* to over 500000 eggs in *Awous guamensis* (Ha and

Kinzie, 1996). Many factors complicate the interpretation of fecundity data, especially in relation to the investment of energy. The numbers of eggs produced by the female fishes are dependent on various factors like size, age, condition and type of species (Lagler *et al.,* 1967). Williams (1975) argues that highly fecund fishes are capable of rapidly adjusting their populations to environmental changes. The fishes which are more vulnerable to predation produce more number of eggs (Borek and Sapota, 2005).

The number of mature ova in the ovaries of female *P.ocellatus* during the present study from June 2010 to September 2011 ranged between 21,635-1,79,334 eggs with a mean of 48,973 eggs. In *P.ocellatus* the fecundity of the largest sized fish with total length of 153mm and weight 38.383g was 1,79,334 while in the smallest mature female with length 100 mm and weight 10.072g the fecundity was 29,547. The variation in fecundity was observed in *P.ocellatus* having the same/identical length. A fish of length 108 mm and weight 14.259 was found to have 32,930 eggs while another fish of same length and weight of 14.822 was found to have 37,600 eggs. Similar variation also occurred in the fish with length 125mm where the fecundity was 55,709 and 59,292 eggs. Variation in fecundity of the fish in the same length indicates that fecundity may not necessarily dependent only on the length of the fish. The variations in fecundity also occur due to body weight, length and weight of gonads as reported in *Lepturacanthus savala* (Kader *et al*., 1982), *Hilsa ilisha* (Akter *et al.,* 2007), *Channa gachua* (Gaikwad *et al.,* 2009), *Sillaginopsis panijus* (Islam *et al.,* 2012).

In *P.ocellatus,* the fecundity showed a fairly linear relationship with total length, total weight, ovary length and ovary weight. The positive linear relationship between fecundity and various body parameters was observed by many workers in goby fishes like *Boleophthalmus dussumeiri* (Mutsaddi, 1964), *Glossogobius giuris* (Rao & Rao, 2007), *Stenogobius gymnopomus* (Lekshmi *et al,* 2010).

The exponential value of *P.ocellatus* in relation to fecundity and TL was observed to be 4.3671 indicating that fecundity increases at a rate above the fourth power of TL. The t-test on ‘b’ value revealed that it deviated significantly from the value of ‘3’. The exponential value of fecundity and TW was 1.5195 indicating that fecundity increases at a rate above 1.5 times the TW of the fish and ‘b’ deviated significantly from ‘1’. Similarly the exponential value of fecundity and ovarian length was 4.3385 which

deviated significantly from the value of ‘3’ and that of fecundity and ovarian weight was 1.5182 which deviated significantly from ’1’.

The coefficient of correlation of fecundity with TL, TW, OL, and OW revealed highly significant relationship. The fecundity was correlated with total weight at value of ‘r’ at 0.9756 followed by ovarian length of ‘r’ at 0.9705, ovarian weight of ‘r’ at 0.9633 and total length of ‘r’ at 0.9628. This was similar to the findings in *Glossogobius giuris from* Bangladesh (Nabi *et al.,* 2007). Mutsaddi (1964) reported that weight of the fish, rather than the total length was more reliable factor to estimate fecundity of *Boleophthamus dussumeiri* and Gore (2007) also reported that weight of ovary in *Boleophthalmus boddaerti* was most suitable and reliable method to estimate fecundity. Assessment of fecundity has paramount importance in fisheries management as it provides knowledge about the number of offspring produced in a season and the reproductive capacity of the species (Qasim and Qayyum, 1963).

Thus *P.ocellatus* was found to be highly fecund fish with large range of fecundity. The relationship between fecundity and total length, total weight, ovarian length and ovarian weight showed a straight line. The fecundity was highly correlated with total weight followed by ovarian length, ovarian weight and total length. The results of present study will be helpful in determining the fecundity of *P.ocellatus* from the morphometric external characters like length and weight of the fish and thereby help in deriving estimates on fecundity without actually sacrificing the fish.

Morphology and histology of gonads

Spawning as an activity of reproductive biology signifies beginning of new generation of fish population. This requires a long term strategic planning in the fish involving coordination of all the biological activities diverted towards reproduction especially development of gonads and gametes. The development of gonads in fish involves changes in its morphological, histological and biochemical parameters. The changes, the gonads undergo from immaturity to ripe stage leading to spawning, have been a subject of study for many a biologists.

In the present study of gonad development in *P.ocellatus* a general pattern similar to many teleost fishes was observed. A five point maturity scale for gonads laid by International council for exploration of sea (Lovern and Wood, 1937) for gonads as been accepted as a standard, The same has been described by Jayashankar (1991b). This scale is ideal for most tropical spawners and was used by many authors like Belsare (1962), Qasim (1973a) and Nunez and Duponchelle (2009) to classify stages of development in both male and female fishes. For the present study the above mentioned five points scale has been used to understand the phases of maturation of gonads in *P.ocellatus*.

Gonads and accessory organs in male *P.ocellatus*

The gonads and accessory organs in a mature fish consist of pair of testes, seminal vesicles, sperm ducts and genital papillae. The changes in morphology and histology of these organs reflect on the various stages of maturity leading to reproductive activities. In fact many of these changes occur in a cyclic manner.

The creamy white pair of testes in *P.ocellatus* was narrow, elongated and tubular. Each of the testis continued into sperm ducts; the two sperm ducts joined towards the posterior end to form a common duct which opened at the terminal end into the genital papillae. There was a pair of accessory reproductive organ called seminal vesicles. The seminal vesicles appeared as paired organ and were in late stages usually much larger than the testis. At maturity the vesicles showed the presence of vesicular fluid. In some species like *Gobius cobitis* and *Bathygobius fiscus* similar findings were recorded while in *Buenia jeffreysii* and *Acentrogobius cyanomu*s seminal vesicles were smaller than testis (Fishelson, 1991). The seminal vesicles of *P.ocellatus* were glandular structures lined by cuboidal epithelium.

The testes of male *P.ocellatus* showed regular changes in the testicular cycle with spermatogenic activity. Histological studies showed that the testis was covered by tunical albuginea internally. There were numerous lobules in testis which were separated by conective tissue in which were dispersed the Leydig cells. Each lobule contained numerous seminiferous tubules which showed the presence of germs cells in different stages of developmentment namely: primary spermatogina, secondary

spermatogonia, primary spermatocytes, secondary spermatocytes, spermatids and spermatozoa.

The following five stages of maturity of the gonads and accessory reproductive organs were identified based on morphological and histological observations during the gonadal cycle. They can be seen in the photographs/plates.

Stage-I: Immature gonads and accessory reproductive organs

In *P.ocellatus* the paired white testes were thread like and thin. Seminal vesicles were not apparant in this stage. In the histological preparation primary and secondary spermatogonia could be observed around the periphery of seminiferous tubule. No spermatogenic activity could be observed. The lumen was narrow and clear. A few spermatocytes could be seen in the late stages.

Stage-II: Developing gonads and accessory reproductive organs

In this stage the testes appeared as thick and white paired structures. A pair of seminal vesicles was seen reaching more than half of the length of the testes. The histological preparation showed seminiferous tubule with spermatogonia around the periphery while large number of primary and secondary spermatocytes occurred towards the inner margins. Spermatids were attached to Sertoli cells and few spermatozoa could be seen in the lumen of the tubule.

Stage III Mature gonads and accessory reproductive organs

The creamy white testes were large, elongated, bulging and attained maximum size with crenate margin in *P.ocellatus*. The seminal vesicles increased in length and were longer than the testis. The histological preparation showed that the seminiferous tubule showed presence of spermatozoa in the lumen. Primary spermatocytes, secondary spermatocytes and spematids were observed in the periphery of the tubule. Hardly any spematogonia could be observed.

Stage IV Ripe gonads and accessory reproductive gonads

The milt flowed on application of slight pressure to the thick creamy white testis which appeared almost swollen in this stage. The histological preparation showed that the seminiferous tubules had increased in size considerably due to large number of

spermatozoa in the lumen of the testis. Few spematocytes and spermatids were observed in the tubule. Motile spermatozoa could be observed in the lumen. Some ruptured tubules could be seen with motile spermatozoa liberated in the tubular lumen.

Stage V Spent stage of gonads and accessory reproductive gonads

The flaccid shrunken testis in late stages were covered with dark blood vessels. The seminal vesicles remained longer than the testes initially but in late stages were found to be reduced in size. The histological preparation showed that the lumen of the seminiferous tubules seemed to be empty though few residual spermatozoa could be observed therein. Spermatogonia were observed in the periphery of seminiferous tubule. The testis seemed to be in resting phase.

The morphological and histological structures of male gonads and accessory organs of *P.ocellatus* as described above are similar to those observed in other species of gobies like *Gobius pagnellus* (Miller, 1961), *Oxyeleotris marmoratus* (Suwanjarat *et al*. 2004), *Boleophthalmus boddaerti* (Gore, 2007) and *Padogobius martensi* (Cinquetti and Rinaldi, 2009) and *Periophthalmus papilio* (Lawson, 2011).

Gonads in female *P.ocellatus*

The gonads and accessory organ in female *P.ocellatus* consist of a pair of ovaries, a common oviducts and genital papillae. The ovarian cycle seem to be reflected in the morphological and histological changes in the ovaries. Cyclic changes which can be studied as five distinct stages in terms of maturity and reproductive phases. Pair of ovaries in *P ocellatus* were fusiform, located ventral to the kidneys and suspended from the coelomic wall by meso-ovarian ligament. The two ovaries fused posteriorly forming a common oviduct which opened into a genital papilla. During the present study of *P.ocellatus* five stages of ovarian maturity were identified. Studies on the female gonads and gonadal cycle in *P.ocellatus* is based on macroscopic and microscopic observation of the ovaries.

Many scientists have classified different stages of ovarian cycle on the basis of general appearance, size, shape, weight and area occupied by the ovaries, ova diameter and ovulation. Similar stages have been described by Kadar *et al*. (1988b), Gore (2007), Shamshan (2008) and Dorostghoal *et al*. (2009). This was in agreement with Mazzoldi *et al*. (2005) in other species of gobies. The pattern of oocyte maturation in *P.ocellatus*

is similar to that observed in other teleost fishes (Bara, 1960, 1963). Histologically ovaries showed asynchoronous development in *P.ocellatus* since many different stages of ova development were observed simultaneously. Similar type of development was observed in *Gobius pagnellus, Padogobius martensi, Pomatochistus marmoratus, Gobius vittatus* (Miller, 1984; Cinquetti and Rinaldi, 1987; Mazzoldi and Rosotto, 2001; Kovacic, 2007).

In *P.ocellatus* the diameter of ripe ova ranged between 0.50-0.70mm. Similar narrow range of ova diameter has been reported by Miller (1961) in *Gobius paganellus* with egg diameter 0.95-1.10mm, Gibson (1970) in *Gobius cobitus* of eggs diameter 0.1-1.22mm, Gibson and Ezzi (1978) in *Leseurogobius freisi* with egg diameter of 0.5-0.6mm, Gore (2007) in *Boleophthalmus boddaerti* with egg diameter of 0.68-0.85mm and Lawson (2010) in *Periophthalmus papilio* of egg diameter 0.2-0.5mm.

The following five stages could be distinguished for ovarian development based on morphological and histological observations.

Stage I-Immature gonads

In *P.ocellatus* immature ovaries were small slender and light yellow. The histological preparation showed that the oocytes were immature and devoid of yolk. The oogonia in different stages of maturity occurred in clusters in the germinal epithelium exhibiting asynchronous growth. Similar features were observed in many species of goby by Thacker and Grier (2005).

Stage II- Developing gonads

In this stage the ovaries were thick, elongated and yellow. The vascularisation of ovary was seen in the later stages. The histological preparation showed major developmental changes in the oocyte in this stage. Large number of oocyte in different stages of development was observed. The nucleus was visible in the centre of the developing oocyte. The nucleoli could be seen dispersed towards the periphery of the nucleus. The vitelline membrane was distinct. The ooplasm was peripheral and showed lipid droplets cortical alveoli and small yolk granules in larger oocytes suggestive of endogenous vitellogenesis. Towards the end of this stage ovaries were completely filled with oocytes of different sizes which were clearly visible. This was in

agreement with many species of teleost fishes as described by Nunez and Duponchelle (2008) and gobies like *Oxyeleotris marmoratus* (Boonyoung *et al*., 2003), *Boleophthalmus boddaerti* (Gore, 2007), *Periophthalmus papilio* (Lawson, 2010).

Stage III- Mature gonads

In this stage enlarged, bulging ovaries were dark yellow to orange in colour with well developed vascularisation. Though the diameter of ova was larger as compared to that in stage II, the nucleus was still located in the central position. An indistinct nuclear membrane with many nucleoli at the periphery could be observed. The chorion or zona pellucida and vitelline membrane was visible. The entire ooplasm was filled with yolk granules and lipid globules. The cortical alveoli though present in peripheral ooplasm were hardly visible in later stages. Similar observation of maturing ovary was recorded n many teleost fishes as reported by Nunez and Duponchelle (2009) and in goby *Padogobius martensi* by Cinquetti and Rinaldi (1987). The increasing number of nucleoli in the later stages is an indication of yolk formation suggestive of special role for nucleoli in the formation of rRNA (Al Mokhtar *et al*., 1981). This stage was considered more appropriate to estimate absolute fecundity since the number of oocytes was very close to the number of eggs released (Nunez and Duponchelle, 2008).

Stage IV- Ripe gonads

In stage IV the ovaries of *P.ocellatus* attained maximum size and filled the entire body cavity leading to distended abdomen in the female fish. The genital papillae appeared to be swollen. With slight application of pressure on the abdomen, the eggs were released into the surrounding through the ovaries gonopore. Histological observation showed that the oocytes contained ooplasm completely filled with large yolk globules and lipid droplets restricting the nuclear material towards the periphery of the ooplasm thus leading to the formation of an animal pole. Inner to zona pellucida, vitelline membrane was seen. Similar features were observed in many teleost fishes by Nunez and Duponchelle (2009). The multiple spawners are distinguished from single spawners by the presence of vitellogenic oocytes of different sizes (Nunez and Duponchelle, loc.cit.). In *P.ocellatus* the fully grown vitellogenic oocytes were of uniform size, without any small oocytes between them indicting that the fish is not a multiple spawner during the breeding season.

Stage V- Spent gonads

The ovaries of *P.ocellatus* in this stage were flaccid and small. During the initial phase the vascularisation was visible. The histological preparation showed that ovaries contained remnants of some oocytes, post ovulatory follicles and few atretic oocytes. The vitelline membrane appeared to be disintegrated. Hardly any yolk could be seen probably indicating its reabsorption. Similar observation was recorded in the zebra fish *Danio rerio* (Koc *et al.* 2008). The occurrence of residuary mature oocyte and empty follicle in a state of reabsorption was observed in *Mystus seenghala* (Sathysanesan, 1961), *Boleopththalmus boddaerti* (Gore, 2007) and *Periopththalmus papilio* (Lawson, 2010).

Nunez and Duponchelle (2008) have reported that the ovary with post-ovulatory follicles and atretic oocytes evolve into a resting stage with thicker ovarian wall and large empty spaces within the lamellae. The authors observed that the ovaries remained in this stage until next breeding season when they evolve into stage II.

Atretic oocyte

The process of degeneration (atresia) is a consistent feature of teleost ovary (Agarwal 1988). Atresia occurs regularly in teleost fishes during vitellogenic cycle (Hunter and Macewicz, 1985; Rizzo and Bazzoli, 1995; Tyler and Sumpter, 1996; Miranda *et al*., 1999). Many scientists have elucidated that in the teleost atresia is more relevant during and after spawning (Rai, 1966; Davis, 1977; Htun-Han, 1978a; Al-Daham and Bhatti, 1979).

The atretic oocytes in spent ovary have been recorded by Rajalakshmi (1966) in *Gobius guiris* and Rahemo and Al-Shatter (2012) in *Barbus luteus* and *Varicorhinuus trutta.* On the contrary atretic oocytes in different stages of development were observed by Al Daham and Bhatti, (1979) and Ravaglia and Maggese (2002). In the *P.ocellatus* atretic oocytes were predominantly observed in the spent ovary in the state of degeneration.

From the study of reproductive biology of *P.ocellatus*, it can be concluded that in *P.ocellatus* sexual dimorphism is prominent during spawning months. The sex ratio

tended to be in equilibrium during peak spawning season. In other few breeding months female dominance was observed while in all other months male dominance was prevalent. The study of gonad maturity stages and gonadosomatic index indicates that *P.ocellatus* has an extended breeding season from June to October 2010 and from January to September 2011 with peak spawning from February to April 2011 which is well in agreement with single peak in the frequency polygon of ova diameter. The gonadosomatic index agrees well with the maturity stages of *P.ocellatus*. The gonad maturity stages, frequency polygon of ova diameter and GSI index reveal that the individual fish in a population may probably spawn only once in the year though spawning occurs throughout the year in the population except during November and December 2010.

The study of fecundity in *P.ocellatus* revealed that the fish is highly fecund. The fecundity is correlated with total weight, ovarian length, ovarian weight and total length of the fish. The study of morphology and histology of gonads confirms the gonad maturity stages in *P.ocellatus*. Histological studies of ripe ova revealed that all the oocytes mature together and there is hardly any occytes in any other stage which confirms that *P.ocellatus* is a single spawner unlike other gobies which may spawn many times in a year.

Chapter 9

Biochemical composition of muscles

9.1 Introduction

9.2 Literature review

9.3 Materials and methods

9.4 Results

9.5 Discussions

9.1 Introduction:

Fish is rich in protein with an amino acid composition, which is very well suited to human dietary requirements comparing favourably with egg, milk and meat in the nutritional value of its protein (Waterman, 1976). Fishes are quite different from other animal foods, because they provide calories with high quality proteins, which contain all essential amino acids in easily digestible form and are beneficial nutrition (Weatherley and Gill, 1998).The protein in the fish muscles has relatively high digestibility and is considered to have biological and growth promoting value (Shekhar *et al.,* 2004). Fish constitute a very important component of the diet for many people and often provide the much needed nutrient that is not provided in cereal based diets (Clucas and Sutchitte, 1981).Thus fish as a source of protein seems to have significant role in nutrition, income, employment and foreign exchange earnings of any country.

Fish flesh contains varying proportion of water, protein, fat, carbohydrates, minerals and vitamins. Food and Agricultural Organisation (FAO) of United Nations has reported that fish contains 72% water, 19% protein, 8% fat, 0.5% calcium, 0.25% phosphorus and 0.1% vitamin A, B, C and D. The study proximate biochemical composition of a species helps to assess its nutritional and edible value. Food composition, environment and genetic trait are known to influence chemical composition of fish (Oni *et al.*, 1983). Seasonal cycles of variation in the biochemical constituents, such as proteins, carbohydrates and lipids, are generally attributed to the complex interaction between environmental parameters, food availability, growth and reproductive activity (Venkataramanujam and Ramanathan, 1994). The authors

further state that the study of variation in energy storage in the form of protein, glycogen and lipids is helpful in understanding the ecology and overall economy of the species. Thus a sound knowledge of variations in biochemical composition in different stages of development of fish is essential in exploiting the fish when their nutritional value is high.

Sidhu (2003) has reported that fish meat has preventive effects against cardiovascular diseases and some types of cancer including colon, breast and prostrate. Carlson and Werkman (1996) have reported that polyunsaturated fatty acids (PUFA) found in fish oils have been recognised as important component with beneficial properties for the improvement of visual function. Calder (2003) reported that PUFA can also be used to prevent atherosclerosis and thrombosis. The proximate composition study is therefore essential not only to know the nutritional status of fish but also to explore its therapeutic potential.

9.2 Review of literature

Several studies deal with the proximate composition of many commercially important fishes. (Parulekar, 1964; Nair, 1965; Raja, 1969; Qasim, 1972; Ramaiyan, *et. al.* 1976; Sivakami, *et.al.* 1986; Sinha and Pal, 1990; Das and Sahu 2001). Jafri and Khwaja (1968) determined the chemical composition and nutritional value of some small fishes. Gopalan *et al.* (1978); Govindan (1985); Rubbi *et al.* (1987); Banu *et al.* (1991) determined, analysed and compared the fish nutrients in different species. Mohanty and Samantaray (1993) observed the biochemical composition of juvenile *Channa striatus*. Murthy *et al.* (1999) studied body composition of *Oreochromis mossambicus*. Pawar (2003) studied the biochemical composition of some edible fishes belonging to Gobiidae and Siluridae. Shamsan (2008) studied the biochemical composition of *Sillago sihama* in relation to season and size. Ahmed *et al.* (1984) investigated the variation of biochemical composition of seven species of goby fish in respect of sex and season. Seasonal variation in the biochemical composition of some of the goby fishes has been reported by number of authors namely *Glossogobius giuris* (Islam and Joadder, 2005), *Boleophtalmus dussuimeri* (Rathod, 2005) and *Boleophthalmus boddaerti* (Gore, 2007).

Literature survey revealed several studies on proximate composition of many commercial fishes but hardly any report is available on the study of proximal composition of *Parachaeturichthys ocellatus*. Therefore the present study was under taken to understand the biochemical composition especially in the muscles of *P. ocellatus* and the seasonal and size wise variation in the same if any.

9.3 Materials and Methods

Samples of *P.ocellatus* were collected during the period from June 2010 to September 2011 from the creeks of Mumbai. The specimens were properly cleaned in the laboratory and the total length, total weight and sex were determined. Muscle tissue was collected from the fish and subjected to biochemical analysis. Proximate composition was estimated every month and biochemical analyses was carried out in every length group and expressed in mg%. In addition some of the commercially important fishes like *Mugil cephalus, Tilapia mossambica, Boleophthalmus dussumeiri* and *Arius spp* were also collected and their biochemical composition analysed to determine the nutritional value of *P.ocellatus* vis a vis the commonly important fish.

Estimation of moisture content

The moisture content was estimated by oven drying the pre weighed sample of tissue at 60-80º C. The difference in weight was calculated and expressed as percentage moisture content of the tissue. Percentage was calculated by the following formula suggested by Sebastian (2012):

$$\text{Percentage of moisture} = \frac{\text{Wet weight - Dry weight}}{\text{Wet weight}} \times 100$$

Estimation of Protein

Protein content was estimated by colorimetric method of Lowry *et al.*(1951). The Folin-Ciocalteau phenol reagent contains phosphomolybdic acid and tungstate. The aromatic amino acid residues such as tyrosine and tryptophan, present in protein react with the components of the Folin-Ciocalteau phenol reagent and produce a stable blue colour. The extinction of the coloured solution was read at 625nm. Bovine serum albumin was used as standard. The values are expressed in mg %.

Estimation of carbohydrate

Carbohydrate content was estimated according to the method of Hedge and Hofreiter (1962). Carbohydrates are hydrolysed into simple sugars using dilute hydrochloric acid. In hot acidic medium glucose is dehydrated to hydroxymethyl furfural. This reacts

with anthrone and gives a green colour. Glucose solution is used as standard. The extinction is read at 630nm and the values are expressed in mg %.

Estimation of Lipid

Lipid content was estimated gravimetrically according to the method of Folch (1957). The total lipid from the muscle tissue was estimated after extraction in chloroform: methanol (1:1v/v). The lipid content was estimated by the following formula:

$$\text{Lipid \%} = \frac{\text{Weight of lipid (mg)}}{\text{Weight of the sample (mg)}} \times 100$$

The result is expressed as mg % of lipid content in the muscle tissue

Estimation of Ash

Ash was estimated by incineration of known weight of fish muscle kept in a porcelain crucible in a furnace at 150^0 C, the white charred remains were weighed and expressed as percentage.

Proximal composition in terms of calories per/g wet weight

Caloric content was calculated by multiplying the concentration of various components with conversion factors 4.15, 9.4 and 5.65 for carbohydrate, lipid and protein respectively as per the method adopted by Shamsan (2008). The caloric values were expressed as calories per gram wet weight of the fish.

9.4 Results

The average proximal composition of *P.ocellatus* male, female and juvenile were as follows:

Fish	Male	Female	Juvenile
Moisture (%)	79.98	80.05	79.66
Protein (%)	14.86	14.09	14.45
Lipid (%)	1.45	2.08	2.08
Carbohydrate (%)	0.09	0.10	0.07
Ash (%)	3.15	3.19	3.24

Average analysis revealed high protein content in male, while females had high lipid, carbohydrate and ash content but the difference male and female were not significant at $p<0.05$.

Monthly variation of proximate composition in mg % and cal/g in male, female and juvenile *P.ocellatus* is presented in Table no. 9.1a, 9.1b and 9.1c respectively. Comparative presentation of moisture, protein, lipid, carbohydrate and ash in male, female and juvenile is graphically depicted in Fig.9.1 a, 9.1 b, 9.1c, 9.1d and 9.1e. Moisture is the major component of fish followed by protein, fat and carbohydrate

.

Seasonal variation in the proximate composition of *P.ocellatus*

The seasonal variation of moisture content was in the range of 77.86-82.29% in male, 76.15-81.75% in female and 78.17-80.90% in juvenile. Monthly variation showed highest percentage of moisture content in males at 82.29% in April 2011 and lowest at 77.86% in October 2010. In females it was found to be highest in March 2011 at 81.75% and lowest December 2010 at 76.15%. In juveniles highest percentage was observed in September 2010 at 80.90% and lowest in March 2011 at 78.15%.

Protein content in male varied from 12.63% in April 2011 to 16.18% in June 2011. In females it was highest at 15.95% in December 2010 and lowest at 12.75% in August 2011. In juveniles protein content was found to be highest at 16.95% in February 2011 and lowest at 12.60 % in August 2010.

In males lipid content was found to be highest at 2.13% in September 2010 and lowest at 0.78% in May 2011 while in females it was highest at 3.85% in December 2010 and lowest at 0.83% in May 2011. In juveniles highest lipid content was observed at 2.98% in August 2011 and lowest at 1.12% in June 2011.

Carbohydrate content was found to be in a very small amount in the muscles of fish. In males it was highest at 0.18% in August 2010 and lowest at 0.04% in April 2011. In females high percentage of carbohydrate content was observed at 0.18% in September 2010 and July 2011 and lowest at 0.05% in February 2011. In juveniles high carbohydrate content was found to be high at 0.14 in September 2010 and lowest at 0.03 in June 2011.

Ash as incinerated remain was found to be highest in males at 3.87% in November 2010 and lowest at 2.01% in September 2011. In females it was found to be highest at 3.92% in October 2010 and lowest at 2.12 % in February 2011.In juveniles it was found to be highest at 3.98% in October 2010 and lowest at 2.55% in July 2010.

Total average caloric content of the male *P.ocellatus* was 979.07 cal/g wet weight while in female value was 995.44 cal/g and in juveniles the value was 951.57cal/g. The caloric content showed seasonal variation depending on the percentage of protein, lipid and carbohydrate content in the muscles of the *P.ocellatus*. High caloric value was recorded in October 2010 at 1093.09 cal/g in males and in November 2010 at 1139 cal/g in females. The low caloric value was recorded in April 2011 in males and May 2011 in females.

Analysis of variance on moisture, protein, lipid, carbohydrate and ash are presented in Table no 9.2a to 9.2e. There was no significant difference in the proximate composition between male and female *P.ocellatus*.

Variation in proximate composition in terms of total length in *P.ocellatus*

Analysis of moisture content, protein content, lipid content, carbohydrate content and ash in terms of %mg is recorded in Table no. 9.4. The comparison of moisture content , protein content, lipid content, carbohydrate content and ash in various length group of male and female are depicted in Figure 9.2a, 9.2b, 9.2c, 9.2dand 9.2e.

High moisture content at 82.69% and 82.58% were observed in males and females of length group 66-75mm. The lowest value at 78.52% in males and 78.50% in females were found in the length group of 126-135mm.

Protein content was highest at 16.18% in males in length group 96-105mm and 15.85% in females of length group 106-115mm and lowest at 13.97% and 12.61% in males and females at length group 66-75mm.

Lipid content was highest at 1.96% in males of length group 106-115mm and lowest at 1.05% in length group 166-175mm. In females it was found to be highest at 2.41% in length group 106-115mm and lowest at 1.24% in length group 136-145mm.

Carbohydrate content was highest at 0.19% in males of length group 156-165mm and 166-175mm and lowest at 0.02% in length group of 66-75mm. In females carbohydrate content was highest at 0.19% was in length group of 96-105mm and lowest at 0.06% in 76-85mm.

In males ash as incinerated remains was found to be highest at 3.92% in males of length group of 76-85mm and lowest at 2% in length group of 146-155mm. In females it was found to be highest at 3.92% in length group 146-155mm and lowest at 1.78% in length group of 106-115mm.

The correlation between the moisture, protein, lipid, carbohydrate and ash content in male, female and juvenile is presented in Table no.9.3. The following observations were recorded.

1) A negative correlation was observed between moisture and protein in male, female and juvenile *P.ocellatus*. The values were significant at $p<0.01$ in all the three cases.
2) A negative correlation was obtained between moisture and lipid in male and female *P.ocellatus* while the juveniles had positive correlation. The values obtained in males and juveniles were not significant while it was significant in females at $p<0.01$.
3) A negative correlation was found between moisture and carbohydrate in male and female while juveniles had positive correlation but none of the values were significant.
4) A negative but significant correlation at $p<0.05$ was observed between moisture and ash in male *P.ocellatus*. In females and juvenile the values were not significant.
5) A negative and non significant correlationship exists between protein and lipid in males while in females it was positive and significant at $p<0.05$. In juveniles a negative and significant relationship at $p<0.01$ was observed.
6) Insignificantly low correlation was observed between protein and carbohydrate in male and female *P.ocellatus* while in juvenile it was negative correlation significant at $p<0.05$.

7) Insignificant and low correlation was obtained between protein and ash; lipd and carbohydrate; lipid and ash and carbohydrate and ash in male female and juvenile *P.ocellatus*.

The comparison of proximate composition of *P.ocellatus* with fishes like *Mugil cephalus, Tilapia mossambica, Boleophthalmus dussumeiri* and *Arius arius* are presented in Table no.9.5. The moisture content *P.ocellatus* is higher compared to other fishes while fat content is the lowest. The protein was higher than *Tilapia spp* and *Boleophthalmus spp* but lower that *Mugil* and *Arius spp*. The ash content of *P.ocelltus* also showed very slight variation compared to other fishes. The carbohydrate content was slightly more than *Boleophthalmus dussuimeiri* but lower than all other fishes. The caloric value of *P.ocellatus* is less compared to that of *Mugil, Tilapia* and *Arius* probably due to the low fat content.

Table no.9.1a: Biochemical composition of muscles in male *P ocellatus* during different months.

Months	Moisture	Protein (mg %)	Protein (cal/g)	Lipid (mg%)	Lipid (cal/g)	Carbohydrate (mg%)	Carbohydrate (cal/g)	Ash (mg%)	Total cal/g
Jun-10	79.86	15.49	875.18	0.89	83.66	0.07	2.90	3.45	961.75
Jul-10	81.06	14.49	818.68	1.23	115.62	0.08	3.32	2.78	937.62
Aug-10	80.45	14.9	841.85	1.4	131.60	0.18	7.38	2.59	980.83
Sept-10	78.29	14.84	838.46	2.13	200.22	0.13	5.51	3.69	1044.20
Oct-10	77.86	15.92	899.48	2.02	189.88	0.09	3.73	3.52	1093.09
Nov-10	78.45	14.85	839.02	1.98	186.12	0.07	2.90	3.87	1028.05
Dec-10	80.05	15.21	859.36	1.25	117.50	0.07	2.90	2.75	979.77
Jan-11	79.24	14.67	828.85	1.75	164.50	0.07	2.90	3.93	996.26
Feb-11	80.27	14.34	810.21	1.2	112.80	0.08	3.32	3.69	926.33
Mar-11	81.28	13.74	776.31	1.4	131.60	0.10	4.15	3.22	912.06
Aprl-11	82.29	12.63	713.59	1.88	176.72	0.04	1.66	2.88	891.97
May-11	80.29	15.76	890.44	0.78	73.32	0.09	3.73	3.04	967.49
Jun-11	80.19	16.18	914.17	0.79	74.26	0.06	2.49	2.24	990.92
Jul-11	79.45	15.26	862.19	1.15	108.10	0.05	2.07	3.90	972.36
Aug-11	79.45	15.21	859.36	1.44	135.36	0.12	4.98	2.89	999.70
Sept-11	78.98	14.23	803.99	1.84	172.96	0.14	5.81	2.01	982.76
Average	79.98	14.86	839.44	1.45	135.88	0.09	3.73	3.15	979.07

Table no.9.1b: Biochemical composition of muscles in female *P ocellatus* during different months.

Months	Moisture (mg %)	Protein (mg %)	Protein (cal/g)	Lipid (mg %)	Lipid (cal/g)	Carbohydrate (mg%)	Carbohydrate (cal/g)	Ash (mg %)	Total cal/g
Jun-10	81.45	13.45	759.92	1.78	167.32	0.06	2.49	3.25	929.73
Jul-10	79.85	14.85	839.02	2.01	188.94	0.09	3.73	**2.55**	1031.70
Aug-10	80.99	13.42	758.23	1.87	175.78	0.15	6.22	3.42	940.23
Sep-10	80.13	13.3	751.45	1.8	169.20	0.18	7.47	3.88	928.12
Oct-10	78.95	14.27	806.25	2.25	211.50	0.05	2.07	3.92	1019.83
Nov-10	77.65	15.15	855.97	2.98	280.12	0.08	3.32	3.88	1139.41
Dec-10	76.15	15.95	901.17	3.85	361.90	0.10	3.98	3.52	1267.05
Jan-11	79.54	15.04	849.76	2.39	224.66	0.07	2.90	2.93	1077.32
Feb-11	81.24	13.73	775.74	1.97	185.18	0.05	2.07	2.12	963
Mar-11	81.75	13.64	770.66	1.1	103.40	0.09	3.77	2.74	877.83
Apr-11	80.09	14.31	808.51	1.79	168.26	0.08	3.44	3.42	980.21
May-11	81.24	14.11	797.21	0.83	78.02	0.09	3.73	3.51	878.97
Jun-11	79.73	15.03	849.19	1.97	185.18	0.14	5.81	2.5	1040.18
Jul-11	79.52	13.39	756.53	2.89	271.66	0.18	7.47	2.85	1035.66
Aug-11	81.42	12.75	720.37	1.98	186.12	0.09	3.73	3.12	910.23
Sep-11	80.85	13.05	737.32	1.78	167.32	0.07	2.90	3.35	907.55
Average	80.05	14.09	796.08	2.08	195.28	0.10	4.07	3.19	995.44

Table no. 9.1c: Biochemical composition of juvenile *P. ocellatus* during different months

Months	Moisture (mg %)	Protein (mg%)	Protein (cal/g)	Lipid (mg %)	Lipid (cal/g)	Carbohydrate (mg %)	Carbohydrate (cal/g)	Ash (mg %)	Total cal/g
Jun-10	79.45	15.01	848.06	1.95	183.30	0.05	1.86	2.75	1033.23
Jul-10	80.15	14.45	816.42	2.12	199.28	0.07	2.90	2.55	1018.61
Aug-10	80.45	12.60	711.90	2.45	230.30	0.08	3.32	3.85	945.52
Sep-10	80.90	12.85	726.02	2.70	253.80	0.14	5.81	3.02	985.63
Oct-10	79.79	13.55	765.57	2.05	192.70	0.07	2.90	3.98	961.18
Nov-10	80.05	14.02	792.13	2.12	199.28	0.09	3.73	3.65	995.14
Dec-10	79.09	14.31	808.51	1.98	186.12	0.12	4.98	3.91	999.61
Jan-11	80.55	13.45	759.92	1.75	164.50	0.05	1.90	3.93	926.33
Feb-11	78.45	16.95	957.67	1.41	132.54	0.03	1.20	2.91	1091.41
May-11	78.37	16.12	910.78	1.90	178.6	0.05	1.99	2.96	1091.37
Jun-11	79.69	15.85	895.52	1.12	105.28	0.03	1.03	2.88	1001.84
Jul-11	79.21	14.45	816.42	2.85	267.90	0.05	2.24	3.01	1086.56
Aug-11	79.85	13.95	788.17	2.98	280.12	0.07	2.69	2.75	1070.99
Sep-11	80.75	13.01	735.06	2.55	239.70	0.06	2.28	2.65	977.04
Average	79.66	14.45	765.43	2.08	183.59	0.07	2.54	3.24	951.57

Table no. 9.2a Analysis of variance on moisture content in the muscles of male and female *P.ocellatus*

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*	*p*
Between Groups	37.13515	15	2.475677	2.180997	2.352223	Not Significant
Within Groups	18.1618	16	1.135113			
Total	55.29695	31				

Table no. 9.2b Analysis of variance on protein content in the muscles of male and female *P.ocellatus*

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*	p
Between Groups	13.19965	15	0.879977	0.922027	2.352223	Not Significant
Within Groups	15.2703	16	0.954394			
Total	28.46995	31				

Table no. 9.2c Analysis of variance on lipid content in the muscles of male and female *P.ocellatus*

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*	*p*
Between Groups	6.124872	15	0.408325	0.850594	2.352223	Not Significant
Within Groups	7.68075	16	0.480047			
Total	13.80562	31				

Table no. 9.2d Analysis of variance on carbohydrate content in the muscles of male and female *P.ocellatus*

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*	*p*
Between Groups	0.027993	15	0.001866	1.592546	2.352223	Not significant
Within Groups	0.01875	16	0.001172			
Total	0.046743	31				

Table no. 9.2e Analysis of variance on ash from muscles of male and female *P.ocellatus*

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*	*p*
Between Groups	5.2594	15	0.350627	1.276735	2.352223	Not significant
Within Groups	4.39404	16	0.274628			
Total	9.65344	31				

Table no. 9.3: Correlation between moisture, protein, carbohydrate and ash in male, female and juvenile *P.ocellatus*

Variable	Male 'r'	Significance	Female 'r'	Significance	Juvenile 'r'	Significance
Moisture/Protein	-0.6334	Significant at p<0.01	-0.7822	**Significant at p<0.01**	-0.8545	**Significant at p<0.01**
Moisture/lipid	-0.3175	Not significant	-0.8681	**Significant at p<0.01**	0.3946	Not significant
Moisture/Carbohydrate	-0.0701	Not significant	-0.0603	Not significant	0.3873	Not significant
Moisture/Ash	-0.5921	**Significant at P<0.05**	-0.3773	Not significant	0.1164	Not significant
Protein/Lipid	-0.4173	Not significant	0.5413	**Significant at P<0.05**	-0.6501	**Significant at p<0.01**
Protein/Carbohydrate	0.0410	Not significant	-0.1773	Not significant	-0.5906	**Significant at p<0.05**
Protein/Ash	0.0331	Not significant	0.0231	Not significant	-0.3866	Not significant
Lipid/Carbohydrate	0.2363	Not significant	0.0867	Not significant	0.4811	Not significant
Lipid/Ash	0.2434	Not significant	0.1549	Not significant	-0.1145	Not significant
Carbohydrate/Ash	-0.3333	Not significant	0.0546	Not significant	0.3429	Not significant

Table no. 9.4: Biochemical composition of muscles in *P.ocellatus* male and female in different length groups

Length group	Moisture (mg %)		Protein (mg %)		Lipid (mg %)		Carbohydrate (mg %)		Ash (mg %)	
	male	female	male	female	male	female	male	female	male	female
66-75	82.69	82.58	13.97	12.61	1.28	1.89	0.02	0.08	2.00	2.10
76-85	79.18	80.65	14.66	13.19	1.52	2.05	0.04	0.06	3.72	3.45
86-95	79.80	80.26	14.51	14.09	1.77	2.13	0.05	0.10	3.45	2.96
96-105	78.59	80.05	16.18	14.15	1.48	2.41	0.06	0.19	2.85	1.85
106-115	79.95	79.73	15.72	15.85	1.96	2.35	0.08	0.09	2.06	1.78
116-125	78.55	78.75	15.96	15.05	1.47	2.25	0.10	0.09	3.45	3.85
126-135	78.52	78.50	15.91	14.78	1.58	2.58	0.12	0.07	3.79	4.02
136-145	79.90	79.46	14.38	14.05	1.45	1.24	0.08	0.11	3.42	4.89
146-155	80.52	80.54	14.45	13.06	1.35	1.89	0.09	0.07	3.02	3.92
156-165	79.76	-	14.15	-	1.34	-	0.19	-	3.92	-
166-175	81.55	-	14.05	-	1.05	-	0.19	-	2.95	-
176-185	80.81	-	14.45	-	1.15	-	0.08	-	3.15	-
Average	79.99	80.06	14.87	14.09	1.45	2.09	0.09	0.12	3.15	3.20

Table no.9.5: Biochemical composition of different fishes in creeks of Mumbai.

Name of the fish	Moisture (mg%)	Protein (mg%)	Cal/g	Lipid (mg%)	Cal/g	Carbohydrate (mg%)	Cal/g	Ash (mg%)	Total cal/g
Parachaeturichthys ocellatus	79.05	14.47	817.56	1.77	166.38	0.96	39.84	3.63	1023.78
Mugil cephalus	74.74	15.62	882.53	3.4	319.60	2.1	87.15	3.84	1289.28
Tilapia mossambica	75.92	14.08	795.52	2.86	268.84	2.3	95.45	4.54	1159.81
Boleophthalmus dussumeiri	78.32	13.76	777.44	2.08	195.52	1.2	49.80	4.04	1022.76
Arius arius	75.37	16.01	904.57	3.39	318.66	1.1	45.65	3.58	1268.88

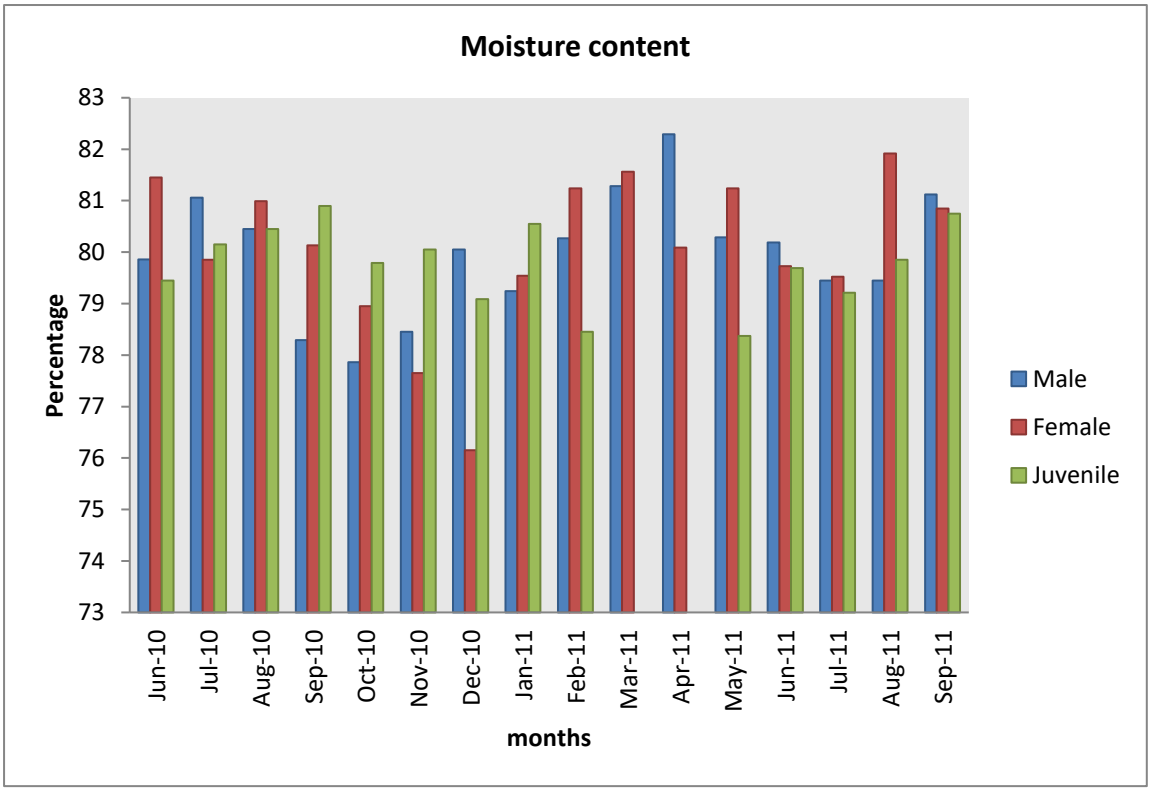


Fig 9.1a: Variations in moisture content in the muscles of *P.ocellatus* male, female and juvenile during different months.

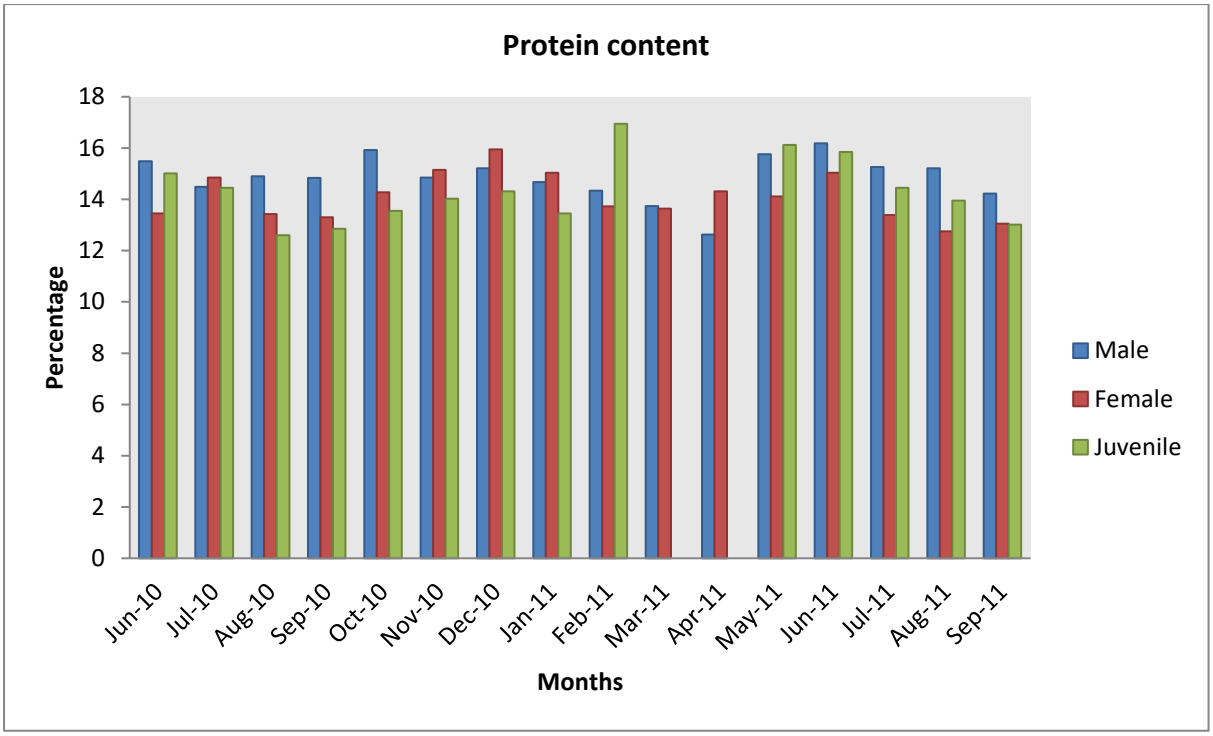


Fig 9.1b: Variations in protein content in the muscles of *P.ocellatus* male, female and juvenile during different months.

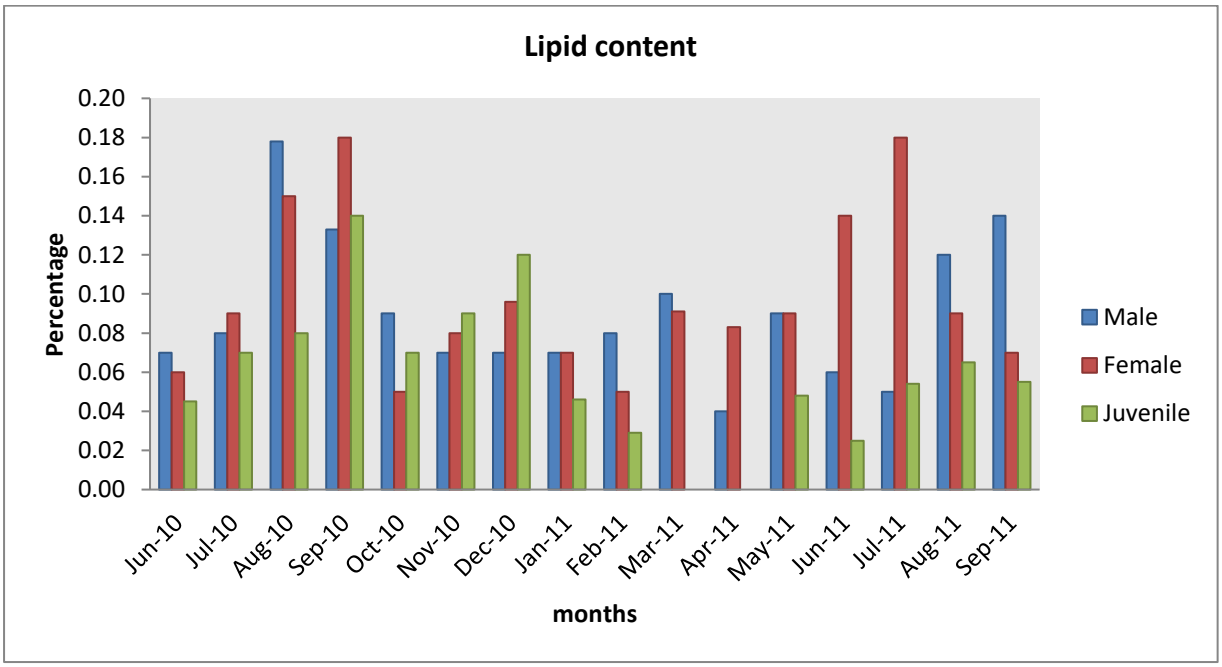


Fig 9.1d: Variations in lipid content in the muscles of *P.ocellatus* male, female and juvenile during different months.

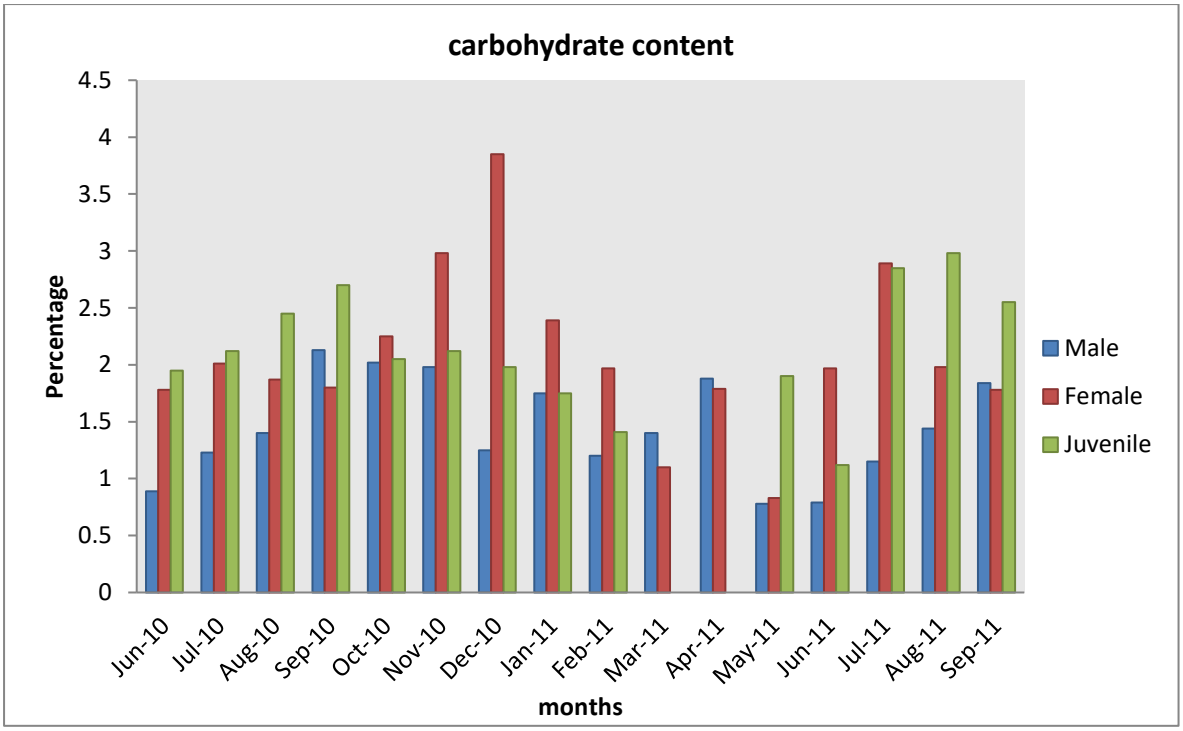


Fig 9.1c: Variations in carbohydrate content in the muscles of *P.ocellatus* male, female and juvenile during different months.

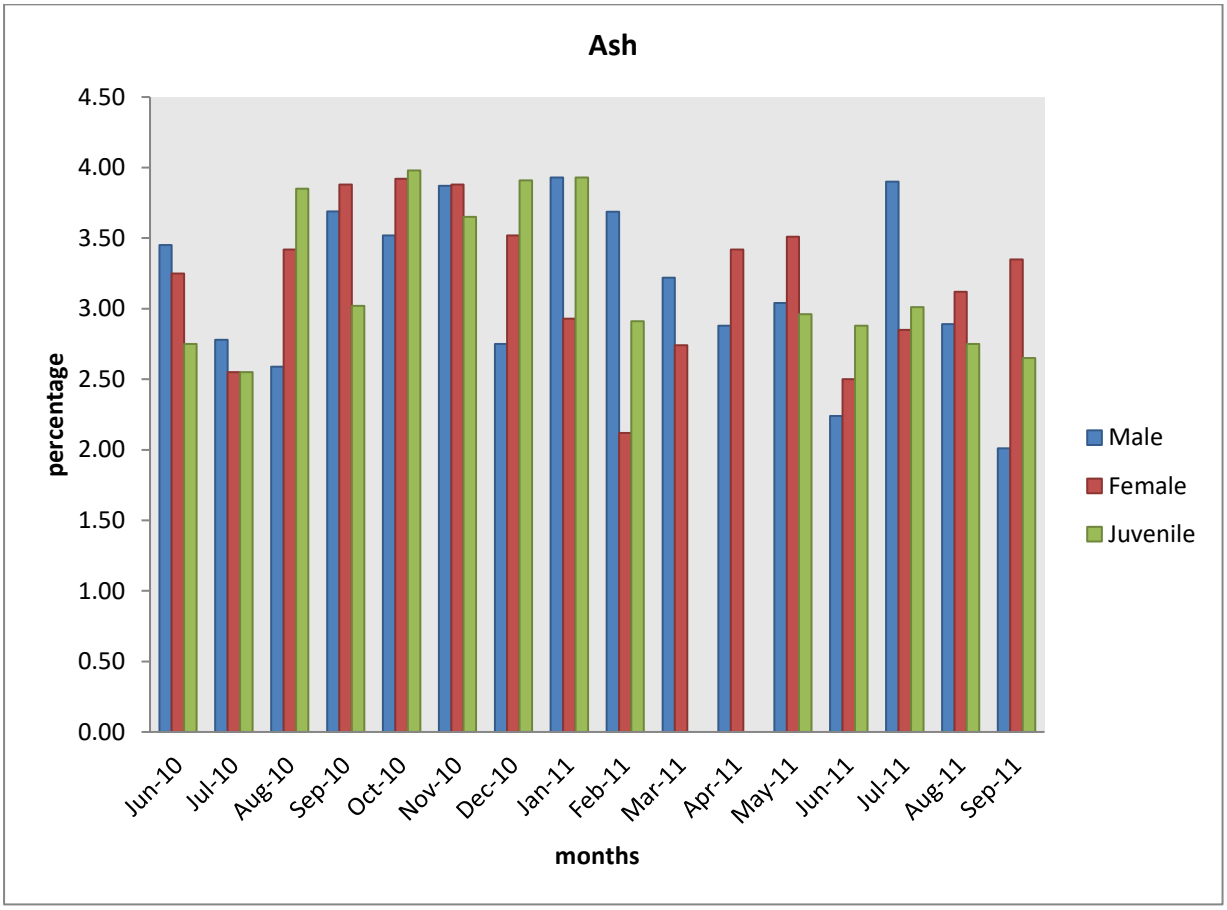


Fig 9.1e: Variations in the ash content from incinerated muscles of *P.ocellatus* male, female and juvenile during different months.

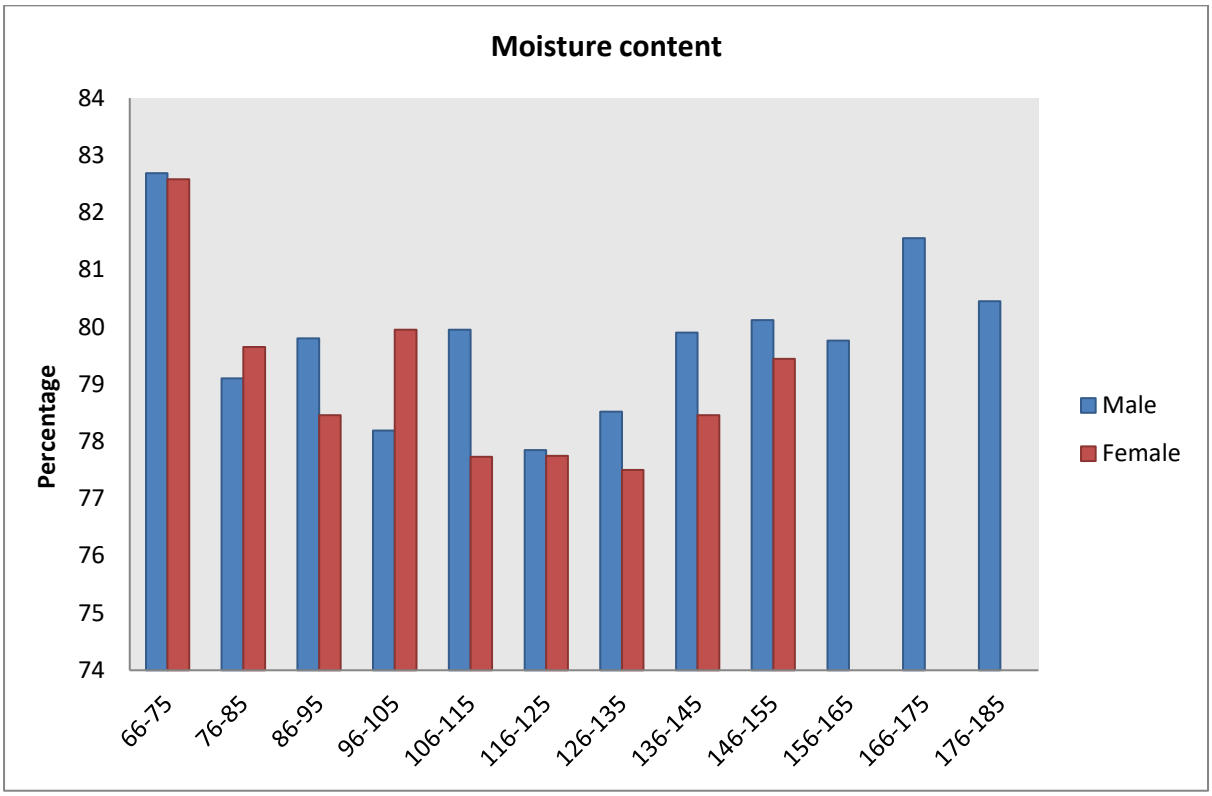


Fig 9.2a: Variations in moisture content in the muscles of *P.ocellatus* male and female in different length groups.

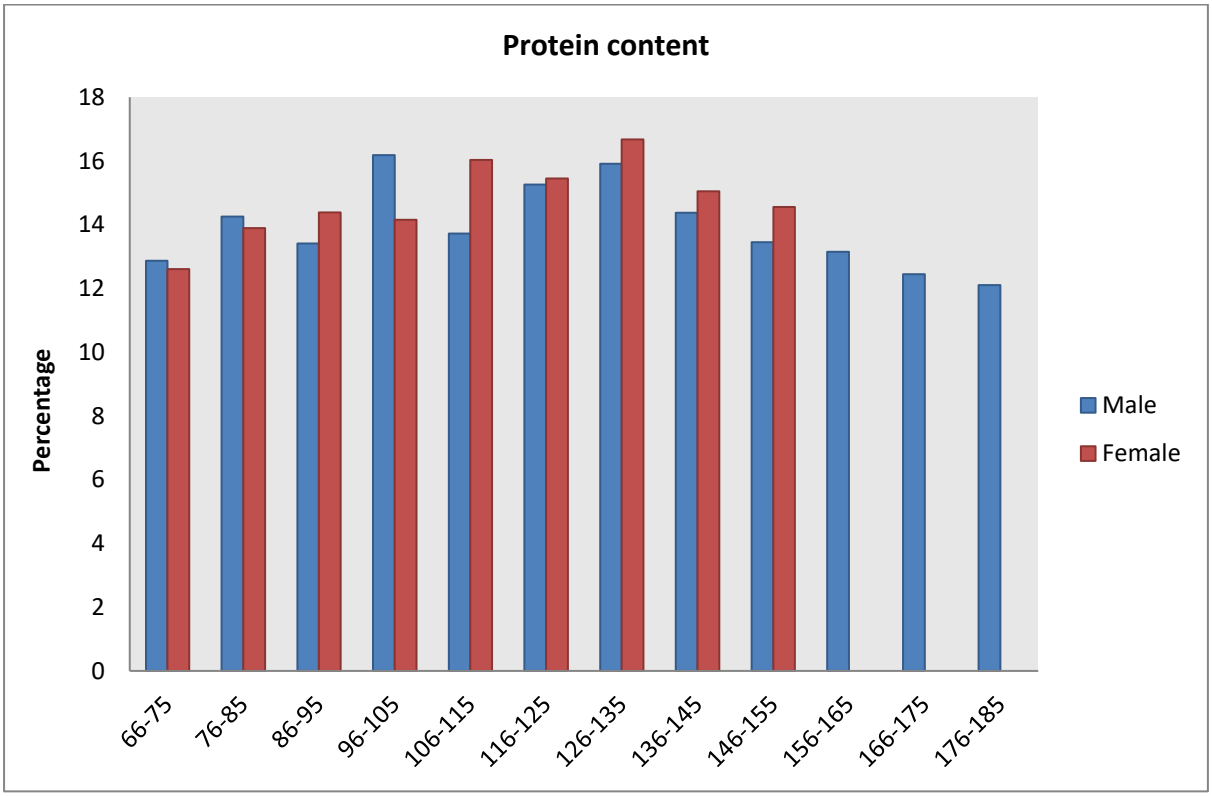


Fig 9.2b: Variations in protein content in the muscles of *P.ocellatus* male and female in different length groups.

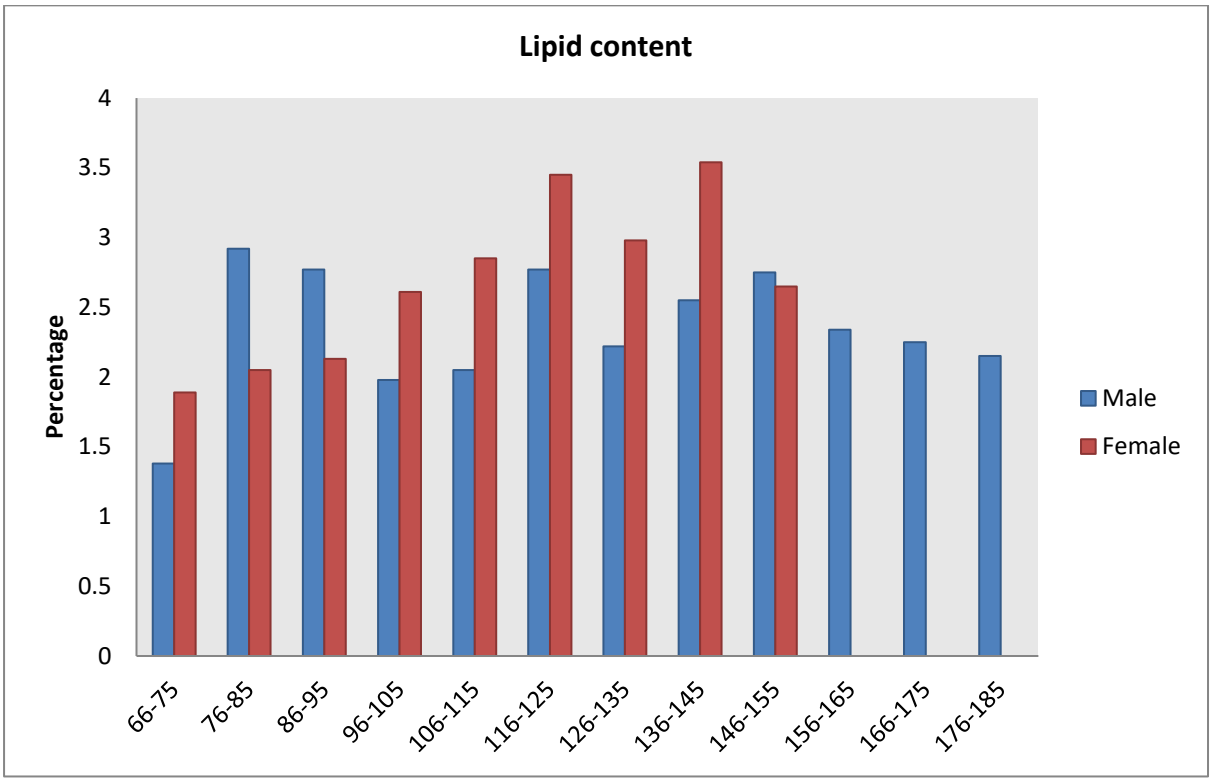


Fig 9.2c: Variations in lipid content in the muscles of *P.ocellatus* male and female in different length groups.

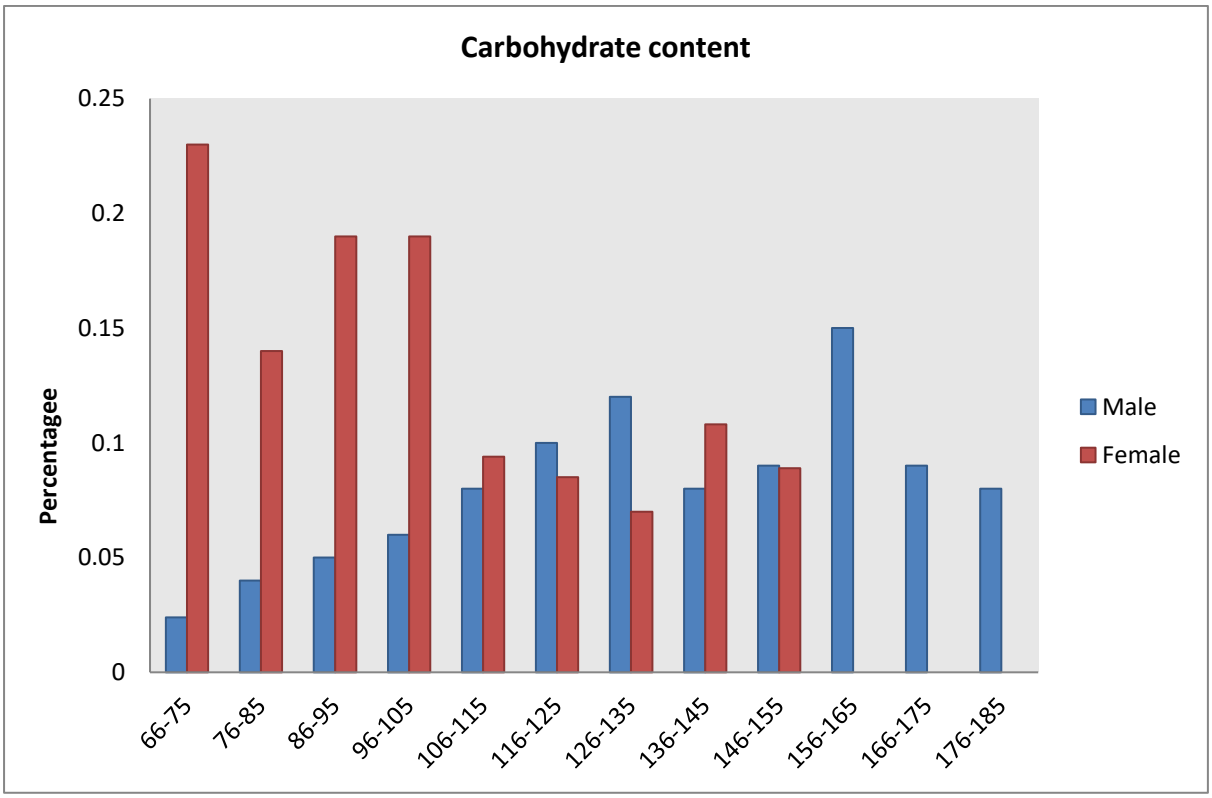


Fig 9.2d: Variations in carbohydrate content in the muscles of *P.ocellatus* male and female in different length groups.

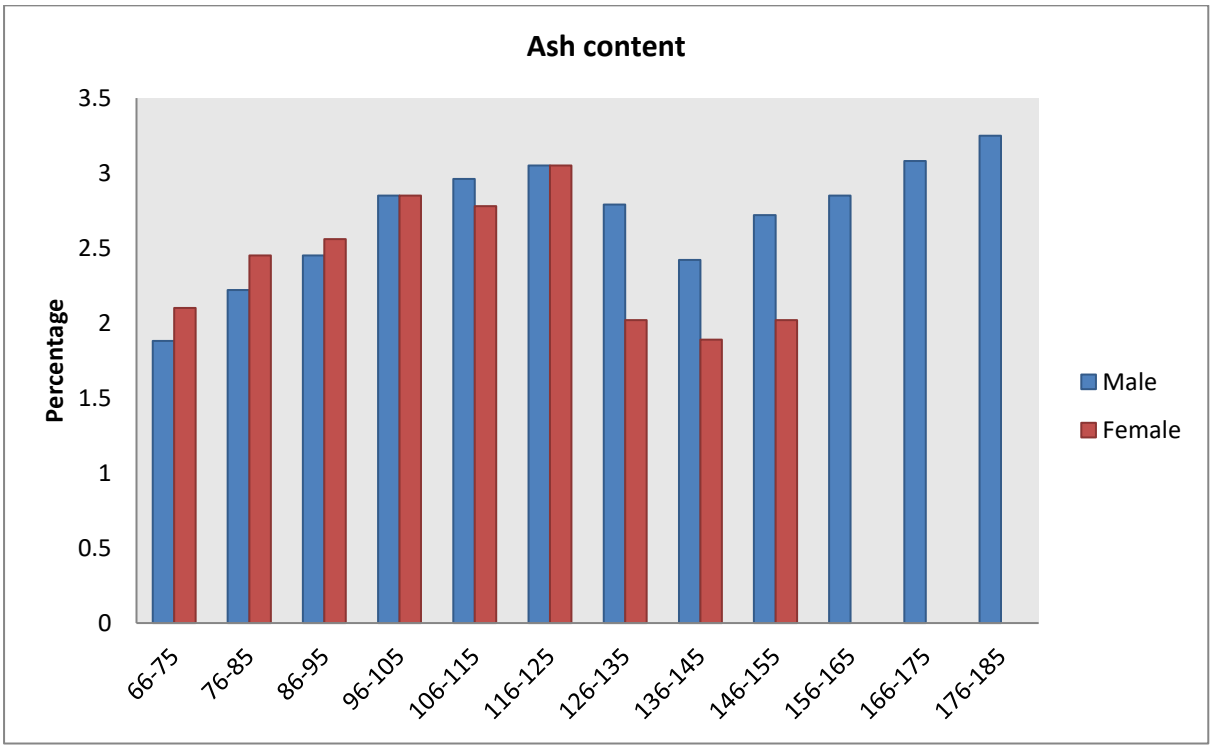


Fig 9.2e: Variations in ash content from the incinerated muscles of *P.ocellatus* male and female in different length groups.

9.5 Discussion

The study of proximal composition of fish is essential since the nutritive value is reflected in its biochemical contents. The principle constituents of fish are water (66-84%), protein (12-24%), lipids (0.1-22%) minerals (0.8-2%) and sugar in very minute quantity (Jacquot, 1961). According to Nair and Susheela (2000), the range of proximate composition of Indian fishes is as follows: moisture (65-90%), protein (10-22%), lipid (1-20%) and mineral (0.5-5%). In the present study, the range of values obtained for proximal composition of adult *P.ocellatus* were: 78.05-81.51% of moisture, 13.47-15.65% of protein, 0.8-2.55% of Lipids, 0.06-0.16% of carbohydrates and 2.37-3.87% of ash. The range of proximal composition observed in the present study is in accordance with in the ranges recorded in many fishes studied by Muraleedharan *et al.* (1996), Islam and Joadder *et al.* (2005) Abdulrahman and D'Souza (2008) Shamsan (2008) and Sebastian (2012).

The present study on biochemical composition of *P.ocellatus* deals with the understanding of nutritive value of fish in terms of percentage composition and caloric

content. Monthly variation, lengthwise variation and sex wise variation in the biochemical composition were also recorded. The present study also deals with comparison of the nutritive value of fish with few other fishes from the creeks of Malad, Vasai, Thane and Mahul. The major component of *P.ocellatus* muscle was moisture followed by protein, fat and carbohydrate. Love (1974) indicated that the availability of food at different times of the year has considerable effect on proximate composition of the muscle.

The moisture content in the male was maximum in April 2011 while in female it maximum in March 2011. There exists a negative correlation between moisture and protein content in male, female and juvenile respectively. The correlation values were highly significant at $p<0.01$. The maximum moisture content in male *P.ocellatus* coincided with minimum protein content while in the female minimum moisture content coincided with maximum protein content. Similar observations were recorded in the moisture and protein content in *Glossogobius giuris* (Islam and Joadder, 2005) and *Anbus testudineus* (Nargis, 2006).

Protein content of the fish showed variation in different months. The protein was maximum in male *P.ocellatus* in June 2011 and minimum in April 2011 while in female it was maximum in December 2010 and minimum in August 2011. The spawning season of *P.ocellatus* is at peak from February to April. Hence in males the protein content increased after spawning and decreased to the lowest during spawning months while in females it was maximum during pre spawning period and decreased to minimum in post spawning month. In females the variation in protein content may probably be due to the development of gametes, proteins might have contributed in the process of growth and development of gametes. The male fishes might have recovered the lost protein by active feeding immediately after spawning. Sivakami *et al.* (1986) had found in *Cyprinus carpio* that protein for germ building was mobilized from the muscle in stages I to IV of maturity. Protein content showed sudden increase from April 2011 to June 2011 in male and female *P.ocelltaus*. This may be due to intense feeding and feeding on larger organisms like crustaceans and fish in post spawning period. Jafri and Khawaja (1967) reported that in *Ophicephalus punctatus* there is intense feeding immediately after spawning. Islam and Joadder (2005) reported that fish while spawning incurs energy expenditure along with the loss of

gonadal elements and recoups to compensate the expenditure through vigorous feeding activity.

The lipid content was maximum in September 2010 and December 2010 in male and female respectively while it was minimum in May 2011 in both male and female. The low values of lipid content in May 2011 in both male and female may probably be due to post spawning phase of *P.ocellatus*. Depletion of fat during and after spawning in the tissues has been reported in many species of fishes by Hickling,(1947); Idler& Bitners, (1958); Das, (1978); Bumb (1992). Ahmed *et al* (1984) observed differences in seasons and availability of food at different time of the year has a considerable effect on the tissue component of fish particularly fat. A positive and significant correlation at $p<0.05$ exists between protein and fat in female *P.ocellatus* while a negative and non significant correlation exists in male *P.ocellatus*.

Ackman (1989) grouped fish into four categories depending on the level of fat: lean fish (<2%), low fat fish (2-4%), medium fat fish (4-8%) and high fat fish (>8%). *P.ocelltus* has an average fat content in the range of 0.8-2.55% and can be grouped as low fat fish. Amney (1988) reported lower values of fat in carnivorous fish *Megalops cyprinoides* when compared to *Scatophagus argus,* an omnivore. *P.ocellatus* is a carnivorous fish feeding predominantly on crustaceans and biochemical composition revealed it to be a low fat fish. The low lipid content is in agreement with that observed that Amney (loc.cit.).

Carbohydrate content formed a very minor percentage of 0.09% in male and 0.1% in females. It showed variation in different months. The low values of carbohydrates in fishes could be because glycogen does not contribute to the reserves in the body (Jayashree *et al*., 1994). In male *P.ocellatus* carbohydrate content was maximum in August 2010 and minimum in April 2011 while in females it was maximum in July 2011 and minimum in February 2011. The lower values of carbohydrate content were observed in the spawning months in both male and female. Vijayakumaran (1979) has stated that carbohydrates play a minor role as energy reserves in *Ambassis gymnocephalus* and depletion due to spawning is negligible. Selvaraj (1984) reported minimum content of carbohydrate in the muscle of *Ilisha melastoma* and concluded that its role in the mobilization of energy during maturation and spawning may be

negligible. In *P.ocellatus* carbohydrates were found to be slightly higher in females compared to males.

The ash in incinerated remains of *P.ocellatus* was maximum in January 2011 and minimum in September 2011 while in females it was maximum in October 2010 and minimum in February 2011. The variation in the ash in tissues of fishes may be because of the variation in mineral constituents, higher ash values observed in the tissues during certain seasons of the year may be attributed to the higher mineral demand of the body (Jafri and Khawaja, 1967).

The Analysis of Variance (ANOVA) between male and female *P.ocellatus* showed no significant difference in the biochemical composition in terms of content of moisture, protein, lipid, carbohydrate and ash. The variations in the biochemical composition observed may be due to the feeding and reproductive stages of the fish.

The biochemical composition of juveniles showed an average of 79.66% of moisture content, 14.45 % of protein content, 2.08% of fat content, 0.07% of carbohydrates content and 3.24% of ash as incinerated remains. The values obtained did not deviate significantly from those of adult *P.ocellatus*. In juveniles the maximum moisture content was observed in September 2010 and minimum in March 2011. The protein content was maximum in February 2011 and low in August 2010. The fat content was maximum in August 2011 and minimum in June 2011 while the carbohydrate was maximum in September 2010 and minimum in June 2011 and the ash content was maximum in December 2010 and minimum in July 2010. Although there was no significant difference in the proximate composition of adults and juveniles, the variations observed in different months were different from those of adults. These differences may be due to the availability of food and growth of the juveniles.

Total caloric value of the proximal composition of *P.ocellatus* was calculated as 979.07cal/g in males and 995.44cal/g in females. It was higher in females due to high fat content compared to males. The seasonal variation in caloric content in *P.ocellatus* revealed maximum cal/g in males in October 2010 and minimum in July 2010 while in females maximum was in December 2010 and minimum in May 2011. The caloric content of the *P.ocellatus* was maximum during pre spawning months and minimum

in post spawning months. This may probably be due to the high demand of energy during spawning in *P.ocellatus*. Thus the biochemical composition revealed that *P.ocellatus* is a nutritious fish throughout the year.

Length wise analysis showed that moisture content was highest in the length group of 66-75mm in both male and female and was lowest in the length group of 126-135mm. The variation with increase in length probably may be due to the changes in the feeding and reproduction in fishes. The length wise analysis of protein content showed maximum protein in the length group of 96-105mm in males and 106-115mm in females. It was lowest in the length group of 66-75mm in both male and female and increased with the increase in length. The protein seems to build up in the muscle of fish as it grows depending on the feeding habits and reproductive stages. Length wise analysis of fat content showed high fat content in the length group of 106-115mm in male and 96-105mm in female. Minimum fat content was observed in the length group of 166-175mm in male and 136-145mm in female. The low fat values in the large sized fish indicate that beyond a certain size the fish becomes leaner. Similar findings were reported by Shekaran (1950) and Shamsan (2008). The length wise analysis revealed maximum carbohydrate content in males of length group 156-165mm and females in the length group of 96-105mm. This variation may be due to difference in feeding and reproduction in fishes.

The comparison of proximal composition of *P.ocellatus* with other creek fishes like *Mugil cephalus*, *Tilapia mossabica, Boleophthalmus dussumeiri* and *Arius arius* revealed that it is very low in fat content compared to other fishes. The protein content of *P.ocellatus* was higher compared *Tilapia* and *Boleophthalmus*. The protein showed slight variation from other two species like *Mugil* and *Arius*. The lipid was lower In *P.ocellatus* compared to all other species of fish studied. Thus *P.ocellatus* is a fish of high nutritive value. The biochemical composition of *P.ocellatus* is at par with other creek fishes. It can provide sufficient amount of nutrition to the fish eaters.

The biochemical composition of *P.ocellatus* revealed that it is a high protein and low fat fish with negligible carbohydrates. The seasonal variation observed in *P.ocellatus* was probably due to the reproductive cycle of the fish. The fish was found to be high in protein, fat and carbohydrates in pre spawning months and the value decreased in

post spawning months. The biochemical constitution with respect to protein and fat increased with increase in length of both male and female *P.ocellatus*, while in larger adults the same tends to decrease probably due to mobilization during reproduction. In conclusion it can be stated that *P.ocellatus* was found to be nutritious like any other creek fishes which are exploited commercially and hence can be used as food of high nutritive value.

Chapter 10

Condition indices

10.1 Introduction

10.2 Review of literature

10.3 Materials and methods

10.4 Results

10.5 Discussion

10.1 Introduction

Macromolecular indices like RNA concentration, RNA : DNA ratios, RNA : protein ratios and protein: DNA ratios are frequently measured as indicators of protein synthesis potential and growth in marine fishes and invertebrates (Bulow, 1970; Carter *et al*.,1998; Buckely *et al*.,1999). These indices are particularly useful for evaluating recent environmental conditions as they reflect differences in growth rates over a period of several days (Rooker and Holt, 1996; Buckley *et al.,* 1999; Vrede *et al.,* 2002). Individuals in good condition tend to have higher RNA : DNA ratios than those in poorer condition (Clemmesen, 1994). It is valuable for managers of aquatic ecosystems for assessment of the health status of populations (Brown and Austin, 1996). The ratio is thus used to give measure of instantaneous growth in the field, thus avoiding the need for repeated measurements (Buckley *et al*., 1999).

Fulton's condition factor 'K' is calculated from the relationship between length and weight of the fish with the intention of describing the condition of the fish. It indicates the relative robustness or degree of well being of fish and is extensively used in fisheries research as a morphometric condition index and provides a useful tool to examine overall growth (Suthers, 1998). The author further states that a limitation of this classical indicator is its insensitivity to recent events in the life of fish, such as feeding history. The RNA/DNA ratio was developed as a sensitive indicator for recent growth in marine organisms (Bulow, 1970; Buckely *et al.,* 1999). The premise for the application of this index is the fairly constant concentration of DNA in a normal somatic cell (Wallace 1992) where as RNA concentration varies in proportion to protein

synthesis (Buckley, loc.cit.). The RNA : DNA ratio is an index of putative cellular protein synthesis capacity because nucleic acid concentrations and the ratios between them respond rapidly to fluctuations in food availability and are considered reliable indicators of instantaneous condition and growth (Rooker *et al.,* 1997; Okumara *et al.,* 2002; Islam and Tanaka, 2005; Vidal *et al.,* 2006). It is a useful technique to evaluate physiological condition in short period and could be utilized as nutritional condition and/or instantaneous growth for routine check to verify health status in early life of cultivated species (Gil *et al.,* 2003). The RNA : DNA ratios and other nucleic acids derived indices concomitantly with organisms and ecosystem measure responses to climate change (distribution, abundance, activity, metabolic rate, survival) which will allow for the development of more rigorous and realistic predictions of the effects of anthropogenic climate change on marine systems (Chicharo and Chicharo, 2008). It is increasingly used as correlates of nutritional condition and growth in marine species (Roark *et al.,* 2009).

The application of indicators of fish condition is essential for the assessment and protection of nursery habitat quality. RNA : DNA ratios displayed annual and inter specific variability among nursery habitats which indicates a higher sensitivity of these ratios to short term environmental fluctuations (De Raedemaecker *et al*., 2012).

10.2 Review of literature

Literature review revealed that a large number of reports are available on biochemical studies as indicators for growth in juvenile fish such as proteins (Foster *et al*. 1993; McLaughlin *et al*. 1994; Peck *et al.* 2003) and lipids (Wicker and Johnson, 1987). Many studies have found RNA : DNA ratios to be a good measure of recent growth and condition in larval (Bulow, 1970; Buckley, 1982; Ferron and Leggett, 1994; Bergeron, 1997; Buckley *et al.,* 1999; Buckley *et al.,* 2006) and some juvenile marine fish (Malloy and Targett, 1994; Kuropat *et al.,* 2002). Correlations between RNA concentration or RNA-DNA ratio and growth rate have been observed for a wide variety of organisms (Kennell and Magasanik, 1962; Bulow, 1970; Sutcliffe, 1970). Seasonal variation in the concentration of protein, RNA, DNA and their ratios were studied in *Catla catla, Labeo rohita* and *Cirrhina mrigala* (Mustafa and Zofair, 1985). Nucleic acid based condition indices provide a method to infer nutritional condition for

various species based on their responses to changes in feeding activity (Buckley, 1984; Gwak and Tanak, 2001; Johnson *et al.,* 2002; Peck *et al.,* 2003; Mercaldo Allen *et al.,* 2006, 2008; Ciotti *et al.,* 2010). RNA/ DNA ratio was evaluated as an index of physiological condition during larval development of hybrid between *Colossoma macropmum* and *Piaractus brachypomus* (Gil *et al.,* 2003). RNA/DNA ratio of *Tor putitora* and its relationship with growth and hydrobiology was studied by Sivaraman *et al*. (2009). Effect of sex on ratios and concentration of DNA and RNA in *Pomatochistus microps*, *Crangnon crangon* and *Ruditapes decussates* was described by Chicharo *et al.* (2007). RNA : DNA ratio and other nucleic acid derived indices used in marine ecology were studied by Chicharo and Chicharo (2008). Field assessment of condition indices was studied in *Mysis diluviana* by Johannsson *et al*. (2009). Piazza and La Peyre (2010) compared common morphometric and biochemical growth indices on the wild *Gambusia affinis* to examine their usefulness as indicators of habitat quality. RNA/DNA ratios in eel *Anguilla rostrata* were used as evidence for latitudinal variation in physiological status and constraints to oceanic migration (Laflamme *et al.,* 2011). Dependence of RNA : DNA ratios and Fultons condition indices 'K' on environmental characteristics of plaice and dab nursery ground was investigated by De Raedemaecker *et al.* (2011).

RNA : DNA ratio was used as an indicator of nutritional condition and growth in larval naked goby *Gobiosoma Bosc* (Satterwhite, 2003). It is used for analysis of growth in juvenile two-spotted gobies *Gobiusculus flavescens* (Frommel and Clemmesen, 2009).There are hardly any reports on such condition indices in *P.ocellatus*.

The present study of condition indices in *Parachaeturichthys ocellatus* has been carried out to determine indices like RNA and DNA content, RNA : DNA, RNA : protein and RNA : lipid ratios from the muscles of male, female and juveniles to establish their relation to growth and nutritional conditions.

10.3 Materials and methods

The samples for the present study were collected every fortnight at regular intervals from Malad, Vasai, Thane and Mahul creek during the period from June 2010 to September 2011. The fish samples were brought to the laboratory and thoroughly washed, cleaned and wiped. Total length was measured from the tip of the snout to

the tip of the caudal fin in centimetres and weight was noted to the nearest gram. The fish was cut open and the sex was noted by the macroscopic examination of gonads.

The skeletal muscle was excised from the epaxial region of the trunk below the place of the origin of dorsal fin (Buckley and Bulow, 1987). Known weights of the tissue were processed for the extraction of RNA, DNA and Protein by method of Buckley and Bulow (loc.cit.). Techniques of Schneider (1957) were followed for extraction of RNA from the tissues and its concentration was determined by the orcinol reaction. The values were read against standard curve prepared by relating the colour intensity to different concentrations of purified yeast RNA.

DNA was extracted according to the method described by Webb and Levy (1955) and its quantity was estimated by the methodology of (Ashwell 1957). Highly polymerised calf-thymus DNA was used for preparation of calibration curve.

Protein was assayed according to the method of Lowry et al (1951). Bovine serum albumin was used as the standard. Lipid was estimated by the method of Folch (1957). DNA, RNA, protein and lipid was expressed as µg/100mg dry tissue.

10.4 Results

For the present study, the contents of DNA, RNA, protein and lipids from the muscles of *P.ocellatus* have been estimated and various ratios to determine condition indices have been calculated. Variations in RNA and DNA content, RNA : DNA, RNA : protein, RNA : lipid in the muscles of male, female and juvenile *P.ocellatus during* different months is presented in table no. 10.1a, 10.1b, 10.1c and is graphically represented in fig no.10.1a to 10.1e. The **RNA** values ranged between 72-185.6µg in males, 75-160.8µg in females and 105.2-135.25µg in juveniles. Maximum RNA content was observed in February 2011 at 185.6 µg and 160.8µg in male and female respectively. In juvenile maximum value was observed at 135.25µg in August 2011. The minimum RNA content was observed in November 2010 at 72µg, 75µg and 105.2µg in male, female and juvenile respectively. The **DNA** values were in the range of 22.56- 39.31µg in male, 25.20-32.52 µg in female and 22.12- 28.43µg in juvenile. Maximum DNA content was observed in October 2010 in male and August 2010 in female and

juvenile. Minimum DNA content was observed in September 2011 in male and juvenile while in female it was in June 2010.

The **RNA : DNA** values ranged between 2.08 -5.13 in males, 2.92-5.07 in females, and 3.86-5.17 in juveniles. Monthly variation showed that RNA : DNA was lowest in October 2010 at 2.08 and 2.92 in male and female while in juvenile lowest value at 3.86 was observed in November 2010. Maximum value was observed in March 2011 at 5.13 and 5.07 in male and female respectively while juvenile showed maximum value at 5.17 in August 2011.

The **RNA : protein** values ranged between 0.0010-0.0026 in males, 0.0011-0.0022 in females and 0.0015-0.0021 in juveniles. The RNA/protein value was lowest in November 2010 and September 2011 in male, while in female it was lowest in November 2010 and juvenile in November 2010 and February 2011.The highest RNA : protein value was observed in February 2011 in male and female. In female maximum value was further observed in June 2011. In juveniles RNA : protein was lowest in June 2010, November 2010 and January 2011 and highest value in August 2010.

The **RNA : lipid** values ranged between 0.0078-0.0277 in males, 0.0056-0.0241 in females and 0.0081-0.0185 in juveniles. The minimum value was observed in November 2010 in male and female while in juvenile it was lowest in August 2011. Maximum value was observed in June 2010 in male, May 2011 in female and June 20111 in juvenile.

The average value at 4.65 of RNA : DNA was highest in immature fishes than adult fishes. It was higher in female at value 3.99 and male at 3.74. The average value of RNA : protein ratio in male, female and juvenile was 0.0015, 0.0017 and 0.0017 respectively. The average value of RNA : lipid value was 0.017 in male, 0.012 in female and 0.012 in juveniles.

Through the period of study monthly variation was observed in all the above parameters studied as condition indices. RNA : DNA value remained between 2 and 3 from September 2010-December 2010 in males, while it remained above 3 in all other months of study indicating good condition indices of male, The RNA content, RNA : protein ratio and RNA : lipid value also remained low from September 2010 to December 2010 in males while it was higher in other months of study. In females RNA

: DNA ratio was between 2 and 3 in October 2010 and November 2010 while in all other months it was above 3. The values of RNA : DNA in females was found to be better than males indicating more cellular protein synthesis activity in females. The RNA : protein and RNA : lipid values were found to be low from October 2010 to January 2010 in females while in all other months the values were higher. The RNA : DNA values were higher in juvenile immature fishes throughout the year. The values were higher than 3 in all the months of study from June 2010- September 2011. The values showed a decline only in November 2010 while in all other months it ranged between 4 and 6 indicating more cellular protein systhesis activity in immature fishes compared to adults. The RNA : protein and RNA : lipid ratio in juveniles also did not show much fluctuation in monthly values compared to adult fishes.

Length wise analysis of RNA and DNA content, RNA/DNA, RNA/protein, RNA/lipid is represented in Table no. 10.2a and 10.2b and is graphically presented in Figure no. 10.2a to 10.2e. Maximum RNA content was observed in length rage of 96-105mm at 143.55 in males while in females it was observed in length range of 126-135mm at 167.33. Minimum RNA content was observed in length range of 136-145mm at 102.54 in males and 66-75mm at 90 in females. DNA content was maximum in the length group of 176-185mm in male at 37.42 and 146-155mm in female at 35.25. Minimum DNA content was observed in 66-75mm in male and female at 29.4 and 26.5 respectively.

The RNA : DNA ratio showed lowest value in the length group 176-185mm and highest value in 96-105mm in male while in female the lowest value was observed in length group 146-155mm and highest in 106-115mm. The RNA : protein value was the lowest in length group 66-75mm and highest value was obtained in length group 86-95, 96-105 and 126-135mm in males while females showed lowest value in 66-75mm and highest value in 126-135mm. The RNA : lipid showed lowest value in 106-115mm length group and highest value was obtained in 96-105mm length group of male while in female lowest value was obtained in length group of 66-75mm and highest in 136-145mm.

Table no.10.1a: RNA, DNA, RNA: DNA, RNA: protein, RNA: lipid ratios from muscles of male *P.ocellatus* during different months.

Months	RNA µg/100mg dry wt	DNA µg/100mg dry wt	RNA: DNA	RNA: protein	RNA: lipid
Jun-10	122.45	28.5	4.2965	0.0016	0.0277
Jul-10	118.23	32.4	3.6491	0.0015	0.0182
Aug-10	98.22	24.5	4.0090	0.0013	0.0137
Sept-10	96	33.7	2.8487	0.0014	0.0098
Oct-10	82	39.31	2.0860	0.0011	0.0090
Nov-10	72	30.5	2.3607	0.0010	0.0078
Dec-10	89.93	31.56	2.8495	0.0012	0.0144
Jan-11	142.86	31.56	4.5266	0.0020	0.0169
Feb-11	185.6	36.19	5.1285	0.0026	0.0305
Mar-11	176.66	34.43	5.1310	0.0024	0.0236
Apr-11	146	28.82	5.0659	0.0020	0.0138
May-11	106.66	27.21	3.9199	0.0013	0.0270
Jun-11	104.26	26.4	3.9492	0.0013	0.0261
Jul-11	123.22	35.23	3.4976	0.0017	0.0220
Aug-11	99.34	32.45	3.0613	0.0013	0.0142
Sept-11	79	22.56	3.5018	0.0010	0.0081
Avg	115.15	30.95	3.7425	0.0015	0.0176

Table no.10.1b: RNA, DNA, RNA: DNA, RNA: protein, RNA: lipid ratios from muscles of female *P.ocellatus* during different months

Months	RNA µg/100mg dry wt	DNA µg/100mg dry wt	RNA: DNA	RNA: protein	RNA: lipid
Jun-10	98.00	25.20	3.8889	0.0014	0.0102
Jul-10	125.00	32.45	3.8521	0.0017	0.0125
Aug-10	122.00	32.52	3.7515	0.0017	0.0124
Sept-10	94.00	28.05	3.3512	0.0014	0.0104
Oct-10	82.00	28.05	2.9234	0.0012	0.0077
Nov-10	75.00	25.27	2.9679	0.0011	0.0056
Dec-10	98.66	26.69	3.6965	0.0015	0.0061
Jan-11	112.53	25.45	4.4216	0.0015	0.0096
Feb-11	160.8	31.93	5.0360	0.0022	0.0151
Mar-11	145.46	28.69	5.0701	0.0019	0.0241
Apr-11	134.93	28.95	4.6608	0.0019	0.0150
May-11	128.40	29.33	4.3778	0.0017	0.0290
Jun-11	138.20	32.42	4.2628	0.0019	0.0142
Jul-11	142.40	30.34	4.6935	0.0022	0.0101
Aug-11	122.50	32.45	3.7750	0.0018	0.0115
Sept-11	95.50	30.25	3.1570	0.0014	0.0103
Avg	117.21	29.25	3.9929	0.0017	0.0127

Table no. 10.1c: RNA, DNA, RNA: DNA, RNA: protein, RNA: lipids values from muscles of juvenile *P.ocellatus* during different months

Months	RNA µg/100mg dry wt	DNA µg/100mg dry wt	RNA: DNA	RNA: protein	RNA: lipid
Jun-10	112.25	25.42	4.4158	0.0015	0.0118
Jul-10	125.23	26.32	4.7580	0.0017	0.0117
Aug-10	135.25	28.43	4.7573	0.0021	0.0108
Sept-10	120.25	25.12	4.7870	0.0018	0.0085
Oct-10	128.23	26.32	4.8720	0.0019	0.0126
Nov-10	105.20	27.25	3.8606	0.0015	0.0099
Dec-10	112.20	27.34	4.1039	0.0016	0.0118
Jan-11	122.45	28.15	4.3499	0.0018	0.0136
Feb-11	121.25	27.34	4.4349	0.0015	0.0185
Mar-11	-	-	-	-	-
Apr-11	-	-	-	-	-
May -11	120.25	25.43	4.7287	0.0016	0.0137
Jun-11	122.25	26.34	4.6412	0.0016	0.0222
Jul-11	125.45	24.33	5.1562	0.0018	0.0092
Aug-11	120.22	23.22	5.1774	0.0017	0.0081
Sept-11	113.20	22.12	5.1175	0.0017	0.0085
Avg	120.26	25.93	4.6543	0.0017	0.0122

Table no. 10.2a: RNA, DNA, RNA: DNA, RNA: protein, RNA: lipid values from muscles of male *P.ocellatus* in different length groups

Length group (mm)	RNA µg/100mg dry wt	DNA µg/100mg dry wt	RNA: DNA	RNA: protein	RNA: lipid
66-75	105.6	29.4	3.5918	0.0013	0.0143
76-85	125.25	30.23	4.1432	0.0018	0.0172
86-95	134.26	30.4	4.4164	0.0019	0.0153
96-105	143.55	30.25	4.7455	0.0019	0.0208
106-115	138.23	32.12	4.3035	0.0018	0.0141
116-125	125.33	32.98	3.8002	0.0017	0.0183
126-135	142.34	33.45	4.2553	0.0019	0.0194
136-145	102.54	34.34	2.9860	0.0014	0.0142
146-155	118.27	34.23	3.4552	0.0016	0.0171
156-165	113.22	35.12	3.2238	0.0016	0.0171
166-175	112.43	36.25	3.1015	0.0015	0.0198
176-185	108.38	37.42	2.8963	0.0014	0.0181

Table no.10.2b: RNA, DNA, RNA: DNA, RNA: protein, RNA: lipid from muscles of female *P.ocellatus* in different length groups

Length group (mm)	RNA µg/100mg dry wt	DNA µg/100mg dry wt	RNA: DNA	RNA: protein	RNA: lipids
66-75	90	26.5	3.3962	0.0012	0.0083
76-85	99.25	26.82	3.7006	0.0015	0.0094
86-95	105.25	30.43	3.4588	0.0015	0.0098
96-105	132	30.26	4.3622	0.0019	0.0109
106-115	155.73	30.46	5.1126	0.0020	0.0134
116-125	148.4	33.86	4.3828	0.0021	0.0140
126-135	167.33	34.33	4.8742	0.0024	0.0139
136-145	115.23	34.72	3.3188	0.0017	0.0191
146-155	105.25	35.25	2.9858	0.0016	0.0108

Table no.10.1a: RNA, DNA, RNA: DNA, RNA: protein, RNA: lipid ratios from muscles of male *P.ocellatus* during different months.

Months	RNA µg/100mg dry wt	DNA µg/100mg dry wt	RNA: DNA	RNA: protein	RNA: lipid
Jun-10	122.45	28.5	4.2965	0.0016	0.0277
Jul-10	118.23	32.4	3.6491	0.0015	0.0182
Aug-10	98.22	24.5	4.0090	0.0013	0.0137
Sept-10	96	33.7	2.8487	0.0014	0.0098
Oct-10	82	39.31	2.0860	0.0011	0.0090
Nov-10	72	30.5	2.3607	0.0010	0.0078
Dec-10	89.93	31.56	2.8495	0.0012	0.0144
Jan-11	142.86	31.56	4.5266	0.0020	0.0169
Feb-11	185.6	36.19	5.1285	0.0026	0.0305
Mar-11	176.66	34.43	5.1310	0.0024	0.0236
Apr-11	146	28.82	5.0659	0.0020	0.0138
May-11	106.66	27.21	3.9199	0.0013	0.0270
Jun-11	104.26	26.4	3.9492	0.0013	0.0261
Jul-11	123.22	35.23	3.4976	0.0017	0.0220
Aug-11	99.34	32.45	3.0613	0.0013	0.0142
Sept-11	79	22.56	3.5018	0.0010	0.0081
Avg	115.15	30.95	3.7425	0.0015	0.0176

Table no.10.1b: RNA, DNA, RNA: DNA, RNA: protein, RNA: lipid ratios from muscles of female *P.ocellatus* during different months

Months	RNA µg/100mg dry wt	DNA µg/100mg dry wt	RNA: DNA	RNA: protein	RNA: lipid
Jun-10	98.00	25.20	3.8889	0.0014	0.0102
Jul-10	125.00	32.45	3.8521	0.0017	0.0125
Aug-10	122.00	32.52	3.7515	0.0017	0.0124
Sept-10	94.00	28.05	3.3512	0.0014	0.0104
Oct-10	82.00	28.05	2.9234	0.0012	0.0077
Nov-10	75.00	25.27	2.9679	0.0011	0.0056
Dec-10	98.66	26.69	3.6965	0.0015	0.0061
Jan-11	112.53	25.45	4.4216	0.0015	0.0096
Feb-11	160.8	31.93	5.0360	0.0022	0.0151
Mar-11	145.46	28.69	5.0701	0.0019	0.0241
Apr-11	134.93	28.95	4.6608	0.0019	0.0150

May-11	128.40	29.33	4.3778	0.0017	0.0290
Jun-11	138.20	32.42	4.2628	0.0019	0.0142
Jul-11	142.40	30.34	4.6935	0.0022	0.0101
Aug-11	122.50	32.45	3.7750	0.0018	0.0115
Sept-11	95.50	30.25	3.1570	0.0014	0.0103
Avg	117.21	29.25	3.9929	0.0017	0.0127

Table no. 10.1c: RNA, DNA, RNA: DNA, RNA: protein, RNA: lipids values from muscles of juvenile *P.ocellatus* during different months

Months	RNA µg/100mg dry wt	DNA µg/100mg dry wt	RNA: DNA	RNA: protein	RNA: lipid
Jun-10	112.25	25.42	4.4158	0.0015	0.0118
Jul-10	125.23	26.32	4.7580	0.0017	0.0117
Aug-10	135.25	28.43	4.7573	0.0021	0.0108
Sept-10	120.25	25.12	4.7870	0.0018	0.0085
Oct-10	128.23	26.32	4.8720	0.0019	0.0126
Nov-10	105.20	27.25	3.8606	0.0015	0.0099
Dec-10	112.20	27.34	4.1039	0.0016	0.0118
Jan-11	122.45	28.15	4.3499	0.0018	0.0136
Feb-11	121.25	27.34	4.4349	0.0015	0.0185
Mar-11	-	-	-	-	-
Apr-11	-	-	-	-	-
May -11	120.25	25.43	4.7287	0.0016	0.0137
Jun-11	122.25	26.34	4.6412	0.0016	0.0222
Jul-11	125.45	24.33	5.1562	0.0018	0.0092
Aug-11	120.22	23.22	5.1774	0.0017	0.0081
Sept-11	113.20	22.12	5.1175	0.0017	0.0085
Avg	120.26	25.93	4.6543	0.0017	0.0122

Table no. 10.2a: RNA, DNA, RNA: DNA, RNA: protein, RNA: lipid values from muscles of male *P.ocellatus* in different length groups

Length group (mm)	RNA µg/100mg dry wt	DNA µg/100mg dry wt	RNA: DNA	RNA: protein	RNA: lipid
66-75	105.6	29.4	3.5918	0.0013	0.0143
76-85	125.25	30.23	4.1432	0.0018	0.0172
86-95	134.26	30.4	4.4164	0.0019	0.0153
96-105	143.55	30.25	4.7455	0.0019	0.0208
106-115	138.23	32.12	4.3035	0.0018	0.0141
116-125	125.33	32.98	3.8002	0.0017	0.0183
126-135	142.34	33.45	4.2553	0.0019	0.0194
136-145	102.54	34.34	2.9860	0.0014	0.0142
146-155	118.27	34.23	3.4552	0.0016	0.0171
156-165	113.22	35.12	3.2238	0.0016	0.0171
166-175	112.43	36.25	3.1015	0.0015	0.0198
176-185	108.38	37.42	2.8963	0.0014	0.0181

Table no.10.2b: RNA, DNA, RNA: DNA, RNA: protein, RNA: lipid from muscles of female *P.ocellatus* in different length groups

Length group (mm)	RNA µg/100mg dry wt	DNA µg/100mg dry wt	RNA: DNA	RNA: protein	RNA: lipids
66-75	90	26.5	3.3962	0.0012	0.0083
76-85	99.25	26.82	3.7006	0.0015	0.0094
86-95	105.25	30.43	3.4588	0.0015	0.0098
96-105	132	30.26	4.3622	0.0019	0.0109
106-115	155.73	30.46	5.1126	0.0020	0.0134
116-125	148.4	33.86	4.3828	0.0021	0.0140
126-135	167.33	34.33	4.8742	0.0024	0.0139
136-145	115.23	34.72	3.3188	0.0017	0.0191
146-155	105.25	35.25	2.9858	0.0016	0.0108

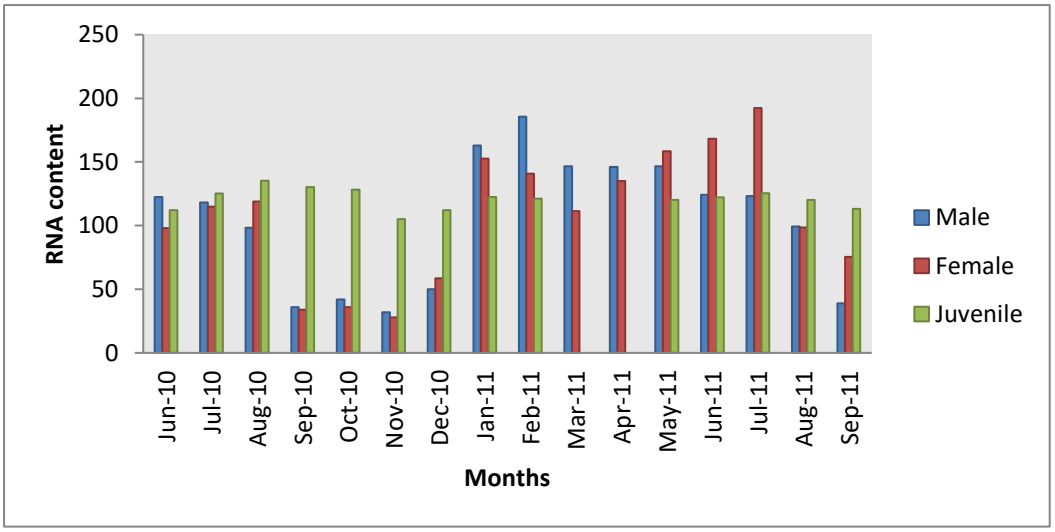


Fig10.1a: Monthly variations in RNA content from muscles of *P.oellatus* male, female and juvenile.

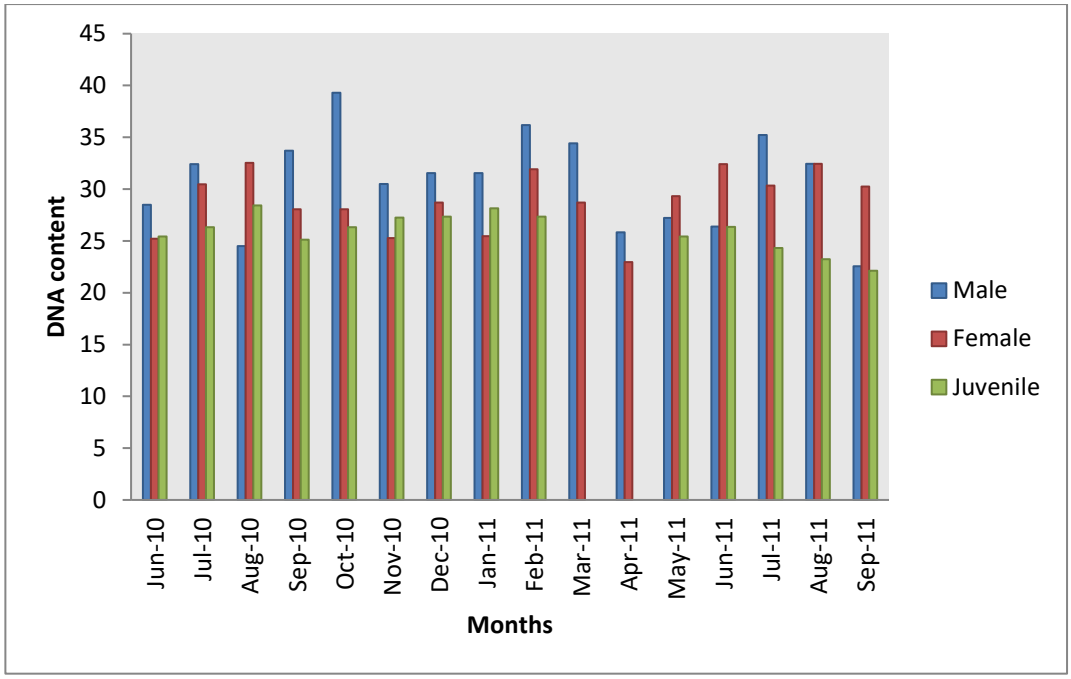


Fig10.1b: Monthly variations in DNA content from muscles of *P.oellatus* male, female and juvenile.

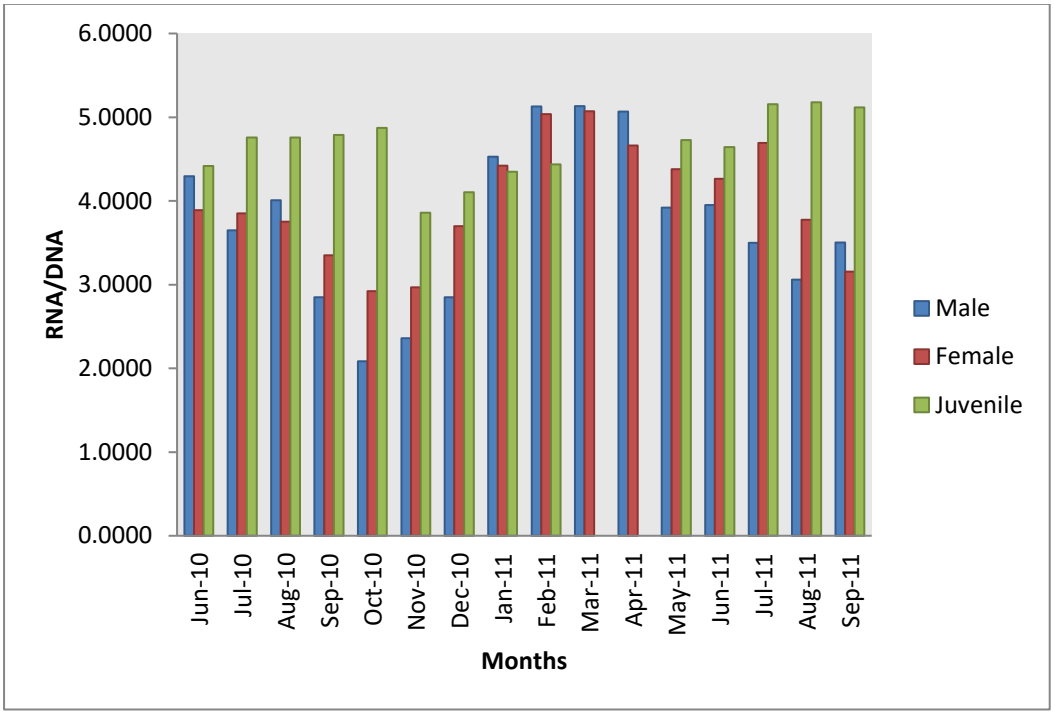


Fig10.1c: Monthly variations in RNA: DNA ratio from muscles of *P.oellatus* male, female and juvenile.

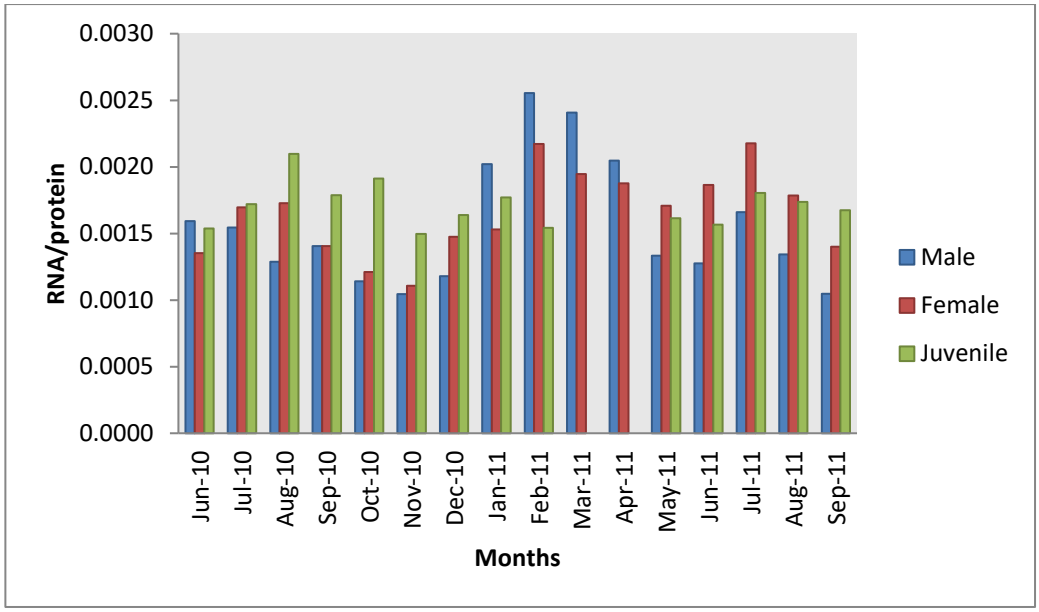


Fig 10.1d: Monthly variations in RNA: protein ratio from muscles of *P.ocellatus* male, female and juvenile.

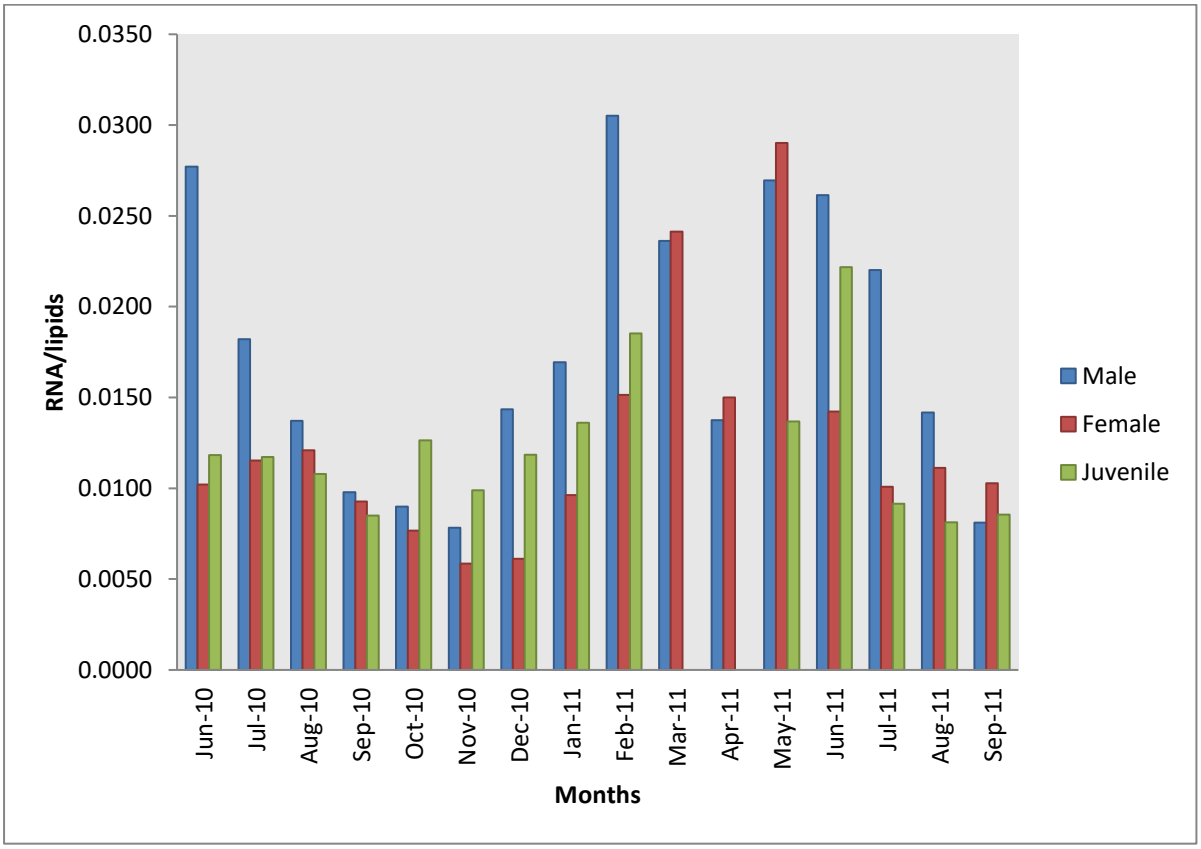


Figure 10.1e: Monthly variations in RNA: lipid ratio from muscles of *P.ocellatus* male, female and juvenile.

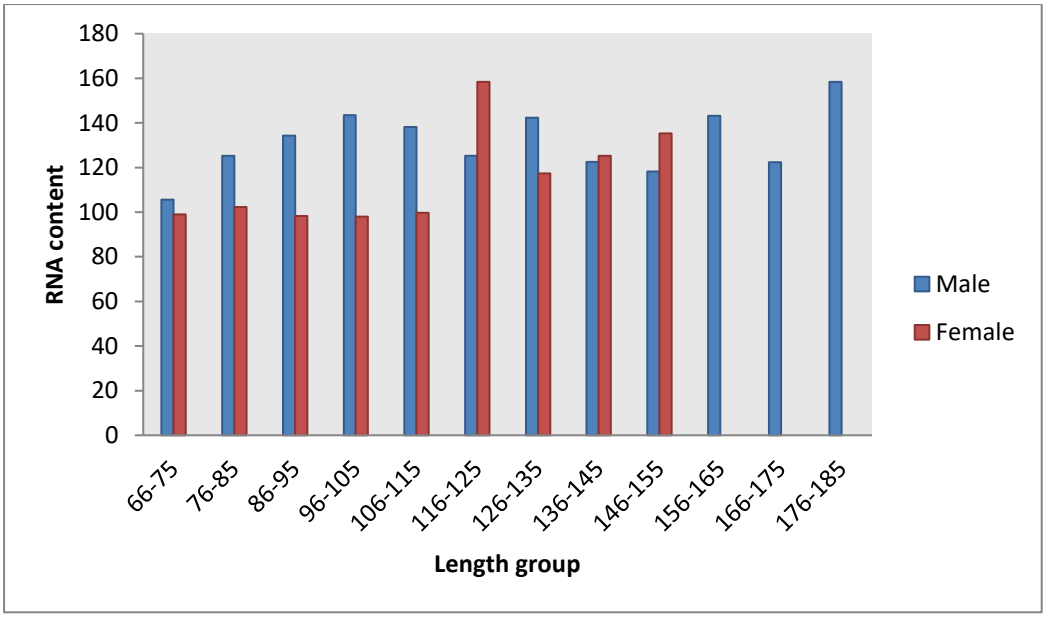


Figure 10.2a: Length wise variations in RNA content from muscles of *P.ocellatus* male and female.

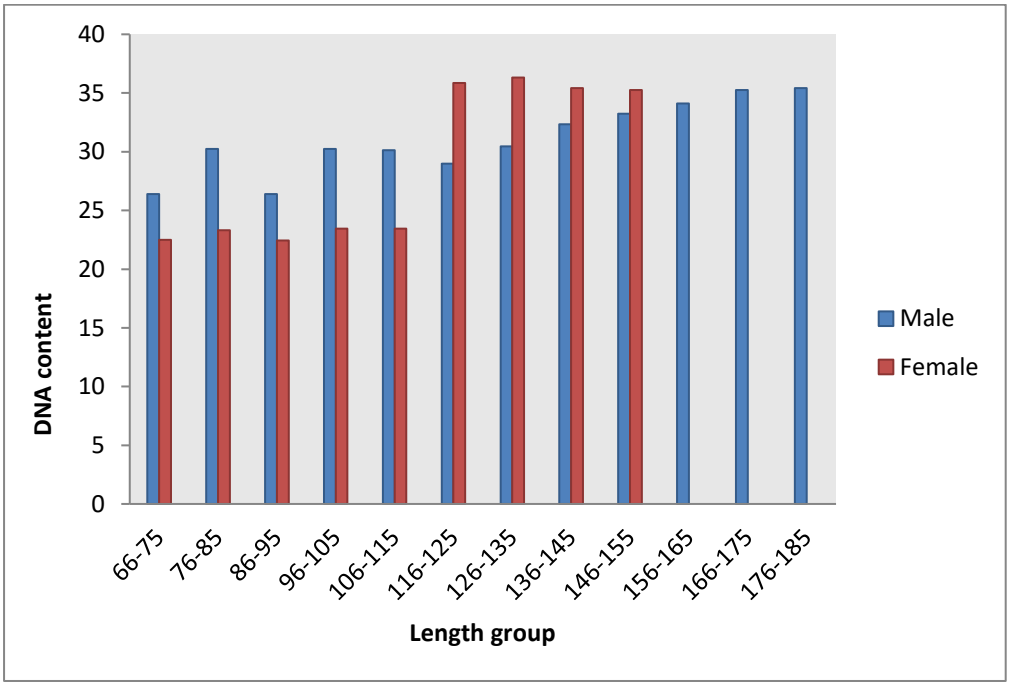


Figure 10.2b: Length wise variations in DNA content from muscles of *P.ocellatus* male and female.

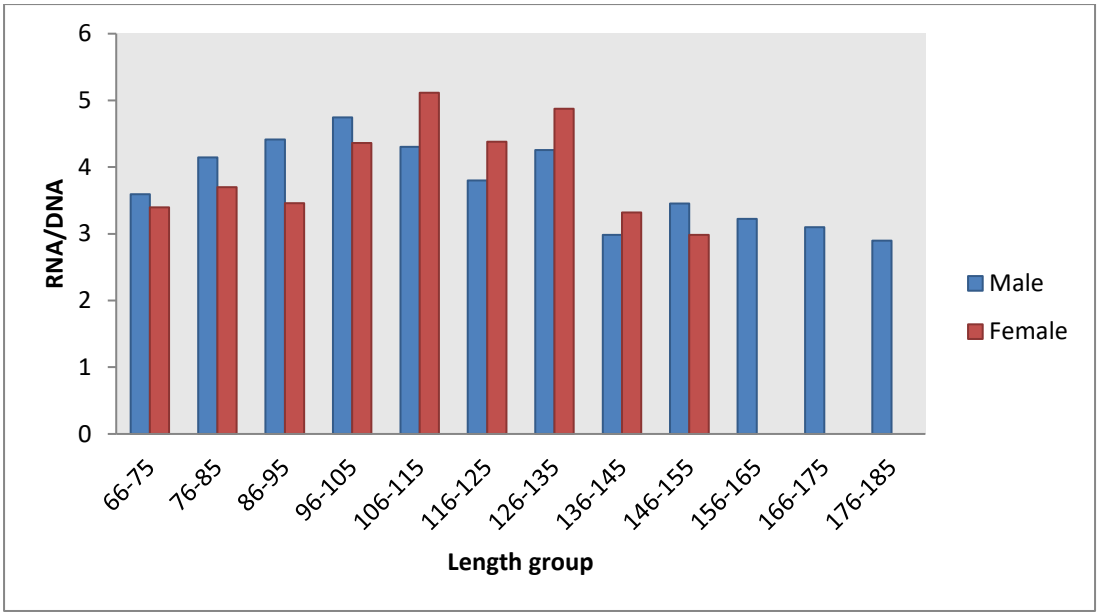


Figure 10.2c: Length wise in RNA: DNA ratios from muscles of *P.ocellatus* male and female.

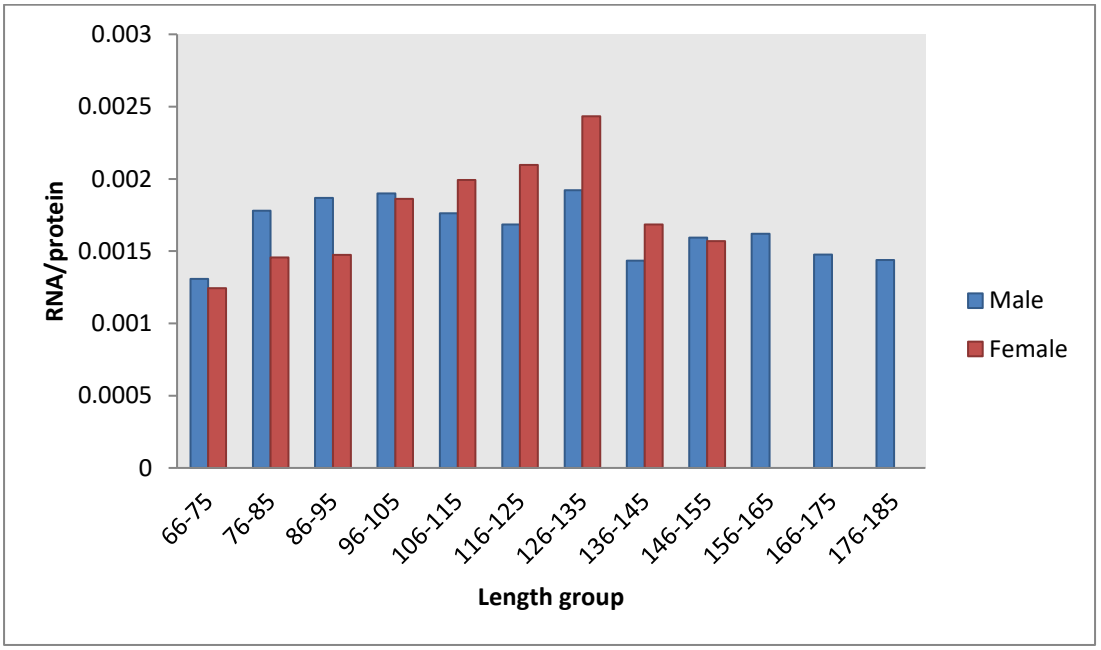


Figure 10.2d: Length wise variations in RNA: protein ratios from muscles of *P.ocellatus* male and female.

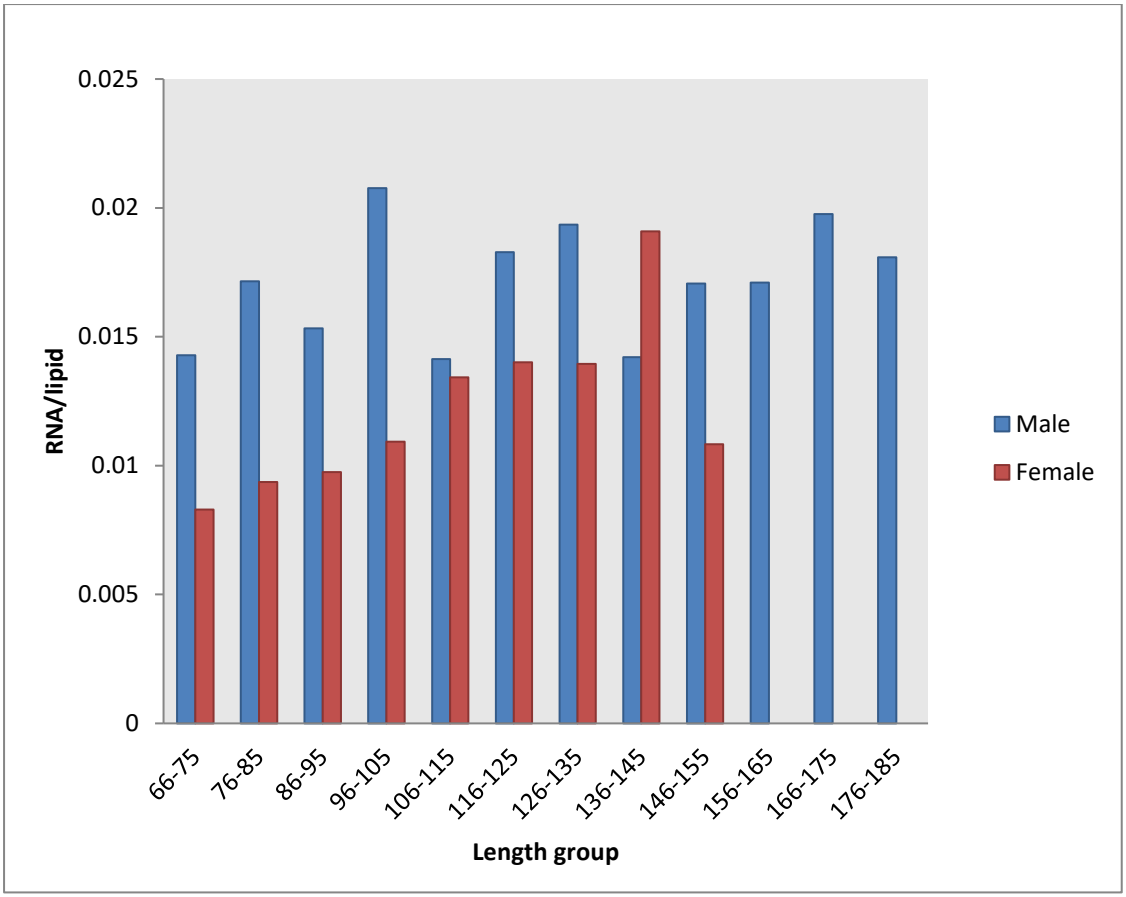


Figure 10.2e: Length wise variations in RNA: lipid ratios from muscles of *P.ocellatus* male and female.

10.5 Discussion

In the present study, RNA and DNA content, RNA : DNA, RNA : protein and RNA : lipid ratio was estimated to determine condition indices in *P.ocellatus* male female and juvenile monthly. The total amount of DNA in a defined amount of dry tissue will depend on cell size which changes with age, stage of the reproductive cycle and nutritional status (Regnault and Luquet, 1974). RNA concentrations depend on factors that affect cell size and are usually more variable than DNA concentration because RNA is required for protein synthesis, which responds quickly to changes in environmental condition (Bulow, 1970). The RNA content was maximum in February 2011 and minimum in November 2010, in male and female while in juvenile maximum value was observed in August 2010 and minimum in November 2010. The range of RNA content in male was 72-185.6 µg/100mg, in female was 82-145.46 µg/100mg and juvenile was105.2-135.256 µg/100mg. The RNA content in male was observed to increase from November 2010 to February 2011and then decrease gradually till June 2011. In female RNA content was found to increase from November 2010 to February

2011 and decreased progressively till May 2011. This increase in RNA content may probably be due to increase in protein synthesis in male and female for the spawning period. The DNA content was maximum in male in October 2010 and minimum in September 2011, in female maximum value was observed in August 2010 and minimum in June 2010 while in juvenile maximum value was in August 2010 and minimum value in September 2011. The range of DNA content in male was 22.56-39.31 µg/100mg, in female was 25.20-32.52 µg/100mg and juvenile was 22.12- 28.43 µg/100mg. In male DNA content was found to increase from November 2010 to February 2011 and then decreased gradually till June 2011. In females the values increased in February 2011 and decreased till May 2011 and further increased in June 2011. DNA content in females showed slight variations every month.

The RNA : DNA ratios ranged between 2.08-5.13 in males 2.92-5.07 in females and 3.86-5.17 in juveniles. In fish RNA : DNA ratio having values lower than 2 have usually been associated with prolonged fasting and an enhanced risk of mortality (Chicharo and Chicharo, 2008). The juvenile *P.ocellatus* showed average value at 4.65 for RNA : DNA ratio as compared to value in male and female which were 3.74 and 3.99 respectively. The lowest value of RNA : DNA ratio in juvenile was 3.86. Thus biochemical indices reflect on a very good condition indices of the juveniles throughout the period of present study from June 2010 to September 2011 Therefore the creeks of Mumbai appears to be suitable nursery ground for this species.

The average RNA : DNA in *P.ocellatus* female was slightly higher compared to that in males. Similar findings were recorded in goby *Pomatochistus microps* (Chicharo *et al.,* 2007). The range for the RNA : DNA in the females was also narrow with the range in the males at 2.08-5.13 while in female it was 2.92-5.07. The lowest value in females is nearing the index 3 while that in the male is nearing 2. Value of RNA : DNA lower than 2 indicate prolonged fasting. Thus though the ratio is nearing 2 it was not below 2 and hence though in some months the ratio indicates poor condition, the average index in male is 3.74, the males enjoy good condition indices. Maturation and reproduction differ between males and females and often require different amounts of energy and the reproductive costs are much greater for females than for males, which imply protein synthesis and therefore RNA : DNA ratio is greater in females than in males (Paon and Kenchington, 1995; Perez Camcho *et al.,* 2003).

An analysis of monthly variation showed that condition values in terms of RNA : DNA ratio increased from October 2010 to March 2011 in both male and female. The value further decreased till June 2011 in male and May 2011 in female. The increase in protein synthesis associated with the development in gonads from November to February might have resulted in the increasing RNA : DNA ratio. The lower values in November and December are in accordance with that observed in *Mysis diliviana* by Johannsson *et al*.(2009) during the pre reproductive season. The RNA : DNA values were found to be higher in reproductive season extending from January 2011 to April 2011 in *P.ocellatus.* RNA : DNA ratio increased during gonad development gradually from the developing to the spent stage (Zaboukas *et al.,* 2006). Buckley *et al* (1999) stated that as the fish mature, seasonal cycles of temperature and gonad development have large effects on nucleic acid levels in different tissues. Increase in RNA : DNA ratio in recovering fishes can be considered as indicator of protein synthesis and growth (Mustafa and Zofair, 1985).

The juveniles of *P. ocellatus* did not show much variation in the RNA : DNA ratio as compared to adults. Nucleic acids have provided useful tools for assessing the instantaneous growth rate and condition of both larval and juvenile fish (Fakuda *et al*., 2001; Kuropat *et al*., 2002). It has been found that the growth in gobies changes from hyperplasia to hypertrophy as they mature (Frommel, 2008). Several authors have suggested that RNA : DNA ratio is more related to the nutritional condition than to the growth (Miglavs and Jobling, 1989; Bergeron, 1997). There was a slight decline in the RNA : DNA in juveniles only in November. The range of 3.86-5.17 and an average of 4.65 in juveniles indicate good condition indices for juvenile *P.ocellatus*.

The RNA : protein ratio showed an average of 0.0015 in males, 0.0017 in females and 0.0017 in juveniles. Monthly variation in terms of RNA : protein showed minimum value in November 2010 in male and female and again in September 2011 in male. The maximum value for the ration was observed in February 2011 in both male and female *P.ocellatus*. In male and female *P.ocellatus* RNA : protein ratio increased from November 2010 to February 2011 which is the progression from resting stage to spawning stage.

The RNA : protein ratio further decreases in the post spawning stage of male. In female it was observed to show an increase in July 2011 probably due to recovery of spent stage. In juvenile minimum value was observed in June, November 2010 and again in February 2011 while maximum value was observed in August 2010. In juveniles it did not show much variation throughout the year. The RNA : protein ratios along with RNA : DNA ratios reflect protein synthetic rates in organisms (Foster *et al.,* 1993; Houlihan *et al.,* 1993). Condition indices shows significant relationship with protein synthesis and growth rates (Houlihan *et al.,* 1993; Smith *et al.,* 2000).

The RNA : lipid ratio showed minimum values in November 2010 in male and female *P.ocellatus*. Maximum values were recorded in June 2010 in males, May 2011 in females. In juveniles minimum value was observed in August 2011 and maximum value in June 2011. No report was available on the ratio of RNA : Lipid in the literature survey carried out by the candidate. The seasonal variations in the lipid content were related to reproduction and food availability in cod fish *Gadus morhua* (Takama *et al.,* 1985).

RNA and DNA content, RNA : DNA, RNA : protein and RNA : lipid ratios were analysed in different length groups in male and female *P.ocellatus.* The maximum value of RNA content in males was observed in the length group of 96-105mm and minimum value in length group of 136-145mm while in female the maximum value was observed in length group of 126-135mm and minimum in length group of 66-75mm. The DNA content in male was maximum in length group of 176-185mm and minimum in length group of 66-75mm while in female the value was maximum in length group of 146-155mm and minimum in length group of 66-75mm.

The analysis of condition indices in terms of RNA : DNA showed higher value in length group 96-105mm in males and 106-115mm in females. Lower values were observed in highest length group 176-185mm in male and 146-155mm in female. The RNA : DNA ratio had higher values in male than in female in the length group from 66-75mm onwards up to 96-105mm and 146-155mm on the other hand. The ratio had a higher value in females than in males in the length group from 106-115mm onwards up to 136-145mm. In the male from the length group of 146-155mm onwards progressively lower values of RNA : DNA ratio were observed till the higher length group 176-185mm. This may be due to the decline in cellular activity, related to growth and protein

synthesis after reaching a certain length group in fishes. The changes in RNA : DNA ratio with increasing length were a result of a combination of changes in biochemical composition, tissue reorganisation and behaviour which leads to changes in the metabolism of the gobies (Frommel and Clemmensen, 2009

The decrease can also be due to low feeding levels of adult fishes. Smith and Buckely (2003) demonstrated that RNA : DNA ratio reflects the feeding condition and growth of the fish. Huang and Chiu (1998) observed the increase in RNA : DNA ratios with increase in size in anchovy larvae of Japan. Sivaraman *et al.* (2009) reported positive correlation between body mass/size of the fish with RNA concentration and RNA : DNA ratios of *Tor Putitora*. Strong correlation between RNA : DNA ratio and growth has been observed in a variety of species such as *Clupea harenges, Ammodyles spp, Theragra chalcogramma, Paralichthys dentatus, Pseudopleuronectes americanus, Gadus morhua, Scomber scombrus and Morone saxatilis* (Buckely, 1984).

Maximum RNA : protein ratio was observed in the length group of 86-95mm and 126-135mm in male. In female also the value was maximum in the length group of 126-135mm. The minimum value was observed in 66-75mm in both male and female. RNA : protein ratio showed variations in different length groups. This may be due to different stages of development of males in various length groups. In female RNA : protein ratio increased in the higher length group and decreased further in the largest length group which may be associated with the reproductive cycles in female. RNA : lipid ratio was maximum in length group of 96-105mm in male and 136-145mm in female. The minimum value was observed in length group of 106-115mm in male and 66-75mm in female. RNA : lipid ratio also showed variations in different length groups of male probably associated with the reproductive stages of male. In female RNA : lipid increased in the larger length groups of female and decreased in the largest length group. This may probably associated with reproductive cycle of females.

Thus RNA : DNA, RNA : protein and RNA : lipid ratios can be used to evaluate conditional status of fishes in general. It is an indicator of the potential for protein and lipid synthesis. It also reflects the feeding, nutritional and growth rate of the fish. The goby fish *P.ocellatus* from the creeks of Malad, Vasai, Thane and Mahul showed good conditional indices in the creeks. This habitat thus seems to be suitable as nursery, feeding and reproductive ground for *P.ocellatus*.

Chapter 11

Comprehensive profile of growth and reproduction

In this thesis titled “Studies on some aspects of biology of goby fish, *P.ocellatus* (Day 1873) from Mumbai coast” few dimensions of biology of the fish have been the object of study. An integrated approach will reflect on a comprehensive profile in terms of growth and reproduction, processes vital for any study of biology.

In the present study in male, female and juvenile *P.ocellatus* a strong correlation was obtained between length and weight. The male and female had negative allometric growth with comparatively greater weight gain in male fish than that in the females for the corresponding increase in their length. On the other hand, the juveniles exhibited an isometric growth i.e. increase in weight with the corresponding increase in length. LWR and linear regression was highly significant in males, females and juveniles. In the males and females a divergence in growth pattern was observed. The males being longer than the females appear to be a distinct sexually dimorphic character in *P.ocellatus* observed during the period of study.

Measuring changes in length and weight is one way of assessing growth. Another way of assessing growth is study of relative condition factor ‘Kn’ which quantifies the well being of the fish. Growth involves increase in biomass as a result of consumption of food. A variety of food is consumed by an organism. The structure of the body and behaviour pattern developed during the evolutionary history of the organism to adapt to variety of foods and feeding. The well being or condition factor thus needs to be related to food and feeding.

According to Le Cren (1951) Kn value of greater than 1 indicated good general condition of fish. In the present study the mean ‘Kn’ value observed in male female and juvenile was greater than 1 indicating an overall good condition of fish in the creeks of Mumbai throughout the year.

The maximum value of RCF in male *P. ocellatus* was observed in November 2010, though the feeding intensity was poor in male *P.ocellatus*. Surprisingly, the male fish

were moderate feeders in December and January 2011 though a gradual decrease in RCF was observed in February 2011. In fact in February the fish were active feeders. A sharp decline from March to May 2011 in RCF values was observed though the fish were moderate feeders. With active feeding activity in May and June 2011 the RCF then increased again from June to August 2011.

In female *P.ocellatus* RCF was maximum in June 2010, when the fish was moderate feeder. A gradual decline in RCF was observed from August to October 2010 though the feeding activity was moderate and active till September followed by poor feeding in October 2010. A gradual increase in RCF was observed though the feeding activity remained poor or moderate till February 2011. The RCF again declined to reach minimum value in May, a period when the feeding was observed to be poor or moderate. However in the month of May 2011, the fish became an active feeder and continued to be active feeder in June and again in September.

The juveniles in *P.ocellatus* are moderate feeders throughout; occasionally the feeding activity is poor. RCF is maximum in August 2010 and minimum in May 2011.

However, the relatively low values of Kn observed during some periods in adult may suggest diversion of molecular resources towards reproductive activities. According to Da Costa and Araujo (2003), relatively lower 'Kn' values are usually due to the fact that a larger part of the energy is allocated for certain activities such as growth and emptying of ovaries. Seasonal variation of 'Kn' is influenced by gonadal development, feeding activity and several other factors (Gowda 1984, Doddamani *et al.,* 2001). The period in which lower condition value is obtained is also a period in which accumulated fat is in use for spawning (Braga *et al*., 1990).

In the male *P.ocellatus* the lipid content was maximum September 2010 and minimum during May 2011. In September when the lipid content was maximum when the RCF was low, while during May both RCF and lipid content were minimum.

In female *P.ocellatus* too the Lipid content was maximum in December 2010 when RCF was gradually increasing. The lipid content was minimum in May 2011 when RCF was also minimum.

P.ocellatus was observed to undergo spawning throughout the period of study from June 2010 to September 2011, except during November and December 2010. The Kn was high during pre spawning phase and declined during peak spawning phase. Utilization of accumulated lipid resources during the spawning period cannot be ruled out considering the fact that the Kn and feeding activity do not quite show a mutually agreeable relationship.

The 'Kn' values in male *P.ocellatus* gradually increases from the length group of 66-75mm through 96-105mm reaching the maximum value in the length group 106-115mm. This probably correlates with the advancing stages of maturity. The lower 'Kn' values in *P.ocellatus* were observed in the large sized individuals with a length of 166-175mm and 175-185mm probably because the male fishes have reached the post spawning stage.

The variation of 'Kn' values observed in different length groups seems to be due to differences in feeding intensity and reproductive cycle.

In female *P.ocellatus* maximum 'Kn' value was observed in smallest length group of 66-75mm. The value slightly decreased in the higher length groups. The lowest value was observed in the length group of 146-155mm. Hence it can be concluded that in male *P.ocellatus* the relative condition factor increased till the males attained maturity and then the factor decreased slightly while the female are in good condition at minimum size of development and later have slight decrease in condition values in the higher length groups with the lowest values in the large sized females.

The food and feeding habits of an organism play a crucial role in the growth and well being.The *P.ocellatus* was found to show seasonal variation in food. The intake of variety of food depends on the availability and the preference of the fish to feed on a particular type of food.

There seems to be definite niche segregation between adults and juveniles in terms of preferred food especially related to the seasons during the period of study.

The length wise analysis of adult *P.ocellatus* revealed greater proportion of larger sized food in the diet of larger fish. This pattern of change in the diet of *P.ocellatus* adults may probably help to reduce intra specific competition among the fish and offer wide spectrum of the food.

Data on feeding intensity revealed male *P.ocellatus* to be actively fed than females. The data on length wise feeding intensity revealed active feeding in *P.ocellatus* in the length group 96-105mm, 106-115mm, 116-125mm and 126-135mm in males and 96-105mm, 106-115mm and116-125mm in females. The developing individuals of lower length groups were found to feed on smaller crustaceans and planktons while the maturing adults fed on larger crustaceans and fishes.

The gastro somatic index in male and female was found to be highest during June 2010 and 2011 which agrees well with the feeding intensity. Length wise gastro somatic index revealed higher value in length group 116-125mm in both male and female. Gastro somatic index was found to decrease in the larger individuals.

An analysis of month wise and length wise variation in food preference and feeding intensity revealed that the male and female *P.ocellatus* had the same preference throughout the seasons which was different from the preference of food, of the juvenile. In the adult fish case preference seems to be function of the size/maturity of the fish rather than the sex, niche segregation in terms of preferred food could probably be a strategy for ensuring survival and growth of the juvenile *P.ocellatus*. The *P. Ocellatus* can thus be described as benthic, carnivorous, predatory, occasionally cannibalistic euryphagic and hyperphagic secondary and tertiary consumer in the food chain.

An absolutely vital characteristic of all living organisms is their capacity to reproduce. Thus along with food and feeding, leading to growth studies on various aspects of reproduction is imperative for biology. The aspects of reproduction selected for the present study are sexual dimorphism, sex ratio, stages of maturity, spawning periodicity, growth and maturity of gonads and gametes to name a few.

P.ocellatus was not sexually dimorphic throughout the life span. dimorphic characters were observed during breeding season in the fish included in the larger length group. In the present study sexual dimorphism was observed prominently during months of

August and September 2010, February, March, April, August and September 2011. In general *P.ocellatus* male tended to be longer and slender while females were shorter and had deeper abdomen. Though the near equilibrium of sex ratio was observed, the females were slightly dominant in the population of *P.ocellatus* in the terms of sex ratio during the months of September 2010, April, May and June 2011 whereas the males dominated in the population in all the other months. In the length group 156-185 only male *P.ocellatus* were prevalent.

In *P.ocellatus* Spawning extends from June to October 2010 and again from January to September 2011 with the peak spawning occurring from February to April 2011.

In the present study following stages of gonad maturity were observed in both male and female *P.ocellatus*: pre spawning stage consisting of immature and developing gonads, spawning stage consisting of mature and ripe gonads and post spawning stage consisting of spent gonads.

Pre spawning was predominantly observed from November 2010 to December 2010 in both male and female *P.ocellatus*. Spawning stages were predominant from February to April in both male and female while post spawning was predominantly observed from April to June 2011 while many of them were found in various stages of maturity in different months indicating that this species had a prolonged breeding season from June 2010 to September 2010 and again from January 2011 to September 2011.

Thus it can be concluded that *P.ocellatus* breeds throughout the year except during November and December 2010 which appears to be a resting phase during the reproductive activity.

The maturing ova were found throughout the period of study except November and December 2010 whereas ripe ova ready to spawn occurred in maximum number during February and March 2011 and few occurred in August and September 2010.

The frequency polygon of ova diameter in different stages of maturity showed only one peak. In the present study the frequency polygons of ova diameter showed a single

peak in each stage suggesting that in *P.ocellatus* individual fish spawns only once in the year.

Analysis of month wise occurrence of *P.ocellatus* in the stages of maturity numbering five revealed a very interesting profile: Immature male *P.ocellatus* occurred throughout the period of study i.e. from June 2010 to September 2011except during February, March and April 201. On the contrary immature females were found in the population during July and August, and November and December 2010. During 2011 immature females were found in January, June July and August. Immature female fish were not obtained in the sample during September and October 2010 and February, March and April 2011.

Developing males were found in the all the months of present study except May 2011 while developing female *P.ocellatus* could not be obtained in the sample from February to May 2011.
Mature male fish were obtained in the sample from August to October 2010; January to April 2011 and July to September 2011. Mature female fish were found in the sample in all the months from June 2010 to September 2011 except during May 2011.

Ripe Male *P.ocellatus* were obtained in the sample from July to September 2010, from February to May 2011 and again from July to September 2011.
Ripe male fish were not obtained in the sample in June 2010, from October to December 2010, January 2011 and June 2011. Ripe female *P.ocellatus* were found in the sample of all the months except July 2010 from November to December 2010, January 2011 and July 2011.

Spent *P.ocellatus* both male and female were obtained in the sample almost in the same months. i.e. June and October 2010; April, May and June 2011. In addition spent male fish were also obtained in the sample during September 2010 and July 2011.

It is interesting to note that maximum maturing male and female *P.ocellatus* occurred together during February, March and April 2011 which is the peak spawning period for the fish whereas during November and December 2010 only immature male and

female fish occurred in the sample and during May 2011 neither immature male nor immature female *P.ocellatus* were obtained in the sample.

Immature oocytes occurred only during November and December 2010 and July 2011 whereas developing oocytes were found all the months from June 2010 to September 2011. Maturing ova occurred in all the months from June 2010 to September 2011 except during November and December 2010. Ripe ova occurred during August and September 2010 and from February to June 2011. Spent ova could be obtained in June 2010, October 2010 and from March to June 2011.

Reproduction is a very planned energy intensive phenomenon in which a number of activities at various biological levels need to take place in a coordinated manner. Thus apart from parameter of assessment of growth like increase in size, increase in length and weight of an organism, studies on indicators of molecular events involved in reproductive processes become imperative. Studies of condition indices in terms of ratios of biological macromolecules are useful tools. Macromolecular indices like RNA concentration, RNA : DNA ratio, RNA : protein ratio and protein : DNA ratios are frequently measured as indicators of protein synthesis potential and growth in marine fishes and invertebrates (Bulow, 1970; Carter *et al*., 1988; Buckley *et al*., 1999).
An analysis of monthly variation showed that conditions indices in terms of RNA : DNA ratio increased from October 2010 to March 2011 in both male and female *P.ocellatus.* However, RNA : DNA ration had lower values during November and December 2010.

RNA: Protein ratio showed minimum value in November 2010 in male and female *P.ocellatus* the ratio increased up to February 2011 in the male fish. The RNA : lipid ratio showed minimum value in November 2010 in male and female *P.ocellatus.* Thus RNA : DNA, RNA : protein, and RNA : lipid can be used to evaluate conditional status of fishes in general. It is an indicator of the potential for protein and lipid synthesis.

A comprehensive view of the reproductive cycle in terms of various aspects discussed above highlights two periods during the cycle, firstly, the period from November to December 2010 and secondly, the period from February to April 2011. The former represents a resting phase in the reproductive cycle while the later represents the peak spawning period. A comparative account of various parameters during these two

contradictory but essential phases during the reproductive cycle of *P.ocellatus brings out the usefulness of various indices of growth and reproduction.*

Male *P. ocellatus*-Some of the conditions indices

November, December 2010 and January 2011: Resting Phase

- Feeding intensity was poor / moderate in male and female
- GaSI was minimum in November and started increasing in December and January.
- RNA content was minimum in November.
- RNA : DNA ration was minimum in October, one month prior to entry into resting phase.
- RNA : Protein, and RNA : Lipid ratios too were minimum during November.

Female *P.ocellatus*-Some of the conditions indices

November, December 2010 and January 2011: Resting Phase

- Feeding intensity was poor / moderate in female
- GaSI was low in November and started increasing in December and January.
- RNA content was minimum in November.
- RNA : DNA ration was minimum in October, one month prior to entry into resting phase.
- RNA : Protein, and RNA : Lipid ratios too were minimum during November.

Male and female *P.ocellatus*-Some of the conditions indices

February-March-April 2011 Peak breeding season

- No immature males/females, nor immature ova.
- February and March only developing males but not females
- February, March and April : maturing and ripe individuals
- February no spent individuals.
- March only spent females
- April spent males and females.

- February to April developing, mature and ripe ova.
- March-April spent ova
- GSI maximum in males in February, high but not maximum in females
- GSI in March high in males, minimum in females
- GSI in April low in both male and female.
- RNA content in male and female, maximum in February.
- RNA : DNA maximum in males in March, in females
- RNA : Proteins - Maximum in males in March, in July in females
- RNA : Lipids - Maximum in males in March, in May in females.

Thus various aspects of biology of *P.ocellatus* presented in this thesis highlight two phases in the reproductive cycle of the fish i.e. resting (November to December 2010) and Peak spawning period (February to April 2011). All the parameters studied have characteristic dimensions during the two diagonally opposite periods, both aimed at maximizing the energy intake, enhance the growth and direct all the strategies towards reproduction and survival of the species.

Chapter 12

Summary and Conclusion

The study of biology of any fish is of utmost importance in fishery biology. It gives an understanding of the morphometric and meristic characters, length weight relationship, relative condition factor, food and feeding habits and reproductive biology of the fish. The present fish under study *Parachaeturichthys ocellatus* from the creeks of Mumbai forms a part of fishery of some importance in Mumbai and Ratnagiri coast. The fact that no data is available about the biology of *P.ocellatus* has provided an impetus to take upon the present study on some aspects of its biology like morphometric and meristic characters, length weight relationship and relative condition factor, food and feeding habits and reproductive biology. The nutritional status of the fish is reflected in its biochemical composition and condition indices. The present study was undertaken for a period of sixteen months from June 2010 to September 2011.

Taxonomy and Systematics

The history of gobioid classification with detailed description up to family genera and species is described according to Day (1878) and Larson and Murdy (2001) and the key to subfamilies and genera of gobiidae is described to establish the exact identification of *P.ocellatus*. The systematic position of *P.ocellatus* was correctly established. The local name of *P.ocellatus* along with its unambiguous synonym and valid name is furnished. A detailed description of morphology of *P.ocellatus* along with its habitat and occurrence is also furnished.

Morphometry and meristic characters

Morphometry of the fish is beneficial to understand the growth rate of different morphometric characters in relation to one other. It also gives us knowledge whether the habitat is suitable for the growth of fish. In all nineteen morphometric characters were observed and recorded in *P.ocellatus.* A high degree of positive correlation significant at $p<0.01$ was observed between various morphometric characters in male, female and juvenile *P.ocellatus* The study reflects that the fish grows well in the creeks of Mumbai. The growth of fish exhibited allometric and isometric growth between different parameters.

In the male *P.ocellatus* isometry of growth was observed in standard length while all other measurements showed negative allometry. In the female fish isometric growth was observed in three characters, viz second dorsal length, pre pectoral length and pre anal length. The standard length in female fish exhibits positive allometry and all other characters showed negative allometry. Sexual dimorphism is exhibited in some of the morphometric characters in *P.ocellatus*. In the juvenile fish standard length showed positive allometry while all other characters showed negative allometry. The correlation between the four sites from where the fishes were collected did not show any significant differences indicating homogeneity in the population of *P.ocellatus* in the creeks of Mumbai.

Meristic characters are useful to understand variation in the meristic counts between sexes. They are also useful to establish sexual dimorphism. Eleven meristic characters were recorded in *P.ocellatus*. The highest variation was observed in anal fin rays in male and pelvic fin rays in female. In the present study there was no significant difference in the meristic characters between the male and the female fish. Hence the population seems to be homogenous in the creeks of Mumbai. The comparison of meristic characters in present study with those studied by Day (1858) revealed marked difference in caudal fin rays. The caudal fin rays reported by Day (1858) were 12 while in the present study it was in the range of 17-29. The variations observed in meristic characters of *P.ocellatus* from four different creeks did not merit their being placed into separate population.

Length weight relationship and relative condition values

Length weight relationship was established to derive mathematical relationship between length and weight. A high correlation was observed between length and weight of the male, the female and the juvenile *P.ocellatus*. Length weight relationship indicated a negative allometric growth in male and female fish while juveniles exhibited an isometric growth rate. The allometric values indicate a good growth rate of *P.ocellatus*.

The relative condition factor (Kn) was found to be more than 1 in the male, the female and the juvenile fish indicating condition conducive for growth of the fish. Both males and females exhibited difference in relative condition values. In the male it was maximum in pre spawning month while in the female maximum values were observed

in post spawning month. The difference of condition value may be attributed to their difference in reproductive potential and feeding between the sexes.

Food and feeding

The study of of food and feeding habits is useful to understand the type of food the fish would feed on. The morphological features of the *P.ocellatus*, relative gut length and the analysis of the type of food indicated that *P.ocellatus* is a carnivorous fish. Analysis of food components revealed dominance of crustaceans followed by mollusc and Pisces. Phytoplanktons also constitute a part of the food. The rate of feeding in the male fish was found to be higher than the female. Active feeding intensity was observed in both the males and the females in different months while juveniles were moderate feeders throughout. Gastrosomatic index showed higher values in June 2011. Empty guts also occurred throughout the period of study barring few months. *P.ocellatus* was found to be euryphagus and predatory fish. It was also hyperphagic consuming larger preys and at times showed cannibalism although; cannibalism is not a common occurrence. The fish belongs to secondary and tertiary level of consumers in the estuarine food chain.

Reproduction

Sexual dimorphism was prominent during the breeding season for some characters thought in general *P.ocellatus* was large and slender while the female was short and deeper at the abdomen. The male and female *P.ocellatus* could be identified by morphological characters like colouration around the pelvic and anal fin, length and depth of the body, length of the second fin ray of first dorsal fin, sturdiness of pectoral fin, shape of pelvic fin and length and shape of urinogenital papillae. The overall sex ratio indicated dominance of the male *P.ocellatus* throughout the year. Equilibrium of sex ratio was observed during spawning months.

In all five maturity stages consisting of Immature, developing, maturing, ripe and spent gonads were observed in the male and the female *P.ocellatus*. The fishes were observed to spawn from January to October with peak spawning activity from February to April.

The frequency polygon of ova diameter in different stages of development and different spawning months exhibited a single peak indicating single spawning season.

Gonadosomatic index revealed that the phases related to spawning are as follows: pre spawning from November to January, spawning from February to April and post spawning in May. Low GSI values occurred in the months of November and May and high GSI values were found from February to April. *P.ocellatus* was found to be highly fecund fish with fecundity ranging between 21,635-1, 79,334 eggs. Fecundity was highly correlated with total weight, ovary length, ovary weight and total length of fish.

The study of ova diameter frequency polygon and histology of mature ovary revealed that *P.ocellatus* is a single spawner. The gonado somatic index and stages of maturity revealed that the spawning season in the fish extends from January to October with peak spawning activity from February to April. Morphological and histological study of gonads revealed five maturity stages of development. The histological study revealed that the mature ovary did not have vitelline oocytes of different stages between the full grown oocytes. This indicates that *P.ocellatus* does not belong to group of multiple spawners. The study of reproduction thus indicates that *P.ocellatus* as individual fish has a single spawning instance but the population as whole may spawn from January to October.

Biochemical composition

The biochemical analysis of *P.ocellatus* revealed that it was a high protein low fat fish with negligible carbohydrates. The caloric content of the female is higher than that of the male fish due to the female fish's high fat content. Seasonal variation was observed in the biochemical composition of adult *P.ocellatus*. High protein content and high lipid content were observed in male in June and September respectively. In female both protein and lipid content were high in December. There is no significant difference in the biochemical composition of muscle of adult *P.ocellatus* in different months though the monthly variations were observed in the biochemical composition of the muscle in *P.ocellatus*, the difference were not statistically significant. These may be ascribed to the feeding intensity and for reproductive condition of the fishes. Length wise analysis of contents of protein and lipid revealed that the proximal composition increased with increase in length in the length group of 66-75mm to 96-105mm in male and 66-75mm to 106-115mm in female and gradually decreased in higher length groups in the range 126-135mm in both male and female . The juveniles also exhibited high protein and low fat values similar to adults. The comparison of *P.ocellatus* with few commercial

fishes of the creek revealed that the biochemical composition was at par with other commercial fishes. The nutritional status of *P.ocellatus* is thus related to the feeding and the reproductive condition of the fish.

Condition indices

The various ratios mentioned in terms of RNA: DNA, RNA: protein and RNA: lipid reflects on the macromolecular indices of the fish. The analysis of such condition indices in the male, the female and the juvenile P.ocellatus revealed high values which indicate that growth of *P.ocellatus* in the creeks of Mumbai is indeed satisfactory.

High RNA: DNA ratio and RNA: protein ratio was obtained in February 2011 in the males while in the females high RNA: DNA ratio was obtained in February and March 2011. RNA: protein ratio was high in February 2011 and again in July 2011. Lower RNA: DNA and RNA: protein ratio was observed in November 2010 in both the male and female fish. The values of these condition indices seem to be attributable to the feeding and reproductive status of fish.

Conclusion

The present study of biology of fish will help in providing the information about the taxonomy, morphometric and meristic characters, length weight relationship, relative condition factor, food and feeding habits and reproductive biology of fish. In the present study of biology of *P.ocellatus*, the morphological characters of *P.ocellatus* observed by Day (1858) and those observed in the present study are recorded. The present study did not reveal any change in the morphological characters of *P.ocellatus* for the fish to merit to be grouped as a separate population. The morphometric studies revealed that there is high correlation between the morphometric characters of *P.ocellatus*. The growth pattern of standard length vs total length in the male showed isometry while in female it was positive allometry. The other characters like second dorsal length, pre pectoral length and pre anal length in male showed negative allometry while in female it showed isometry. Hence the male and the female fish exhibited a slight sexually dimorphic growth pattern.

Meristic characters studied showed high variations in the anal fin rays of male and pelvic fin rays of female. The variations were not significant to be considered as sexually dimorphic characters. Comparison of meristic characters with those studied by Day (1858) revealed highest variation in caudal fin rays in present study indicating a change in the meristic characters of *P.ocellatus*. This change in the meristic characters of *P.ocellatus* may be due to climatic and/or habit change. The other meristic counts exhibited slight changes which were not significant. It is therefore essential to know the morphometric and meristic characters of a fish so that these characters can be compared with those of fish of other locations to understand the suitability of a particular environment for the growth of the fish. It is also essential to understand any difference in morphometric or meristic characters by which the fish can be separated from other fish of different population. The present study of *P.ocellatus* from the four different creeks of Mumbai did not reveal any significant difference in the morphometric or meristic characters. Hence the population of *P.ocellatus* from the four creeks of Mumbai belong to the same stock of population.

The length weight relationship exhibited significant difference in the growth rate of male and female *P.ocellatus* though both exhibited negative allometry. The juveniles exhibited isometric growth in LWR. Thus there seems to be divergence in growth pattern between male and female and adults and juveniles of *P.ocellatus*.

The study of relative condition factor revealed that *P.ocellatus* is in good condition in the creeks of Mumbai. The female were found to be in better condition than the males. There is difference in condition values exhibited by the male and the female fish. In the male relative condition value was high in November 2010. The male fish obtained during this period were immature and developing individuals of smaller size. They exhibited poor feeding intensity, low gastrosomatic index, gonadosomatic index while their biochemical composition revealed high protein content in October 2010 and high lipid content in September and October 2010. The high relative condition value in male fish may be due to the fact that it acquires good condition during November and allocates the energy for the development of gonads as the condition value was found to decrease in the pre spawning and the spawning period in the male. The relative condition value further decreased immensely after spawning but was found to increase sharply in the post spawning months. This increase of relative condition factor may be due to active feeding by the male fish. Unlike the males, in female *P.ocellatus* the

relative condition factor was found to increase from pre spawning (November to January) to spawning months (February to April) and declined sharply after spawning. In female high protein content and lipid content were observed in December 2010. The increase of relative condition factor in females may be due to increase in weight of the female due to the development of vitelline oocytes. The relative condition factor decreases sharply after spawning which may be attributed to the release of gonads by the fish. The value of 'Kn' was found to increase with the increase in feeding intensity in the post spawning month of June. A slight decrease of relative condition values in male and female was observed in September 2010 as well as September 2011 probably due to spawning occurring in the relatively young fishes. Thus relative condition factor of *P.ocellatus* seemed to be related to reproduction, feeding activity and biochemical composition of the fish.

The study of food and feeding habits revealed that *P.ocellatus* is carnivorus, euryphagus and predatory. The fish occupies position of secondary and tertiary consumers in the food chain. Food and Feeding habits indicate active feeding in the post spawning months of June 2010 and 2011 in both male and female. Feeding intensity changed in both male and female. The most preferred food of both the male and the female fish after spawning was crustaceans and fishes. The males were active feeders in January and February 2011 when the gonads were mature while females were moderately fed during the month as gonads may have occupied larger space in the abdominal cavity. The male fish showed moderate feeding during spawning months of March and April while the females were less fed in these months.

Reproductive biology of *P.ocellatus* revealed that the fish exhibited sexually dimorphic characters mostly in breeding season. The sex ratio hinted at dominance of the males although the females also showed dominance during spawning period. The spawning in *P.ocellatus* was found to be from June to October 2010 and January to September 2011 with peak spawning from February to April 2011.

The population as a whole may spawn only once in the year, though spawning extends from June to October 2010 and January to September 2011. This can be confirmed from the frequency polygon of ova diameter in different stages of maturity and during different months. The study of maturity stages of gonads also confirmed the fact. Study of morphology and histology of gonads established the fact that the fish is a single

spawner. *P.ocellatus* is a highly fecund fish. Gonado somatic index indicated high values in male in February 2011 and lowest value in November 2010. In female GSI was found to increase from December 2010 to February 2011. Maximum Gonado somatic index was observed in the August 2010. Many of the young and developing females spawn during this period. All the males and the females below 75mm were found to be immature. The length at which 50% of males attained maturity was 91mm while that of female was 94mm.

The biochemical composition of muscles of *P.ocellatus* revealed that protein content was maximum in males in June 2011 which is the post reproductive and active feeding phase. High percentage of protein in the muscle was observed in October 2010 while high value of muscle lipid was observed in September and October 2010. This might be the reason for high relative condition value of male in November with subsequent decease till spawning and post spawning period. In female high protein content and lipid content was observed in December 2010 which is the pre spawning phase and decreases in the spawning phase. The lipid was maximum in male in September 2010 and decreased till the spawning months.

The study of molecular conditional indices revealed that the ratio of RNA/DNA is high in male and female during the spawning month of February 2011 and March 2011. The ratio of RNA/protein was high in both male and female in February 2011 which is the peak spawning period of *P.ocellatus*. RNA/Lipid ratio was also high in the spawning period of February 2011 in male and March 2011 in female. The highest RNA/lipid ratio in female was also high in May 2011, probably due to very low lipid content. The condition indices are a sensitive indicator for recent growth in marine organisms (Bulow 1970; Buckely *et al* 1999). The present study of condition indices in *P.ocellatus* indicated that the fish in the creeks of Mumbai had good health status reflected through the study of its macromolecular indices. The condition indices studies indicate that the cellular activity of *P.ocellatus* is maximum in the spawning months.

Thus the present study on some aspects of biology of *P.ocellatus* has presented data on taxonomy, morphomterics, meristics, LWR, relative condition factor, food and feeding, reproductive biology, biochemical composition and condition indices.

Additional information on aspects like: behaviour, shoaling, enzyme, molecular biology, environmental preference, embryology, population dynamics, age, skeletal studies, neurobiology, osmoregulation is still required for comprehensive understanding of biology of *P.ocellatus* as an individual as well as *P.ocellatus* as a part of estuarine community. The condition indices in terms of macromolecular ratio of RNA, DNA, protein and lipids may provide useful information on the estuarine ecosystem as well as data on fishery management. Biology is a vast ocean, the more one studies the more one realizes that there is much more to be known and research is the only avenue.

Bibliography

Able, K.W. (2005), A re-examination of fish estuarine dependence: evidence for connectivity between estuarine and ocean habits, *Est coast shelf Sci*, 64 (1): 5-17.

Abdulrahman, O. M. and D'Souza, R., (2008), Chemical composition of raw fish consumed in Bahrain. *Pak. J. Biol. Sci.*, 11(1): 55-61

Abowei, J.F.N. (2009), The abundance, condition factor and length- weight relationship of *Cynoglossus senegalensis* (Kaup, 1958) from Nkoro river Niger delta, Nigeria, *Advance Technology 1* (1): 57-62.

Abowei, J.F.N. (2010), The condition factor, length- weight relationship and abundance of *Ilisha africana* (Block, 1795) from Nkoro river Niger delta, Nigeria, *Advance J. Food. Technol*., 2(1): 6-11.

Abrams, P.A. and Rowe, L. (1996), The effect of predation on the age and size of maturity of prey, *Evolution*, 50: 1052-1061.

Absawy, M.A. (2010), The reproductive biology and the histological and ultrastructural characteristics in ovaries of the female gadidae fish *Merluccius merluccius* from the Egyptian Mediterranean water, *Afr. J. Biotechnol*, Vol 9(17): 2544-2559.

Abu-Hakima, R. (1984), Some aspects of the reproductive biology of *Acanthopagrus spp* (Family: Sparidae), *Journal of Fish Biology*, 25: 515-526.

Abuzinadah, O.A. (1995), Gill raker morphology in some red sea fishes of different feeding preferences, *JKAU: Mar.Sci*., Vol 6 pp 93-122.

Acharya, P. (1980), Morphology and biology of *Nemipterus japonicas* (Bloch) of Bombay coast, M.Sc thesis, Univ. Bombay.

Ackman, R. G., 1989. Nutritional composition of fats in sea foods. *Prog. Food Nutr. Sci.*, 13: 161-289.

Adeboyejo, O.A. (2011), Meristic, Morphometric characteristics of frill fin goby (*Bathygobius soporator* valenciennes, 1837) from Lagos Lagoon, Nigeria, *Nature and Science*, 9(3): 16-23.

Adite, A., Winemiller, K.O., and Fiogbe, E.D. (2006), Population structure and reproduction of the African bonytongue *Heterotis niloticus* in the So river flood plain system (West Africa): implication for management, *Ecology of fresh water fishes*, 15: 30-39.

Ahirrao, S. D. (2002), Status of gonads in relation to total length (TL) and gonadosomatic index (GSI) in fresh water spiny eel (pisces) *Mastacembelus armatus* (Lamcepede) from Marathwada region Maharashtra, *J.Aqua.Biol*, 17 (2): 55- 57.

Ahmed, A.T.A., Mustafa, G. and Alam, M.Z. (1984), Biochemical composition of seven species of gobi fish, *J.Asiatic Soc*. Bangladesh, X: 107-111.

*Agarwal, N. K. (1988), Studies in the gonadal cycle and spawning ecology of *Schizothorax plagiostomus* in Garhwall Himalaya, Ph.D. thesis, HNB Garhwal University, Srinagar, Garhwal.

*Agorreta, A., San, Mauro.D., Schliewen, U., Van Tassell, J.L., Kovacic , M., Zardoya, R., Ruber, L. (2013), Molecular phylogenetics of Gobioidei and phylogenetic placement of European gobies, *Mol. Phylogenet. Evol*. 69, 619–633.

*Akamca, E., Mavruk, S., Ozyurt, C.E. and Kiyaga, V. B. (2011), Aquatic Invasions Volume 6, Supplement 1: 519-521.

*Akhito, P. (1963), On the scapula of gobioid fishes. Japan, *J.Icthyol*.11:1-26.

*Akhito, P. (1967), On four species of gobiid fishes of the genus Eleotris found in Japan, *Japan Ichthyol*., 14:135-166.
*Akihito, A., Iwata, K., Ikeo, T., Imanishi, H., Ono, Y., Umehara, C., Hamamatsu, K., Sugiyama, Y., Ikeda, K., Sakamoto, A., Fumihito, S., Ohno and Gojobori, T. (2000), Evolutionary aspects of gobioid fishes based on a phylogenetic analysis of mitochondrial cytochrome *b* genes, *Gene,* 259: 5-15.

Akombo, P.M., Atile, J.I., Adikwn, I.A. and Araoye, P.A. (2013), Morphometric measurements and growth patterns of four species of the genus *Synodontis* (Cuvier, 1816) from Lower Benne River, Makurdi, Nigeria, *International Journal of Biological Research*, Vol (1) (4), pp 059-065.
Akter, M.A., Hossain, M.D., Hossain, M.K., Afza, R., and Bhuiyan, A.S. (2007), The fecundity of *Hilsa illisha* from the river Padma near Godagari of Rajshahi district, *Univ.J.Zool*, Rajshahi Univ, 26, 41-44.

Al-Daham, N.K. and Bhatti, M.N. (1979), Annual changes in the ovarian activity of the freshwater teleost, *Barbus luteus* (Heckle) from southern Iraq, *J. Fish. Biol*., 14:381-387.
*Alexander, R.M.N. (1967), Functional design in fishes, Hutchinson University Library, London, pp.160.
Al-Hasan, L.A.J. and Miller, P.J. (1987), *Rhonogobius brunneus* (Gobiidae) in the Arabiam Gulf, *Japan.J Ichthyol*., 33(4), 405-408.
Alikunhi, K.H., Rao, G.L., and Jacob, P.K. (1951), Bionomics and development of *Glossobius giuris* (Hamilton), *J.Madras. Univ*. 21(B): 238-248.
Ali, A.B., and Kadir, B.K.A. (1996), The reproductive biology of the cyprinid *Thynnicthys thynnoides* (Bleeker) in the Chenderoh reservoir- a small tropical reservoir in Malaysia, *Hydrobiologia*, 318:139-151.
Allen, G. and Robertson, D. (1994), Fishes of the Tropical Eastern Pacific, Honolulu, Hawaii, Univ of Hawaii Press.
Allenderof, F.W. (1988), Conservation of biology of fishes, *Conserv. Biol*, 2:145-148.
Allsop, D.J. and West, A.S. (2004), Sex allocation in the sex changing marine goby, *Coryphopterus personatus*, on a toll-fringing reefs. *J. Evolutionary Ecology Research*, 6:843-855.
Allsteadt, J., Savitzk, A.H., Peterson, C.E., and Naik, D.N. (2006), Geogrphic variation in the morphology of *Crotalus horridus* (Serpentes: Viperidae), Herpetol Monogr., 20: 1-63.
Alonso-Fernandez, A., Vallejo, A.C., Saborido-Ray, F., Marua, H. and Trippel, E.A. (2009), Fecundity estimation of Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) of Georges Bank: Application of the autodiametric method, *Fisheries Research*, 99: 47-54.
Al-Masoodi, S.H. S. (2012), Comparative histological, ultra structure and histochemical study of the testes from twofish species, M.Sc Thesis, Umm Al-Qura Univ, Saudi Arabia.
Al-Mokhtar, K., Al-Khateeb, A. and Abdul Kareem, M.A. (1981), Embryology, Dar Al-Khoteb, Baghdad, 41-43.
Ambak, M.A., Dinh, T.D., Hasan, A. and Phuong, N .T. (2007), Reproductive Biology of the goby *Pseudapocryptes lanceolatus* in the coastal mud flat areas of the Mekong Delta Journal of Sustainability Science and Management 2(2): 21- 30.
*Anandale, F. (1919), The fauna of certain small streams of Bombay Presidency, *Rec.Ind. Mus*, 16: 125- 129.

Anderson, R.O. and Neumann, R.M. (1983), Length weight and associated structural indices, Fisheries techniques, *American Fisheries Society*, 447-481.
Anene, A and Okorie, P.U. (2008), Some aspect of the reproductive biology of *Tilapia mariae* (Boulenger 1901) in a small lake in south-eastern Nigeria, *African Journal of Biotechnology*, 7 (14): 2478-2482.
*Anney, K. M., (1988), Studies on some aspects of biology of some estuarine fishes, *Megalops cyprinoides* and *Scatophagus argus,* Ph.D. Thesis, Cochin University of Science and Technology. pp.170.

*Angelescu, V., Gueri, F. S. and Nani, A., 1958. La merluza del mar argentine (biología y taxonomía). *Publico Sew. Hidrogr. Nav. Buenos Aires,* 1004:1-224.

Apparao, T. (1966), On some aspects of the biology of *Lactarius lactarius* (Schneider), Indian .J.Fish 13: 334-349.
Arruda, L.M., Azevedo, J.N. and Neto, A.I. (1993), Abundance age structure and growth and reproduction of gobies (Pisces: Gobiidae) in the Ria de Aveiro Lagoon (Portugal), Estuarine, coastal and Shelf Sciances, 37: 509-523.
Asahina, K., Suzuki, K., Aida, K., Hibiya, T. and Tamaoki, B. (1985), Relationship between the structure and steroidogenic functions of the testes of the urohaze-goby (*Glossogobius olivaceus*) Gen. Comp. Endocrinol, 57:282-292.
Ashwell, G. (1957), Colorimeteric analysis of sugars: cysteine reaction of DNA In Colowick, S.P and N.O>kalpan eds: methods in enzymology Vol.3 Academic Press, New York, pp.1154.
Ault, J.S., Bohnsack, J.A., and Meester, G.A. (1998), A retrospective (1979-1996) multispecies assessment of coral reef fish stocks in the Florida, *Keys Fish Bull*, 96(3): 395-414.
Azevedo, J.M.N. and Simas, A.M.V. (2000), Age and growth, reproduction and diet of a sublittoral population of the rock goby *Gobius paganellus* (Teleostei, Gobiidae) *Hydrobiol*, 440: 129-135.
Babu Rao, M. (1964), Some observations on the biology of *Hilsa kanagurta* (Bleeker). *Ichthyologica* III, 63-76.
Babu Rao, M. (1966), Biometric studies on *Stolephorus insularis*, Hadenberg.2. Comparison of *S.Insularis insularis* Harderberg on east coast of India, *Ichthyologica*, V, 29-44.
Bagenal, T.B. (1957), The breeding and fecundity of the long rough dab, *Hippoglossoides platessoides* (Fabr) and the associated cycle in condition, *J.Mar.Biol.Ass*., U.K 5, 339-373.
Bagenal, T.B. (1969), The relationship between food supply and fecundity in brown trout, *Salmon trutta*, *J. Fish. Biol*., 1: 169-182.
Bagenal, T.B. (1978), Fecundity In: *Methods for the assessment of fish production in freshwaters*, Bagenal T.B (Ed). 3rd Edn, Blackwell Scientific Publications, Oxford: 159-169.
Bagenal, T.B and Tesh, F.W. (1978), Age and growth In: *Methods for assessment fish production in fresh waters*, 3rd edn (Bagenal, T.B.,ed.), Oxford, England:Blackwell Scientific Publication, pp.101-136.
Bagenal, T.B. (1979), Methods for assessment of fish production in freshwater, 3rd edition, Blackwell Scientific Publication Oxford, London p.365.
Baglin, R.E. (1982), Reproductive biology of western Atlantic Blue fin Tuna, *Fish Bull*, 80: 121- 134.

Bahuguna, S.N. and Khatri, S. (2009), Studies on fecundity of a hill stream loach *Moemacheilus montanus* (McClelland) in relation to total length, total weight, ovary length and ovary Weight, *Our Nature*, 7: 116-121.
Bal, D.V. and Rao, K.V. (1984), Marine fisheries ,Tata Mcgraw Hill Publishing Company Ltd, New Delhi pp:301-306.
Baltanas, A. and Danielpol, D.L. (2011), Geometric Morphometrics and its use in Ostracod research: a short guide, *Joamnea Geol. Palaont* 11: 235-272.
Baltz, D. M., Rakocinski, C. and Fleeger. J. W. (1993). Microhabitat use by marsh-edge fishes in a Louisiana estuary, *Environmental Biology of Fishes,* 36:109-126.

Bannerjee,V. and Venlateshwarlu, T. (1968), A biometric study of *Gadusia chapra* (Ham). *Patna Univ.Journal*, 23, 39-41.
Banu, C.P., Sayeed, S. and Quazi, S. (1991), Mineral content of fresh water fish and meat, *Bangladesh J. Zool*., 19: 59-63.
Bara, G. (1960), Histological and cytological changes in the ovaries of the mackerel, *Scomber scombrus* L. during the annual cycle, *Rev. Fac. Sci. Univ*., Istanbul, Ser.B, 26: 49-86.
Barlow, G. W., 1961. Causes and significance of morphological variations in fishes. *Syst. Zool*., 10: 105-117.

Barman, R.P., Mukherjee, P. and Kar, S. (2000), Marine and estuarine fishes. Fauna of Gujarat State Fauna Series, Zoological survey of India, 8, 311-411.

Barnham, C. and Baxter, A. (1998), Condition factor K, for Salmonid fish, Fisheries notes, Victoria, pp 1-3.
Beacham, T.D., Gould, A.P, and Stefanson, A.P. (1983), Size, age, meristics and morphometrics of chum Salmon returning to southern British Columbia during 1981-1982, *Canadian Technical Report of Fisheries and Aquatic Sciences*, 1207: 1-37.
Beck, M.W., Heck, K.L., Able, K.W., Childers, D.L., Eggleston, D.B., Gillander, B.M., Halpern, B., Hays, C.G., Hoshino, K., Minello, T.J., Orth, R.J., Sheridan, P.F. and Weinten M.R. (2001), The identification, conservation and management of estuarine and marine nurseries for fish and invertebrates, *Bio.Science* 51 (8): 633-641.
Bell, J.D., Steffe, A.S. and Talbot, R.B. (1987), The Oriental Goby, *Acanthogobius flavimanus*, colonizes a third estuary in New South Wales, Australia, *Japanese Journal of Ichthyology,* Vol.34 No.2.
Belsare, D.K. (1962), Seasonal changes in the ovaries of *Ophicephalus punctatus* (Bloch), *Indian.J.Fish*., 9(1): 140-154.
*Berra, T.M. (1981), An Atlas of Distribution of the Fresh water Fish Families of the World, Univ. of Nebrasks Press.
*Berra, T. (2001). Freshwater Fish Distribution. San Diego, CA: Academic Press
*Berg, L.S. (1940), Classification of fishes both recent and fossil. Reprint1965, Applied scientific Research Corporation of Thailand, Bangkok, Thailand: pp 346-517.
Bergeron, J.P. (1997), Nucleic acids in ichthyoplankton ecology: a review, with emphasis on recent advances for new perspectives, *J.Fish.Biol*. 5(Suppl.A): 284-302.
Beevi, K.S.J. and Ramchandran, A. (2005), Sex ratio in *Puntius vittatus* (Day) in the fresh water bodies of Ernakulam district, Kerala, *Zoos' Print Journal*, 20(9): 1989-1990.

Bhatnagar, G.K. (1972), Maturity, fecundity, spawning season and certain related aspects of *Labeo fimbriatus* (Bloch) of river Narmada near Hoshengabad. *J. Inland Fish. Soc*, India, 4: 26-37.
Bhatt, V.S. (1970), Studies on the biology of some fresh water fishes, Part IV: *Mystus seenghala* (Sykes), *J.Bombay.Nat.Hist.Soc*., 67, 194-211.
Bhatt, V.S. (1971), Studies on the biology of some fresh water fishes, Part IV: *Mystus cavassius* (Ham). Hydrobiologica, 38, 289-302.
Bhowmick, R.M. (1963), Studies on some aspects of the biology of *Glossogobius giuris* (Ham) with notes on its fishery in the Hoogly estuary, Proceedings of Indo-Pacific Fishery Commission II: 99-115.
*Bhuiyan, A.L. (1964), Fishes of Dacca, Asiatic.Soc.Pakistan Publ, No.13, Dacca, pp 96-97.
Bhuiyan, A.S., Begum, M. and Nessa, Q. (1997), Observation of the food and feeding habit of *Clupisoma atherinoides* (Bloch) (Siluriformes: Schilbidae), *Univ. J. Zool*., Rajshahi.Univ, 16: 1-5.
Bhuiyan, A.S., Nessa, Q. and Begum, M. (1998), The food and feeding habit of *Puntius gonionotus* (Bleeker) (Cyprinidae: Cypriniformes) Bangladesh, *J.Zool*, 26 (1): 73-78.
Bhuiyan, A.S., Nessa, Q. and Hossain, M.D. (1999), Seasonal pattern of feeding of grey mullet, *Mugil cephalus* (L) (Mugiliformes: Mugilidae), *Pakistan. J. Zool*., 31(1): 295-297.
Bhuiyan, A.S., Afroz,,S. and Zaman, T. (2006), Food and feeding habit of the juvenile and adult snake head, *Channa punctatus* (Bloch), *J. Life Earth .Sci*. 1(2): 53-54.
Biradar, R.S. and Gulati, D.K. (1987), A note on the morphometric and meristic analyses of *Epinephelus fasciatus* off the Maharashtra coast *Geobios*, 14,140-143.
Biswas, N. (1979), Studies on some aspects of the respiratory physiology of certain brackish water fish, Ph.D Thesis, Bhagalpur Univ, Bhagalpur.
*Blaber, S.J.M. (2000), Tropical estuarine fishes: Ecology, exploitation and conservation, Blackwell Science, pp 372.
Blazer, V.S. (2002), Histopathological assessment of gonadal tissue in wild fishes, Fish Physiol, Biochem. 26: 85-101.
*Bleeker, P. (1874), Esquisse d'un systeme naturel des Gobioides. Arch. Neerland, *Sci. Nat*., 9:289-331.
Blegvad, H. (1917), On the food of fish in the Danish waters within the Skaw, *Rep.Dan.Biol*.Stn.24:17-72.
*Bloch, M.E. and Schneider, J.G. (1801). M.E. Blochii, systema ichthyologiae iconibus cx illustratum. Post obitum auctoris opus inchoatum absolvit, correxit, interpolavit Jo. Gottlob Schneider, Saxo. Berolini, Sumtibus Austoris Impressum et Bibliopolio Sanderiano Commissum: Berlin. 584 p.
*Bloch, M.E. and Schneider, J.G. (1801), Systema Ichthyologia Berolini: pp1-584.
Boonyoung, P., Suwanjarat, J. and Amornsakun, T. (2003), Reproductive cycles and ovarian structure of sand goby, *Oyelotris marmoratus* (Bleeker, 1852), M.Sc. Thesis, Prince of Songkla Univ Songkha, Thailand pp 3-4.
Borek, K.W. and Sapota, M.R. (2005), Breeding characteristics of the sand goby (*Pomatoschistus minutus*) one of the most abundant goby species in the coastal waters of the Gulf of Gdansla region (Southern Baltic Sea). *Oceanological an Hydrobiological Studies* 34: 47-55.

Borkar, M.V., Quadros, G., Athalye R.P. (2002), Phytoplankton of Ulhas River Estuary and Thane creek, Proceedings of the National Seminar on Creek, Estuaries and Mangrove-Pollution and Conservation pp 86-92.
Bouchereau, J.L., Quignard, J.P., Joyeux, J.C. and Tomasini, J.A. (1991), Strategies et tactiques de reproduction de *Pomatochistus microps* (Kroyer 1838) et de *Pomatochistus minutus* (Pallas 1770) (Pisces Gobiidae) dans le Golfe du Lion (France). Nids determines de la sedentarite et de la migration cybium 15: 315-346.
Bowering, W.R. (1976), Distribution, age and growth and sexual maturity of witch flounder (*Glyptocephalus cynoglossus*) in new foundland waters, *J.Fish. Res. Board. Can*., 33: 1574-1584.
Bowman, R. E. and Bowman, E. W. (1980), Diurnal variation in the feeding intensity and catchability of silver hake (*Merluccius bilinearis*). *Can. J. Fish. Aquat. Sci.,* 37: 1565-1572.

Brackvelt, C.R. and McMillan, D.M. (1967), Cyclic changes in the ovary of the brook stickle back, *Eucalia inconstans*, *J.Morpho*, 123, 373-395
Bradstreet, M.S.W. and Brown, R.G.B. (1985), Feeding ecology of the Atlantic Alcidae pp 263-318 In Nettleship D.N& Birkhead, T.R (eds). The Atlantic Alcidae, Academic Press.
*Braga, F.M., Dos, S. and Gennari, F. (1990), Contribuicao para o conhecimento da reproducao de Moenkhausia intermedia (Characidae, Tetragonopterinae), na represa de Barra Bonita, rio Piracicaba, Sao Paulo, *Naturalia*, 15: 171-188.
Brito, M. F. G., Bazzoli, N. (2003), Reproduction of the Surubim catfish (Pisces Pimelodidae) in the Sao Fransisco river Pirapora region, Minas Gerais, Brazil, *Arq. Bras. Med. Vet. Zootee* 55: 624-633.
Brown, T. (1985), The Food and Feeding relationships of non-cichlid fish in Ikpoba river downstream of dam', M.Sc. Thesis, Department of Zoology, University of Benin, Nigeria, pp:18-30.
Brown, M.L. and Austin, D.J. (1996), Data management and statistical techniques. In: B.R. Murphy. D.W. Willis (eds). Fisheries Techniques, American Fisheries Society, Bethesda, Maryland, pp 17-61.
Bromage, N., Hardiman, P., Jones, J., Springate, J. and Bye,V. (1990), Fecundity eggs size and total egg volume differences in 12 stocks of rainbow trout, *Aquaculture Fishery Management*., 21: 269-284.
Brusle, J., Brusle, S. and Fourcault, B. (1998), Gonad of groupers (Serranidae) from Muroroa and Hao (Franch Polynesia) used as indicators of the quality of the coral reef environment: Histology and ultra structural aspects, *Cybius*, 22(4): 371-382.
Bucholtz, R.H., Kiewicz, T.J. and Dalskov, J. (2008), Mannual to determine gonadal maturity of Baltic herring (*Clupea harengus* L) DTU Aqua report 197-08 Charlottenlund: National Institute of Aquatic Resources 45pp.
Buckley, L.J. (1982), Effects of temperature on growth and biochemical composition of larval winter flounder (*Pseudopleuronectes americanus*) *Mar.Ecol.Prog.Ser*.8:181-186.
Buckley, L. (1984), RNA-DNA ratio: An index of larval fish growth in the sea, *Mar. Biol*., 80: 291-298.
Buckley, L.J. and Bulow, F.J. (1987), Techniques for the estimation of RNA,DNA and protein in fish. In age and Growth of fish (eds.) summerfelt and Hall, Iowa State University Press Ames, IOWA.
Buckley, L.J., Smigielski, A.S., Cladarone, E.M. (1991), Winter flounder, *Pseudopleuronectes americanus* reproductive success II. Effect of spawning time and

female size on size, composition and viability of egg and larvae, Marine Ecology Progress series, 74: 125-135.
Buckely, L.J., Cladorone, E. and Ong, T.L., (1999), RNA-DNA ratio and other nucleic acid based indicators for growth and condition of marine fishes, *Hydrobiologia*., 401: 265-277.
Buckley, L.J., Cladarone, E., Lough, R.G. and St Onge-Burns J.M. (2006), Ontogenetic and seasonal trends in recent growth rates of Atlantic cod and haddock larvae on Georges Bank: Effects of photoperiod and temperature., *Mar.Ecol.Prog.Ser*., 325: 205-226.
Bulow, F.J. (1970), RNA-DNA ratio as indicators of recent growth rates of a fish, *J.Fish. Res*. *Board .Can*., 27: 2343-2349.
Bumb, S. (1992), Studies on the Biology of Commersoni's Glassy Perchlet *Ambassiss commersoni* (Cuvier), Ph.D Thesis, Goa University.
Bundit, J. (2007), The Nutrition and feeding of a native Thai species, the marble goby (*Oxyeleotris marmoratus*) involving on farm and experimental studies, Ph.D Thesis, University of Stirling, Scotland.
Burbnik, F.T. (2001), Systematics of the North American rat snake complex (*Elaphe obsolete*). *Herpetol. Monogr*. 15: 1-53.
Burton, B.I. (1965), The Heinz Handbook of Nutrition, McGraw Hill, NewYork, 99pp.
Bowman, R.E. and Bowman, E.W., (1980), Diurnal Variation in the Feeding Intensity and Catchability of Silver Lake (*Merluccius bilinearis*). *Canadian Journal of Fisheries and Aquatic Sciences*, 37: 1565-1572.
Buxton, C.D. (1990), The Reproductive Biology of *Chrysoblephus laticeps* and *C. cristiceps* (Teleosteii: Sparidae), *J. Zool*., 220, 497-511.
Campbell, J.A. and Frost, D.R. (1993), Anguid lizards of the genus *Abronia* Revisionary notes, descriptions of four new species, phylogenetic analysis and key, *Bull.Am.Mus.Nat.His*., 216:1-121.
Caputo, V., Mesa, M.L., Candi, G. and Cerioni, P.N. (2003), The Reproductive Biology of the Crystal goby with a comparison to that of the transparent goby, *J.Fish.Biol*., 62: 375-385.
Caputo, V., Candi, G., La Mesa. M. and Arneri, B. (2000), Pattern of Gonad Maturation and the question of Semelparity in the Paedomorphic goby *Aphia minuta*, *Journal of Fish Biology* 58: 656-669.
Calder, P. C., 2003. New evidence in support of the cardiovascular benefits of long-chain n-3 fatty acids. *Ital. Heart J*., 4: 427- 429.

Carlson, S. E. and Werkman, S. H., 1996. A randomized trial of visual attention of preterm infant fed docosahexaenoic acid until two months. *Lipids,* 31: 85-90.

Carnevale. G. and Bannikov, A.F. (2006), Description of a new Stromateoid Fish from the Miocene of St. Eugene, Algeria, *Acta Palaeontologica Polonica* 51: 489-497.
Carpenter, K.E., Sommer III H.J. and Marcus, L.F. (1996), Converting Truss Interland Mark distances to Cartesian Coordinates. In L.F Marcus, M corti, A loy, G, Naylor, D.E slice, eds. Advances in morphometrics ATO ASI series A, Life Science New York Plenum publ., 284: 103-111.
Carter, C.G., Seeto, G.S., Smart, A., Clarke, S. And Van Barneveld , R.J. (1998), Correlates of growth in farmed juvenile Southern blue fin tuna *Thunnus maccoyi* (Castelnan), *Aquaculture* 161:107-119.

Cavalcanti, M.J., Monteiro, L.R., Lopes, P.R.D. (1999), Land mark based morphometric analysis in selected species of serranid fishes (Perciformes : Teleostei), *Zool.Stud*, 38: 287-294.
Chan, E.H. and Chua, T.E. (1980), Reproduction in the Green Grey Mullet, *Liza subviridis* (Valenciennes, 1836). *J.Fish. Biol*. 16, 505-519.
Charlebois, P.M., Marsden, J.E., Goettel, R.G., Wolfe, R.K., Jude, D.J. and Rudnika, S. (1997), The round goby *Neogobius melanostomus* (Pallas). A Review of European and North American literature Illinois- Indian Sea Grant program and Illinois Natural History Survey, Illinois, 76pp.
Charlebois.P.M, Corkum, L.D., Jude, D.J. and Knight, C. (2001), The round goby *Neogobius melanostomus* invasion: Current research and future needs, *Journal of Great Lakes Research* 27:263-266.
Chaves, P.T.C. (1991), Testiculos: Estrutura e dinamica de matura cao, pp 47-50, In Histologia de peixes. Ed. FUNEP, Jaboticabal, pp.77.
Chen, S.I. and Fang, S.L. (1997), Note on the new record of the marine gobiid genus *Lubrigobius* (Perciformes:Gobiidae) from Taiwan, *Acta. Zool. Taiwan*., 8 (2) :93-96.
Chen, I., Yang, J. and Chen, Y (1999), A new goby of the genus *Rhinogobius* (Teleostei: Gobiidae) from the Honghe Basin, Yunnan Province, China *Acta. Zool. Taiwan*., 10(1): 43-48.
Chen, I.S., Kottelat, M. (2003), *Papuligobius uniporus*, a new genus and species of freshwater goby (Perciformes:Gobiidae) from north-eastern Laos Ichthyol. Explor. Freshwater, Vol.14, No.3, pp 243-248.
Chen, I., Jaafar, Z. and Shao, K. (2012), A new *Obliquogobius koumans*,1941 (Teleostei: Gobiidae) from Kumejima, Ryuku Islands, Japan, Zootaxa, 3367: 269-273.
Chícharo, M.A., Chícharo, L., López-Jamar, E., Valdes, L, and Ré, P. (1998) Estimation of starvation and diel variation of the RNA/DNA ratios of field caught Sardina pilchardus larvae off north of Spain. *Mar Ecol Prog Ser* 164:273–283

Chicharo, A.A., Pedro, M. and Luic, C. (2007), Effect of sex on ratios and concentration of DNA and RNA in three marine species, Marine Ecology Progress Sereis Vol. 332: 241-245.
Chicharo, M.A. and Chicharo, L. (2008), RNA:DNA ratio and other nucleic acid derived indices in marine ecology, *Intl. J.Mol.Sci*., 9, 1453-1471.
Chiu, S.T. (1987), Aspects of the ecology of *Athocidaris crassispina* (Echinodermata: Echinoidea) in Hongkong, Ph.D Thesis, University of Hongkong, Hongkong.
Choudhary, P.S. and Dwivedi, S.N. (1984), Meristic and morphometric studies of *Lactarius lactarius* (Schneider), of Bombay coast Matsya 10, 33-37.
Chung, E.Y., Ah, C.M. and Lee, T.Y. (1991), Sexual maturation of the blue spotted mud hopper *Boleophthalmus pectinirostris* (Linnaeus), *J. Korean Fish. Soc*., 24, 167-176.
Chukwu, K.O., Deekae, S,N. and Gabriel, U.V. (2010), Reproductive biology of *Periophthalmus barbarus* (Linneaus 1766) in new Calabar river, Nigeria, *Agric. Biol*. *J.N.Am*., 1(6) :1158-1161.
Cinquetti, R. and Rinaldi, L. (2009), Changes in the gonadal histology of *Padogobius martenzi* (Pisces, Gobiidae) during the reproductive cycle, *Bull. Zool*., 54(3): 233- 241.

Ciotti, B.J., Targett, T.E., Nash, R.D.M., Batty, R.S., Burrows, M.T. and Geffen, A.J. (2010), Devolpment, validation and field application of an RNA-based growth index in juvenile plaice *Pleuronectes platessa*, *Journal of Fish Biology*, 77, 2181-2209.
Clark, F.N. (1934), Maturity of California sardine (*Sardine caerulea*) determined by ova diameter measurements, Calif.Div.Fish, *Game Fish.Bull*. 42, 1-49.
Clemmensen, C. (1994), The effect of food availability, age or size on the RNA/DNA ratio of individually measured herring larvae: laboratory calibration, *Mar.Biol*., 118: 377-382.
Coad, B.W. (2006), The freshwater fishes of Iran, Family Gobiidae, Genus *Neogobius* www.briancoad.com.
Coad, B.W. (2009), Fresh water fishes of Iran , www.briancoad.com /main.asp.
Colombo, L. and Burighel, P. (1974), Fine structure of the testis gland of the black goby, *Gobius jazo*, *L.Cell Tissue Res*, 154: 39-49.
Cole, K.S. and Hoese, D.F. (2001), Gonad morphology, colony demography and evidence for hermaphroditism in Gobiodon Okinawae (Teleostei, Gobiidae), *Environ. Biol. Fish*., 61(2): 151-173.
Contente, R.F., Stefanoni, M.F. and Spach, H.L. (2012), Feeding ecology of the American freshwater goby *Ctenogobius shufeldti* (Gobiidae, Perciformes) in a sub-tropical estuary, *Journal of Fish Biology*, 80, 2357-2373.
Cortes, S.M., Martinez-Arez, J.A. and Peterson, M.S. (2004), Feeding habits and dimorphism of the violet goby,*Gobioides Broussoneti* Lacepede (Pisces:Gobiidae) in the estuarine system of Tecolutla, Veracruz, Mexico, *Gulf and Caribbean Research*, Vol 16, 89-93.
Corpuz, M.N.C., Camcho, M.C. and Ocampo, P.P. (2013), Morphometric and morphomeristic variations in five populations of indigenous celebs goby *Glossogobius celebius* (Perciformes: Gobiidae) from Southern Luzon, Phillippines, *Philipp Agric Scientist*, Vol 96(1): 75-85.
Costanza, R., d'Arge, R., de-Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neil, R., Paruelo, J., Raskin, R., Sutton, P., van den Belt, J. (1997), The value of the worlds ecosystem services and natural capital. *Ecol. Econom*. 25 (1), 3–15.

Clucas, I.J. and Sutcliffe, P.J. (1981), An introduction to fish Hand and Processing Tropical Products Institute, London., pp. 86-91.
Da Costa, M. R. and Araujo, F. G. (2003). Length weight relationship and condition factor of *Microponias furnieri* (Desmarest) (Perciformes, Sciaenidae) in the Sepatiba Bay, Rio de Janerio State, Brazil. *Rev. Bras.Zool*., 20(4): 685-690.

Dadzie, S., Abouseedo, F. and Alshallal, T. (2000b), Histological and histochemical study of oocyte development in the silver promfret, *Pampus argentens* (Euphrasen) in Kuwait waters, Arabian Gulf.J.Sci.Res., 18: 23-31.
Daly, H.V. (1985), Insect morphometrics, *Annual Review of Entomology*, 30, pp 415-438.
Darcy, G.H. (1980), Comparison of ecological and life history information on gobiid fishes with emphasis on the south eastern United States, NOAA Technical Memorandum, NMFS/SFC, 15: 1-53.
Darcy, G.H. (1978), Ecology of the crested goby, *Lophogobius cypriniodes* (Pisces:Gobiidae) in southern Florida, M.S. Thesis,Univ.Miami.283p.

Das, H. P. (1978), Seasonal variations in the chemical composition and caloric content of *Mugil cephalus Linneaus* from the Goa waters. *Mahasagar-Bulletin of the National Institute of Oceanography*, 2 (3&4): 177-184.

Das, S. and Sahu, B.K. (2001), Biochemical composition and calorific content of fishes and shellfishes from Rushikulya Estuary, South Orissa coast of India. *Indian Journal of Fisheries*, 48: 297-302.

Davis, T.L.O. (1977), Reproductive biology of the freshwater car fish *Tandanus tandanus* Mitchell in the Guiydir river, Australian I. Structure of gonads. *Aust. J.Mar. Frshwat. Res.* 28,139-158.

Davies, B., Bromage, N. and Swanson, P.(1999), The brain–pituitary– gonadal axis of female rainbow trout *Oncorhynchus mykiss*: effects of photoperiod manipulation. *Gen. Comp. Endocrinol.*, 115: 155–166.

Dawson, C.E. (1966), Studies on the gobies (Pisces: Gobiidae) of Mississippi sound and adjacent waters. I.Gobiosoma.Am.Midl.Nat, 76:379-409.

Day, F. (1858), The Fishes of India, Willaim Dawson & Sons Ltd, 495pp.

Day, F. (1873), On new and imperfectly known fishes of India. Proceedings of the Zoological Society of London (pt I): 236-240.

Day, F. (1876), The Fishes of India; being a natural history of the fishes known to inhabit the seas and fresh waters of India, Burma and Ceylon, Bernard Quaritch London, 28, 1-320.

Day, F. (1878), The fishes on India; being a natural history of the fishes known to inhabit the seas and freshwaters of India, Burma and Ceylon,Vols I&II, William Dawson and Sons, London.

Day, F. (1889), The fauna of British India including Ceylon and Burma Vols I&II Taylor and Francis, London.

De buse, V.J., Addison, J.T. and Reynolds, J.D. (1999), The effects of sex ratio on sexual competition in the European lobster, *Anim.Behav*., 58: 973-981.

De Raedemaecker, F.; Keating, J.; Brophy, D.; O'Connor, I.; Mc Grath, D. (2011), Spatial variability in diet, condition and growth of juvenile plaice (*Pleuronectes platessa*) at sandy beach nursery grounds on the south-west coast of Ireland. *J. Mar. Biol. Ass. U.K. 91(Special Issue 06 (Fish Ecology))*: 1215-1223.

De Raedemaecker, F., De Brophy, D., O'Connor, I. and O'Neil, B., (2012), Dependence of RNA: DNA ratios and Fulton's K condition indices on environmental characteristics of plaice and dab nursery grounds, *Estuarine Coastal and Shelf Science*, 98: 60-70.

Desai, V.R. (1970), Studies on the fishery and biology of *Tor tor* (Ham) from river Narbada, *J. Indian.Fish.Soc*., 2: 101-112.

De Sylva, D.P. (1975), Nektonic food webs in estuaries, E.cronin, ed. Estuarine research, Vol.1, *Academic Press*, New York, 587:420-447.

De Vlaming, V.L. (1972), Reproductive cycling in the estuarine gobiid fish *Gillichthys mirabillis Copeia* 2, 278-291.

Devlin, R.H. and Nagahama, Y. (2002), Sex determination and differentiation in fish: An overview of genetic, physiological, and environmental influences. Aquaculture, Vol.208 (3-4), pg.191-364

Dinh, T.D., Ambak, M.A., Hassan, A. and Phuong, N.T. (2007), Biology and Population dynamics of the goby *Pseudapocryptes elongates* in the coastal mud flat areas of the Mekong delta, Vietnam, *Pak. J. Biol. Sci*., 10: 3284-3294.
Dhanya, V.M.R., Jaiswar, A.K., Palaniswamy, R. and Chakraborty, S.K. (2004), Morphometry and length-weight relationship of *Coila dussumieri*, Valenciennes, 1848 from Mumbai waters, *J. Ind. Fish. Asso*., 31:65-70.
Doddamani, M., Rameshanand, T.J., Shanbhague, S.L. (2001), Length-weight relationship and condition factor of *Stolephorua bactaviensis* from Mangalore Area, *Indian.J.fish*, 48: 329-332.
Doha, S. (1974), Investigation into the biology of the gobi, *Glossogobius giuris* (Ham. and Buch.) (Perciformes: Gobiidae), *Bangledesh.J.Zool*. 2(2):95-106.
Dorado, E. (2010), Sexual dimorphism in body shapes of the white goby, *Glossogobius giuris* (Hamilton and Bauchanan, 1822) of lake Buluan in Mindanao, A dissertation MSU-IIT, Iligan city.
Dorostghoal, M., Peyghan, R., Papan, F. and Khali, L. (2009), Macroscopic and microscopic studies of annual ovarian maturation cycle of Shirbot *Barbus gyrypus* in Karoon river of Iran, Iranian. J of Vert.Res., 10 (2): 172-179.
Dos-Santos, J.E., Bazzoli, N., Rizzo, E., and Santos, G.B. (2004), Reproduction of the catfish, *Iheringichthys labrosus* (Lutken) (Pisces, Siluriformes) in Furnas reservoir, Minais Gerais, Brazil. Revista Brasileira de Zoologia., 21: 193-200.
Dotu.Y. and Mito.S. (1955a), On the breeding-habits, larvae and young of a goby, *Acanthogobius flavimanus* (Temminck et Schlegel)., *Jap.J.Ichthyol*., 4: 153-161.
Dotu.Y. (1961), The bionomics and life history of the gobioid fish *Apocryptodon bleekeri* (Day), *Bull. Fac. Fish*, Nagasaki Univ., 127-131.
Dotu, Y. (1961a), The bionomics and life history of the gobioid fish, *Rhinogobius giurinus* (Rutter), *Bull. Fac. Fish*, Nagasaki Univ., 10:120-125.
Dotu, Y., Mito, S. and Ueno, M. (1955), The life history of a goby, *Chaeturichthys hexanema* (Bleeker), *Sci. Bull. Fac. Agr*., Kyushu Univ, 15: 359-365.
Dotu, Y. (1955), On the life history of a gobioid fish, *Eutaeniichthys' gilli* (Jor et sy). Printed by Science sha: 338-344.
Dotu, Y. (1955a), The life history of an eleotrid goby, *Parioglossus taeniatus* Regan. *Sci. Bull*. *Fac. Agr*., Kyushu Univ., 15: 489-496.
Dotu, Y. (1955b), Life history of a goby, *Gobius poecilichthys* Jordan et Synder, *Sci.Bull.Fac.Agr*., Kyushu Univ., 15:77-85.
Dotu, Y. (1958a), The bionomics and life history of Gobioid fish, *Paleatogobius uchidae, Takagi.Japan.J.Ichthyol*., 6:97-104.
Dotu, Y. (1965), On the life history of a gobioid fish, *Eutaeniichthys gilli* Jordan et Synder, *Bull.Biogeogr.Soc.Jap.*, 16-19:338-344.
Dube, K. and Dubey, G.P. (1987), Biometric studies of Indian mahaseer *Tor tor* (Ham) from Narmada river , Matsya 13. 126-132.
*Duncker. G. (1928), Gobiiformes. In G. Grimne and E Wagler.eds. Die Tierwelt des Nord und Ostsee., *Leipzig*, 12:121-148.
Durham, B.W. and Wilde, G.R. (2008), Asyncyhronous and Synchronous spawning by small eye shiner *Notopteris buccula* from the Brazos River, Texas, *Ecol. Freshw. Fish*., 17 : 528-541.
Dutt, S. and Rao, B.V.S. (1981), Biometric comparison of samples of the clupeid fish *Escualosa thoracata* (Val.) from two localities. *Matsya*, 7, 50-63.
Dwivedi, S.N. and Menezes, M.R. (1974), A note on the morphometry and ecology of *Brachirus crientalis* ((Bloch and Schneider) in the estuaries of Goa, *Geobios*, 1, 80-83.

Engin, S. and Bektas,.Y. (2010), Morphologic and habitat characteristics of Black Sea's endemic goby *Neogobius platyrostris* (Gobiidae) *Turk.J.Fish. Aquatic. Sci*. 10: 262-267.
Engin, S. and Dalgic, C. (2008), First record of *Chromogobius zebratus* (Gobiidae) for the Mediterranean coast of Turkey, *Turk. J. Zool*., 32: 197-199.
Engin, S. and Seyhan, K. (2009), Biological characteristics of rock goby *Gobius paganellus* (Actinopterygii: Perciformes: Gobiidae) in the South-Eastern Black sea, Acta. Ichthyol. Piscat., 39 (2): 111-118.
El–Agami, A. E. (1988), Age determination and growth studies of *Gerres oyena* (Forskall 1775) in the Arabian Gulf waters, *Mahasagar,* 21(1): 23–34.

Elliot, M., Whitfeild, A.Q.K., Potter, I.C., Blaber, S.J.M., Cyrus, D.P., Nordlie, F.G. and Harrison, T.D. (2007), The guild approach to categorizing estuarine fish assemblages: a global review. *Fish and Fisheries* 8 (3): 241-268.
Erdman, D.S. (1961), Notes on the biology of the gobiid fish *Sicydium plumieri* in Puerto Rico., *Bull.Mar.Sci.Gulf Caribb*., 11:448-456.
Epperly, S.P. (1989), A meristic morphometric and biochemical investigation of Atlantic menhaden, *Brevortia tyrannus* (Latrobe). *J.Fish.Biol*. 35, 139-152.
*Epple A. (1967), A staining sequence for A, B and D cells of pancreatic islets. Stain Techn., 42, 53-61.

Eschmeyer, W.N (ed) (2003), Catalog of fishes updated database version of March 2003, Catalog database as made available to Fish Base.
Ezzat, A.A., Hashem, M.T. and El-Gharabawy, M.M. (1979), Biometric variations in *Solea vulgaris* acclimatized in Lake Quarun, Upper Egypt, *J. Fish. Biol*. 14, 39-46.
Fabi, G. and Froglia, C. (1984), A note on biology and fishery of the black goby (*Gobius niger*) in the Adriatic Sea, FAO, *Fish Rep*., 290:167-170.
Fagade, S.O. and Olaniyan, C.I.O. (1978), The food of Tilapia species in Lake Kainji, *J. Fish***.** *Biol.* 4: 138-150.
Farran, G.P. (1938), On the size and number of ova of Irish herrings, J.Cons. Int., *Explor. Mer*., 13: 91- 100.
Fakuda, M., Sako, H., Shigeta, T. and Shibata, R. (2001), Relationship between growth and Biochemical indices in laboratory reared juveniles Japanese flounder (*Paralichthys olivaceus*) and its application to wild fish, *Mar. Biol*., 138:47-55.
Fakuda, N., Kuroki, M., Shinoda, A., Yamada, Y., Okamura, A., Aoyama, J. and Tsukamoto, K. (2009), Influence of water temperature and feeding regime on otolith growth in *Anguilla japonica* glass eels and elvers: Does otolith growth cease at low temperatures? *J.Fish.Biol*., 74: 1915-1933.
Favaloro, E. and Mazzola, A. (2000), Meristic character analysis and skeletal anomalies during growth in reared sharpsnout seabream, *Aquaculture International* 8: 417-430.
Fishelson, L. (1991), Comparative cytology and morphology of seminal vesicles in male gobiid fishes. *Japanese Journal of Ichthyology*, *38*(1), 17-30.

Fitch, J.E. and Lavenberg, R.J. (1975), Tidepool and nearshore fishes of California. Calif. Nat. Hist. Guide38. Univ. Calif. Press, Berkeley, Calif., 156p.
Ferraris Jr, C.J., McGronther, M.A. and Parkinson, K.L. (2000), A Critical Review of the Types and Putative Types of Southern Asian Marine and Freshwater fish species in the Australian Museum Named by Francis Day, Records of the Aus. Mus ISSN 0067 Vol.52: 289-306.

Ferreri, F. Nicolais, C. Boglione, C. Bmertoline, B. (2000), Skeletal characterization of wild and reared zebra fish: anomalies and meristic characters., *J.Fish. Biol*., 56 (5): 1115-1128.
Ferron, A. and Leggett, W.C. (1994), An appraisal of condition measures for marines fish larvae, *Adv. Mar. Biol*. 30:207-303.
Filiz, H. and Togulga, M. (2009), Age and growth, reproduction and diet of the black goby (*Gobius niger*) from Aegean Sea, Turkey, *Journal of Fisheries Science.Com*, 3:243-265.
Fitzsomons, J., Williston, B., Williston, G., Bravener, G., Jonas, J.L., Claramunt, R.M., Marsden, J.E. and Ellrott, B.J. (2006), Laboratory estimates of Salmonine Egg predation by round gobies(*Neogobius melanostomus*), Sculpins(*Cottus cognatus* and *C.bairdi*) and ceay fish(*Orconectes propinquus*), *Journal of Great Lakes Research*, 32(2): 227-241.
Fowler, H.W. (1929), Fishes from Florida and the WestIndies , Proc. The academy of Natural Sciences of Philadelphia, 80:451-473.
Fisher, R.A. (1930), The genetical theory of Natural Selection Oxford: Oxford University Press.
Fishelson, L., Goren, M., VanVuren, J. and Manelis, R. (1996), Some aspects of the reproductive biology of *Barbus spp*. *Capoeta damascina* and their hybrids (Cyprinidae Teleostei) in Israel, *Hydrobiologia*, 317, 79-88.
Fonds, M. (1973), Sand gobies of the Dutch Wadden Sea (*Pomatochistus,* Gobiidae, Pisces) Netherlands, Journal of Sea Research, 6, 417-478.
Folch, J., Less, M. and Slone, S. (1957), A simple method for the isolation and purification of total lipids from animal tissues, *J.Biol. Chem*., 266: 497-509.
Foster, G.D., Houlihan, D.F. and Hall, H.J. (1993), Effects of nutritional regime on correlates of growth rate in juvenile Atlantic cod (*Gadus morhua*) comparison of morphological and biochemical measurements, *Can. J. Fish. Aquat. Sci*., 50: 502-512.
Fox. N.C. (2007), Seasonal abundance, age structure, gonado somatic index and gonad histology of yellow bass *Morone mississippiensis* in the upper Barataria estuary, Louisiana, M.Sc Thesis, B.S Tennesse, Technological University.
Fowler, J.A.(1970), Control of vertebral number in teleosts- an embryological problem, *Quaterly review of Biology*, 45: 148-167.
Franco, A., Elliot, M., Franzoi, P. and Torricelli P. (2008), Life strategies of fishes in European estuaries: the functional guild approach, *Mar. ecol. Prog. Ser*., 354: 219-228.
Frank, K.T. and Brickman, D. (2001). Cotemporary management issues confronting fisheries science, *J. Sea. Res*., 45: 173-187.
Froese, R. (2006), Cubelaw, condition factor and weight-length relationships: history, meta-analysis and recommendations, *Journal of Applied Ichthyology*, 22 pp 241-253.
Frommel, A.Y. (2008), Influence of temperature on growthand biochemical based indicators of growth in juvenile Gobiids of the Baltic sea, Master Thesis Univ, Southern Denmark.
Frosta, I. O., Costa P. A. S., and Braga, A. C. (2004), Length-weight relationships of marine fishes from the Central Brazilian Coast. *Naga, World Fish Centre Quarterly*, 27(182): 20-26.

Frommel, A. and Clemmesen, C. (2009), Use of biochemical indices for analysis of growth in juvenile two-spotted gobies (*Gobiusculus flavescens*) of the Baltic Sea, *Sci.Mar*., 73S1: 159-170.
Gaikwad, M.V., Pathan, T.S., Gaikwad, S.L., Hiwarale, D.K., Davne, P.M., Sonwane, D.L. and Khillare, Y.K.(2009), Feeding and growth patterns in three fresh water fishes from river Godavari in Maharashtra (India), *Rec. Res. Sci. Tech*., (5): 223-234.
Geevarghese, C. (1976), Studies on some aspects of the biology of *Glossogobius giuris* (Ham) with a taxonomic note on six gobioid fishes occurring in and around Trivandrum M.Phil Dissertation, Department of Aquatic Biology and Fisheries, Kerala University, 90pp.
Geevarghese, C. (1981), Studies on Gobioid fishes of south-west coast of India, Ph.D Thesis, Department of Aquatic Biology and Fisheries, Kerala University.
Geevarghese, C. and John, P.A. (1982), On the new goby, *Ctenogobius valiensis* (Teleostei:Gobiidae) from the south west coast of India, *Journal of Natural history* 16: 655-661.
Geevarghese, C. and John, P.A. (1983), A new goby *Glossogobius minutus* (Teleostei: Gobiidae) from the south west coast of India, *Journal of fish biology*, Vol.22 2: 231- 240.
Geevarghese, C. (1984), Morphohistology of the reproductive organs of a gobiid fish *Oligolepis acutipennis* (Cuv & Val) from the southern west coast of India. *J. Fish Biol*. 23, 611-624.
Georgakopoulou, E., Sfakianakis, D.G., Kouttouki, S., Divanach, P., Kentouri, M., Koumoundouros, G. (2007), The influence of temperature during early life on phenotypic expression at later ontogenetic stages in sea bass, *J.Fish.Biol* 70 (1): 278-291.
Gerritsen, H.D. and McGrath, D. (2007), Significant differences in the length-weight relationships of neighbouring stocks can result in biased biomass estimates: examples of haddock (*Melanogrammus aeglefinus*.L) and whiting (*Merlangius merlangius*, L), *Fish.Res*., 85: 106-111.
Gibson, R.N. (1970), Observations on the biology of the giant goby *Gobius cobitus* (Pallas), *J.Fish.Biol*., 2: 282-288.
Gibson, R.N. and Ezzi, I.A. (1978), The biology of a Scottish population of Fries goby, *Lesuerigobius friesii*, *J.Fish.Biol*., 2, 281-288.
Gil, H., Chung, K.S., Lemus, M. and Altuve, D. (2003*),* RNA/DNA ratio as an index of physiological condition of Colossoma macropomum and Piaractus branchypomus (Pisces: Characiformes) during embryonic development, *Rev. Biol. Trop* 51.Supl 4 (2003): 91-96.

Gill, H.S. (1994). Phylogenetic relationships of the members of the *Bathygobius* and *Priolepis* groupings (sensu Birdsong *et al*., 1988) which possess a longitudinal papillae pattern, In: *Proceedings of the Fourth Indo-Pacifi c Fish Conference: Systematics and Evolution of Indo-Pacifi c Fishes*. Bangkok, Thailand, pp. 40-59.

Gill, H.S., Bradley, F.L.S. and Miller P.J. (1992), Validation of the use of Cephalic lateral line papillae patterns for postulation relationship among gobioid genera, *Zool. J. of the Linn.Soc*., 106:97-114.

Gill, A.C. and Jewett, S.L. (2004), *Eviota hoesei* and *Eviota readerae*, new species of fish from the Southwest Pacific with comments on the identity of *E.corneliae*

Fricke (Perciformes:Gobiidae), Records of the Australian Museum Vol.56:235-240 ISSN 0067.
*Ginsburg, I. (1933a), Description of new and imperfectly known species and genera of gobioid and pleuronectid fishes in the United States National Museum. Proc. U.S. Nat .Mus., 82 (2961):1-23.
Godsil, H.C. (1948), A preliminary population study of the yellow fin tuna and the Albacore. Calf., *Fish. and Game.,* 70, 90.
Golberg, S.R. (1977), Seasonal ovarian cycle of the tide water goby, *Euclogobius newberryi* (Gobiidae), Southwestern Naturalist, Vol.22 no.4 pp 557-559.
Gonclaves, J.M.S., Bentes, L., Lino, P.G., Ribeiro, J., Canario, A.V.M. and Erzini, K. (1997), Weight-length relationship for selected fish species of the small scale demersal fisheries of the south and south-west coast of Portugal, *Fish. Res*. 30: 253-256.
Goncalves, T.L., Bazzoli, N and Brito, M.F.G. (2006), Gametogenesis and reproduction-of the matrinxa, *Brycon orthotaenia* (Gunther, 1864) (Pisces, Characidae) in the-Sao Francisco River, Minas Gerais, Brazil. Brazilian J. Biol., 66: 513-522.
Gopalan, C., Ramasastri, B.V. and Balasubramanian, S.C. (1978), Nutritive value of Indian foods. National Institute of Nutrition, Indian council of medical research, Hyderabad, India, pp 46-103.
Gore, B.M. (2007), Biometry of mudskipper *Boleophthalmus boddarti*, PhD Thesis, University of Mumbai.
Goren, M., Gayer, K. and Lazarus, N. (2009). First record of the Far East Chameleon goby *Tridentiger trigonocephalus* (Gill, 1859) in the Mediterranean Sea Aquatic Invasions Volume 4, Issue 2: 413-415.
*Gosline,W.A. (1955), The osteology and relationship of certain gobioid fishes, with particular references to the genera Kraemeria and Microdesmus. *Pac.Sci*, 9:158-170.
Gosline, W.A. (1996), Structures associated with feeding in three broad mouthed benthic fish groups, *Environ.Biol.Fish*., 47(4): 399-405.
Govindan, T.K. (1985), Fish processing technology: Oxford and IBH publishing Co., New Delhi, Bombay and Calcutta, pp: 47-48, 180-198.
Gowda, H.H. (1984), Observations on the bilogy of the Indian sand whitting, *Sillago sihama* (Forska), M.F.Sc. Thesis, 116pp, University of Agricutural Sciences, Bangalore.
Grandcourt, E.M., Al-Abdessalaam, T.Z., Francis, F., Al-Shamsi, A.T. and Hartman, S.A. (2009), Reproduction biology and implications for management of the orange-spotted grouper *Epinephelus coioides* in the southern Arabian Gulf, *Journal of Fish Biology*, 74: 820-841.
Greenfield, D.W. and Longenecker, K.R. (2005), *Vanderhorstia bellas*, a new goby from Fiji (Teleostei:Gobiidae) Proceedings of the California academy of Sciences Fourth series Volume 56., 2 : 619-623.
Greenwood, P., Rosen, D., Weitzman, S,. and Myers, G. (1966), Phyletic studies of teleostean fishes, with a provisional classification of living forms. Bulletin of the American Museum of Natural History;131: 339 - 456.
Greenfield, D.W. and Longenecker, K.R. (2005), *Vanderhorstia bella*, anew goby from Fiji (Teleostei:Gobiidae) Proceedings of the California academy of Sciences Fourth Series Volume 56,(2): 619-623.
*Gunther, A.C. (1861b) Catalogue of the Acanthopterygion fishes in the collection of the British Musuem 3:1-586.

Gupta, J.P. and Shrivastava, S.P. (2001), Maturity determination by gonadosomatic index during Annual Reproductive Cycle.
Gurkhan, S. (2008), The biometric analysis of pipe fish species from Camalty (Izmir bay, Aegean Lagoon Sea)., *J. Fish. Aquat. Sci*., 25 (1): 53- 56.
Gwak, W.S. and Tanak, M. (2001), Developmental change in RNA: DNA ratios of fed and starved laboratory reared Japanese Flounder larvae and juveniles and its application for wild fish, *Journal of Fish Biology*., 59, 902-915.
Hadi, A.A. (2008), Some observation on the age and growth of *Tilapia zilli* (Gervais 1848) in Umhfein Lake (Libya), *J.Applied. Sci*., 2(1): 12-21.
Haddon, M.and Willis, T.J. (1995), Morphometric and meristic comparison of orange roughly *Hoplostethus atlanticus*: Trachichthyidae from the Puysegur Bank and Lord Howe Rise, New Zealand and its implications for stock structure., *Mar.Biol*., 123: 19-27.
Ha, P.Y. and Kinzie III, R.A. (1996), Reproductive biology of *Awaous guamensis*, an amphidromous Hawaiian goby, *Environmental Biology of Fishes.*, 45: 383-396.
Haedrich, R.L. (1983), Estuarine fishes. In Ketchum B H (ed). Ecosystems of the World, Book 26 Estuaries and enclosed seas Elsevier, Amsterdam, Netherlands, pp 182- 207.
Hails, A.J. and Abdullah, Z. (1982), Reproductive biology of the tropical fish *Trichogaaster pectoralis* (Regan), *J.Fish. Biol*., 21, 157-170.
Hajji, F. Ouannes-Ghorbel, A. Ghorbel, M. and Jarboni, O. (2012), Reproductive biology of the rock goby *Gobius paganellus* (Actonopterygii: Perciformes: Gobiidae) on the southern Tunisian coast (Gulf of Gabes).
Hara, M. (2004), Diversity of the sperm morphology in gobioid fishes, *Jap.J.Ichthyol*., 1: 1-32.
Hart, P.J.B. (1997), Foraging tactics pp 104-113, In: Godin J.G.J (ed) Behavioural ecology of teleost fishes, oxford University Press, New York.
Harold, A.S., Winterbottom,R., Munday, P.L. and Chapman. R.W. (2008), Phylogenetic relationships of Indo-Pacifi c coral gobies of the genus *Gobiodon* (Teleostei: Gobiidae) based on morphological and molecular data, *Bulletin of Marine Science* 82: 119-136.

Hay, D.E. and Brett, B.R. (1988), Maturation and fecundity of Pacific herring (*Clupea harengus* Pallas) an experimental study with comparison to natural populations., *Can. J. Fish. Aquatic. Sci*., 45: 399-406.
Hedge, J.E. and Hofreiter, B.T. (1962), In: Carbohydrate Chemistry 17 (eds Histtler R L and Miller J.N) Academic Press, New York.
Healey, M.C. (1971), Gonad development and fecundity of the sand goby, *Gobius minutus* (Pallas) *Trans. Am. Fish. Soc*., 100, 520-526.
Healey, M.C.(1971a), The distribution and abundance of sand gobies, *Gobius minutus* in the Ythan Estuary, Journal of Zoology, London 163, 177-229.
Hendon, J. R., Peterson, M. S. and Comyns. B. H. (2000), Spatio-temporal distribution of larval *Gobiosoma boss* in waters adjacent to natural and altered marsh-edge habitats of Mississippi coastal waters. Bulletin of Marine Science 66(1): in press.

Hermida, M., Fernandez, J.C., Amaro, F. and SanMignel, E. (2005), Morphometric and meristic variation in Galician three spine strickle back populations, Northwest Spain, *Environment and Biology of Fish*., 73: 189-200.

*Herre, W.C. (1939), On a collection of Littoral and fresh water fish from Andaman Islands, *Rec.Ind.Mus*., 41 : 329-403.
*Herre, W.C. (1940), Fishes of Andaman Islands, Mem. Ind. Mus., 42 : 1-18.
Hesthegen,I. (1971), The winter food of the gobies from one of the deeper channels of the Baltic Sea, with particular reference to the sand goby *Pomatochistus minutus(*Pallas), *Kieler Meeresforsh*, 29:28-35.
Hickling, C.F. and Rutenberg, E. (1936), The ovary as an indicator of spawning period of fishes, *J.Mar.Biol. Assoc*., U.K, 21: 311-317.
Hickling, C.F. (1940), The fecundity of the herring of Southern North Sea, *J.Mar.Biol.Ass*. U.K. 24, 619-632.
Hickling, C.F. (1947), The seasonal cycle in the Cornish Pilchard, *Sardina Pilchardus* Walbaum, *J.Mar. Biol. Ass.* U.K 26: 115-138.
Hildebrand, S.F. and Schroeder, (1928), Fishes of Chesapeake Bay, *Bull.U.S.Bur.Fish*., 43 : 1-366.
Hile, R. (1936), Age and growth of the *Cisco leucicthysartedi* (Le Sweur) in the lakes of the north western highlands, Wisconsin, *Bull. U.S. Bur. Fish*, 48, 211-317.
Hoda, S.M.S. (1980), A contribution to the gobioid fishes of Pakistan, Preoceedings of the 1st Pakistan Congress of Zoology B, 469-482.
Hoda, S.M.S. (1986 a), Maturation and fecundity of the mudskipper *Boleophthalmus dussumieri* Cuv & Val from the Karachi coast, Mahasagar- Bulletin of the National Institute of Oceanography, 19: 73-78.
Hoda, S.M.S. (1987), Relative growth of body parts and length-weight relationships in *Boleophthalmus dussumieri* and *B. detatus* of Karachi coast, *Indian journal of Fisheries*, 34, 120-127.
Hoda, S.M.S.(1991), Feeding habits and length-weight relationship of *Acentrogobius virdipunctatus* (Cuv& Val) from Karachi coast, *Indian. J. Fish*., 38 (3): 177-182.
Hoda, S.M.S. and Akhtar, Y. (1983), Mudskippers from mangrove swamps of Karachi coast. National workshop on Mangroves, University of Karachi, P.A R.C, 49- 52.
Hoda, S.M.S. and Akhtar, Y. (1985), Maturation and Fecundity of mudskipper *Boleophthalmus dentatus* in the Northern Arabian sea, *Indian. J. Fish*, 32, 64-73.
Hoese, D.F. (1971), A revision of the eastern Pacific species of the gobiid fish genus Gobiosoma with a discussion of relationships of the genus.Univ of Cal.San Diego, Ph.D., Zoology.
*Hoese, D.F (1983) Sensory pappila patterns of the cheek lateralis system in the Gobiid fishes *Acentrogobius* and *Glossogobius* and their significance for the classification of gobioid fishes, *Rec. Aust .Mus*., 35:223-229.
*Hoese, D.F. and Gill, A.C. (1993), Phylogenetic relationships of eleotrid fishes (Perciformes: Gobiidae), *Bull. Mar. Sci*., 52(1):415-440.
*Hoese, D. (1998), In: Enclyclopedia of Fishes, Eschemeyer, W.N and J.R Paxton(Eds), 2nd Edn, California Academic Press, San Diego, pp:218.
Hossain, M.Y Ohtomi, J Ahmed, Z.F Ibrahim, A.H.M and Jasmine (2009b), Length-weight and morphometric relationships of the tank goby, *Glossogobius giuris* (Hamilton 1822) (Perciformes : Gobiidae) in the Ganges of the North western Bangladesh, Asian Fisheries Science, 22 (3): 961-969.
Hossler, F.E., Ruby, J.R. and Mcilwain, T.D. (1979), The gill arch of the mullet *Mugil cephalus* I-surface ultrastructure, *Jour. Exp. Zool.* New York, 208: 379-398.
Hora, S.L. (1915), Fias (part V), Mem. Ind. Mus., 5: 739-764.
Hora, S.L. (1923), Fauna of the Chilka Lake fish, Pt IV, Mem.Ind.Mus., 5: 712:769.
Hora, S.L. (1924), On a new genus of gobiod, Rec.Ind.Mus., 26: 156-163.

Hora, S.L. (1934), The Systematic Position of Hamilton's species of Gobioid Fishes from the Ganges Indian Mus. Records .*J.Indian Zool*, 36:483-489.
Hora, S.L. (1935), Notes on fishes from Indian Museum, Rec. Ind. Mus., 27:453-470.
Hora, S.L. (1936), Ecology and Bionomics of the Gobioid fishes of Gangetic Delta, Comt. Reud. XII, Congr, International. Zool., 340-364.
Hora, S.L. (1940), On a collection of fish from the hard waters of the Mahanadi river, Rec.Ind. Mus. XL: 365-374.
Hora, S.L. (1941), New records of fresh water fishes from Travancore, Rec.Ind.Mus.XL3: 387-394.
Houlihan, D.F., Pannevis, M.C. and Heba, H. (1993), Protein synthesis in juvenile Tilapia *Oreochromis mossambicus*, *J.World. Aquac. Soc*., 24, 145-151.
Htun-Han, M. (1978a), The reproductive biology of the dab *Limanda limanda* (L) in the North Sea: Seasonal changes in the ovary, *J.Fish.Biol*. 13, 351-359
Hubbs, C.L. (1922), Variation in the number of vertebrate and other meristic characters of fish correlated with the temperature of water during development, *Amer.Natur*, 56:360-372.
Humason, G.L. (1967), Animal Tissue Techniques, W.H Freeman and Company, San Fransisco and London.
Hunter, J.R. and Macewicz, B.J. (1985), Rates of atresia in the ovary of captive and wild northern anchovy, *Engraulis mordax*., *Fish.Bull*., 83, 119-136.
Hutchings, J.A. and Reynolds, J.D. (2004), Marine fish population collapses: consequences for recovery and extinction, *Bio Science*, 54: 297-309.
Huang, J.B. and Chiu, T.S. (1998), Comparison in nutritional status of larval Japanese anchovy collected from four Kuroshio related waters off North eastern Taiwan, *Fisheries Science*, 64(5) 844-845.
Hynes, H.B.N. (1950), The food of the freshwater sticklebacks (*Gastrosteus aculeatus* and *Pygosteus pungitius*) with a review of methods used in studies of the food of fishes, *J. Anim. Ecol*, 19: 36-58.
Hyslop, E.J. (1980), Stomach content analysis: a review of methods and their application, *J. Fish. Biol*, 17:411-429.
Idler, D.R. and Bitners, I. (1958), Biochemical studies in Sockeye Salmon during spawning migration II cholestrol, fat, protein and water in the flesh of standard fish, *Can. J. Bioch. Physiol*., 36: 793-798.
Idris, H.B., Ambak, M.A. and Ikhwanuddin, M. (2012), Sex determination in *Oxyeleotris marmorata* (Bleeker 1852) based on morphometric features, *Advances in Natural and Applied Sciences*, 6(6): 763-771.
Islam, M.N. (2004), Ecobiology of freshwater gobi, *Glossogobius giuris* of the river Padma in relation to its fishery; A review, *Journal of Biological Sciences*, 4(6); 780-793 ISSN 1727-30.
Islam, M.N. and Joadder, M.A.R. (2005), Seasonal variation of the freshwater gobi *Glossogobius giuris* (Hamilton) from the river Padma, *Pak. J. Biol. Sci*, 8 (4): 532-536.

Islam, M.S. and Tanaka, M. (2005), Nutritional condition, starvation status and growth of early juvenile Japanese seabrass (*Lateolabrax japonicas*) related to prey distribution and feeding in the nursery ground, J. Exp. Mar. Biol. Ecol., 323: 171-183.
Islam, M.R., Sultana, N., Hossain, M.B. and Mondal. S.(2012), Estimation of fecundity and gonadosomatic index (GSI) of gangetic whiting *Sillaginopsis pannijus*

(Hamilton, 1822) from the Meghna river estuary, Bangladesh, *World Appl. Sci. J*., 17: 1253-1260.
Jafri, A.K. and Khawaja, D.K. (1967), Acid and alkaline phosphatise activity in the developing oocytes of the freshwater Murrel, *Ophicephalus punctatus* Bloch, *Enzymologia*, 30: 33 (5): 274-8.
Jafri, A.K. and Khawaja, K.D. (1968), Seasonal changes in the Biochemical composition of the freshwater Murrel, *Ophiocephalus punctatus* Bloch, *Hydrobiologia*, 32: 206-218.
Jaiswar, A.K., Parida, P.K., Chakraborty, S.K. and Palaniswamy, R. (2004), Morphometry and length-weight relationship of Obtuse barracuda *Sphyraena obtusata* (Cuvier) (Teleostomi) Actinopterygii/ Sphyraenidae) from Bombay waters, West coast of India, *Indian. J. Mar. Sci*., 33: 307-309.
Jasra, S.K., Arbuckle, W.J., Corkum, L.D., Li, W., Scott, A.P. and Zielinski, B. (2007), The seminal vesicle synthesizes steroids in the round goby *Neogobius melanostomus*, Comp. Biochem. Physiol. Part A. *Mol. Integr. Physiol*., 148, 117-123.
Jayashankar, P. (1989), Studies on the reproduction of Indian whiting *Sillago sihama* (Forskal) (Percoidei, Sillaginidae), Ph.D Thesis, Cochin Univ. Sci, 6 Technol.
Jayasankar, P. (1991b), Sillginid fishes of Palk Bay and Gulf of Mannar with an account on the maturation and spawning of Indian Sandwhiting, *Sillago sihama* (Forskal), Indian. J. Fish, 38(1): 13-25.
Jayashree, V.A., Parulekar, H., Wahidulla, S. and Kamat, S.Y. (1994), Seasonal changes in Biochemical composition of *Holothuria vleucospilota* (Echinodermata). *Indian. J. Mar. Sci*., 23: 17-119.
Jhingran, V.G. (1961), Studies on the maturity and fecundity of the Gangetic Anchovy *Setipinna phasa* (Hamilton), *Indian.J.Fish*., 8, 291- 311.
Jhingran, V.G. (1968), Synipsis of biological data on Catla, *Catla catla* (Hamilton, 1822), FAO Fish Synopsis, 32: rev.1.
Jhingran, V.G. (1972), Fluctuations i n the Ponderal index of the Gangetic Anchovy *Setipinna phasa* (Hamilton), *J.Inland Fish. Soc*., India, IV, 1-9.
Joadder, A.R. (2009), Length-weight relationship and condition factor (Kn) of gobi *Glossogobius giuris* (Hamilton) from Atrai river in the northern part of Bangladesh, *Journal of Fisheries International*, 4 (1): 1-4.
*Jobling, M. (1995), Environmental Biology of Fishes London Chapman and Hall pp 4-55.
Johnson, M.W., Rooker, J.R., Gatlin, D.M. and Holt, G.J. (2002), Effects of variable ratio levels on direct and indirect measures of growth in juvenile red drum (*Sciaenops ocellatus*), *Journal of Experimental Marine Biology and Ecology*, 274, 141-157.
Johannsson, O.E., Bowen, K.L., Arts, M.T., and Smith, R.W. (2009), Field assessment of condition indices (nucleic acid and protein) in *Mysis diliviana*, aquat.Biol.5:249-262.
Jonna, R. (2004), Actinopterygii, Animal Diversity Web.
Jones, J.W. (1940), Histology changes in the testis in the cycle of male Salmon Parr, *Salmo salar*, Proc. R. Soc. 128, 499-509.
Jones, G.D. and Miranda, L.E. (1997), Ovarian weight as an index of fecundity, maturity and spawning periodicity, *Journal of Fish Biology*, 50: 150-156.
Jones, S. and Kumaran, M. (1980), Fishes of Laccadive Archipelago, Mathrubhumi Press, Cochin, 662-676.

Jordon, D.S. (1891), Relationship of temperature to vertebra among fishes, Proc, Am.Nat. Mus: 14: 107-120.
Joyeux, J.C., Bouchereau, J.L. and Tomasini, J.A. (1991b), La reproduction de *Gobius niger* (Pisces Gobiiidae) dans lagune de Maugui-France: rapports gonosomatiques, fecondites, ponte, oenfs et larves, vie et Millieu 41: 97-106.
Joyeux, J.C., Tomasini, J.A. and Bouchereau, J.L. (1992), Modalities de la reproduction de *Gobius niger* (Teleostei, Gobiidae) dans une lagune mediterraneanne Vie et Milieu, 42: 1-13.
Jude, D.J., Reider, R.H. and Smith, G.R. (1992), Establishment of Gobiidae in the Great Lakes basin, *Can.J.fish.Aquat.Sci*., 49:416-421.
June, F.C. (1953), Spawning of yellow fin tuna in Hawaiian waters, U.S Fish and Wild Life Service Fish Bull., 54, 47-64.
*Jordan, D.S. (1905), A Guide to the study of fishes, Vol 2, Henry Holt and Co., New York., 599p.
*Jordan, D.S. (1923), A classification of fishes, Stanford U.Publ.Biol., Sci3 (2): 79-243.
Jones, D. and Miller P.J. (1966), Seasonal Migration of the Common Goby *Pomatochistus microps* (Kroyer), in Morecambe Bay and elsewhere, *Hydrobiologia* Vol.27.3-4:515-528.
Jonsson, N. and Jonsson, B. (1999), Trade-off between egg mass and egg number in brown trout, *Journal of Fish Biology*, 55: 767-783.
Kader, M.A, Bhuiyan, A.L. and Manzur-I-Khuda, A.R.M.M. (1988a), Food and feeding habits of *Gobioides rubicundus* and some feeding experiments on it, Indian.J.Fish., 35(4): 312-316.
Kader, M.A., Bhuuuiyan, A.L., Mansur, A.R.M.M. and Khuda, I. (1988b), The reproductive biology of *Gobioides rubicundus* (Ham.Buch) in the Karnatphuli river estuary, Chittagong, *India.J.Fish*, 35: 239-250.
Kader, M.A., Hossain, M.A. and Mohi, A (1982), The fecundity of *Lepturacanthus savala* James. J. Asiatic Soc. Bangladesh, (Sci.), VIII(1): 53-57.
Kagwade, P.V. (1968), Hermaphroditism in *Polydactylus indicus* (Shaw)., *J.Mar. Biol*. Ass India, 10(2): 399- 400.
Kalayci, F., Samsun, N., Bilgin, S. and Samsun, O. (2007), Length weight relationship of 10 fish species caught by bottom trawl from the middle Black sea, Turkey, *Turkish. J. Fish*. *Aquat.Sci*., 7:33-36.
Kalita, N. and Jayabalan, N. (1997), Age and Growth of the carangid *Alepes para* (Class: Osteichthyes) from Mangalore coast, *Indian Journal of Marine Science*, 26: 107-108.
Kanabashira, Y., Sakai, H. and Yasuda, F. (1980), Early development and reproductive behaviour of the gobiid fish, *Mugilogobius abei*, *Japanese Journal of Ichthyology* 27: 191- 198.
Kannan, K., Sureshkumar, K., Ranjith, L., Joshi, K.K., Madan, M.S., and John, S. (2013), First record of the two stripe goby, Valenciennea helsdingenii (Gobiidae, Gobiifromes) from the southeast coast of India, *Zookeys*, 323: 91-97.
Kapoor, B.J., Smith, H. and Verighina, I.A. (1975), The alimentary canal and digestion in teleosts, In: Advances in marine biology (F.S. Russell and M.younge eds) London. Academic Press, Pp 109-239.

Karbhari, J.P. (1982), Scientific,Common and local names of commercially important marine fishes and shell fishes of Maharashtra and Gujarat coasts, Marine Fisheries Information Service, Technical and Extension Series, 44.pp., 18-23.

Karekar, P.S. and Bal D.V. (1960), A study on maturity and spawning of the Horse Mackerel *Carnax kalla* (Cuv and Val). *Indian.J.Fish*., 147-164.
Karna, S. K. and Panda, S. (2012), Length-weight Relationship (LWR) of 20 fish species in Chilka Lagoon, Odisha (India), *Asian .J Exp. Biol. Sci*., Vol 3 (1) 243-246.
Keast, A. and Webb, D. (1966), Mouth and body form relative to feeding ecology in the fish fauna of a small lake, Lake Opinicon, Ontario, *Journal of Fishes Research Board of Canada*., 23 (12) : 1845-1874.
Keenleyside, M.H.A. (1979), Diversity and adaptation in fish behaviour, *Zoogegraphy*, 11: 208pp.
Kendall, B.W. and Gray, C.A. (2008), Reproductive biology of two co-occuring mugillids, *Liza argentea* and *Myxus elongates* in south-easttern Australia, *Journal of Fish Biology*, 73: 963-979.
Kennel, D. and Magasani, K. (1962), The relation of ribose content to the rate of enzyme synthesis in *Aerobactes aerogenes*, *Biochem. Biophys. Acta.*, 55,139-151.
Kestevan, G.L. (1942), Studies on the biology of the Australian mullets. 1. Account of the fishery and preliminary statement of the biology of *Mugil dubula* (Gunther), Bull. Aus. Common Wealth., Sci Ind. Res. Org. Melb., 157: 1-99.
Khaironizam, M.Z. and Norman-Rashid, Y. (2002), Length–weight relationship of mudskippers (Gobiidae) in the Coastal Areas of Selangor, Malaysia, Naga and World fish center quarterly, 25 (3&4): 21-22.
Khan, M.S., Ambak, M.A. and Mohsin, A.K.M. (1988), Food and feeding biology of a tropical cat fish*, Mystis nemurus* with reference to its functional morphology, *Indian J. Fish*, 35: 78-84.
Khan (2007) (http://www.fishbase.org 20/7/2013).
Khan (2011) (http://www.fishbase.org 20/7/2013).
Kim, J.K., Back, H., Kim, J., Chang, D. and Kim, J. (2011), Sexual maturity and early life history of the mud skipper *Scartelaos gigas* (Pisces, Gobiidae): Implication for conservation, *Fish Aquat Sci*., 14 (4), 403- 410.

Kim, S.Y., Park, C.B., Kang, J.W., Choi, Y.C., Rho, S., Bawk, H.J., Kim, H.B. and Lee, Y.D. (2004), Gonadal development and reproductive cycle of gluttonous goby *Chasmichthys gulosus* (Guichenot), *Korean. J. Ichthyol*., 16, 216-270.
King, M. (1995), Fisheries Biology, Assessment and Management, Fishing News Books (Blackwell).
Kiran, B. R. and Puttaiah, E. T. (2004) Food and feeding habits of *Salmostoma untrahi* from Bhadra Reservoir, Karnataka. *Indian J.Fish.*, 51(3): 335-344.

Koc, N.D., Ayrekin, A. and Yuce, R. (2008), Ovary maturation stages and histological investigation of ovary of the zebra fish (*Danio rerio*), *Braz. Arch. Biol. Tech*., 51: 513-522.
Koshy, B.E. and Pillay, S.O. (2003), A study of morphological characteristics in Malaysisn freshwater angel fish (*Pterophyllum scalare*) using meristic tools, Seminar Penyelidikan Jangka Pendek (Vol F).
Koumans, F.P. (1941), Gobioid fishes of India Mem.Ind.Mus., 8(3): 205-329.
Koumans, F.P. (1942), Gobioid fishes of India, Mem.Ind.Mus.,13: 206-329.
Koumans, F.P. (1953), Gobiodea. In M Weber and L.F. de Beaufort, eds. The fishes of Indo Autralian Archipelago, X. E, *J. Brill Leiden*, pp 1-423.

Koutrakis, E.T. and Tsikliras, A.C. (2009), Reproductive biology of the marbled goby *Pomatochistus marmoratus* (Pisces, Gobiidae), in a northern Aegean estuarine system (Greece), Folia (2001), 58(4): 447.
Kovac, V., Copp, G.H.and Francis, M.P. (1999), Morphometry of the stone loach Barbatula barbatula : Do mensural characters reflect the species life history thresholds?, *Environ. Biol. Fish*, 56: 105-115.
Kovacic, M. and Miller P.J. (2000), A new species of Gobius (Teleostei; Gobiidae) from the northern Adriatic Sea, *Cybium*, V.24 (no.3): 231- 239.
Kovacic, M. (2001), The biology of Roule's goby in the Kvarner area, northern Adriatic sea, *J.Fish.Biol*., 59: 795-809.
Kovacic, M. (2002), A northern Adriatic population of *Buenia affinis* (Gobiidae), *Cybium*, 26(3) 197-201.
Kovacic, M. (2006), Age structure, growth and mortality of the striped goby, *Gobius vittatus* (Gobiidae) in the northern Adriatic sea, *Scientia-Marina*, 70: 635-641.
Kovacic, M. (2007), Reproductive biology of the striped goby *Gobius vittatus* (Gobiidae) in the northern Adriatic Sea, *Sci.Mar*., 71 (1): 145-151.
Kovtun, I.F. Nekrasova, M.Ja., and Revina, N.I. (1974), On the diet of round goby *Neogobius melanostomus*, in relation to year-class strength in the sea of Azov, *J.Ichthyol*., 19:161-163.
Kovtun, T.F. (1976), Materials on the ecology of the goby, *Pomatochistus microps* leopardinus, from the Sea of Azov, *J.Ichthyol*., 16:28-34.
Kramer A.and Patzner R.A. (2008) Morphological and developmental studies on the eggs of four *Coryphopterus* species (Actinopterygii: Gobiidae) in the Caribbean Sea. Acta Ichthyol. Piscat. 38 (2): 97- 102.
Kraus, G., Tomkiewicz, J., and Koste, F.W. (2002), Egg production of Baltic cod (*Gadus morhua*) in relation to variable sex ration, maturity and fecundity, *Canadian Journal of Fisheries and Aquatic Sciences*, 59 (12): 1908-1920.
Kruitwagen, G., Hecht, T., Pratap, H.B. and Wendelaar Bonga, S.E. (2006), Changes in morphology and growth of the mudskipper (*Periophthalmus argentilineatus*) associated with coastal pollution, *Marine Biology*, 149 (2), 201-211.
Krumholz, L.A. and Cavanah, H.S. (1968), Comparative Morphometry of fresh water Drum from two Midwestern localities., Trans. Am.Fish.Soc., 97, 429-441.
Kullander, S.O. and Ferreira, E.J.G. (2006), A review of the South American cichlid genus Cichla with description of nine new species (Teleostei: Cichlidae) *Ichthyological Exploration of Freshwaters*, 17: 289-398.
Kulkarni, R.D. (1936), The structure of the mudskipper Periophathalmus barbarous (Linn) with a note on its bionomics and respiration, M.Sc.Thesis, Institute of Science.
Kume, G., Yamaguchi, A., Aoki, I. and Taniuchi, T. (2000), Reproductive biology of the Carnidal fish *Apogon lineatus* in Tokyo Bay, *Japan Fisheries Sciences*, 66: 947-954.
Kumar, D. and Roy, S.P. (2009), Food and feeding habits of some representatives fishes of different trophic guids of Kharagpur Lake with a note on their role in energy harvest, *The Ecoscan*, 3 (1&2) : 169-176.
Kumar, K. and Siddiqui, M.S. (1989), Food feeding habits of the carp *Labeo calbasul* (Ham) in north Indian waters, *Acta. Ichthyol. Pisc*, 19: 33-48.

Kuropat, C., Mercaldo-Allen, R., Caldorone, E., Goldberg, R., Phelan, B. and Thurberg, F. (2002), Evaluation of RNA concentration as an indicator of growth in

young of the year winter flounder *Pseudopleuronectes americanus* and tautog *Tauoga onitis*, *Mar. Ecol. Prog. Ser*., 230: 265-274.
Kurup, B.M. and Samuel, C.T. (1987), Length-weight relationship and relative condition factor in Day *Sciaena albida* (Cuv) and *Gerres filamentosus* (Cuv) Fishery Tech, 24: 88-92.
Kurup, B.M. (1990), Population characteristics, Bionomic and culture of *Labeo dussumieri* (Val), Final Report submitted to Indian council of Agricutural Research, 108 pp.
*Lancepede.B.G.E. (1798-1803), Histoire Naturelle des Poissons, Paris.1798, vol.
*Lacepede, B.G.E. (1800), Histoire Naturelle des Poissons, 1: 598, 600-603.
Laflamme, S., Cote, C., Gagnaire, P., Costonguay, M. and Bernatchez, L. (2012), RNA/DNA ratios in American glass eels (*Anguilla rostrata*): evidence for latitudinal variation in physiological status and constraints to oceanographic migration, *Ecol.Evol*., 2(5): 875-884.
*Lagler, K.F. (1949), Studies on fresh water biology, Ann Arbor, Michhigan.
*Lagler, K.F., Bardach, J.E. and Miller, R.R. (1967), Ichthyology John Willey& some, some, Inc New York, London, Sydney, pp 271- 274.
Lambert.Y. (2008), Why should we closely monitor fecundity in marine fish population? *Journal of Northwest Atlantic Fisheries Sciences*, 41: 93-106.
La Mesa, M. (2010), Planktonic and Paedomorphic gobioids. In R.A.Patzner, J. L. Van Tassell, M.Kovacic and B.G Kapoor (eds.), The Biology of Gobies, Science Publisher Inc.Enfield, in Press.
La Mesa, M. (2001), Age and Growth of *Crstallogobius linearis* (von Duberi 1845) (Teleostei: Gobiidae) from the Adriatic Sea Scientia Marina 65(4): 375-381.
Larson, H.K (2001), A revision of the gobiid fish genus *Mugilogobius* (Teleostei: Gobioidei) and its systematic placement, Rec. West Australian Mus. Supplement, 62:1-233.
Larson, H.K. and Murdy, E.O. (2001), Gobiidae. Gobies In K.E Carpenter and V.Niem (eds) FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific, Vol.6, Bony fishes part 4, p.3578-3603.
Larson H.K. and Chen, I.S (2007), A new species of *Tryssogobius* (Teleostei: Gobiidae) from Hianan Island, China and Taiwan, *Zool. Stud*., 46 (2): 155-161.
Lashari, P.K., Narejo, N.T., Laghari, M.Y., and Mastoi, A.M., (2007), Studies on gonadosomatic index and fecundity of a carp *Cirrhinus reba* (Hamilton) from fish ponds of district Jacobabad, Sind Pakistan, *Pakistan Journal of Zoology*, 39 (2) : 95-98.
Lawing, M.A., Meik, J.M., Schargel, W.E., (2008), Coding meristic characters for phylogenetic analysis: a comparison of step matrix gap-weighting and generalized frequency coding, *Syst. Biol.,* 57 (1), 167-173.
Lawson, E.O. (2010), Morphometric measurements and meristic counts in mudskipper (*Periophthalmus papilio*) from mangrove swamps of Lagos lagoon, Nigeria, *Journal of Applied Bioscience*, 34: 2166-2172.
Lawson, E.O. (2010), Aspects of reproductive biology in mudskipper, *Periophthalmus papilio* from mangrove swamps of Lagos Lagoon, Lagos Nigeria, *New York Science Journal*, 3(11): 103-110.
Lawson, E. O. and Thomas E.A. (2010), Food and feeding habits and reproduction in frillfin goby, *Bathygobius soporator* (Cuvier and Valenciennes,1837) in the Badagry creek, Lagos, *Nigeria Int. J of Biodiversity and Conservation*, Vol.2(12), pp 414-421.

Lawson, E.O. and Jimoh, A.A.A. (2010), Aspects of the biology of grey mullet, *Mugil cephalus* in Lagos lagoon, Nigeria, *AACL Bioflux*, 3(3): 181- 194.
Lawson, E.O. and Ajibola, E.T. (2010), Food and feeding habits and reproduction in Frillfin goby, Bathygobius soporator (Cuvier and Valenciennes, 1837) in the Badagry creek, Lagos, Nigeria, *International Journal of Biodiversity and Conservation*, 2(12): 414-412.

Lawson, E.O. (2011), Length-weight relationship and fecundity estimates in mudskipper, *Periophthalmus papiplio* (Block and Schneider 1801) caught from the mangrove swamps of Lagos Lagoon, Nigeria, *Journal of Fisheries and Aquatic Science*, 6 : 264-271.
Lawson, E.O., Thomas, A.E. and Nwabueze, A.A. (2011), Seasonal abundance, morphometric measurements and growth patterns in frill fin goby *Bathogobius soporator* from Badagry creek, Lagos, Nigeria, *Asian Journal of Biological Sciences*, 4: 325-339.
Le Cren, E.D. (1951), Length-weight relationship and seasonal cycle in gonad weight and condition in the Perch *Percha fluviatilis*, *J. Anim. Ecol*., 20: 201-239.
Lederer, A., Massart, J. and Janssen, J. 2006, Impact of round gobies (*Neogobius melanostomus*) on dreissenids (*Dreissena polymorpha* and *Dreissena bugensis*) and the associated macro invertebrate community across in invasion front, *Journal of Great Lakes Research*, 32(1):1-10.
Lee, J.S., Kim, J.W., Kang, J.C., Shin, Y.K. and Chin, P. (2000), Reproductive cycle and gonadal development of the naked–headed goby *Favonigobius gymnauchen* (Teleostei: Gobiidae), *J.Korean. Fish. Soc*., 33, 219-224.
Lehri, G.K. (1968), Cyclical changes in the ovary of catfish *Clarius batrachus*, *Acta Anat.,* 69: 105-124.
Lehman, B.A. (1953), Fecundity of Hudson River Shad. Rev. Rep. U.S Fish and WildLife Services., 33. 320-323.
Lekshmi, S., Prasad, G. and Ritukumari, S.D. (2010), Bionomics of lesser known goby, *Stenogobius gymnopomus* (Bleeker 1853) (Perciformes: Gobiidae) from Southern Kerala, India, *Journal of Threatened Taxa*, 2(13): 1359-1364.
Leslie, J.K. and Timmins, C.A. (2004), Description of age-0 round goby, *Neogobius melanostomus* Pallas (Gobiidae), and ecotone utilisation in St. Clair lowland water, *Ontario Canadian Feild-Naturalist*, 118(3): 318-325.
Lima Junior, S.E. Cadone, I.B. and Goiten, R. (2002), Determination of a method for calculation of Allometric condition factor of fish, *Acta Scientiarum*, 24 (2): 397-400.
Lindsey, C.C. (1958), Modification of meristic characters by light duration in kokanee (*Oncorhynchus nerka*), *Copeia*, 1958: 134-136.
Lindsey, C.C. (1962), Experimental study of meristic variation in a population of three spine stickel backs, *Gasterosteus aculeatus*, *Canadian Journal of Zoology*, 40: 271- 312.
*Linberg, G.O. (1974), Fishes of the World. A key to families and a checklist. John Wiley & Sons, NewYork, Toronto, Israel program for scientific translations, Jerusalem & London, 1-545.
*Linnaeus, C. (1758), Systema Naturae, Regnum Animalie Guilielni Engel man, Lipsisiae pp 1-824.
Lizama, M., de los, A. P. and Ambrosio, A. M. (2002), Condition factor in the nine species of fish of the characidae family in the upper Parana River floodplain, Brazil. *Braz. J. Biol*., 62(1): 113-124.

Longhurst, A.R. and Pauly, D. (1987), Ecology of tropical oceans; Academic press, Orlando, Florida; pp.407.
Lowere-Barbieri, S.K. (2009), Reproduction in relation to conservation and exploitation of marine fishes. In: J amieson BGM (ed) Reproductive biology and phylogeny of fishes (Agnathans aand bonyfishes), Vol 9, Part B. Science Publishers, Enfeild, C.T, pp 371- 394.
Love, R.M (1974), The Chemical Biology of Fishes, 2nd Ed., Academic Press, New York, 547.
Love, R.M (1980), The Chemical Biology of Fishes, Vol II, Academic Press London, PP 547.
Lovern, J.A. and Wood, T.H. (1937), Variation in the Chemical Composition of Herring, *J. Mar. Biol. Assoc*., U.K., 22: 281- 293.
Lowry, O. H., Roserrough, N. J., Farr, A.L. and Randall, R.J. (1951), Protein Measurements with the Folin Phenol Reagent, *J. Biol. Chem*., 193, 265-276.
Macer, C.T. (1974), The reproductive biology of the horse mackerel, *Trachurus trachurus* (L) in the North Sea and English Channel, *J.Fish.Biol*., 6: 415-438.
Macinnis, A.J. and Corkum, D. (2000), Age and Growth of Rpound Goby *Neogobius melanostomus* in the upper Detroit River, Transactions of the Americal Fisheries Society 129: 852-858.
Maddock, D.M. and Burton, M.P.M. (1999), Gross and Histological observations of ovarian development and related condition changes in American plaice, *J.Fish.Biol*., 53: 928-944.
Madhupratap, M., Nair, K.N.V., Gopalkrishnan, T.C., Haridas, P Nair, K.K.C., Venugopal, P. and Gauns, M. (2001), Arabian Sea oceanography and fisheries of the west coast of India, *Current Science*, Vol 81, No.4, pp 355-361.
Mahmud, H.H. (2009), Gondal maturation and histological observations of *Epinephelus areolatus* and *Lethrinus nebulosus* in Halaieb/ Shalatien Area, Red Sea Egypt, *Global Veterinaria*, 3: 414-423.

Malloy, K.D. and Targett, T.E. (1994), The use of RNA: DNA ratios to predict growth limitation of juvenile summer flounder (*Paralichthys dentatus*) from Delaware and North Carolina estuaries, *Mar. Biol*., 118: 367-375.
Manacop, P.R. (1953), The life history and habis of the goby *Sicyopterus extraneus* Herre(anga) Gobiidae with an account of goby fry fishery of Cagayan River,Oriental Misamis.Philipp.J.Fish.2:1-58.
Marentette, J.R., Fitzpatrick, J.L., Berger, R.G. and Balshine, S. (2009), Multiple male reproductive morphs in the invasive round goby (*Apollonia melanostoma*), *Journal of Great Lakes Research*, 35, 302-308.
Marioka, S. and Sano, K. (2009), Growth and maturation of the bumble-bee goby *Brachygobius mekongensis* (Perciformes:Gobiidae) occurring in the Mekong basin, In Vientiane Province, Central Laos, *Ichthyol. Explor. Freshwaters*, Vol.20,3: 267-275.
Marimuthu, K., Hanifa, M.A. and Rahman, M.A. (2009), Spawning performance of native threatened spotted snakehead fish,*Channa punctatus* (Actinopterygii: Perciformes) induced with ovatide, *Acta Ichthyologica et Piscatoria*, 39 (1) : 1-5.
Martin, W.R. (1949), The mechanism of environmental control of body form in fishes, Univ. Toronto. Stud. Biol. Ser.no. 58, Publ. Ontario, Fish. Res. Lab.no. 70, 1-91.

Marquez, J.R.S. (1960), Age and size at sexual maturity of white goby (*Glossogobius giuris*) a common species of fish of Laguna de Bay, with notes on its food habits, *Phillippines Journal of Fisheries*, 8(1): 71-101.
Marquez, J.R.S. (1968), Age and size at sexual maturity of white goby (*Glossogobius giuris*), a common sepecies of fish of Laguna de Bay, with notes on its food habits, *Philipp.J.Fish*., 8(1):71-100.
Marr, A. C. (1955), The use of morphometric data on systematic and relative growth studies in fishes. *Copiea,* 13: 23-41.

Marshall, C.T., O' Brien, L., Tomkiewiez, J., Koster, F.W., Kraus, G., Marteindottir, G., Morgan, M.J., Saborido-Ray, F., Morgan, M.J., Saborido-Ray, F., Blanchard, J.L., Secor, D.H., Wright, P.J., Mukhina, N.V. and Bjornsson, H. (2003), Developing alternative indices of reproductive potential for use in fisheries management, case studies for stocks spanning an information gradient, *Journal of Northwest Atlantic Fisheries Society*., 33: 161-190.

Mata Cortes, S. Matinez-Perez, J.A. and Peterson, M.S. (2004), Feeding habits and sexual dimorphism of the violet goby *Gobioides broussoneti* Lacepe (Pisces: Gobiidae) in the estuarine system of Tecolutla, Veracruz, *Mexico Gulf and Caribbean Research*, Vol 16, 89-93.
Mat-Isa, M., Doroh, N. I. A., Ambri, F.K.and Keong, N.G.W., (2012), Reproductive biology of the sleeper goby *Butis gymnopomus* (Bleeker, 1853) from the Merbok Estuary, Kedah, Malaysia, *Indian. J. Fish*., 59 (4): 147-155.
*Mayr, E., Linsley, E. G. and Usinger, R. L. (1953) Methods and principles of systematic zoology. McGraw-Hill, New York.

Mayer, I., Shackley, S.E and Ryland, J.S. (1988), Aspects of the reproductive biology of the bass, *Dicentrarchus labrax.L.* An histological and histochemical study of oocyte development, *J.Fish.Biol*, 33,609-622.

Mazzoldi, C. and Rosotto, M.B. (2001), Extended breeding season in the marbled goby, *Pomatochistus marmoratus* (Teleostei: Gobiidae) in the Venetain lagoon, *Environ. Biol.Fishes*. 61: 175-183.
Mazzoldi, C. and Rosotto, M.B. (2002), Alternative male mating tactics in the black goby, *Gobius niger* (Teleostei Gobiidae), *J.Fish.Biol*. 61: 157-172.
Mazzoldi, C., Poltronieri, C. and Rosotto, M.B. (2002), Egg size variability and mating system in the marbled goby *Pomatochistus marmoratus* (Pisces:Gobiidae), *Mar. Ecol. Progr. Ser*., 233: 231- 239.
Mazzoldi, C. Peterson, C.W. and Rosotto, M.B. (2005), The influence of mating system on seminal vesicle variability among gobies (Teleostei, Gobiidae), *J. Zoolog*. *Syst. Evol*., *Res.*, 43: 307- 314.
Mc Lusky, D.S. and Elliot, M. (2004), The estuarine ecosystem: ecology, threats and management, 3rd ed. Oxford University Press, 214pp.
McLaughlin, R.L., Ferguson, M.M. and Noakes, D.L.G. (1994), Tissue concentrations of RNA and protein for juvenile brook trout (*Savelinus fontinalis*): lagged responses to fluctuations in food availability, *Fish Physiol. Biochem*., 14 (6): 459-469.

Mein, V.A. (1927), Observations on the yearly variations of the ovaries in the perch (*Perca fluviatilis L*.) *Russk.Zool.Zh*.,7, Vyp. 4.
Mendonca, A., Isidro, E., Menezes, G., Puiho, M.R., Melo.O. and Estacio. S. (2006), New Contribution to the Reproductive features of blue mouth *Helicolennus dactrylopterus dactrylopterus* from the north Atlantic (Azores Archipelago) *Scientia marina*, 70: 697-698.
Mercaldo-Allen, R., Kuropat, C. and Caldarone, E.M. (2006), A model to estimate growth in young of the year tautog *Tautoga onitis*, based on RNA/DNA ratio and sea water temperature, *Journal of Experimental Marine Biology and Ecology*, 329: 187-195.
Mercaldo-Allen, R., Kuropat, C. and Caldarone, E.M. (2008), An RNA: DNA based growth model for young of the year winter flounder *Pseudopleuronectes americanus* (Walbaum) *Journal of Fish. Biology*, 72, 1321-1331.
Menzes, N. (2005), Malad's mangrove massacre, Indian Express, retrieved on 10/04/2009.
Metin, G., Ilkyaz, A.T., Soykan, O.and Kinacigil, H.T. (2011), Age, growth and reproduction of four- spotted goby, *Deltentosteus quadrimaculatus* (Valenciennes, 1837), In Izmir Bay (Central Aegean Sea), *Turk. J. Zool*, 35 (5) 711-716.
Miglava, I. and Jobling, M. (1989), Effect of feeding regime on food consumption, growth rates and tissue nucleic acids in juvenile Artic charr (*Salvenius alpinus*) with particular respect to compensatory growth, *J.Fish.Biol*., 34 : 947-957.
Miller, P.J. (1961), Age, growth and reproduction of the rock goby *Gobius paganellus* L, in the Isle of Man., *J. Mar. Biol. Ass*., U.K 41, 737-769.
Miller, P.J (1963), Taxonomy and Biology of the genus *Lebetus* (Teleostei-Gobioidae), *Bull. Brit. Mus. Nat. His. (Zool.*), 10 (3) 207-256.
Miller, P.J. (1969), A new species of *Pomatochistus* (Teleostei: Gobiidae) from the Western Sicily, Museo Civico Di Soria Naturale Giacomo Doria Annal. 77:221-231.
Miller, P.J. (1973), The ostelogy and adaptive features of *Rhyacichthys aspro* (Teleostei: Gobioidei) and the classification of gobioid fishes.*J.Zool*, Lond, 171:397-434.
Miller, P.J. (1975), Age structure and life span in the common goby *Pomatochistus microps*, *J. Zool*, Lond 177: 425-448.
*Miller, P.J.(1984), The tokology of Gobioid fishes, In G.W Potts & R.J Wotton (Eds), Fish Reproduction Strategies and Tactics (pp 119-154), New York : Academic Press.
*Miller, P.J. (1989), The tokology of Gobioid Fishes, pp 118-153 In; Potts.G.W& R.J Wotton 9eds) Fish Reproduction: Strategies and Tactics, Academic Press, New York.
Miller.P.J.(1992a), The sperm duct gland: a visceral synapomorphy for the gobioid fishes, *Copeia* (2) 253-256.
Miller, P.J.(1992b), A new species of *Didogobius* (Teleostei:Gobiidae from the Adriatic Sea, *J.Nat.His*., 26:1413.
Miranda, A.C.L. Bazzoli, N. Rizzo, E. and Sato, Y. (1999), Ovarian follicular atresia in two teleost species: a histological and ultra structural study. Tissue Cell, 31: 480-488.
Mishra.S. and Saksena, D.N. (2012), Gonadosomatic Index and Fecundity of an Indian Major Carp *Labeo calbasu*, in Gobhad Resevoir, *The Bioscan*., 7(1) 43-46.
Miyazaki, I. (1940), Studies on the Japanese common goby, *Acanthogobius flavimanus* (Temminck et Schlegel), *Bull. Jap. Sci. Fish*., 9:159-180.

Moazzam, M. Ajazuddin, S. and Ziaullah, (2004), Some observation on the morphometry of Kelee Shad *Hilsa kelee* (Pisces: Clupeidae) from Pakistani coast, *Rec. Surv. Pakistan*, 15: 34-41.
Mohan, D. and Jhajhria, A. (2001), Comparative growth and production of carps in Skekhawat pond Jodhpur, *J.Nate,* 13 (2): 123-130.
Mohanty, S. S. and Samantaray, K. (1996), Seasonal variation in the biochemical composition of juvenile *Channa striatus* (Bloch). The Third Indian Fisheries Forum, Proceedings, 11-14 October, 1993, Pant Nagar, U.P. pp. 191-192.

Mollah, M.F.A., Yeasmine, S., Hossen, M.B. and Ahammad, A.K.S. (2012), Land mark based morphometric and meristic variations of *Glossogobius giuris* in three stocks, J.Bangladesh.Agril.Univ, 10(2): 375-384.

Morato, T.P., Afonso, P., Lourinho, P., Barreiros, J.P., Santos, R.S and Nash, R.D.M (2001), Length-weight relationships for 21 coastal fish species of the Azores, North-Eastern Atlantic, *Fish. Res*., 50: 297-302.
Morgan, M. D. and Beeton, A. M.(1978). Life history and abundance of *Mysis relicta* in lake Michigan, *J. Fish. Res.* Bd., Can. 35: 1165 1170
Morgan, M.J. (2008), Integrating Reproductive Biology into scientific advice for fisheries management, *Journal of the North west Atlantic Fisheries Science*., 41: 37-51.
Morrison, C.M. (1990), Histology of the Atlantic Cod, *Gardus morhua*: An Atlas Part Three, Reproductive Tract, Canadian Special Publication of Fisheries and Aquatic Sciences, Washington, pp: 110.
Morris, R.W. (1977), An analysis of some meristic characters of the Stoghorn sculpin *Leptocottus armatus* Girard. Pac. Sci. 31 (3): 259 -277.
Mourant, J.R., Gibson, R.R., Johnson, T.M., Carpenter, S., Short, K.W., Yamada, Y.R. and Freyer, J.P. (2003), Methods of measuring the infra red spectra of biological cells, *Phys. Med. Biol*., 48: 243-257.
*Moyle, P.B. and Cech Jr, J.J. (1988), Fishes: *An Introduction to Ichthyology* , 2nd ed. Prentice-Hall, Inc, Englewood Cliffs, New Jersey, pp.593
*Moyle.P.B. (1993), Fish: *An Enthusiast's Guide*, Univ. of California Press.
Muchlisin, Z.A. Musman, M. and Azizah, M.N.S. (2010), Length-weight relationship and condition factors of two threatened fishes*, Rasbora tawarensis* and *Poropuntius tawarensis*, endemic to Lake Laut Tawar, Aceh Province, Indonesia, *Journal of Applied Ichthyology* 26 (6) : 949-953.
Muchlisin, Z.A. Musman, M. Siti-Azizah and M.N. (2010), Spawning seasons of *Rasbora tawarensis* (Pisces: Cyprinadae) In Lake Laut Tawar, aceh Province, Indonesia, Reproductive Biology and Endocrinology, 8: 49.
Muchilisin, Z.A. Musman, M. Fadli, N. and Siti-Azizah, M.N. (2011), Fecundity and Spawning frequency of *Rasbora tawarensis* (Pisces: Cyprinidae) an endemic species from Lake Laut Tawar, Aceh, Indonesia, AACL Bioflux, Volume 4 (3); 272-279.
Murdy E.O. and Hoese D.F. (2004), Bony fishes Gobioidei: 1778-1782.
Murdy E.O. (2006), A revision of the gobiid fish genus *Trypauchen* (Gobiidae: Amblyopinae), *Zootaxa*, 1343: 55-68.
Murdy, E.O and Shibukawa K. (2001), A revision of the gobiid fish genus *Odontamblyopus* (Gobiidae:Amblyopinae), *Ichthyological Research* ,48(1), 31-43.
Muraleedharan, V., Antony, K. P., Perigreen, P. A. and Gopakumar, K. (1996), Utilization of unconventional fish resources for surimi preparation. Proceedings of the

second workshop on scientific results of FORV SAGAR Sampada, Dept. of ocean development, New Delhi, (India), pp. 539-543.

Murray, C.B. and Beacham, T.D. (1989), Responses of meristic characters in chum Salmon (*Onccorhynchus keta*) to temperature changes during development, *Canadian Journal of Zoology*, 67 (3): 596-600.
Murta, A.G.(2000), Morphological variation of horse mackerel (*Trachurus trachurus*) in the Iberian and North African Atlantic: implications for stock identification ICES, *Journal of Marine Science*, 57 : 1240-1248.
*Murty, V.S. (1969), Catalogue of fishes (excluding from the Laccadives) in the reference collections of the central marine fisheries research institute, ICAR. *Bull. Cent. Mar. Fish. Res. Inst*: No.10.
*Murty, V.S (2002), Marine ornamental fish resources of Lakshadweep, CMFRI, Special Publication 72: 1-134.
Mustafa, S. and Zofair, S.M. (1985), Sesonal variations in Protein, RNA and DNA concentrations in major carps, *Catla catla*, *Labeo rohita* and *Cirrhina mrigala*, *Japanese Journal of Ichthyology*, Vol 32 (2) 258-262.
Murthy H. S., Ramchandra A. T. and Ramesh T. J. (1999), Growth, Survival & body composition of Tilapia, *Oreochromis mossambica* fed graded levels of stress care. *Fishery Technology*, Vol. 36(2): 125-128.

Mutsaddi, K.B. (1964), A study on a gobioid, Boleophthalmus dussumeiri (Cuv. And Val.), Ph.D Thesis, University of Bombay.
Mutsaddi, K.B. and Bal, D.V. (1970), Maturation and Spawning of *Boleophthalmus dussumieri*, *Journal of the University of Bombay* 39, 58-76.
Mutsaddi, K.B. and Bal D.V. (1973), Gobies from the intertidal region of Bombay, *Indian J.Fish*, 20, pp475-486.
Murua, H. and Saborido-Rey, F. (2003), Female reproductive strategies of marine fish species of the North Atlantic., *J.Northw. Atl. Fish. Sci*., 33: 23-31.
Nabi, M.R., Rahman, H.A., Mustafa, S. and Kader, M.A. (2007), Population dynamics of estuarine set bag net fishery of Bangladesh. Chiang Mai Journal of Science, 34(3): 355-365.

Nacua, S.S., Dorado, E.L., Anthony, M., Torres, J., Cesar, G and Demayo (2010), Body shape variation between two populations of the White goby, *Glossogobius giuris* (Hamilton and Buchanan), *Research Journal of Fisheries and Hydrobiology* 5(1): 44-51.
Nair, M.R. (1965). A preliminary study of the changes associated with lipid breakdown in oil sardine, S.longiceps stored at refrigerated temperature, *Indian.J.Fish*., 9: 126-132.

Nair, P. G. V. and Suseela, M. (2000), Biochemical composition of fish and shell fish. CIFT Technology Advisory Series, Central Institute of Fisheries Technology, Cochin.

Nakatami, K., Agostinho,A. A., Baumgartner, G., Bialetzki, A., Sanches, P.V., Makrakis, M.C. and Pavanelli, C.S. (2001), Eggs and Larvae of Freshwater Fishes: Development and identification manual Eduem, Maringa, pp. 378.
Nagahama, Y., (1983), The functional morphology of teleost gonads. In: Fish Physiology, Vol, IX A (Hoar W.S Randall D.J and Donaldson E.M eds), New York: Academic Press pp 223-276.

Nargis, A. (2006), Sesonal variation in the chemical composition of body flesh of Koi fish *Anabas testudineus* (Bloch) (Anabantidae: Perciformes) Bangladesh, *J.Sci.Ind.Res*., 41 (3-4), 219-226.
Narejo, N.T., Rahmatullah, S.M. and Mamnur.M. (2002), Length-weight relationship and Relative condition factor (Kn) of *Monopterus cuchia* (Hamilton), *Indian Journal of Fisheries,* 8: 54-59.
Nash, R.B.M (1982), The biology of fries goby, *Lesuerigobius friesii* (Malam) in the firth of Clyde, Scotland and a comparison with other stocks, *J.Fish.Biol*., 21, 69-95,
Nataranjan, A.V. and Jhingran, V.G.(1961), Index of preponderance: a method of grading the food elements in the stomach analysis of fishes, *Indian J.Fish*., 8:54-59.
*Nayman, (1965), Growth and Ecology of fish population, *Journal of Animal Ecology*, 20: 201-219.
Neelakantan, B. and Pai, M.V. (1985), Relative condition factor in marine fish *Lactarius lactarius* (Bloch and Schneider) Matsya, 11: 36-41.
*Nelson, J.S. (1976), Fishes of the World, Wiley Inter Science Publication, New York, 523pp.
Nellbrings, (1986), A quantative and experimental study of goby (*Pomatochistus spp*) nests on a shallow soft bottom, northern Baltic proper Ophelia, 25(1) : 15-23.
Nieland, D.L. and Wilson, C.A. (1993), Reproductive biology and annual variation of reproductive variables of black drum in the Northern Gulf of Mexico, Transactions of the American Fisheries Society, 122: 318-327.
*Nikolsky, G.V. (1963), The ecology of fishes, Academic press NewYork, pp 362.
*Nikolsky, G.V. (1980), Theory of fish population dynamics Bishen Singh Mahendra Pal Singh, India Ottokoeltz Science Publishers (W. Germany), 317pp.
Nunez, J. and Duponchelle, F. (2009), Towards a universal scale to assess sexual maturation and related life history traits in oviparous teleost fishes, *Fish Physiol.* Biochem., 35 (1): 167-180.
Ockiya, J.F.A. (2001), Study of food habits of goby, *Porogobius schlegeli* (Gunther,1861) from Elechi creek, off Bonny river, Niger delta, Nigeria.
*Odum, W.E. (1970), Pathways of energy flow in a South Florida estuary, Ph.D Dissertation, Univ.Miami, 162 p.
*Okada, Y. (1955), Fishes of Japan. Maruzen Co. Ltd., Tokyo.434p.
Okumara, T., Nagasawa, T., Hayashi, I. and Sato.Y. (2002), Effects of starvation on RNA: DNA ratio,glycogen content and C:N ratio in columellar muscle of the Japanese Turban Shell Turbo (Batillus) Cornutus (Gastropoda), *Fisheries Sci.*, 68: 306-312.
Olivotto,I., Zenobi, A., Rollo, A., Migliarini, B., Avella, M. and Carnevali, O. (2005), Breeding rearing and feeding studies in the cleaner goby *Gobiosoma evelynae* Science @direct Aquaculture 250 175-182.
Ojha, P., Mandloi, A. and Dube, K.K. (2007), Length-weight relationship and condition factor of *Catla catla*, *Ecol. Env & Cons*., 13 (3) : 605- 610.
Oni, S. K., Olayemi, J. Y. and Adegboye, J. D. (1983), Comparative physiology of three ecologically distinct freshwater fishes, *Alestes nurse* Ruppell, *Synodontis schall*, Bloch and Schneider and *Tilapia Zilli*, Gervais. *J. Fish. Biol.,* 22: 105-1099.

Ormerod, S.J. (2003), Restoration in applied ecology: editor's Introduction, *Journal of Applied Ecology*, **40**, 44–50.

Osse, J.W.M. (1985), Jaw protrusion, an optimization of the feeding apparatus of teleosts? *Acta Biotheoritica*, 34: 219-232.
Ota, D. Marchesan, M. and Ferrero, E.A. (1996), Sperm release behaviour and fertilization in the grass goby, *J. Fish. Biol*., 49, 246-256.
Otobo, F.L. (1978), The reproductive biology of *Pellonula afzeliusi* (Johnels) and *Sierrathrissa leonensis* (Thys Audenaerde) In Lake Kainji, Nigeria, *Hydrobiologia*, 61: 99-122.
Palazon-Fernandez, J. L., Arias, A. M. and Sarasquete, C. (2001), Aspects of the reproductive biology of the toadfish, *Halobatrachus didactylus* (Schneider, 1801) (Pisces: Batrachoididae). *Sci. Mar*., 65(2): 131-138.

Pannikar, N.K. (1937), The brackish water fauna of Madras .Proc. Ind. Acad. Sc., 6: 284-336.
Pandey, A.C. and Sharma, M.K. (1997), A Preliminary study on the relative condition factor of exotic carps cultivated on Sodic soil pond conditions in U.P, *Indian. J. Fish*, 45: 207-210.
Pandey, K. and Shukla, J.P. (2005), Fish and Fisheries, Rastogi publications, Meerut pp 504.
Panthulu, V. R. (1961), Determination of age and growth of *Mystus gulio* (Ham.) by the use of pectoral spines, with observations on its biology and fishery in Hoogly estuary, *Proc. Mat. Inst. Sci. India,* 27: 198-225.

Paon, L.A. and Kenchington, E.L.R. (1995), Changes in somatic and reproductive tissues during artificial conditioning of sea scallop, *Placopecten magellanicus* (Gmelin, 1791), *J. Shell. Fish Res*., 14: 53-58.
Parrish, R.H., Mallicoate, D.L. and Klingbell, R.A. (1986), Age dependent fecundity number of spawning per year, sex ratio and maturation stages in nortern anchovy, *Engraulis mordax*, *Fish.Bull*., 83: 503-517.
Parker, G.A. and Simmon, L.W. (1996), Parental investment and the control of sexual selection: predicting the direction of selection: predicting the direction of sexual competition, Proceedings of the Royal Society of London, Series B, 263, 315-321.
Parenti, L.R. and Grier, H. J. (2004), Evolution and Phylogeny of Gonad Morphology in bony fish, *Integrative and Comparative Biology*, 44: 333-348.
Parulekar, A. H. (1964), A study on *Bregmaceros mc clellandi* (Thompson) Ph.D Thesis Submitted to University of Bombay.

Parulekar, A.H., Dhargalkar, V.K. and Singbal S.Y.S. (1980), Benthic studies in Goa estuaries: Part III. Annual cycle of macrofaunal distribution, production and trophic relation, *Ind. J. Mar.Sci*., 9,189-200.
*Parvathi, M.R. (1980), Influence of prolactin and melatonin on the physiology of reproduction in the female freshwater fish, Mystis vittatus (Bloch), Ph.D Theis.J. Annamalai University.
Perez Camacho, A., Delgado, M., Fernandez, R.M.J. and Labarta, U. (2003), Energy balance, gonad deveolpemt and biochemical composition in the clam *Ruditapes decussates*, *Mar. Ecol. Prog. Ser*., 258: 133-145.
Pathak, S. C. and Jhingran, A.G. (1977), Maturity and fecundity of *Labeo calbasu* (Hamilton) of Loni reservoir. , *Inland Fish. Soc. India, 9:* 72-83.

Patil, N.N, Quadros, G. Somani V.U. ,Kurve P.N. and ,Athalye, R.P. (2002), Study of zooplankton distribution from Ulhas River Estuary and Thane creek, Proceedings of the National Seminar on Creek, Estuaries and Mangroves-Pollution and Conservation, pp109-115.
Patzner, R.A., Van Tassell, J.L., Kovacic, M., Kapoor, B.G. (Eds.), (2011), The Biology of Gobies, Science Publishers, Enfield, NH.
Paulinose V.T., Lalithambika devi C.B., Govindan, K., Gajbhiye, S.N. and Nair, V.R 2004, The Larvae of Decapods and Fishes of Amba Estuary, Maharashtra, *Mar. Ecosystem*, pp515-525.
Paulo-Martins, C., DaCunha, P.L. and De Almeida, P.R. (2004), Biology of sanzo's goby *Lesueurogobius sanzoi* (de Buen, 1918), off Cabo Raso, *Portugal, Sci. Mar*. 68 (2): 285-294.
Pauly, D.P. (1993), Editotorial Fishbyte Section Naga, ICLARM Q, 16 (2-3): 26.
Pauly, D., Christensen, V., Guenette, S., Pitcher, T., Sumaila, U.R., Walters, C., Watson, R. and Zeller, D. (2002), Towards sustainability in world fisheries, *Nature*, 418: 689-695.
Pawar, C.T. (1989), Impact of Irrigation A Regional Perspective, Himalaya Publishing House Bombay, Delhi and Nagpur.
Pawar, B.A. (2003), Reproductive physiology of some edible fishes belonging to Gobiidae and Siluridae from Sadatpur lake near Pravaranagar, Maharashtra, Ph.D Thesis, Dr. Babasaheb Ambedkar Marathwada Univ. Aurangabad.
Peck, M.A., Buckley, l.J. and Bengtson, D.A. (2003), The effects of body size and temperature on energy losses due to routine and feeding metabolism in early juvenile Atlantic cod (*Gadus morhua* and haddock *Melanogrammus aeglefinus*), *Mar.Ecol. Prog. Ser*., Vol.251: 233-243.
Petersen, C.G.J. (1917), On the development of our common gobies (Gobius) from the egg to the adult stages, etc, *Rep. Dan. Biol. Stn.*, 24: 3-16.
Petrakis, G. and Stergiou, K.I. (1995), Weight-Length relationships for 33 fish species in Greek waters, *Fish. Res*, 21: 465-469.
Pezold, F. (1993) Evidence for the monophyletic Gobiidae, Copeia (3): 634-643.
Pezold, F. (1998), Three new species of *Oxyurichthys* (Teleostei: Gobiidae) from the Indian and Pacific oceans, *Copeia*, 3: 687-695.
Piazza, B.P and La Peyre, M.K. (2010), Using *Gambusia affinis* growth and condition to assess estuarine habitat quality: a comparison of indices. Mar Ecol Prog Ser 412:231-245.
*Pillay, S.N. (1929), A list of fishes taken from Travancore, J.Bomb. Nat. Hist. Soc. 33, 347-379.
Pillay, T.V.R. and Sarojini, K.K. (1950), On the larval development of the Indian transparent goby *Gobiopterus chuno* (Ham) with observations on its bionomics, Proc. Natl. Inst. Sci. India. 16, 181-187.
Pillay, T.V.R. (1952), A critique of the methods of study of food of fishes, *J.Zool.Soc. India,* 4: 185-200.
Pillay, T. V. R. (1957), A morphometric study of the population of hilsa, *Hilsa ilisha* (Hamilton) of the river Hooghly and of the Chilka lake. *Indian J.Fish.,* 4 (2): 344-386.

*Pillay, T.V.R. (1990), Aquaculture principles and practices, Fishes News Books, Lond.
Pilo, B., Kumar, A.B., Murukesh, V.K., Vinod, K.R. and Kumari, S. (1996), Biological diversity of Gujarat, Gujarat Ecological Commission pp 962-963.

Piska, R.S. (1990), Racial analysis of carp Minnow, *Salmostoma clupeoides* (Bloch) *Indian. J. Fish*, 37, 265-268.
Piska, R.S. Waghray, S. and Vijayakumar, G. (1991), Population study of fresh water cyprinid *Ampblypharyngodon mola* with reference to its genetic races, *Indian. J. Anim. Sci*., 61, 119-121.
Pirria, M., Treer, T., Tomljanovic, T., Sprem, N., Matulic, D., Anicic, I. and Safner, R. (2011), First record of monkey goby *Neogobius fluviatilis* (Pallas, 1814) in the barbell zone of the Sava River, Croatia, *Journal of Applied Ichthyology*, 27 : 1383-1384.
Pitcher, T.J. and Hart, P.J.B. (1982), Fisheries ecology A VI Publishing Co. Westport, Connecticut pp.414.
Polacik, M., Janac, M., Vassilev, M. and Trichkova, T. (2012), Morphometric comparison of native and non native populations of round goby *Neogobius melanostomus* from the river Danube, *Folia. Zool*. 61 (1): 1-8.

Polgar, G., Jaafar, Z. and Konstantinidis, P. (2013). A new species of mudskipper, *Boleophthalmus poti* (Teleostei: Gobiidae: Oxudercinae) from the Gulf of Papua, Papua New Guinea, and a key to the genus. *The Raffles Bulletin of Zoology*., 61 (1): 311-321

Poortenaar, C.W. Hooker, S.H. and Sharp, N. (2001), Assessment of yellow tail king fish (*Seriolo lalandi lalandi*) reproductive physiology, as a basis for aquaculture 201: 271-286.
Prokofiev, A.M. (2007), A new species of *Lubrigobius* (Perciformes: Gobiidae) from Nha Trang Bay, Vietnam, *Journal of Ichthyology*, Vol 49, 5: pp 416-419
Prabhu, M.S. (1956a), Maturation of intra ovarian eggs and spawning periodicities of fishes, *Indian. J. Fish*., 3, 59-90.
Privitera, L.A. (2002), Reproductive biology of the coralreef goby *Asterropteryx semipunctata*, in Kaneohe bay, Hawai, *Environmental biology of fishes*, 65:289-310.
Qasim, S.Z. (1972), The dynamics of food and feeding habits of some marine fishes, *Indian.J.Fish*, 19:11-28.
Qasim, S.Z. (1973a), An appraisal of the studies on maturation and spawning in marine teleosts from the Indian waters, *Indian. J. Fish*., 20, 166-181.
Qasim, S.Z. and Qayyum, A. (1961), Spawning frequencies and breeding seasons of some freshwater fishes with special reference to those occurring in the plains of northern India, *Indian. J. Fish*, 8, 24- 43.
Qasim, S. Z. and Qayyum, A. (1963), Fecundities of some freshwater fish, *Proc. Nat. Inst. Sci*. *India*, 29: 373-382.

Quadros, G. and Athalye, R.P. (2002), Intertidal macrobenthos from Ulhas River Estuary and Thane creek, Proceedings of the National seminar on Creek, Estuaries and Mangroves-Pollution and Conservation, pp.216-222.
Raby, G.D., Gutowsky, L.F.G. and Fox, M.G. (2010), Diet Compostion and consumption rate in round goby *Neogobius malanostomus* in its expansion phase in the Trent River, Ontario, *Environmental Biology of Fishes*, 89: 143- 150.
Rahemo, Z.I.F. and Al-Shatter, N.M.S. (2012), Observations on reproductive organs and tissues of two freshwater cyprinid fishes, *DAV. Interl. J. Sci.,* Vol 1 (2): 141- 146.
Rahimov, D.B. (1991), The Caspian Sea Gobiidae, Senpeterzburgh-Russia 602P.

Rahimibashar, M.R., Alipor, V., Hamidi, P. and Hakimi, B. (2012), Biometric characteristics, diet and gonad index of Lizard fish (*Saurida tumbil*, Bloch 1795) in the North of the Persian Gulf, World, *J.Fishand Mar.Sci*., 4 (1): 1-6.
Rai, B.P. (1966), The corpora atretica and the so called corpora lutea in the ovary of *Tor tor* (Ham), *Anat. Anz*., 119, 459-465.
Raja, B.T.A. (1969), The Indian oil Sardine: *Bull Cent. Mar. Fish. Res. Inst*., 16: 1-128.
Rajalakshmi, M. (1966), Atresia of oocytes and ruptured follicles in *Gobius giuris* (Ham-Buch), *Gen. Comp. Endocrinol*., 6, 378- 384.
Ramaiyan, V., Paul, A.L. and Pandian, T.J. (1976), Biochemical studies on the Fishes of the Order clupeiformes, *J. Mar. Biol. Assoc. India*, 18(3): 516-524.
Ramanathan, N.P., Vuayaa, V., Ramaiya, and Natarajan, (1977), On the Biology of the large called Tongue Sole *Cynoglossus macrolepidolus* (Bleeker): *Indian. J. Fish.*, 24 (1&2): 83-89.
Randall, J.E. (1967), Food habits of reef fishes of the West Indies, In Proceedings of the International Conference on Tropical Oceanography, Miami Beach, Florida, *Stud. Trp. Oceanogr*., 5, pp.665-847.
Rangarajan, K. (1968), A new species of *Callogobius* (Family Gobiidae: Pisces) from Gulf of Mannar, *India J. Mar. Biol. Ass. India* 10(2): 347-353.
Randall, J.E. (2007), *Vanderhorstia opercularis*, a new shrimp goby from the Northern Red Sea, *Electronic Journal of Ichthyology*, 1:18-25.
*Rao, H.S. (1939), Consolidated report on the shell fisheries in the Andamans during the years 1930-35, *Zool. Surv. India*, Calcutta, pp130
Rao, M. (1985), Ecology and biology of the flat fish *Cynoglossus macrolepidotus* (Bleeker, 1851) off Bombay coast, Ph.D Thesis, Univ of Bombay.
Rao, R.V. (1990), Studies on Certain Aspects of Reproductive Biology of Pearl Spot *Etroplus suratensis* (Bloch), Ph.d Thesis, Osmania University.
Rao, D.M. and Rao, K.S. (1991), Food and Feeding behaviour of *Nemipterus japonicas* (Bloch) populations of Visakhapatnam South India, *J. Mar. Biol. Assoc*., India, 33(1-2) : 335-345.
Rao, L.M., Reddy, K.S. and Hymavathy, V. (1999), Breeding biology and fecundity in *Mystus* species from Mehadrigedda Stream of Vishakapatnam, Ecol. Env. and Cons., 5(1): 25-28.

Rao, L.M. and Rao, S.P. (2002), Food and feeding habits of *Glossogobius guiris* from Gosthani estuary, *Inland.J.Fish*, Vol.49.no.1, pp.35-40.
Rao, P.S. and Rao, L.M.(2007), Sex ratio, Fecundity, Maturity and Spawning details of *Glossogobius guiris* (Hamilton) from Gosthani estuary near Vishakapatnam, *The IUP Journal of Life Sciences.*
Rathod, S.D., Patil, N.N., Quadros, G., and Athalye, R.P. (2002), Qualitative study of fin fish and shell fish fauna of Thane creek and Ulhas river Estuary, In Proc.of the National Seminar on creeks, Estuaries and Mangroves-Pollution and conservation, pp.135-141.
Rathod, S.D. (2005), Effect of pollution on mudskipper fishery of Ulhas river Estuary with a special reference to the biology of *Boleophthalmus dussumieri* (Cuv& Val). A minor project, Univ of Mumbai.
Rathod, S.D. and Patil, N.N. (2009), 'Feeding habits of *Boleophthalmus dussumieri* (Cuv.& Val.) from Ulhas river estuary near Thane city, Maharashtra state, *J.Aqua.Biol.,* 24(2): 153-159.

*Ravi, V. (2000), Studies on Eco-Biology of the mudskipper, *Boelophthalmus boddaerti* (Pallas), Ph.D.Thesis, Annamalai University.
Ravaglia, A.M. and Maggese, M.C. (2002), Oogenesis in the swamp eel *Synbranchus marmoratus* (Bloch, 1795) (Teleostei:Synbranchidae) Ovarian anatomy, stages of oocyte development and micropyle structure, *Biocell.*, 26 (3): 325-337.
Reddy, P.B. (1979), The fecundity of *Channa punctata* (Bloch) from Guntur, India, Proc. Indian. Acad. Sci. 88, 99-106.
Reddy, C.R. and Neelakantaan, B. (1991), Relative Condition Factor and Gonado somatic Index in *Sillago sihama* (Forskal): *Indian.J.Fish*, 40 (3): 171-174.
Reid, G.K. Jr. (1954), An ecological study of the Gulf of Mexico fishes in the vicinity of Cedarkey , *Florida. Bull. Mar. Sci.*, Gulf Caribb., 4:1-94.
*Reiss, M.J. (1989) The Allametry of Growth and Reproduction. Cambridge University Press, New York

Regan, C.T. (1911), The osteology and classification of the gobioid fishes, *Ann. Mag*. *Nat. His. Ser*., 8, 8:729-733.
Regnault, M. and Luquet, P. (1974), Study by evolution of nucleic acid content of prepuberal growth in the shrimp, *Crangon vulgaris*., *Mar. Biol*., 25: 291- 298.
Reynolds, J. D. (1974), Biology of small pelagic fishes in the new Volta Lake in Ghana. Part II: Sex and reproduction. *Hydrobiologia*, 45: 489-508.

Ricker, W.E.(1975), Computation and interpretation of biological statistics of fish populations, Bulletin (Fisheris Res. Bd. Canada) 191, Dept. Environment, Fisheries and Marine Service, Ottawa, Ontario, Canada, pp382.
Riehl, R. (1978), Zur Fisch Fauna Von Ibiza, Balearen. Sencken bergiana boil. 59: 173-182.
Ritakumari, S.D. and Nair, N.B. (1979b), Oogenesis in hill stream loach, Noemacheilus triangularis (Day), *Zool. Anz*., 203, 259-271.
Ritakumari, S.D. and Padmanabhan, K.G.(1976), Oogenesis in pearl spot *Etroplus suratensis* (Bloch), *Zool. Anz*., 196, 133-143.
Rizzo, E. and Bazzoli, N. (1995), Follicular atresia in curimata-pioa *Prochilodus affinis* Reinhardt, 1874. (Pisces Characoformes *), Rev Bras Biol*., 55: 697-703.
Roark, A.M., Bjorndal, K.A. and Bolten, A.B. (2009), Compensatory responses to food restriction in juvenile green turtles (*Chelonia mydas*), *Ecology* 90 (9): 2524-2534.
Rohlf , F.J. (1990), Annual Review of Ecology and Systematics, Vol. 21. (1990), pp. 299-316.

Rooker, J.R and Holt, G.J. (1996), Application of RNA: DNA ratios to evaluate the condition and growth of larval and juvenile red drum (*Sciaenops ocellatus*), *Mar. Freshwater Res.* 47: 283-290.
Rooker, J.R., Holt, G.J. and Holt, S.A. (1997), Condition of larval and juvenile red drum (*Sciaenops ocellatus*) from estuarines nursery habitats, *Mar. Biol.,* 127: 387-394.
Rounsefell, G.A. (1957), Fecundity of North American Salmonidae, U.S Fish and Wild life Service, *Fishery Bull*. 122. Vol.57 pp 451-468.
Rubbi, S.F., Rahman, M.M., Khan, A.R., Jahan, S.S., and Begum, M. (1987), Proximate composition and quality of some commercial species of freshwater fish, Bangladesh. *J. Sci*., 5: 1-20.

Rüber, L., Van Tassell, J.L. and Zardoya, R. (2003), Rapid speciation and ecological divergence in the American seven-spined gobies (Gobiidae, Gobiosomatini) inferred from molecular phylogeny. *Evolution* 57: 1584-1598.
Rüber, L.J. and A. Agorreta. 2011. Molecular phylogeny of gobioid fishes. In: *The Biology of Gobies*, R.A. Patzner, J.L. Van Tassell, M. Kovačić and B.G. Kapoor (eds.), Science Publisher Inc., Enfield, pp. 23-50.

Sadovy.Y. and Shapiro, D.Y. (1987), Criteria for the diagnosis of hermaphroditism in fishes, *Copeia* (1): 136-156.
Said, M.Z., Mohsin, A.K.M. and Ambak, M.A. (1994), Food feeding habits of *Nemipterus peronii* (Valenciennes) from the South China Sea Pertanika, *J.Trop.Aric*. *Sci*., 17 (2): 125- 131.
Saksena, D.N. (1976 a), On the Reproductive Organs and Reproductive cycle of Male Indian Freshwater goby *Glossogobius giuris* (Ham), *Zool. Jahrb.Abt*. *Anat.u.Ontog. Tiere*., 95 (1); 121-146.
Saksena, D.N. (1976 b), Reproductive Organs and Reproductive cycle of Female Indian Freshwater goby *Glossogobius giuris* (Ham) *Zool. Jahrb.Abt. Anat.u.Ontog*. Tiere., 96: 45-73.
Saksena. D.N. (1987), On the use of gonadosomatic index and volume of the gonads as indicators of gonadal state in Indian Freshwater goby *Glossogobius giuris* (Ham) with a note on the role of temperature in fish reproduction, *Intl. J.Ichthyol*., 8 (1): 1-8.
Salim, S. and Shamsi, M.J.K. (1981), Morphometric study of *Puntius saroma* (Ham) of the river Kali., *Geobios*., 8: 17-21.
Samat, A. Shukor, M.N. Mazlan, A.G. Arshad, A. and Fatimah, M.Y. (2008), Length weight relationship and condition factor of Pterygoplichthys pardalis (Pisces: Loricariidae) in Malaysia Peninsula, *Research.Journal of Fisheries and Hydribiology* 3 (2) , 48- 53.
*Sanzo, L. (1911). Distribuzione delle papille cutanee (organi ciatiform) e suo valore sistematice nei Gobi, *Mitt.Zool.Sta.Naples*, 20:249-328.
Sapota, M.R. (2006), NOBANIS- Invasive Alien Species fact sheet- *Neogobius melaonostomus* from Online Database of the North European and Baltic Network on Invasive Alien Species www.nobanis org 10/10/2010.
Sarkar, U.K., Deepak, P.K. and Negi R.S. (2009), Length-weight relationship of clownfish *Chitala chitala* (Hamilton 1822) from the River Ganga basin, *Indian Journal of Applied Ichthyology*, 25 (2): 232-233.
Sarma, G.H.R. (1973), Comparative biometric studies of two species of Hilsa, *Hilisa kanagurta* (Bleeker) and *H.toli*, *Indian. J. Zool*., 14, 23- 30.
Sarojini, K.K (1958), Biology and fisheries of the grey mullets of Bengal. II Biology of *Mugil cunnensius* (Val), *Indian J. Fish.* 5, 56-76.
Sasi, H and Berber, S (2010), Some biological characteristics of monkey goby in Anatolia, *Asian.J.Anim*., *Vet.Adv*., 5, 229-233.
Satter white, M.C, (2003), RNA: DNA as indicator of Nutritional condition and growth in larval naked goby *Gobiosoma bosc*, M.Sc. Thesis, Lousiana State University, Lousiana.
Sathyanesan, A.G. (1961b), A histological study of the ovular atresia in the cat fish *Mystus seengala* (Sykes), *Rec. Ind. Museum*., 59, 75-82.

Saxena, O.P. (1980), Relationship of buccopharynx with food and feeding habits of *Labeo dero*(Ham), Proc.Indian natn.Sci.Acad, B 46:41-47.
Sazima, I, Filho, A.C. and Sazima, C. (2008), A new cleaner species of *Elacatinus* (Actinopterygii: Gobiidae) from the South western Atlantic, *Zootaxa*, 1932:27-32.
Scalici, M. & Gibertini, G. (2012), Meristics of the Etruscan goby *Padogobius nigricans*, *Hydrobiologica* 22 (2): 174- 180.
*Schaperclause, W. (1933) *US Department of Interior, Fish Wildl. Serv. Fish leafl.*No. 31, 261 pp.

Schneider, W.C. (1957), Determination of nucleic acids in tissues by pentose analysis. In Colowick, S.P and N.O Kalpan eds: Methods in Enzymology Vol.3 Academic Press, New York, pp1154.
Schneider, J.C., Laarman, P.W. and Gowing, H. (2000), Length-weight Relationships, In: Manual of Fisheries Survey Methods II: with Periodic Updates Fisheries Special Report 25, Schneider J.C (Ed.0 Michigan Department of Natural Resources, Michigam, U.S.A.
Sealici. M. and Gibertini, (2009), Freshwater goby life history in a Mediterranean stream, *Hydrobiology,*Springer Science Business media, 628:177-189.
Sebastian, R. (2011), Biology of flat Toad fish, *Coletteichthys dussumieri* (Valenciennes, 1837) of Cochin Estuary, Ph.D Thesis, Cochin University of Science and Technology.
Seoka, M., Kato, K., Kubo, T., Mukai, Y., Sakamoto, W., Kumai, H. and Murato. O. (2007), Gonadal maturation of Pacific bluefin Tuna, Thunnus orientalis in captivity, *Aquac.Sci*., 55: 289-292.
Sekharan, K.V. (1950), Fat content of the Muscles of the Indian Herring *Pellona hoevenii* (Blkr), *J. Madras Univ*., 20 (3) 49-65.
Sekharan, K.V. (1968), Length-weight relationship in *Sardinella albella* (Val.) and *S. Gibbosa* (Bloch), *Indian. J. Fish*, 15, 166- 174.
Selvaraj, G. S. D. (1984), A note on the biochemical composition of the Indian shad *Ilisha melastoma* (Schneider)*. Indian J. Fish.*, 31 (1): 162-165.

Serajuddin, M., Khan, A.A. and Mustafa, S. (1998), Food and Feeding habits of the spiny eel, *Masta cembelus armatus*, *Asian Fish Sci*, 11: 271- 278.
Serajuddin, M. and Ali, R. (2005), Food and feeding habits of striped spiny eel, *Macrognathus pancalus* (Hamilton), *Indian. J. Fish*, 52 (1): 81-86.
Sfakianakis, D.G. Leris, I. and Kentouri, M. (2011), Effect of developmental temperature on swimming performance of zebra fish (*Danio rerio*) juveniles. *Environmental Biology of Fishes*, 90: 421-427.
Shafi, S. (2012), Study on fecundity and GSI of *Carassius carassius* (Linneaus, 1758) introduced from Dal Lake Kashmir. *Journal of Biology, Agriculture and Health care*, Vol.2 (3): 68-76.
Shallof, K.A.S. and Salama, H.M.M. (2008), Investigations on some aspects of reproductive biology in *Oreochromis niloticus* (Linneaus, 1757) inhabited Abu-zabal Lake, Egypt Global Veterinaria 2(6); 351-359.
Shamsan, E.F.S. (2008), Ecobiology and Fisheries of a Economically Important Estuarine Fish *Sillago sihama* (Forsskal), Ph.D Thesis, Goa University.
Shankar, D.S. and R. S. Kulkarni, 2005. Somatic condition of the fish, *Notopterus notopterus (Pallas)* during different phases of the reproductive cycle. I. *Environ.Biol*, 26: 49-53.

Shanti Prabha, Y. and Manjulatha, C. (2008), Food and Feeding habits of *Upeneus vittatus* (Forskal, 1775) from Vishakhapatnam coast (Andhra Pradesh) of India, *International Journal of Zoological Research*, 4: 59-63.
Shanbhag, A.B. and Nadkarni, V.B. (1981), Identification of steroidogenic tissues in the ovary of fish, *Channa gachua* during different phases of reproductive cycle, *J. Anim. Morphol. Physiol*., 28, 128-134.
Shashi, B.S. and Akela, B.P. (1996), Determination of maturity and spawning period by gonadosomatic index and measurement of mean ova diameter in certain teleosts. *Environ. Ecol*., 14: 399-403.
Shekhar, C., Rao, A. P. and Abidi, A. B. (2004), Changes in muscle biochemical composition of *Labeo rohita* (Ham.) in relation to season. *Indian J. Fish*., 51(3): 319-323.

Shettu, N. (1993), Studies on certain aspects of biology of the gobid fish *Boleophthalmus dentatus*(Cuv.& Val.), Ph.D Thesis, CIFE.
Shiogaki, M. and Dotu, Y. (1974), The life history of the gobiid fish, *Zonogobius boreus*, *Bull. Fac.Fish*., Nagasaki Univ, 37: 1-8.
Shinkafi, B.A., Ipinjolu, J.K. and Hassan, W.A. (2011), Gonad Maturation Stages of *Auchenoglanis occidentalis* (Valenciennes 1840) in River Rimo, North-Western Nigeria, *Journal of Fisheries and Aquatic Science*, 6: 236-246.
Sidhu, K. S. (2003), Health benefits and potential risks related to consumption of fish or fish oil, *Regul*. *Toxicol. Pharm*., 38: 336-344.
Silas, E.G. (1952), Notes on the bionomics of the red goby, *Trypauchen vagina* (Bloch & Schneider), *J.Bombay. Nat. Hist. Soc*., 50, 679-681.
Simonovic, P. Paunovic, M. and Popovics, S. (2001), Morphology, feeding and reproduction of the round goby *Neogobius melanostomus*(Pallas) in the Danube river basin, Yugoslavia, *J.GreatLakes Res,* 27(3): 281-289.
*Simpson, A.C. (1951), The fecundity of plaice. Fishery Invest. Lond. (Series 2) 17, 1-17.
Sinha, G.M. and Pal, P.C. (1990). Seasonal Variation in Protein, Lipid and Carbohydrate contents of Ovary, Liver and Body muscle in relation to Gonadosomatic index and Oogenesis of *Clarias batrachus* (Linn): [In: Impacts of Environment on Animals and Aquaculture (Eds): Manna, G.K and Jana, B.B], Univ of Kalyani, pp 107-112.
Sivakami, S., Ayyapan, S., Rahman, M.F. and Govind, B.V. (1986), Biochemical Composition of *Cyprinus carpio* (Linneaus) cultured in cage in relation to maturity, *Indian. J. Fish*., 33 (1): 180-187.
Sivakami, S. (1996), On the food habits of the fishes of the family Carangidae- A review, *J. Mar. Biol. Assoc*. India, 38 (1&2): 118-123.
Sivaraman, G.K., Kapila, R. and Mahanta, P.C. (2009), RNA-DNA ratios as an indicator of fish growth in Golden Mahaseer (*Tor putitora*), *Asian Fisheries Science* 22 (1) 117-123.
Skazkina, Y.P. and Kostyuchenko, V.A. (1968), Food consumption of the Azov goby *Neogobius melanostomus*(Pallas), *Probl Ichthyol*, 8:238-245.
*Smith, H.M. (1901), The food fish of Lake Buhi, Luzon, *Bull.U.S.Fish.comm.*, 21:167-171.
Smith, L.S. (1989), Digestive functions in teleost fish. In fish nutrition (J.E Halvert, ed.) San Diego: Academic Press, pp.331-421.
Smith, R.W., Palmer, P.M. and Houlihan, D.F. (2000), RNA turn over and protein synthesis in fish cells, *J.Comp. Physiol*., (B) 170: 135-144.

Smith, T.R. and Buckley, L.J. (2003), RNA-DNA ratio in scales from juvenile cod provides a nonlethal measure of feeding condition, Transactions of the American Fisheries Society, 132: 9- 17.
Smith, B.B. and Walker, K.F, (2004), Spawning dynamics of carp (*Cyprinus carpio*, L) in the river Murray, South Australia, shown by macroscopic and histological staging of gonads, *J. Fish. Biol*., 64: 1-19.
Smith, W.L. and Sparks, J.S. (2007) *Gobius lagocephallus* Pallas, 1770 (currently Sicyopterus lagocephalus, Osteichthyes, Teleostei, Gobiidae): proposed suppressionof the specific name case 3383 ,*Bulletin of zoological nomenclature* 64(2).
Smith, O. (2008), Reproductive potential and life history of spotted gar *Lepisosteus oculatus* in the upper Barataria Estuary, Louisiana, Master's Thesis, Nicholls State University, Thibodaux, Louisiana.
Snedecor, G.W. (1946), Statistical methods: Applied to experiments in agriculture and biology (4th ed) Ames, I.A, U.S: Iowa State University Press, pp 1-476.
Snedecor, G. W. and Cochran, W. G. (1967), Statistical Methods; Oxford and IBH publ. Co., New Delhi. pp. 593.

Sole, M. Kopecka, J. and de la Parra, G.L.M. (2006), Seasonal variations of selected biomarkers in sand gobies *Pomatochistus minutus* from the Guadalquivir estuary, Southwest Spain, *Arch. Environ. Contam. Toxicol*., 50: 249-255.

Sompong, H. (1980). Life history of sand goby *Oxyeleotris marmoratus* Bleeker (in Thai), Technical Paper, Royal Thai Department of Fisheries, No.13, pp 42.
Soni, V.C. and George, B. (1986), Age determination and length-weight relationship in the mudskipper *Boleophthalmus dentatus*, *Indian. J. Fish*., 33, 231- 234.
Springer.V.G. and Mcerlean A.J. (1961) Spawning seasons and growth of the code goby *Gobiosoma robustum* (Pisces: Gobiidae) in the Tampa bay area Tulane studies in Zoology, Vol 9, 2: 87-98
Springer V.G. (1983), Tyson belos, New Genus and species of Western Pacific fish (Gobiidae, Xenisthminae)with Discussions of Gobioid Osteology and Classification Smithsonia Contributions to Zoology, 390:1-40.
Srivastava, G.J. (1968), Fishes of U.P and Bihar, Vishwa Vidyalaya Prakashan,Varanasi., ppXX+ 207,Fig 113.
Srivastava, C.B.L. (1999), A Text Book of Fishery Science and Indian Fisheries, Keitab Mahal, Allahabad, pp 527.
Stanely, H., Chief fi, G. and Botte, V. (1965), Histological and histochemical observations on the testis of *Gobius paganellus*, *Zellforsch mikrosk Anat*. 65, 350-362.
Strauss, R.E. (1985), Evolutionary allometry and variation in body form in the South American cat fish genus *Corydoras (*Callichthyidae), *Systematic Zoology*, 34: 381-396.
Strauss, R.E and Bond, C.E, (1990), Taxonomic methods: Morphology, In: Schreck, C.B and Moyle (Eds.) Methods for Fish Biology, Americ Fisheries Society, Bethesda, Maryland, pp 109-140.
Stergiou, K.I. Economicdics, P. and Sinis, A. (1996), Sex ratio, spawning season and size at maturity of red band fish in the Western Aegean Sea, *J.Fish. Biol*., 49: 561-572.

Subla, B.A. (1970), Studies on the functional morphology of the feeding apparatus feeding habits and the food of the nine Kashmir Fishes, Ph.D Thesis, University of Kashmir.
Sugilar, H., Park, T.C., Lee, N.H., Han, D.W., and Han, K.N., (2012), Population dynamics of the swimming crab *Portunus trituberculatus* (Mier, 1876) (Brachyura, Portunidae) from the West Sea of Korea, *Int. J. Oceanogr. Mar. Ecol. System* 1(2): 36-49.
Sundararaj, B. I. (1959), A study on the correlation between the structure of the pituitary gland of the Indian Catfish *Heterpneustes* and the seasonal changes in the ovary, *Acta. Anat*. 37: 47-80.
Sundararaj, B. I. and Vasal, S., 1976. Photoperiod and temperature control in the regulation of reproduction in the female catfish, *Heteropneustes fossilis* (Bloch.). *J. Fish Res. Board Can.*, 33: 959–973.

Sulistiono,L.C., Irma,H., Wirajoatmodjo, S., Watnabe, S. and Yokota, M. (2003), Some biological aspects of butini fish *Glossogobius matanensis* in Matano Lake South Sulawesi Indonesia.
Sunobe, T., Nakamura, M., Kobayashi, Y. and Kobayashi, T. (2005), Gonadal structure and P450Scc and 3ß-HSD immune reactivity in the gobiid fish Trimma okinawae during bidirectional sex change, *Ichthyol. Res*., 52: 27-32.
Susan, J. S.and Nair, N.B. (1983) Reproductive biology of the larvivorous fish *Macropodus cupanus* (Cuv.& Val.), Proc. Indian. Acad. Sci. 92, 159-170.
Sutcliffe, W.H. (1970), Relationship between growth rate and ribonucleic acid concentration in some invertebrates., *J. Fish. Res. Bd. Can*. 27: 606-609.
Suthers, I. M.(1998), Bigger? fatter? Or is faster growth better? Considerations on condition in larval and juvenile coral reef fish, *Australian Journal of Ecology* 23: 265–273.

Suwanjarat. J, Amornsakun. T, Thongboon, L, and Boonyoung, P. (2005), Seasonal changes of spermatogenesis in male and goby *Oxyeleotris marmoratus* Bleeker, 1852 (Teleostei, Gobiidae) Songklanakarin, *J. Sci. Technol*., 27: 425-436.
Suzuki, K. and Kimura, S. (1979), Biology of the Gobiid fish, *Chaeturichthys sciistius* in the spawning season at Ise Bay, *Japanese Journal of Ichthyology*., Vol.26 no.2.
Swain, D.P., Ridell, B.E. and Murray, C.D. (1991) Morpholigical differences between hatchery and wild populations of Coho salmon (Oncorhynchus kisutch): envireonmental versus genetic origin. *Can.J.Fish.Aquact.Sci*. 48(9):1783-1791.
Sweat, L.H. (2009), Smithsonian Marine Station at Fort Pierce http:// www.sms.si.edu/irlspec
Swift .C *et al.,* (1979) Natural History Museum of Los Angeles County: LACM Vertebrate Collection, Accessed via http://www.gbif.org/occurrence /813534310 25/07/2014.
Tandon, K.K. (1962), Biology and fishery of Chooparai *Selaroides leptolepsis* (C&V) *Indian J. Fish*, 8:127-144.
Tandon, K.K.(1962), Biology of *Channa punctatus*(Bloch) and *Glossogobius giuris* (Ham.), Research Bulletin. Punjab University, New Series: Science 13:263-268.
Taning, A.V. (1952), Experimental study of meristic characters in fishes. *Bio.Rev*. Cambridge. Philo. Soc.
*Takagi, K..(1967), Topologie du Systeme Sensoriel Cephalique des Gobioidei. La Mer. (Bulletin da la Societe france-japonaise d' Oceanographic). Tome 5, No. 2:37-51.

Takama, K., Love, R.M. and Smith, G.L. (1985), Selectivity in mobilisation of stored fatty scids by maturing cod *Gadus morhua*, L, *Comp. Biochem. Physiol*. SOB 713-718.
Tarkan, A.S., Gaygusuz, O., Acipinar, H., Gursay, C. and Ozulug, M. (2006), Length weight relationship of fishes from the Marmara region (NW- Turkey), *Journal of Applied Ichthyology*, 22 (4): 271-273.
Taylor, M.S. and Tasseli, J.l. (2002), Obervations on Microhabitat Utilization by three widely distributed Neotropical Gobies of the Genus *Elacatinus*, *Copeia*, (4) pp 1134-1136.
Taylor, M.S. and Hellberg, M.E. (2003), Genetic evidence for local retention of pelagic larvae in a Caribbean reef fish, *Science* 299: 107-109.

Taylor, M.S. and Hellberg.M.E. (2005), Marine radiations at small geographic scales:speciation in neotropical reef gobies (*Elacatinus*). *Evolution* 59: 374-385.

Tesch, F.W. (1968), Age and Growth in Methods for Assessment of Fish Production in Freshwater (Ed. W.E Ricker), IBP Handbook No.3, Blackwell, Oxford pp 93-123.
Tesch, F.W. (1971), Age and Growth In: W.E. Ricker (Ed) Methods for Assessment of Fish Production in Freshwaters Blackwell Scientific Publications, Oxford pp 99-130.
Thacker, C.E. (2000), Phylogeny of the Wormfishes (Teleostei: Gobioidei: Microdesmidae). *Copeia* 2000: 940-957.

Thacker, C.E. and Cole, K.S.(2002), Phylogeny and evolution of the gobiid genus *Coryphopterus*. *Bulletin of Marine Science* 70: 837-850.

Thacker, C.E.(2003), Molecular phylogeny of the gobioid fishes (Teleostei:Perciformes: Gobioidei). *Molecular Phylogentics and Evolution* 26: 354-368.

Thacker, C.E. and Grier, H. (2005), Unusual gonad structure in the Paedomorphic teleost *Schindleria praematura* (Teleostei: Gobioidei): a comparison with other gobioid fishes, *Journal of Fish Biology*, 66: 378-391.

Thacker, C.E. and Hardman, M.A. (2005), Molecular phylogeny of basal gobioid fishes: Rhyacichthyidae, Odontobutidae, Xenisthmidae, Eleotridae (Teleostei: Perciformes: Gobioidei). *Molecular Phylogenetics and Evolution* 37: 858-871.

Thacker, C.E. (2009), Phylogeny of Gobioidei and placement within Acanthomorpha, with a new classification and investigation of diversifi cation and character evolution, *Copeia*: 93-104.

Thacker, C. E. (2011), Systematics of Gobiidae, *The Biology of Gobies. Science Publisher Inc., Enfield* , 129-136.

Thacker, C.E. (2011a), Systematics of Butidae and Eleotridae. In: Patzner, R.A., Van Tassell, J.L., Kovacˇic´, M., Kapoor, B.G. (Eds.), The Biology of Gobies. *Science Publishers, Enfield*, NH, pp. 79–85.

Thacker, C.E. (2013). Phylogenetic placement of the European sand gobies in Gobionellidae and characterization of gobionellid lineages (Gobiiformes:Gobioidei), *Zootaxa*, 3619, 369–382.

*Thresher, R. (1984), Reproduction in reef fishes, Neptune City, T. F. H. Publications, New Jersey, pp 399.
Tolan, J.M. and Newstead, D.A. (2004), Descriptions of larval, prejuvenile and juvenile finescale menhaden (*Brevoortia gunteri*) (Family Clupeidae) and Comparisons to Gulf menhaden (*B.patronus*), *Fish Bulletin of Seattle*, 102: 723-732.
Toor, H.S., Kapur, K. And Rai, B. (1979), Follicular atresia in the ovary of the teleost fish, *Puntius ticto*, *J.Anim. Morphol. Physiol*., 26, 85-92.
Tornabene, L., Van Tassell, J.L and Robertson, D.R. (2012), *Microgobius urraca* (Teleostei: Gobiidae), a new species of goby from the tropical eastern Pacific, *Zootaxa* 3347:41-55.
Torricelli, P., Lugli, M. and Gandolfi, G. (1985), A Qualitative analysis of fanning activity in the male *Padogobius martensi* (Pisces: Gobiidae), *Anim. Behav*, Vol.92, pp 2 88-301.
Treasurer, J.W. and Holiday, F.G.T. (1981), Some aspects of the reproductive biology of perch *Perca fluviatilis* (L). A histological description of the reproductive cycle, *J. Fish. Biol*., 18, 359-376.
Turan, D., Berbeer, S. and Topkara, E.T. (2005), A first record of *Knipowitschia longicaudata* (Kessler 1877) for the fish fauna of Lake Manyas, *Turk J*., 29:171-176.
Tudela, S. (1999), Morphological variability in a Mediterranean, genetically homogenous population of the European anchovy *Engraulis encrasicolus*, *Fish. Res*., 42 (3): 229-243.
Tyler, C.R. and Sumpter, J.P. (1996), Oocyte growth and development in Teleosts, *Rev. Fish. Biol. Fish*, 6: 287-318.
Udo, M.T. (2002), Trophic attributes of the mudskipper, *Periophthalmus barbus* (Gobiidae:Oxudercinae) in the mangrove swamps of Imo river estuary Nigeria, *Journal of Environmental Sciences*, Vol.14, No.4, pp 508-517.
Unal, G., Cetinkaya, O. and Elp, M. (1999), Histological Investigation of Gonad Development of *Chalcalburhus tarichi*, *Tr. J. of Zoology*, 23 (1): 329-338.
Unito-Ceniza, K.M., Torres, M.A.J. and Demayo, C.G. (2012), Describing body shape of goby *Glossogobius giuris* (Hamilton, 1822) from Lake Mainit, surigao Del Norte using landmark based geometric morphometrics, 1st Mae Fah Luang University International conference, mfu.ac.th.
Vachhrajani, K.D., Shukla, M.L., Trivedi, J.N., Soni, G.M. and Patel, B.K. (2014), Mudskipper (Gobiidae: Oxudercinae) fauna of Northern Gulf of Khambhat with two new record of the species from Gujarat, India, *Euro.J.Zool.Res*, 3(3): 67-74.
Vaidya, N.G., Dineshbabu, A.P., Kakati, V.S., Sreeram, M.P. and Dinesh,C.K. (2010), Shoreseine (Yendi) operations during the monsoons at Karwar, Uttar Kannada District of Karnataka, Marine fisheries Information Service T&E Ser.no.206,15-18.
Van Tassell, J.L. (1998). History of Gobioid Classification. Gobioid Research institute. http://gobiidae.com/histgoby.htm .20/07/2013.
*Vasil'eva, E.D. and Kuga, T.I. (2007), Gobies of the genus *Rhinogobius* (Gobiidae) of Primorye and water bodies of Central Asia and Kazakhstan:II ,Comparative craniological analysis of gobies introduced to Central Asia ISS0032-9452, *Journal of Ichthyology*, Vol.48, no.1, pp 29-36.

Vassileva, M.V.,Trichkova, T.A., Ureche, D., Stoica, I., Battes, K. and Zivkov, M.T. (2008), Distribution of gobiid species(Gobiidae, Pisces) in the Yantra river (Danube basin, Bulgaria), Proceedings of the anniversary Scientific Conference of Ecology Eds, Iliana G, pp163.
Venkateshwarlu, T. and Rama Rao, V. (1986), Ecology and distribution of Gobiid fishes of Madras and its Environs**, *ACTA Ichthyologica.et.Piscatoria*, Vol 16, Fasc.1.
Venkatramnujam, K and Ramanathan, N (1994), Manual of finfish biology, Oxford & IBH Publishing Co. Pvt. Ltd, New Delhi, pp 1-106.
Verep, B., Turan, D. and Kovac, V. (2006), Preliminary results on morphometry of barbell (*Barbustauricus* Kessler, 1877) in the streams of Rize and Artvin Provinces (Turkey), *Turk. J. Fish. Aquat. Sci*., 6: 17- 21.
Vazzoler, A.E.A.M. (1996), Reproductive biology of teleosts fishes: theory and practice. Eduem, Maringa pp.169.
Verma, A., Balchandran, S., Chaturvedi, N. and Patil, V. (2004), A Preliminary report on the Biodiversity of Mahul creek, Mumbai, India with special reference to Avifauna, *Zoos'Print J*, 19(9): 1599-1605.
Vidal, E.A.G., Di Marco, P. and Lee, P. (2006), Effects of starvation and recovery on the survival growth and RNA/DNA ratio Loliginid squid paralarvae, *Aquaculture*, 260: 94-105.
Vidalis, K.G., Markakis, and Tsimenides, N. (1997), Description between population of picarel [*Spicaria smaris*. L. (1758)] in the Aegean Sea, using multivariate analysis of phonetic characters, *Fishery Research*, 30: 191-197.
Vijayakumaran, M. (1979), Chemical Composition and Caloric Content of *Ambassis gymnocephalus*, *J. Mar. Biol. Assoc. India*, 21 (1&2): 182- 184.
Vrede, T., Persson, J. and Aronsen, G. (2002), The influence of food quality (P:C ratio) on RNA: DNA ratio and somatic growth rate of *Daphnia Limnol*., *Oceanogr*. 47: 487-494.
Vu, C.L., Yang, Y. and Changkwei, L. (2005), Cove culture of marble goby (*Oxyeleotris marmorata* Bleeker) and carps in Tri An reservoir of Vietnem, *Aquaculture*, 244:97-109.
Walsh, M.G., Bain, M.B., Squiers, T. Jr., Waldman, J.R. and Wirgin, I. (2001), Morphological and genetic variation among short nose sturgeon *Acipenser brevirostrum* from adjacent and distant rivers, *Estuaries*, 42: 41-48.
Waldman, J.R. (2005), Meristics In Cadrin, S.X, K.D Fried land & J.R Walman (Eds), Stock identification methods: application in fishery science, *Academic Press*, Amsterdam, pp 197-210.
Wallace, B. (1992), The search for the gene, Cornwell University Press, Ithaca, N.Y.
Wang, R. (2001), Osteology, Phylogeny and Biogeography of parioglossus, M.Sc, Department of Zoology, University of Toronto.
Wang, H.Y., Tsai, M.P., Dean, J. and Lee, S.C. (2001), Molecular phylogeny based on mitochondrial 12S rRNA sequences, *Molecular Phylogenetics and Evolution*, 20: 390-408.

Ward-Campbell, B.M.S., Beamish, F.W.H. and Kongchaiya, C. (2005), Morphological characteristics in relation to diet in five coexisting Thai fish species, *Journal of Fish Biology*, 67:1266-1279.
Waterman, (1976), The Production of dried fish, FAO Fish. Tech. Paper (160): 115-120.

Weatherley, A. H. and Gill, H. S. (1987). The Biology of Fish Growth. Academic Press, London. pp. 443.

Weatherley, A.H. (1972), Growth and Ecology of Fish Population, *Academic Press*, London.
Weber, M. and De Beaufort, L.F. (1953), The fishes of the Indo-Australian archipelago. X. Gobioidea, A.J. Reprints Agency, New Delhi. 423 p.

Webb, J.M. and Levy, H.B. (1955), A sensitive method for the determination of deoxyribonucleic acid in tissues and microorganisms, *J. Biol. Chem*, 213: 107-117.
Weisel, G.F. (1955), Variations in the number of fin rays of two cyprinid fishes correlated with natural water temperature, *Ecology*., 36: 1-6.
West, G. (1990), Methods of assessing ovarian development in fishes, a review, *Aust. J. Mar*. *Freshwat. Res.,* 199-222.
White, D.B., Wyanski, D.M. and Sedberry, G.R. (1998), Age, growth and reproductive biology of the black belly rose fish from the Carolinas, USA, *J. Fish. Biol*, 53: 1274-1291.
Wicker, A.M. and Johnson, W.E. (1987), Relationships among fat content, condition factor and first year survival of Florida largemouth bass, *T. Am. Fish. Soc*, 116: 264-271.
Wiens, J.J. (1995), Polymorphic characters in phylogenetic systematics, *Syst. Biol*. 44: 482-500.
Wiens, J.J. and Servedio, M.R. (1998), Phylognetic analysis and intra specific variation: Performance of parsimony, likelihood and distance methods. *Syst. Biol*., 47: 228-253.
Wiley, J.W. (1973), Life history of the Western North American goby Coryphopterus nicholsi (Bean), Proc. S Diego. Soc. Nat. Hist., 17: 187-208.
Williams, G.C. (1975), Sex and Evolution Princeton University Press, Princeton, pp.200.
Williams, K. (2007), Evaluation of macroscopic staging method for determining maturity of female Walleye Pollock, *Theragra chalcogramma* in Shelikof strait, Alaska, *Alaska Fish Res. Bull*., 12: 252-263.
Wimberger, P.H. (1992), Plasticity of fish body shape-the effects of diet, development, family and age in two species of Geophagus (Pisces: Cichlidae), *Bio. J. Linn.Soc*, 45:197-218.
Winemiller, K.O. and Rose, K.A. (1992), Patterns of life history diversification in North American fishes: implications for population regulation, *Can. J. Fish. Aquat. Sci*. 49: 2196-2218.
Witthames, P.R., Walker, G.M., Dinis, M.T., and Whiting, C.L., (1995), The geographical variation in the potential annual fecundity of dover sole, *Solea solea* from European shelf waters during 1991, Neth.J.Sea.Res., 34: 45-58.
Witthames, P.R. and Marshall, C.T. (2008), The importance of reproductive dynamics in fish stock assessment, In : Payne, A, Cotter, J. Potter, T (Eds.) Advances in Fisheries Science: 50 Years on from Beverton and Holt. Wiley-Blackwell, pp 306-324.
Weber, M. and De Beaufort, L.F. (1953), The Fishes of the Indo-Australian archipelago. Gobioidea. A.J Reprints Agency, New Delhi. Pp 423.
Wootton, R.J. (1973), The effects of size of food ration on egg production in the female three-spined stickle back, *Gasterosteus aculeatus*, *L.J Fish. Biol*, 5: 89-96.

Wootton, R.J. (1984), Introduction: tactics and strategies in fish reproduction. In fish reproduction: strategies and tactics. G.W. Potts and R.J. Wootton (eds). Academic Press, New York, pp 1-12.
Wootton, R.J. (1990), Ecology of teleost fishes, Chapman and Hall London, pp 404.
Wootton, R.J. (1998), Ecology of teleost fishes, 2nd edn, Fish and Fisheris Sereis no.24. Kluwer Academic Publishers, London.
Xiangyun, X. and Qiyoung, Z. (1990), Studies on the development in the female mudskipper *Boleophthalmus pectinirostris*, *J.*Oceanogor (Taiwan), 9, 217-221.

Yamshita, Y., Mochizuki, K. and Piamthipmanus, M. (1991), Gut contents Alaysis of fishes sampled from the Gulf of Thailand, *Bull.Japan.Soc.Fish.Oceangr*., Vol.55.No.3.
Yamaguchi, A., Todoroki, T. and Kume, G. (2006), Reproductive cycle, sexual maturity and diet-reproductive periodicity of white croaker, *Pennahia argentata* (Sciaenidae) In Ariake Sound, *Japan Fish. Res*, 82: 95-100.
Yokoo, T., Kanou, K., Motek, M., Kohno, H., Tongnunui, P. and Kurokura, H. (2008), Juvenile morphology of three *Pseudogobius* species (Gobiidae) occurring in a mangrove estuary,Southern Thailand Languna 15 pp 77-82.
Yokoo, T., Kanou, K., Moteki, M., Kohno, H., Tongnunui, P. and Kurokura, H. (2006), Juvenile morphology and occurrence patterns of three Butis species (Gobiidae: Eleotridae) in a mangrove estuary, Southern Thailand, *Ichthyological research,* Vol 53. 4: 330-336.
Yoshihara, K., Sugita, H., Aono, E. and Peguchi, Y. (1999), Length-weight Relationship of Goby collected at the Inner part of Tokyo Bay, Vol. 47 (4) 497-503.
*Yuen, H.S.H.(1955), Maturity and feeding of big eye tuna in the Pacific, *Spec. Sci*. *Rep. U.S. Fish Wild Serv Fish*., 150, 1-30.
Zaboukas, N., Milious, H., Megalofonou, P and Moraitou- Apostolpoulou, M (2006), Biochemical composition of the Atlantic bonito *Sarda sarda* from the Aegean Sea (eastern Mediterranean Sea) in different stages of sexual maturity, Journal of Fish Biology (2006) 69, 347–362

Zacharia,,P.O. and Abdurahiman, K.P. (2004), Methods of Stomach content analysis of fishes, Winter School on Towards Ecosystem Based Management of Marine Fisheries- Building Mass Balance Trophic and Simulation Models (Teaching Resource), CMFRI Mangalore, 148-158.
Zhang, Q.Y., Hong, W.S., Dai, Q.N., Zhang, J., Cai, Y.Y. and Huang, J.L. (1989), Studies on induced ovulation, embryonic development and larval rearing of the mudkipper *Boleophthalmus pectinirostris*, *J.Fish.China*, 14, 179-188.
Zingde, M.D. and Govindan, K. (2000), Health status of the coastal waters of Mumbai and regions around'in: Sharmw, V.K, (ed) environmental problems of coastal areas in India, Publisher, Bookwell, NewDelhi,pp 119-132.
Zutshi, B. and Murthy, P.S. (2001), Ultra structural changes in testis of gobiid fish *Glossogobius giuris* (Ham) induced by fenthion, *Indian. J. Exp. Biol*., 39 (2): 170-3.
*Not referred in original.

Websites

The Gazetteers Department Kolaba, http://www.maharashtra.gov.in/english/gazetteer /KOLABA/gen fish. html, 23/03/2010.
Maharashtra State Gazetteers Ratnagiri district 1962, Revised edition of Vol X of original Gazetteer of the Bombay Presidency relating to Ratnagiri and Sawantwadi,

http://www.maharashra.gov.in/english/gazetteer/ RATNAGIRI/ preface html, 23/03/2010.
Detailed Ecological Assessment of Fauna, including Limnology Studies at Keti Bunder 2007-2008 Report, Indus for All Programme, WWF-Pakistan http://foreverindus.org/ifap_sites_ketibunder.php
Shindikar, Coastal Areas and Problems and conservation http://mangrovecell.org/attachments/conservationof_mangroves_maharashtra 15/10/2012.
http://www.mumbai.org.uk/geographical.locat. 20/7/2013
http:/en.wikipedia.org/wiki/thane. 20/7/2013
http://www.fishbase.org 20/7/2013
www.fishbase.org.20/7/2014
http://www.discoverlife.org 20/7/2013
http://en.wikipedia.org 16/10/2012
http://www.fishbase.us 15/7/2012

OUTLINE OF THE SYNOPSIS SUBMITTED TO THE UNIVERSITY OF MUMBAI FOR THE DOCTOR OF PHILOSOPHY (SCIENCE) DEGREE IN ZOOLOGY

Title of proposal: Studies on some aspects of biology of goby fish, *Parachaeturichthys ocellatus* (Day 1873) from Mumbai coast.

Name of the candidate: Mrs Bindu Ajaykumar Panicker

Basic Qualification of candidate: M Sc. (Marine Zoology), B.Ed.

Name of the Research Supervisor: Dr (Mrs) V.I.Katchi
(M.Sc.,M.Phil.,Ph.D.)

Designation of Research Supervisor: HOD, Dept of Zoology & Principal,
Bhavan's College,
Andheri (W).

Place of Research Work: Zoology Department,
Bhavan's College,
Andheri (W).

Date of submission of Synopsis: 28/04/2014

No. and Date of Registration: 56 - 08/07/2010

Signature of the candidate:

Signature of the Research:
Supervisor

Synopsis

Introduction

The Gobiidae is the largest family of marine fishes, comprising more than 220 genera and 1500 species in the Western Central Pacific (Murdy and Hoese 2004) and 1875 species around the world (Jonna 2004). Gobies inhabit shallow tropical and subtropical waters and have invaded all benthic habitats from freshwater to the shoreline up to depths exceeding 500m (Murdy and Hoese loc cit). Gobiids are one of the most abundant groups of species in marsh edge habitats and presumably play important role in the ecology of coastal environment (Baltz *et al*. 1998, Hendon *et al*. 2000). Some of them spend their lives in freshwater, others migrate back and forth between freshwater and brackish water environments or between marine and brackish waters. Some species of gobies live in close association with other animals like sea urchins and shrimps (Allaby 1999) and some with soft corals and other fishes. 'Gobi' or 'Goby' is a Latin word which means a fish of small value, gudgeon and from greek word 'Kobios' (http://www.fishbase.org).

Gobies, although small, are of considerable importance ecologically and commercially. They can be very abundant at certain localities, where they form an important component of the food web (de Sylva 1975). Petersen (1917) has stated that gobies are among the most common fishes of Denmark and play an extremely important role in the nourishment of larger fishes. Several species of gobies are fished commercially for food, especially in the Far East. Adult gobies are considered delicacies in Japan (Miyazaki 1940; Okada 1955). The majority of goby fishes being

small, constitute a small fishery in Bangladesh but *Glossogobius giuris* which attains a length of about a foot forms a fishery of some magnitude in southern part of Bangladesh (Islam 2004). *Oxyeleotris marmoratus* commonly called 'Marble gobies' are highly prized nutritionally by Asian consumers as they are lean, boneless and their firm white flesh has no off-flavour taste (Sompong 1980). These gobies are considered a species of high economic value and fetch the highest price of any edible fresh water fish in Thailand (Bundit 2007). Gobies are popular aquarium fishes often due to their bright colours, interesting behaviour and general hardiness, with many species appearing in the commercial aquarium trade. Most commonly sold species are the neon gobies, *Gobiosoma oceanops* occurring in Florida coral reefs.

Many species of gobiids occurring in the coastal waters of India and Burma have been identified by Day (1889). Twenty one species of gobiidae are reported from different creeks of Mumbai by Mutsaddi and Bal (1973). The biology of few species of mudskippers along the Mumbai coast was studied by few authors like *Boleophthalmus dussumeiri* (Mutsaddi 1964), *Boleophthalmus dentatus* (Shettu 1993), *Boleophtalmus boddaerti* (Gore 2007). The gobiid fish under present study, *Parachaeturichthys ocellatus* is native to Mumbai coast (Day1858). It occurs in the muddy creeks of Colaba, Worli, Mahim, Danda, Madh, Mahul, and Thane (Mutsaddi and Bal 1973). It forms a part of fishery along Mumbai and Ratnagiri coasts (The Gazetteers Dept of Ratnagiri 1962 and Kolaba 1964). It was identified by Day (1873). It inhabits demersal marine environment in deep waters (www.fishbase.org). A brief description of the species is available in The Fishes of India (Day 1878), Gobiidae (Larson and Murdy 2001) and Catalogue of Fishes (Eschmeyer 2003). So far no study on the biology of this species has been reported in the literature survey carried out by the candidate.

The fact that not much data about the biology of the fish or its fishery was available has provided an impetus to select *Parachaeturichthys ocellatus* for the present study which reflects on various aspects of fish biology like its systematic position, morphometric and meristic characters, length weight relationship, ponderal index, food and feeding habits and reproductive biology.

Fish is a rich source of protein with composition of amino acid which is well suited to human dietary requirements, comparing favourably with egg, milk and meat in the nutritional value of its protein (Waterman 1976). Literature survey revealed several studies on proximal composition of many commercial fishes, little attention is paid though to the study of gobies in general and *Parachaeturichthys ocellatus* in particular.

Therefore the present study has been undertaken to determine proximal composition, nutritional value and energy value of *P.ocellatus* and compare the same with some of the commonly available fishes from selected creeks of Mumbai.

Macromolecular indices like RNA concentration, RNA: DNA ratios, RNA: Protein ratios and Protein: DNA ratios are frequently measured as indicators of protein synthesis potential and growth in marine fishes and invertebrates (Bulow 1970; Carter *et al* 1998; Buckely *et al* 1999). These indices are particularly useful for evaluating environmental conditions as they reflect on differences in growth rates over a period of several days (Rooker and Holt 1996; Buckley *et al* 1999; Vrede *et al* 2002). The present study aims at analyzing the nutritional condition and growth of the fish in terms of its macromolecular contents and their ratios.

Rationale

The present study of biology of *Parachaeturichthys ocellatus* from different creeks of Mumbai will help in planning conservation strategy for maintenance of fish population thereby to facilitate judicious exploitation and management of the fishery.

Some of the aspects of biology which the present study elucidates are:

1. Taxonomy and Systematics, 2. Morphometry, 3. Meristic characters,
4. Length weight relationship, 5. Relative condition factor, 6. Food and feeding habits,
7. Reproductive biology, 8. Proximal composition and 9. Condition indices.

1] Taxonomy and Systematics will give the history of gobioid classification as per the key up to order, family, genera, species and systematic position of *P.ocellatus* will help provide a condensed expression of the phylogeny of the species.

2] The morphometry of *P.ocellatus* will be useful to

a) identify the fish accurately and completely

b) determine morphological differences between sexes

c) determine differences if any between same species at different localities

d) establish relationship between various morphometric characters

3] The meristic characters will help to find

a) variations among the fish due to geographical locations

b) whether the variations observed are temporary and liable to disappear with change in habitat

c) compare the meristic count with those observed by various authors.

4] The length weight relationship of the fish *P.ocellatus* will be useful to

a) derive a mathematical relationship between length and weight so as to infer one from the other,

b) explore any deviation from the established length weight relationship as a measure of effect of ecological factors like disease, food scarcity as an indicator of stress due to exposure to pollutants.

5] The coefficient of condition or Ponderal index obtained by the ratio of average weight and average length is useful in explaining

a) differences among individuals of the same length,

b) differences arising from seasonal changes in relation to age and sex,

c) differences between condition of individuals of same species in different locations.

6] The studies on food and feeding habits will be useful in

a) prediction of availability of fishes based on the availability of the food,

b) prediction of migration of fishes based on the knowledge of decrease in preferred food,

c) designing of suitable feeding strategy for maximum production.

7] The reproductive biology of the fish *P.ocellatus* is useful to determine/understand

a) sexual dimorphism so as to distinguish between male and female fishes in the population,

b) sex ratio to evaluate the reproductive potentialities,

c) spawning periodicity and size at maturity which can provide the base line data for increasing the yield of fishery,

d) gonado somatic index which gives a detailed idea regarding fish reproduction, reproductive status and ascertaining spawning period in fishes,

e) fecundity and fecundity size relationship in recruitment related studies and population growth rate for fisheries management,

f) morphology and histology of gonads, pattern of oogenesis, pattern of spawning, stages of development , length of gonad maturation and the reproductive potential of fishes.

8] The study of proximal composition of the *P.ocellatus* shall provide information about

a) variations in different months, length groups and sexes if any in moisture, protein, fat, carbohydrate and ash content of the fish in terms of energy values which will determine the nutritional status of the fish,

b) comparison of proximal composition with some other fishes from the creeks in terms of their nutritive and edible value.

9] The study on monthly condition indices in terms of contents and ratio of RNA, DNA, RNA/DNA, RNA/protein and RNA/lipid monthly will serve as an indicator of protein synthesis potential for growth and nutritional condition of the fish.

Aims and Objectives

The aims and objectives of the present study are as follows

1) To study the taxonomy and systematic position of *P.ocellatus* with its historical account and salient features of the order, family, genus and species.

2) To study 19 different morphometric characters of the fish of different sizes and their relationship with one another.

3) To study meristic characters like the number of fin rays and spines in dorsal, anal, pectoral, pelvic, caudal fin, longitudinal scales, transverse scales, gill rakers and vertebrae.

4) To determine length weight relationship separately for males, females and juveniles.

5) To assess the relative condition factor 'k' value or ponderal index which is the ratio of average weight and average length, separately, for each sex and to calculate the fluctuations in the condition factor in different months.

6) To study food and feeding habits in *P.ocellatus* by analyzing the gut content of fish to ascertain the food composition, to determine degree of preference and feeding status of fish in different months.

7) To study the reproductive biology of *P.ocellatus* with respect to different parameters like sexual dimorphism, sex ratio, spawning periodicity, gonado somatic index, fecundity; morphology and histology of gonads.

8) To elucidate nutritional status and edible value of *P.ocellatus* by estimating its proximal composition and its analysis with reference to length, sex and energy value, and to compare these parameters with those of few other fishes from the selected creeks.

9) To determine nucleic acid derived condition indices like RNA, DNA, RNA/DNA, RNA/protein and RNA/lipid in male, female and juvenile seasonally to establish their relation to growth and nutritional conditions.

Materials and Methods

1) Location and periodicity of collection of sample: The fishes were collected every fortnight at regular intervals from four different coastal locations in Mumbai: viz Thane creek, Vasai creek, Malad creek and Mahul creek over a period of 16 months from June 2010 to September 2011.

2) Taxonomy and Systematics: The fishes were identified based on the key given by Day (1878) and Larson and Murdy (2001) and were classified up to order, family, genera and species

3) Study of morphometric characters: Morphometric measurements were recorded carefully in millimetres using a pair of fine dividers on a measuring board. In all nineteen morphometric characters were noted viz total length, standard length, head length, snout length, inter orbit length, eye diameter, first pre dorsal length, first dorsal length, second pre dorsal length, second dorsal length, pre pectoral length, pectoral length, pre pelvic length, pelvic length, pre anal length, anal length, body depth, caudal depth and caudal length. The standard methods described and adopted by Snedecor (1946), Dwivedi and Menezes (1974), Acharya (1980) and Rao (1985) were used. Statistical parameters like mean, standard deviation, standard error, correlation coefficient and regression coefficient were calculated.

4) Study of Meristic characters: In all ten meristic characters were studied namely: number of first dorsal fin rays, second dorsal fin rays, pectoral rays, pelvic rays, anal rays, caudal rays, number of longitudinal scales, number of transverse scales, number of vertebrae and number of gill rakers. The study was based on the standard procedure described by Apparao (1966) and Dwivedi and Menzes (1974). Meristic characters were subjected to standard statistical analysis in terms of range, mean, mode, standard deviation, standard error, variance and coefficient of variation.

5) Length weight relationship: The length weight relationship was determined separately for the males, females and juveniles by measuring the total length from the tip of the snout to the tip of the caudal fin and recording the wet weight of the fish in grams. The formula advocated by Le Cren (1951) was used for deriving the relationship.

6) Relative condition factor: The relative condition factor Kn was calculated using the formula of Le Cren (loc cit).

7) Food and feeding habits: The fish was cut open through the vent and sex, stage of maturity and degree of fullness of stomach were noted. After removal of the alimentary canal its length and weight were recorded. The alimentary canal was then

preserved in 5% formaldehyde. The gut contents were analysed according to the methods of Hynes (1950), Pillay (1952) and Natrajan and Jhingran (1961). Relative gut length, feeding index and Gastro somatic index were calculated.

8) Reproductive biology: A number of different aspects to understand reproductive biology were studied as follows:

a. Sexual dimorphism and sex ratio: The fishes were carefully examined to record external characters to understand sexual dimorphism. Sexes were determined by dissecting the fish and observing the gonads. The nature, position, size and weight of gonads were recorded.

b. Spawning periodicity: Maturation and spawning habits were studied according to the methods of Clark (1934), Hickling and Rutenberger (1936) and Karekar and Bal (1960). Ova from preserved ovaries were used for measurement of diameter of ova using ocular micrometer.

c. Gonado somatic index (GSI): The method proposed by June (1953) and Yuen (1955) for studying GSI was followed. The formula used was as follows:

$$GSI = \frac{\text{Gonad weight} \times 100}{\text{Total body weight}}$$

d. Fecundity: The two lobes of ovary were carefully removed and preserved in 5% formaldehyde. Numbers of eggs were counted separately from anterior, middle and posterior portion of the ovaries for each fish. The fecundity was derived as per the following formula:

$$\text{Fecundity} = \frac{\text{Total weight of the ovary}}{\text{Weight of the sample}} \times \text{number of mature eggs in the sample}$$

Statistical analysis was carried out in terms of regression co-efficient, point of intercept and co-efficient of correlations.

e. Morphology and Histology of gonads: Developmental stages of gonads were determined from gross visual examination of preserved gonads. The macroscopic and microscopic observations were used to determine phases of gonad maturation according to the standard laid down by ICES (Lovern and Wood 1937) and Jayashankar (1991b). Histological slides were prepared by the procedure suggested by Humason (1967) and Morrison (1990).

9. Proximal composition: Fresh fish were used for estimating proximal composition of muscle. Protein was estimated as per the method of Lowry *et al*. (1951), carbohydrate as per the method of Hedge and Hofreiter (1962) and Lipids as per the

method of Folch *et al* (1957). The caloric content and energy values were derived. The proximal composition of *P.ocellatus* was compared with that of some fishes of the creek like *Mugil cephalus, Mystus spp, Tilapia mossambica, Boleophthalmus dussumieri* and *Arius arius*.

10. Biochemical indices: Variation in DNA and RNA content was estimated seperately in males, females and juveniles. RNA was estimated by Orcinol method (Schneider 1957). DNA was extracted according to the procedure of Webb and Levy (1955) and estimation was carried out according to the method of Ashwell (1957). Proteins and lipids were estimated by Lowry *et al*. (1951) and Folch *et al* (1957) respectively. The ratio of RNA/DNA, RNA/protein and RNA/lipid was calculated.

Results

1] Chapter 1: Introduction

This chapter presents a brief account of distribution of gobiid fishes around the world in general and along Mumbai coast in particular, where the present study of the fish *Parachaeturichthys ocellatus* has been undertaken. This is followed by a report on the gobiid fishery and its relative position in fisheries of the world and in Mumbai. The survey of literature is reviewed followed by description of geographical and habitat studies for *P.ocellatus* from the vast coastline of Mumbai, particularly the areas selected for the present study. The chapter concludes with a declaration of objectives of the present study on 'Studies on some aspects of biology of goby fish, *Parachaeturichthys ocellatus* (Day 1873) from Mumbai coast'.

2] Chapter 2: Taxonomy and Systematics

This chapter describes history of gobioid classification with details upto family, genera and species of gobiidae by Day (1878), key to subfamilies and genera of gobiidae proposed by Larson and Murdy (2001), followed by systematic position, local name, unambiguous synonym and valid name of *P.ocellatus*. The chapter concludes with a brief description of characters of *P.ocellatus*.

3] Chapter 3: Morphometry

In all nineteen morphometric characters were observed and recorded in *P.ocellatus*. Statistical parameters like their range, mean, standard deviation and standard error for each were calculated. Regression analysis was carried out between total length

and other variables. The correlation matrix ‘r’ between various measurements in male, female and juvenile was plotted.

A high degree of positive correlation was observed between various morphometric characters within a range of 0.7-1 in male, female and juveniles, the highest being 0.9943 in male and 0.9511 in female between total length and standard length. A linear relationship between total length and other body parameters in male, female and juvenile growth was obtained in the fish. Different growth patterns in male female and juvenile fish could be observed. In male isometry was observed only in standard length, all other measurements showed negative allometry. In female fish isometry was observed in second dorsal length, pre pectoral length and pre anal length, standard length showed positive allometry while all other measurements showed negative allometry. In juvenile fish positive allometry was observed in standard length while all other characters showed negative allometry.

4] Chapter 4: Meristic characters

This chapter includes data on meristic characters in terms of minimum and maximum value, mean, median, mode, standard deviation, standard error, variance, and coefficient of variation in male, female and juvenile *P.ocellatus*. The highest coefficient of variation was observed in caudal fin rays of male, pelvic fin rays of female and juvenile. The meristic counts were compared with Day (1858) and Mutsaddi and Bal (1973). The comparison reveals variations in second dorsal fin rays, pectoral fin rays, pelvic fin rays, anal fin rays, vertebrae, longitudinal scales and transverse scales. The fin formula obtained in P.ocellatus was as follows:

B.v, D1 6, D2 9-11, P 15-20, V 8-12, A 8-11, C 17-29, Ll 24-36, Ltr 7-11.

5] Chapter 5: Length-weight relationship

The length weight relationship of males, females and juveniles showed a regression value of 2.9159, 2.7226 and 2.7745 respectively indicating a negative allometry in growth rate. It also showed high correlation value of 0.9895 , 0.9699 and 0.8986 in male, female and juvenile respectively indicating a perfect relationship between length and weight in this species.

6] Chapter 6: Relative condition factor

Relative condition values were calculated for a period of 16 months from June 2010 to September 2011. The mean relative condition factor was 1.0126, 1.0375 and1.0013 for male, female and juvenile respectively indicating a good general condition of the fish. The higher condition value was observed in November 2010 in male while in

females it was in June 2010. Size wise analysis showed higher relative condition factor of 1.0125 in the group with a range of total length of 106-115mm in males and 1.0204 in the range of total length of 66-75mm in females.

Chapter 7 Food and feeding habits

This chapter deals with the following aspects of study of food and feeding in *P.ocellatus*

1) Morphological features: Body shape, size, position of mouth, teeth, and fins of fish are studied in relation to food and feeding habits.

2) Relative gut length showed an average of 0.68 in male, 0.70 in female, 0.79 in juvenile indicating a carnivorous feeding behaviour.

3) Monthly variation in food composition: A detailed monthly account of percentage of different food items in the gut of male, female and juveniles is recorded. The gut contents revealed that the fish fed mainly on Arthropods (mostly crustaceans), molluscs and pisces, while the amount of phytoplankton varied from month to month, while sand and mud probably ingested with food formed an important constituent of the gut content.

4) Length wise variation in food composition: A detailed account of food consumed by fishes of different length groups in male and female is described. The food composition showed some significant change in feeding habits of fish with the increase in the length.

5) Feeding intensity: Is recorded as the percentage variation in terms of feeding intensity in different months, in different length groups in male and female fish. Increased feeding intensity was observed in males and females respectively in pre spawning and post spawning months.

6) Gastro somatic index: GSI value was higher in males and females in the post spawning month.

Chapter 8 Reproductive biology

This chapter describes various aspects of reproductive studied like sexual dimorphism, sex ratio, spawning periodicity, gonadosomatic index, fecundity, morphology and histology of gonads.

Sexual dimorphism: The secondary sexual characters observed in fish were more prominent during the spawning season. The ventral region around the pelvic and anal fins was reddish in male as compared to female. The second dorsal fin ray of male was longer than that of the female of the same size. The pelvic fin of male were

showed bifurcation at the anterior end while in female it was rounded. The urinogenital papilla in male was straight, long, thin and pointed while in female was short, round fleshy and prominent.

Sex ratio: The overall sex ratio was 1M: 0.71 F indicating the dominance of males. The monthly sex ratio showed the female dominance in September 2010, April 2011, May 2011 and June 2011.

Spawning periodicity: The percentage occurrence of males and females in various stages of maturity was recorded. Maximum percentage of mature males was 56%, females was 77%. The size at which 50% of the males attained maturity was 91mm and the while value for females was 94mm.

Gonadosomatic index: The monthly GSI value varied in male between 0.18-0.91 and in case of the female fish between 1.58-12.67.

Fecundity: The fecundity values observed in the females with total length between 94-153mm was found to be in the range of 21,635-179,334 with a mean value of 48,973. The correlation coefficient between fecundity and total length was 0.9628, fecundity and total weight was 0.9756, fecundity and ovary length was 0.9705 and fecundity and ovary weight was 0.9633 respectively.

Morphology and Histology of gonads: Five different maturity stages were observed in the morphological and histological studies of the testis and ovary of male and female fish and are categorised as follows: Stage I Immature, Stage II Developing, Stage III Maturing, Stage IV Ripe, and Stage V Spent.

Chapter 9 Proximal composition

Monthly variation in proximal composition of muscles of *P.ocellatus* in male, female and juvenile fish is recorded in this chapter. The average proximal composition is expressed in terms of g% of proteins, lipids and carbohydrates and their energy values expressed as cal/g as in the following table:

Type of Fish	**Proteins**		**Lipids**		**Carbohydrates**		**Total energy value cal/g**
	Content g%	Energy value cal/g	Content g%	Energy value cal/g	Content g%	Energy value cal/g	
Male	14.86	839.44	1.45	135.88	0.09	3.73	979.07
Female	14.09	796.08	2.08	195.28	0.1	4.07	995.44

Juvenile	14.45	765.43	2.08	183.59	0.07	2.54	951.57

The values of proximal composition of *P.ocellatus* were compared with those of few fishes like *Mugil cephalus, Mystus spp, Tilapia mossambica, Boleophthalmus dussumieri* and *Arius arius*. *P.ocellatus* seems to be a low fat fish as compared to other fishes while protein content in *P.ocellatus* seems to be higher than that of fishes like *Tilapia* and *Boleophthalmus.*

Chapter 10 Condition indices

This chapter records month wise and lengthwise variation in RNA and DNA content and the ratios of RNA/DNA, RNA/protein, RNA/lipids in male female and juvenile *P ocellatus*. The value of RNA/DNA ranged between 2.08-5.13 in males, 2.92-5.07 in females and 3.86-5.17 in juveniles. The values of RNA/protein ranged between 0.0010-0.0026 in males, 0.0011-0.0022 in females and 0.0015-0.0021 in juveniles. The value of RNA/lipid ranged between 0.0078-0.0277 in males, 0.0056-0.0241 in females and 0.0081-0.0185 in juveniles.

In conclusion it can be stated that the present study will provide the baseline data on the biology of *P.ocellatus* which will help in enhancing the productivity and judicious management of fishery of the fish in the creeks of Mumbai.

References:

Acharya, P. (1980) 'Morphology and biology of *Nemipterus japonicas (Bloch)* of Bombay coast', M.Sc Thesis, Univ. Bombay.

Allaby, M. (1999) 'Gobiidae' A Dictionary of Zoology, Enclyopedia.com.1 Nov. 2009, <http://www.encylopedia.com/>.

Apparao,T.(1966) On some aspects of the biology of *Lactarius lactarium* (Schneider), *Indian .J.Fish,* 13: 334-349.

Ashwell, G. (1957) 'Colorimeteric analysis of sugars: cysteine reaction of DNA' In Colowick, S.P and N.O Kalpan eds: methods in enzymology Vol.3, Academic Press, New York, pp.1154.

Baltz, D.M.C, Rakacinski and Fleeger, J.W. (1998) Microhabitat use by marsh-edge fishes in a Louisiana estuary, *Environmental Biology of Fishes,* 36:109-126.

Buckely, L.J Cladorone, E, Ong, T.L. (1999) RNA-DNA ratio and other nucleic acid based indicators for growth and condition of marine fishes, *Hydrobiologia*., 401: 265-277.

Bulow, F.J. (1970) RNA-DNA ratio as indicators of recent growth rates of a fish, *J.Fish. Res. Board* .Can., 27: 2343-2349.

Bundit, J. (2007) 'The Nutrition and feeding of a native Thai species, the marble goby (*Oxyeleotris marmoratus*) involving on farm and experimental studies', Ph.D Thesis, University of Stirling, Scotland.

Carter, C.G Seeto, G.S Smart, A Clarke, S Van Barneveld, R.J. (1998) Correlates of growth in farmed juvenile Southern blue fin tuna *Thunnus maccoyi* (Castelnan), *Aquaculture,* 161:107-119.

Clark, F.N. (1934) Maturity of California sardine (*Sardine caerulea*) determined by ova diameter measurements, *Calif.Div.Fish*.*Game Fish Bull*. 42, 1-49.

Day, F. (1858) 'The Fishes of India', Willaim Dawson & Sons Ltd, 495pp.

Day, F. (1873) 'On new and imperfectly known fishes of India', Proceedings of the Zoological Society of London (pt I): 236-240.

Day, F. (1878) 'The fishes on India; being a natural history of the fishes known to inhabit the seas and freshwaters of India, Burma and Ceylon', Vols I&II, William Dawson and Sons, London.

Day,F. (1889)The fauna of British India including Ceylon and Burma Vols I&II Taylor and Francis, London.

de Sylva, D.P. (1975) 'Nektonic food webs in estuaries', E.cronin, ed., Estuarine research,vol.1 Academic Press, New York, 587:420-447.

Dwivedi,S.N and Menezes, M.R. (1974) A note on the morphometry and ecology of *Brachirus crientalis* ((Bloch and Schneider) in the estuaries of Goa, *Geobios* 1, 80-83.

Eschmeyer, W.N (ed). (2003) 'Catalog of fishes' updated database version of March 2003, Catalog database as made available to Fish Base.

Folch, J Less, M and Slone, S. (1957) A simple method for the isolation and purification of total lipids from animal tissues, *J.Biol. Chem*., 266: 497-509.

Gore, B.M. (2007) 'Biometry of mudskipper *Boleophthalmus boddarti*', PhD Thesis, University of Mumbai.

Hedge, J.E and Hofreiter, B.T. (1962) 'In: Carbohydrate Chemistry' 17 (eds histtler R L and Miller J.N) Academic Press, New York.

Hendon,J.R , Peterson,M.S and Comyns ,B.H. (2000) Spatiotemporal distribution of larval *Gobiosoma bosc* in waters adjacent to natural and altered marsh edge habitats of Mississippi coastal waters, *Bulletin of Marine Science,* 66: 143-156.

Hickling, C.F and Rutenberg, E. (1936) The ovary as an indicator of spawning period of fishes, *J.Mar.Biol. Assoc*., U.K, 21: 311-317.

Humason, G.L. (1967) 'Animal Tissue Techniques', W.H Freeman and Company, San Fransisco and London.

Hynes, H.B.N. (1950) 'The food of the freshwater sticklebacks (*Gastrosteus aculeatus* and *Pygosteus pungitius*) with a review of methods used in studies of the food of fishes'., *J. Anim. Ecol*, 19: 36-58.

Islam, M.N. (2004) Ecobiology of freshwater gobi, *Glossogobius giuris* of the river Padma in relation to its fishery, *A review Journal of Biological Sciences 4*(6); 780-793 ISSN 1727-30.

Jayasankar, P. (1991b) Sillginid fishes of Palk Bay and Gulf of Mannar with an account on the maturation and spawning of Indian Sandwhiting, *Sillago sihama* (Forskal), *Indian. J. Fish*, 38(1): 13-25.

Jonna, R. (2004) 'Gobiidae'(Online), Animal Diversity Web, 15 Nov 2009, < http://animaldiversity.ummz.umich.edu/site/accounts/information/Gobiidae.html.

June, F.C. (1953) Spawning of yellow fin tuna in Hawaiian waters, U.S Fish and Wild Life Service Fish Bull., 54, 47-64.

Karekar, P.S and Bal D.V. (1960) A study on maturity and spawning of the Horse Mackerel *Carnax kalla* (Cuv and Val). *Indian.J.Fish*., 147-164.

Larson, H.K and E.O Murdy (2001) 'Gobiidae' Gobies In K.E Carpenter and V.Niem (eds) FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific, Vol.6 Bonyfishes part 4, p.3578-3603.

Le Cren, E.D. (1951) Length-weight relationship and seasonal cycle in gonad weight and condition in the Perch *Percha fluviatilis*, *J. Anim. Ecol*., 20: 201-239.

Lovern, J.A and Wood, T.H. (1937) Variation in the Chemical Composition of Herring, *J. Mar. Biol. Assoc*. U.K., 22: 281- 293.

Lowry, O. H Roserrough, N. J Farr, A.L and Randall, R.J. (1951) Protein Measurements with the Folin Phenol Reagent*, J. Biol. Chem*., 193, 265-276.

Miyazaki, I. (1940) Studies on the Japanese common goby, *Acanthogobius flavimanus* (Temminck et Schlegel). *Bull.Jap.Sci.Fish*., 9:159-180.

Morrison, C.M. (1990) 'Histology of the Atlantic Cod, *Gardus morhua*': An Atlas Part Three, Reproductive Tract, Canadian Special Publication of Fisheries and Aquatic Sciences, Washington, pp: 110.

Murdy, E.O and Hoese, D.F. (2004) 'Bony fishes Gobioidei': 1778-1782

Mutsaddi, K.B. (1964)' A study on a gobioid, *Boleophthalmus dussumieri*(cuv. And Val.)', Ph.D Thesis, University of Bombay.

Mutsaddi ,K.B and Bal D.V. (1973) Gobies from the intertidal region of Bombay, *Indian J.Fish*, 20, pp475-486.

Nataranjan, A.V and Jhingran, V.G.(1961) Index of preponderance: a method of grading the food elements in the stomach analysis of fishes, *Indian J.Fish*., 8:54-59.

Okada, Y. (1955) 'Fishes of Japan', Maruzen Co. Ltd., Tokyo.434p.

Petersen, C.G.J. (1917) On the development of our common gobies (Gobius) from the egg to the adult stages, etc, *Rep. Dan. Biol*., Stn. 24: 3-16.

Pillay, T.V.R (1952) 'A critique of the methods of study of food of fishes', *J.Zool.Soc*. India, 4: 185-200.

Rao, M. (1985) 'Ecology and biology of the flat fish *Cynoglossus macrolepidotus* (Bleeker, 1851) off Bombay coast', Ph.D Thesis, Univ of Bombay.

Rooker, J.R and Holt, G.J. (1996) Application of RNA: DNA ratios to evaluate the condition and growth of larval and juvenile red drum (*Sciaenops ocellatus*), *Mar*. *Freshwater Res*. 47: 283-290.

Schneider, W.C. (1957) Determination of nucleic acids in tissues by pentose analysis. In Colowick, S.P and N.O Kalpan eds: Methods in Enzymology Vol.3 Academic Press, New York, pp1154.

Shettu, N. (1993) 'Studies on certain aspects of biology of the gobid fish *Boleophthalmus dentatus*(Cuv.& Val.)', Ph.D Thesis, CIFE, pp25.

Sompong, H. (1980) Life history of sand goby *Oxyeleotris marmoratus* Bleeker (in Thai), Technical Paper, Royal Thai Department of Fisheries, No.13, pp 42.

Snedecor, G.W. (1946) 'Statistical methods: Applied to experiments in agriculture and biology' (4th ed) Ames, I.A, U.S: Iowa State University Press, pp 1-476.

Vrede, T Persson, J Aronsen, G. (2002) The influence of food quality (P:C ratio) on RNA: DNA ratio and somatic growth rate of Daphnia Limnol. *Oceanogr.,* 47: 487-494.

Waterman (1976) 'The Production of dried fish, FAO Fish'. Tech. Paper (160): 115-120.

Webb, J.M and Levy, H.B. (1955) A sensitive method for the determination of deox-yribonucleic acid in tissues and microorganisms, *J. Biol. Chem*, 213: 107-117.

Yuen, H.S.H. (1955) Maturity and Fecundity of big eye Tuna in the Pacific, *Spec.Sci Rep*, U.S., *Fish Wild Serv.Fish* ,150,1-30.

Others

The Gazetteers Department Kolaba, (1964) http://www.maharashtra.gov.in/ english/gazetteer/ KOLABA/gen fish. html, 23/03/2010.

Maharashtra State Gazetteers Ratnagiri district (1962) Revised edition of Vol X of original Gazetteer of the Bombay Presidency relating to Ratnagiri and Sawantwadi, http://www.maharashra.gov.in/english/gazetteer/RATNAGIRI/preface html, 23/03/2010.