MORPHOMETRIC MEASUREMENTS OF SELECTED FISH SPECIES IN CURTORIM, ZUARI RIVER.

A Dissertation for

Course code and Course Title: MSC 617 Discipline Specific Dissertation

Credits: 16

Submitted in partial fulfilment of Master of Science in Marine Sciences

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DECLARATION BY STUDENT

I hereby declare that the data presented in this dissertation report entitled, "Morphometric measurements of selected fish Species in Curtorim, Zuari River" is based on the results of investigations carried out by me in the Marine Sciences at the School of Earth, Ocean and Atmospheric Sciences, Goa University under the supervision of Dr. C. U. Rivonker and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will not be responsible for the correctness of observations/experimental or other findings given in the dissertation.

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COMPLETION CERTIFICATE

This is to certify that the dissertation report "Morphometric measurements of selected fish Species in Curtorim, Zuari River" is a bonafide work carried out by Ms. P. Persis under my supervision/mentorship in partial fulfilment of the requirements for the award of the degree of Master of Science in the discipline of Marine Sciences at the School of Earth, Ocean and Atmospheric Sciences, Goa University.

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CHAPTER NUMBER	CONTENTS	PAGE NUMBER
CHAPTER 1	**INTRODUCTION** 1.1 Background 1.2 Objectives 1.3 Hypothesis 1.4 Scope	2 – 4
CHAPTER 2	**LITERATURE REVIEW**	6-11
CHAPTER 3	**METHODOLOGY** 3.1.1 Study Area 3.1.2 Temperature and pH 3.1.3 Collection of Fish 3.1.4 Collection of water samples 3.1.5 Laboratory Analysis 3.2.1 Equation to derive Length-Weight Relationships 3.2.2 Condition Factor	13-22
CHAPTER 4	**ANALYSIS AND CONCLUSIONS**	24-47
	CONCLUSIONS	47
	REFERENCES	48-52

PREFACE

This thesis, titled "Morphometric measurements and of Selected Fish Species In Curtorim, Zuari River," looks at the morphometric features of the chosen fish species in the Zuari River in the Curtorim region.

Available information of estuarine local fishes and their morphometrics is very scanty. These studies would enable to understand their growth and distribution pattern is such habitats. The observations made in the present study would provide baseline information on species distribution and their occurrence in such habitats. The growth parameter also provides information on their biological aspects such as maturity and reproduction, thus enabling harvesting and conservation of these species of local importance. The present study would also help in conserving the indigenous fish fauna from these habitats.

ACKNOWLEDGEMENT

Firstly, I would like to extend my sincere gratitude towards my guide, Prof. C. U. Rivonker, Marine Sciences, School of Earth, Ocean and Atmospheric Sciences, for his valuable guidance and seamless effort during the completion of this course of the dissertation. He has been a great source of encouragement towards my writing and timely efforts in my study.

Also, I am grateful to Sr. Prof. Sanjeev C. Ghadi, Dean, School of Earth, Ocean and Atmospheric Sciences, and all the faculties of the Marine Sciences especially towards the Marine Sciences store staff to Ms Sitam, Mrs Mahima, Mrs. Utkarsha and Mrs. Gayatri who were readily willing to help me in providing equipment's for the progress of my field as well as laboratory work whenever approached.

I extend my sincere thanks to the local fishermen Mr Peter and Mr Selvester D' Silva who became partakers in helping me with the collection of samples during the fieldwork. I am grateful to all my friends and classmates Bhagyashree and Varsha for supporting me during the dissertation. I would also like to thank my seniors for encouraging me.

Lastly, I would like to express my heartful gratitude to my parents and my brother Venkatesh for encouraging me and supporting me in all ways for the completion of this course.

Persispitta

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TABLE NUMBER	LIST OF TABLES	PAGE NUMBER
4.1.a	Fish species recorded at study area during post-monsoon	25
4.1.b	Length-weight Relationships of fishes from the study area.	26
4.1.c	Fish species recorded at the study area during Pre-monsoon	27
4.1. d	Length-weight Relationships of fishes from the study area.	28
4.1. e	Variations in pH at sampling sites.	31
4.1. f	Variations in temperature at sampling sites	33
4.1. g	Variations in Salinity at sampling sites	36
4.1.h	Variations in BOD sampling sites	38

FIGURE NUMBER	LIST OF FIGURES	PAGE NUMBER
1	Map showing study sites at Curtorim, Zuari River.	14
2	Fish species found in among the seasonal study in Curtorim	29
3	Seasonal Variation in pH at the sampling sites.	32
4	Seasonal Variation in temperatures at the sampling sites.	34
5	Seasonal Variations in the salinity at the sampling sites.	37
6	Seasonal Variations in Biological Oxygen Demand at the sampling sites	39
7	Length-Weight relationships of *Genidens barbus*	41
8	Length-Weight relationships of *Solea solea*	42
9a	Length-weight relationships of *Tetraodon nigroviridis*	43
9b	Length-weight relationships of *Escualosa thoracata*	44
9c	Length-weight relationships of *Nuchequula nuchalis*	45

	ABBREVATIONS USED
LWRs	Length-weight relationships
IMCs	Indian Major Carps
K	Condition Factor
EEZ	Exclusive Economic Zone
BOD	Biological Oxygen Demand
R^2	Coefficient of Determination

PLATE NUMBER	LIST OF PLATES	PAGE NUMBER
1	Common Mangrove Species found on the species.	15
2A-D	Fish Species	16-18
3	Measurements of Fish Specimens	19

ABSTRACT

Studies have been carried out on fisheries globally to determine the growth pattern, the abundance and the trends in fisheries. This would give insight into the overall change that keeps taking place over the years through the study of morphometry. Morphometric characteristics play an important role in understanding fish growth and its habitat

This study becomes a milestone to learn more about the morphometric characteristics and the morphometric features concerning the seasonal variations, among the selected fish species majorly that of *Genidens barbus,* which is commonly called the white-sea catfish, and the other fish species found during the study focusing on the length-weight relationships of these species which were report a negative growth parameter.

Keywords: Morphometric characteristics, Length-weight relationships, Growth parameter, Condition factor

CHAPTER 1

INTRODUCTION

1.1 Background

Fish fall under phylum chordates and are aquatic vertebrates (Nelson 1994) that have well-developed gills to survive and respirate in water and have streamlined bodies to move through the water, along with fan-like appendages called fins to stroke the waters for mobility in the water column. However, this doesn't hold true for all aquatic residing vertebrates like dolphins and whales that are required to breathe air by coming up to the surface. These are further classified into jawless, cartilaginous fish and bony fish. These could be pelagic, demersal or deepwater fishes that adapt to versatile habitats, which can be freshwater, seawater and brackish waters and are available across different temperature zones. Seawater fishes are also known as marine fishes and reside in environments such as the oceans and the seas.

Estuaries are semi-closed water bodies where the seawater miserably gets diluted by the fresh water and thus are favourable for many fishes and are also potentially nursing and feeding grounds, where these species can grow, and overtime breed, influencing high productivity and enhancing fish biomass eventually supporting the local communities by the course of fisheries.

These environments substantially protect coastal communities from erosion and flooding and contribute towards coastal ecosystems like salt marshes, seagrass or mangroves. Irrespective of the habitats fish biology is studied worldwide to understand the fish measurements and its statistical analysis or biometrics.

One such biometric study are the Length-weight relationships which are the study of morphometric characteristics by examining the weight of the fish related to the length of the fish (Fulton, 1906), which changes over time as they grow, mature and reproduce. Environmental factors, feeding habits, and gonadal maturity, also influence the morphometric relationships (Kuriakose, 2017) thus giving an insight into the fish growth

pattern (Thulasitha and Sivashanth, 2011) and population biomass in a particular area and regions, thereby estimating the abundance (Guzman *et al.,* 2020), thereby estimating abundance, distribution, to determine the health status of fish, which simply is known as stock assessment, thus helping in sustainable fisheries by evaluating the optimum exploitation of aquatic resources by analysing the condition of the fish over time.

Froese (2006) states that the length-weight relationships are of high value, for the estimation of the index called condition factor that represents the role of both biotic and abiotic elements in fish and the growth among species (Gesto *et al.,* 2017). However, the length-weight relationships change from region to region concerning fish species and body shapes.

By deriving the value of the growth parameter 'b', it is understood that the fish can be either in positive, negative or isometric growth, considering the growth parameter 'b' to be 3. If the growth parameter showcases the value less than 3 then it is a negative growth and positive growth if the value indicates more than 3. A static or isometric growth is observed if the value is equal to 3 or any value equivalent.

These studies can further help analyse the total catch in a particular region for each class of fish.

By studying these morphometric characters, the trend in fisheries can be understood and then strategies or mitigations for management and protection towards fishing can be introduced since fish is a staple food consumed as a dietary meal worldwide and is one of the main occupations for livelihood and trade.

1.2 Objectives

In this study we are aiming to study:

1. To study the Length-weight relationships of the *Genidens barbus* and other fish from the Zuari estuary from the Curtorim region.
2. To highlight the fish community found at the study area.

1.3 Hypothesis

1. To study the morphometric relations in selected fish species.
2. To highlight the morphometry and growth parameters of selected fish species.

1.4 Scope

The data collected and analysis carried out during the study period would provide insight into the morphometric characteristics and growth parameters of the common fish community found in the region.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Length-weight relationships play a vital role in fisheries assessment. Several studies have been done to understand these relationships worldwide and across the Indian Continent for a better understanding of fish biometrics and to evaluate the fish biomass. Studies done earlier on LWRs recorded by researchers indicate the ideal value of the growth parameter to be 3 (Levent *et al.,* 2007, Le Cren 1951 Rick and Carter 1958).

The studies are novel in regions and can be an addition to the information in regions about the fish species present (Kumar *et al,.*2014) a total of 271 specimens were collected that had length measurements ranging from 15 centimetres to 57 centimetres and weight that ranged from 25 grams to 155 grams for the recorded species *Channa punctatus, Heteropneustes fossilis (Bloch), Sperata aor, Wallago attu, Notopterus notopterus, Mystus tengara, Clupisoma garua,* among which *Channa punctatus, Heteropneustes fossilis* showed positive growth with values of 'b' as 3.2 and 3.05 respectively whereas the others had values ranging from 2.55 to 2.69 respectively.

The study can also help in recognizing novel species or invasive species in the waterways as a study conducted by De Giosa *et al.,* (2014) recorded the first species of *Carassius gibelio* leading to frequent contribution in fish catch, the author also points out the total catch in the inland waters in the study area in Poland done in different seasons from 2010 to 2011 and reported 'b' values ranging from 2.555 to 3.078 in *Carassius gibelio* over the seasons. The author states that there are differences observed following seasonal variations, which is in correspondence to another study done by Jisr *et al.,* (2018)

who reported the growth parameters in accordance to seasons, in cold and warm periods of three species namely, *Liza ramada and Oblada melanura* and *Epinephelus margintus* and the growth parameters ('b') ranged from 2.175 to 2.282 *Liza ramada*, 2.030 to 2.503 for *Oblada melanura* and 2.356 to 2.503 for *Epinephelus margintus* respectively. However, two species *Liza ramada and Oblada melanura* were reported on seasonal

growth where *Liza ramada* reported a positive growth in summer with a value of 3.115 and negative growth in spring and *Oblada melanura* reported a negative growth in winter and positive growth in winter with the values ranging from 3.091 to 2.203 respectively.

Nevertheless, a recent study done by Mehanna (2021), from April 2008 to July 2010 in the Mediterranean Sea of Egypt and July 2017 to December 2018 in the commercial landing site, concluded that there is a further need for more studies to understand the length-weight relationships of several other species, as the research reported 35 novel length-weight relationships for the species sampled along Egyptian Mediterranean waters and the landing sites, thus giving a novel identity to the study and reported positive growth for 18 fish species with the highest range of isometric growth which were about 22 species.

A study contributed by Kutlu. S *et al.,* recorded length-weight relationships of 4677 individual species belonging to 16 demersal fish species, and the ideal LWRs were processed from the fish base by Froese and Pauly (2008) however, held relationships for two fish species which added to information for fish biologists, namely being *Gobious batrachocephalus* and *Arnoglossus kessleri* where the results for individual fish showed an isometric growth to positive growth having the greater b values of 3.433 for *Trachinus draco* and the isometric growth for 4 different species of fish of which *Hippocampus hippocampus* had the value 2.949.

Research from the Gulf revealed that weight increases in proportion to length. The *Rastelliger karanguta* results in this study indicated a positive growth favouring the value of b to be 3.299, with minimum and maximum lengths of 17 and 25 centimetres, respectively. These results contrast other fish species found in similar areas to that of the *Rastelliger karanguta* (Guzman *et al.,*2020) suggesting more such research studies

favouring to put forth necessary policies, appropriate management, and long-term use of the Gulf fisheries resources.

A study done in India also has similar objectives from the Himalayan region suggesting suitable management strategies and principles for the conservation of fisheries resources in the region (Yousuf *et al*., 2023) where 455 specimens were recorded of which most of the species were recorded for positive growth parameters, namely *Cyprinus carpio, Carassius carassius and Pethia conchonius* and other species *Gambusia holbrooki, Crossocheilus diplochilus, Schizothorax niger and Schizothorax curvifrons* reported for negative growth, and good condition factor for the growth of these fishes.

Studies done in the Indian continent and many other countries gave the morphometric relationships (Length-weight relationships) along with the condition factor which is a critical clause for understanding the environment and the growth of the fish in an aquaculture system or any water body. The feeding habits generally impact the growth of the fish and hence the condition factor.

A study done by Datta, and Kaur *et al.,*(2013) recorded the length-weight relations and the condition factor of the selected fish species for the experimental feed that were grouped as D1, D2, D3, D4, D5, and D6 for *Channa punctata* (Bloch) which were given the formulated feed and the recorded results showed positive growth where the values for 'b' ranged from 2.7675 to 4.3922, however, negative growth was reported in D1 and D6, for the same species suggesting that the growth depends on the fish feeding pattern, either as the natural feeding pattern or the formulated diet, additionally, the K values were higher in the D2 to D6 compared to D1with the values ranging from 1.116, 1.210, 1.171, 1.334, 1.235 and 1.094 respectively.

A study that was done by Ujjania *et al*., (2012) on the Indian Major Carps (IMC) namely *Catla catla, Labeo rohita and Cirrhinus mrigala* were investigated for their LWRs and condition factors from the Mahi Bajaj Sagar, district of Banswara in Rajasthan where a total of 540 specimens of IMCs were collected over the seasons from January to December in 2000, from a commercial landing centre, and grouped among as G1, G2, G3, G4 ang G5. The Length-weight relationships were taken concerning the standard lengths and total lengths with the minimum and maximum lengths of 25 and 75 grams respectively with the corresponding weights of the carps ranging from 700 grams to 12,500 grams, the species of *Cirrhinus mrigala* had the maximum length followed by *Catla catla* and *Labeo rohita* corresponding to different groupings in G1 and G3 respectively. The values for 'b' of the grouped data were above 3.0, where the maximum values ranged to 3.085 for *Catla catla* and 4.574 for *Cirrhinus mrigala* in G5, and the minimum values of 'b' ranged to 3.110 and 2.498 for *rohu* or *Labeo rohita, Catla catla,* and *Cirrhinus mrigala* in G2, and 3.375 for *Cirrhinus mrigala* in G3. The length-weight relationships ranked high starting from *Catla catla*, *rohu* and *Cirrhinus mrigala.*

The study carried out in IMC species indicates an isometric growth i.e. with an increase in both length and weight, positive and negative growth following the standard values of 'b' equivalent to 3. Additionally, the condition factors were also estimated and indicated values of more than 1 reporting the maximum value condition factor in G3 with the highest value of 3.094 for *Catla catla* in G3 while the minimum value was 2.788 in G2. The declining trend in terms of the value of K was in correspondence to sexual maturity. Following this the study of IMCs for the same species was also done in 2005 and 2006 by Ujjania, Sharma and Balai who reported 119 specimens from May to April on the same species was done by Ujjania, Sharma and Kohli, done in Jaisamand Lake, Rajasthan.

However, published in 2017 agreed with the results of somatic growth of the IMCs reported by Ujjania *et al.,* (2012) and the condition factors also showcased similar results following the previous studies indicating the same trend of growth over the years with regards to IMCs in Rajasthan, where the values for condition factor ranged between 2.788 to 3.094 in *Catla catla* and 2.011 to 2.213 in *rohu* and 1.523 to 1.962 in *mrigal* were reported. The published work in 2017 reported the values ranging between 1.385 to 3.006, 0.897 to 1.691 and 0.925 to 1.583 for *Catla catla, rohu* and *mrigal* respectively, and stated that the value of the condition factor appeared to decline which is otherwise a positive impact on the growth in length which is good to have sexual maturity.

2.1.2 Studies from India included the Exclusive Economic Zone of India (EEZ)

Kumar *et* al., (2023) which is 200 nautical miles from the Indian peninsula, wherein studies done on four demersal fishes or bottom-dwelling fishes, including *Alepocephalus blanfordii, Lamprogrammus brunswigi, Parascombrops pellucidus, Pterigotrigla hemisticta,* which are fished or caught often during the deep-sea exploration concerning the depths of the sea and the samples were collected from a fisheries oceanographic research vessel *Sagar Sampada* of The Centre For Marine Living Resources And Ecology (CMLRE) in the month of march 2020, the results found were all recorded as positive in growth except for *Pterigotrigla hemisticta* which were overlooked by the explanation with depth and food availability in the deep-sea, the habitat and the population differences. The study became a novel identity and stands as a benchmark for the modelling and estimating of the population dynamics of the finfishes located in the INDIAN EEZ**.** Condition factors for the following fishes were also studied which reported most of the fishes in poor condition factors except for *Pterigotrigla hemisticta* which was reasoned for its good condition, in accordance to its depth and similar with the other three demersal fin-fishes.

A research study was done that was based on the razorbelly (*Alepes kleinii*) had a total catch of 456 individuals of the species from Mumbai and the Goan coasts which had the highest catch in the Mumbai coast having the catch of 337, between July 2015 to March 2017. The study also focused on the determination of the sex of the specimens caught, among which the males indicated good values of 'K', then in females, however, the growth was observed to be negative on both the coasts, and both the conditions varied concerning seasons (Kudtarkar *et al.,*2018).

The studies on LWRs were conducted in Goa also and suggested a good catch in the estuarine system of the state with somatic growth ranging between positive to negative growth with the values of the growth parameter 'b' to be (Shrihari *et al.,*2018).

CHAPTER 3

METHODOLOGY

3.1.1 Study Area

Goa is located on the Konkan Coast in the South-west coast of India. The study is conducted in the Salcete taluka, South district of Goa, in Curtorim, West Coast of India, 15.298617^{o}, 74.044825^{o} (Figure 1). The study sites included Guirdolim and Macasana. The study site is an intertidal Zone, with local communities supported by regular fishing activity by the estuary passing through mangrove vegetation.

Figure 1: Map showing study sites at Curtorim, Zuari River.

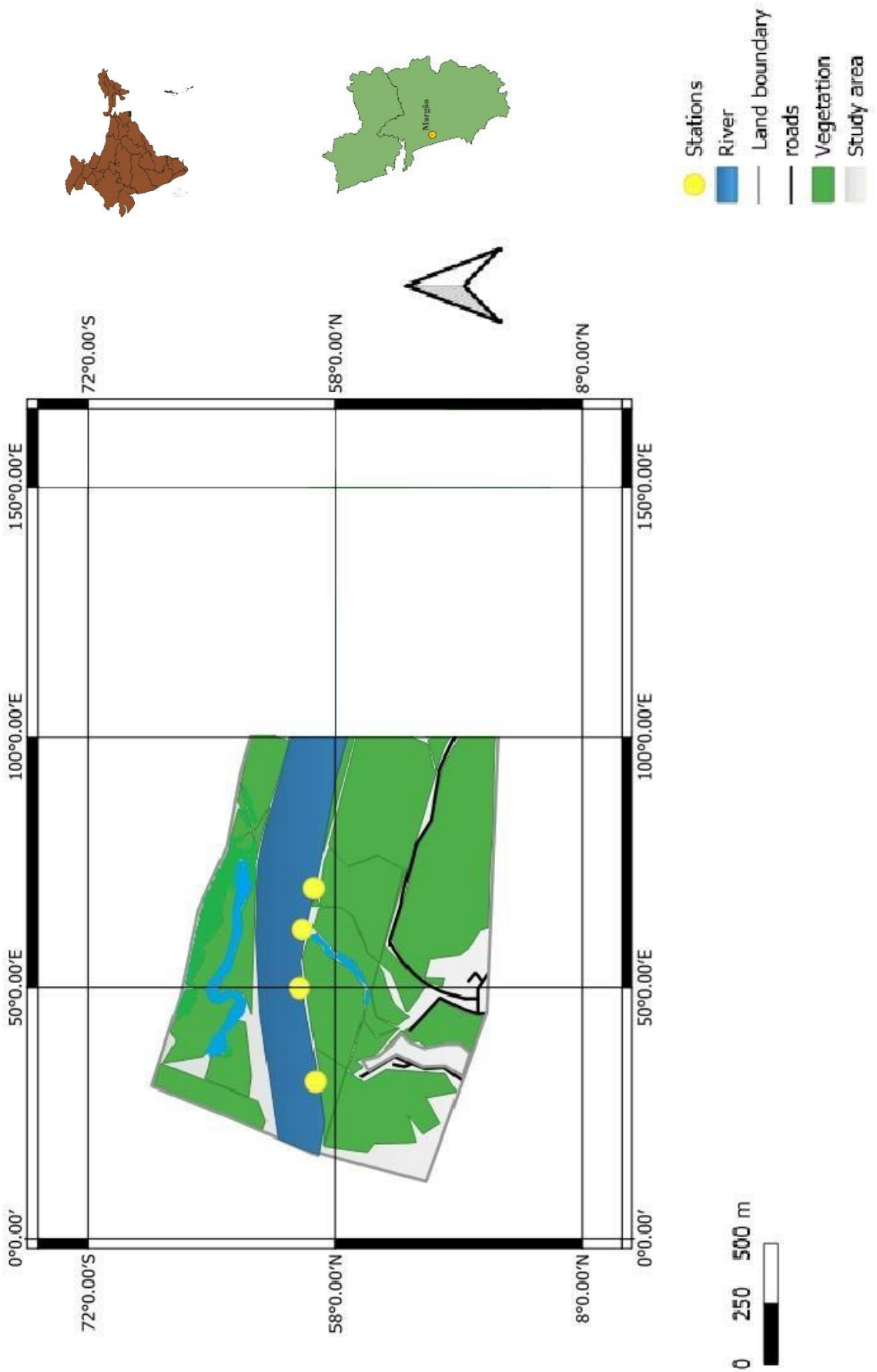


PLATE 1

Common Mangrove Species found on the species

a. *Acanthus ilicifolius.*

b. *Bruguiera cylindrica.*

c. *Kandelia candel.*

d. *Rhizophora mucronata.*

e. *Sonneratia alba.*

PLATE: 2A

Fish Species

a : *Gendius barbus*

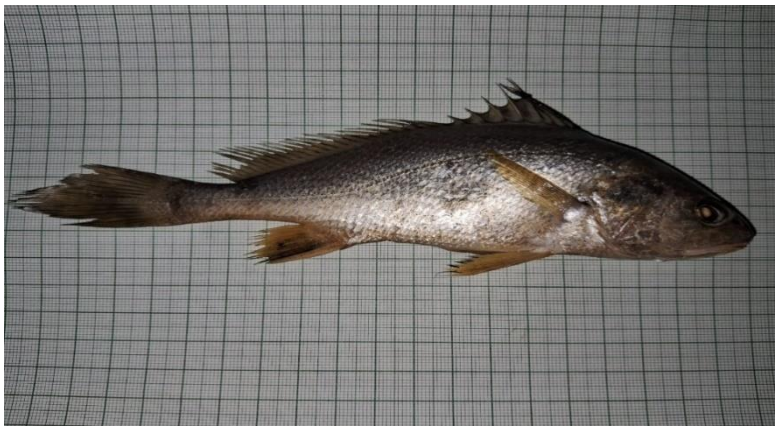
PLATE: 2B

b. *Escualosa thoracata*

c. *Tetraodon nigroviridis*

d. *Nuchequula nuchalis*

PLATE: 2C



e. *Nibea soldado*

Ventral view Dorsal view

f. *Solea solea*

g. *Megalops cyprinoides*

PLATE: 03

Measurements of Fish Specimen

a. Measurement of length using vernier calliper**.**

b. Measurement of length using measuring scale.

c. Measurement of weight on weighing balance

3.1.2 Temperature and pH

The temperature was recorded at the stations with the help of a mercury thermometer, whereas the pH of the water sample was recorded at the laboratory Eutech Instruments pH 700 at the biology and chemistry laboratories of SEOAS, Goa University.

3.1.3 Collection of Fish Samples

The fish samples were gathered with the assistance of a local fisherman throwing a cast from a motor-driven cannon, brought to the laboratory in an ice box, and were preserved in 10% buffered formalin (Joshi *et al.,*2015).

3.1.4 Collection of Water samples

The water samples were collected using a Niskin Sampler.

3.1.5 Laboratory analysis

BOD, Salinity and LWRs were estimated from the samples brought to the laboratory and carried in an ice box.

BOD for the water samples was estimated using Wrinkler's method, (Parsons *et al.,*1984) whereas the salinity was estimated by Mohr Kundru's Method. (Karl Friedrich Mohr, 1856).

3.2.1 Equation to derive Length-Weight Relationships

The Length of the fish was obtained using a vernier calliper, however, the measurement of other larger fishes was done using a measuring scale of 30 cm, and well measured with the help of a marker.

The weight of the fish was evaluated using a digital analytical balance of scaletec in the Marine Biology and Marine chemistry laboratories, SEAOS department.

The LWRs are calculated using the below equation

$$\mathbf{W = aL^b}$$

where,

'a' and 'b are regression coefficients.

'W' is the measured weight of the fish.

'L' is the measured length of the fish.

The above formula is a parabolic formula given by Frose.

Where again these are converted into a logarithmic form to obtain a linear expression of the mathematical model of LWRs (**equation below**)

$$\mathbf{Log\ W = Log\ a + b\ Log\ L}$$

3.2.2 Condition Factor

LWRs were used to assess the condition of a fish through an index that represents the interplay between biotic and abiotic elements in fish physiological circumstances and is termed a condition factor (Getso *et al.,*2017, Kumar *et al.,*2023) which also includes the growth index between species and among species (Theresa Paul, T., Landge *et al.,*2018). This factor depends on the natural variables and food accessibility in a particular water body (N. C Ujjania *et al*.,2012). LWRs are used to determine the condition of a fish through an index known as condition factor.

The condition factor is $K = 100(W/L^b)$ OP *et al,.*(2018), whereas, in another paper by Simon e*t al*., (2008) and Yousuf and Bakhtiyar *et al.,* (2023) apply the below equation for equating the condition Factor put forth by Fulton 1904, according to Simon *et al.,* the formula is considered a homogenous equation. $K = (W/L^3) \times 100$.

The computation and the analysis of the LWRs for the fish are processed using Microsoft Excel 2020.

CHAPTER 4

ANALYSES AND CONCLUSIONS

4.1 The fish specimens collected in November 2023 for post-monsoon or winter samples had the occurrence of *Megalops cyrinoides* and was reported to have a length of 39.8 cm, *Genidens barbus* had a length reported to be 26.4 centimetres and *Nibea soldado* was reported to be 19.1 centimetres. The length of *Tetraodon nigroviridis* had maximum to minimum lengths of 2.5 and 7.9 centimetres, respectively among four individuals of the species, whereas, *Escualosa thoracata* were a total of 6 individuals and had lengths ranging between 4.8 to 5.7 centimetres respectively. *Nuchequula nuchalis* were 2 individuals and ranged a maximum length of 4.1 centimetres (Table 4.1.a and Table 4.1.b and Figure 2).

The fish caught during March 2024 for pre-monsoon or the winter season had an occurrence of two species namely, *Genidens barbus and Solea solea* among which the highest catch was for *Genidens barbus* and had a maximum length of 29.1 cms and the minimum length was 24.3 cms, whereas the highest lengths were observed 20.8 cms and minimum length 13.8 cms with the minimum and maximum weights as 0.09- and 0.115-grams *Solea solea.* (Table 4.1.c and Table 4.1.d and Figure 2).

Table 4.1.a: Fish species recorded during post-monsoon.

Species	Common Name	Number of individuals
Tetraodon nigroviridis	Green spotted puffer fish	4
Genidens barbus	White sea catfish	1
Megalops cyprinoides	Oxeye herring	1
Nibea soldado	Solider croacker	1
Escualosa thoracata	White sardine	6
Nuchequula nuchalis	Ponyfish	2

Table 4.1.b: Length-weight Relationships of fishes from the study area.

Species	'n'	Length in centimetres		Weight in grams		'a'	'b'	Condition factor (K)
		Min	Max	Min	Max			
Nuchequula nuchalis	2	3.3	4.4	0.5226	0.8804	1.3561	0.64597	1.365
Tetraodon nigroviridis	4	2.5	-	58.2184	21.0081	2.56741	1.115152	6.9360
Nibea soldado	1	-	19.5	0	0.055	18.18181818	Less than 1	0.00139
Escualosa thoracata	6	4.8	5.7	1.11	2.05	1	0.2979	1.071717
Megalops cyrinodes	1	-	39.1	0	0.445	0.275520219	Less than 1	0.00137
Genidens barbus	1	-	26.4	87.1058	-	0.27552021	1.21338	0.000869577

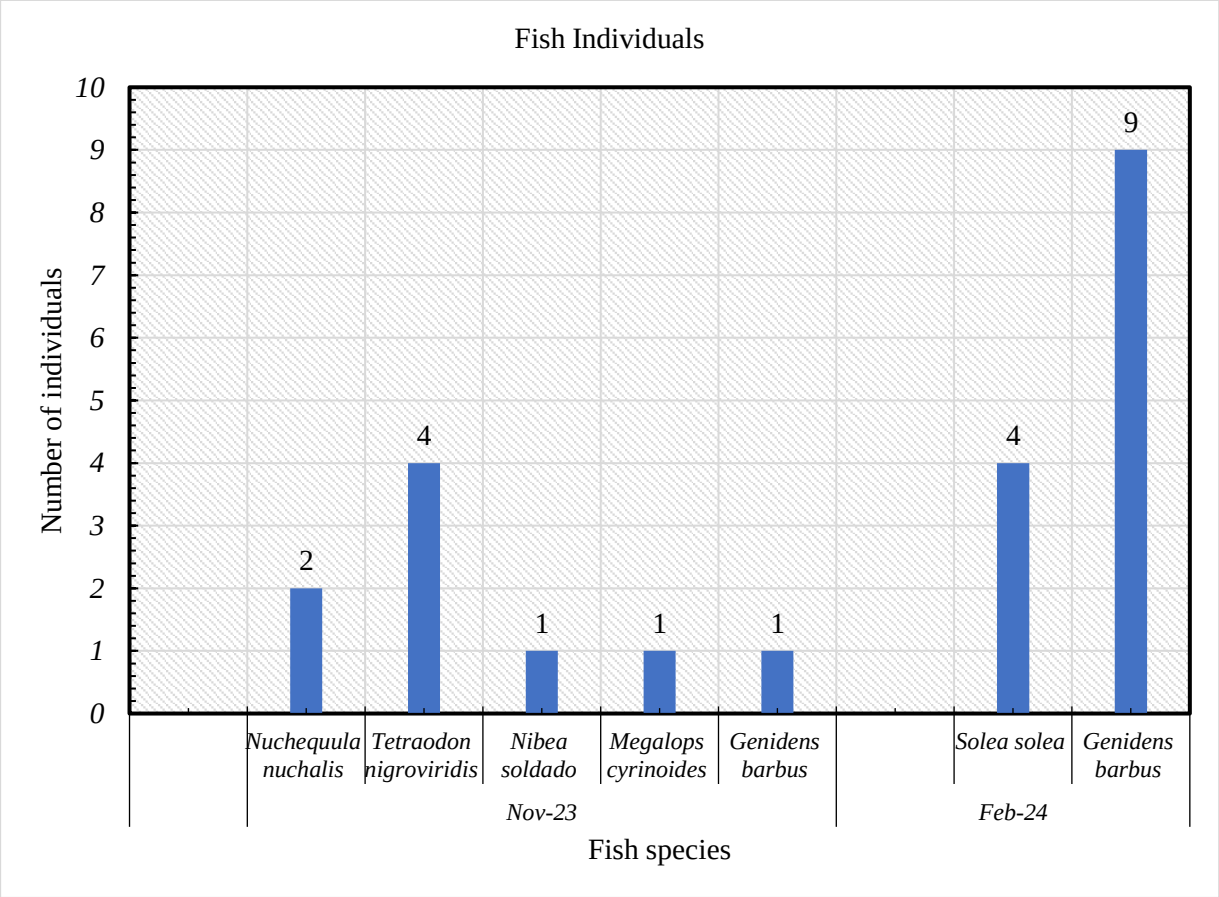
Table 4.1.c: Fish species recorded during Pre-monsoon

Species	Common Name	Number of individuals
Solea solea	Dover sole	4
Genidens barbus	White sea catfish	1

Table 4.1.d: Length-weight Relationships of fishes from the study area.

Species	'n'	Length (centimetres)		Weight (grams)		'a'	'b'	Condition factor (K)
		Min	Max	Min	Max			
Solea solea	4	0.09	0.115	1.139879086	1.31806333	1	Less than 1	0.001519153
Genidens barbus	9	24.3	29.1	0.11	0.172	0.999	Less than 1	0.000771413

Figure 2: Fish species found in among the seasonal study in Curtorim



The pH observed along the estuary was between 6. 5 and 7.2 during the post-monsoon and pre-monsoon seasons respectively, indicating a neutral pH range, which could have been influenced by physical processes like tidal influence (Fatema *et.al.,*2016) and the overtime biological activities and coastal activities by the shore of estuary.

A study done by Husain & Kumar (2022) says that the pH is influenced by the shifting seasons where a low pH was recorded in the winter and a pH of 7.14 in the summer months, a similar pH range was observed in the present study where the pH ranged 6.55 to 6.71 during the post-monsoon season in November 2023 and 6.5 to 7.2 during the pre-monsoon season in February 2024. (Table 4.1.e and Figure 3).

The temperatures during the study ranged from 28^{o} to 30^{o} Celsius during the post-monsoon season (winter) and could have varied due to levels of precipitation during the monsoonal seasons which must have caused a drop in the temperature and are in slight agreement with Matta *et al.,* (2009) where the temperatures for the post-monsoonal period were recorded at 26.5 to 27.8^{o} Celsius. The temperatures that were observed in March 2024 were ranging between 30^{o} to 33^{o} Celsius possibly due to high levels of evaporation during the period. However, the post-monsoonal temperatures of the present study are in contradiction with Matta *et al.,* (2009) where the temperatures for the post-monsoonal period were recorded at 28.0 to 29.50 ^{o} Celsius. (Table 4.1.f and Figure 4).

Table 4.1.e: Variations in pH at sampling sites

Station		
	Post-Monsoon (Winter)	Pre-Monsoon (Summer)
1	6.55	6.9
2	6.4	6.79
3	6.67	7
4	6.71	7.2

Figure 3: Seasonal Variation in pH at the sampling sites.

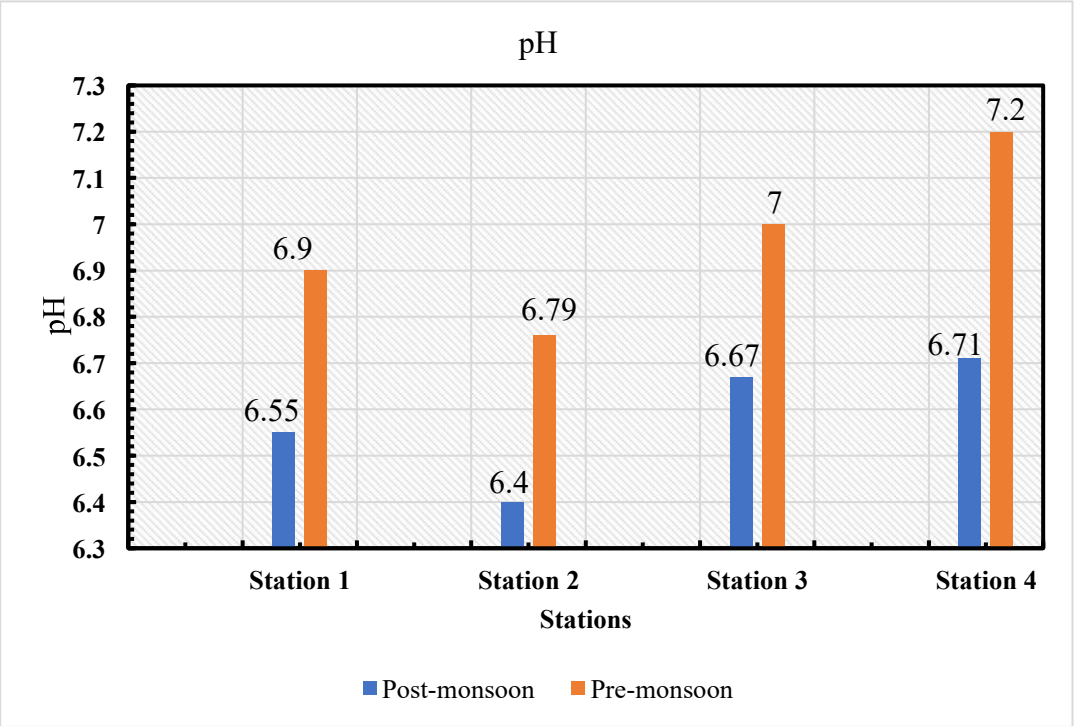
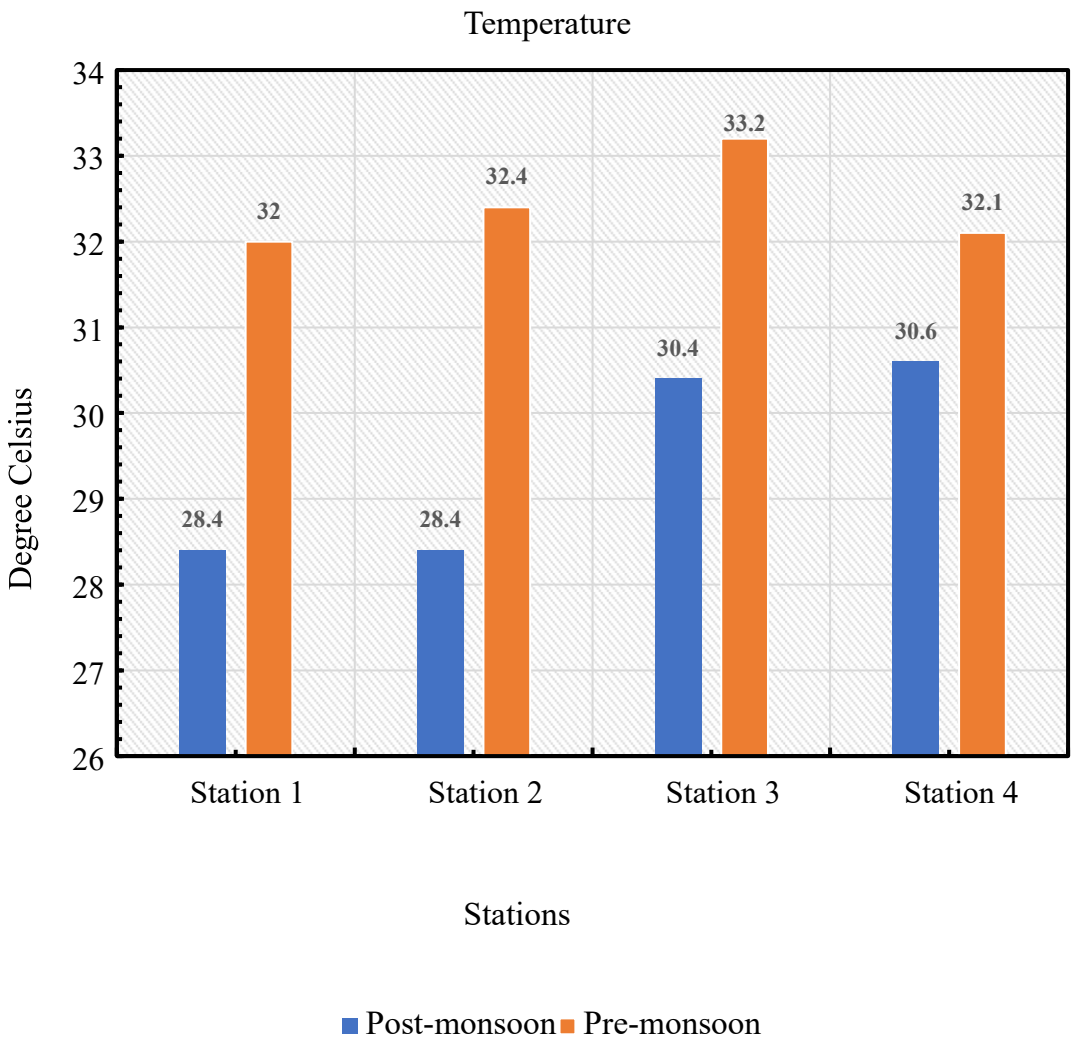


Table 4.1.f: Variations in temperature at sampling sites.

Station	Temperatures in Degree Celsius	
	Post-Monsoon (Winter)	Pre-Monsoon (Summer)
1	28.4	32
2	28.4	32.4
3	30.4	33.2
4	30.6	32.12

Figure 4: Seasonal Variation in temperatures at the sampling sites.



The salinity observed showed an increasing trend during the pre-monsoonal (summer) period than the post-monsoonal (winter) periods (Figure 4.2.4.1) that ranged to the highest value as 21.9 psu, in March 2024 (pre-monsoon), the likely cause is excessive evaporation and reduced freshwater inflow, corresponding to the National Ocean and Atmospheric Administration, which also adds that salinity can change due to tidal fluctuations. (Table 4.1.g and Figure 5).

The Biological oxygen demand shows an increasing trend during the pre-monsoon as compared to the post-monsoonal period, with the highest value observed at station three, 0.6879 mg/L. The variations, however, show not much difference in the trend of BOD levels, possible reasons could be due to the influence likely to be the anthropogenic activities as well the precipitation or the impact of rainfall after the monsoonal period. (Table 4.1.h and Figure 6).

Table 4.1.g: Variations in Salinity at sampling sites

Station	Salinity in psu	
	Post-Monsoon (Winter)	Pre-Monsoon (Summer)
1	0.0541965	5.528043
2	1.80655	10.64058
3	1.625895	15.73505
4	1.44524	21.19083

Figure 5: Seasonal Variations in the salinity at the sampling sites.

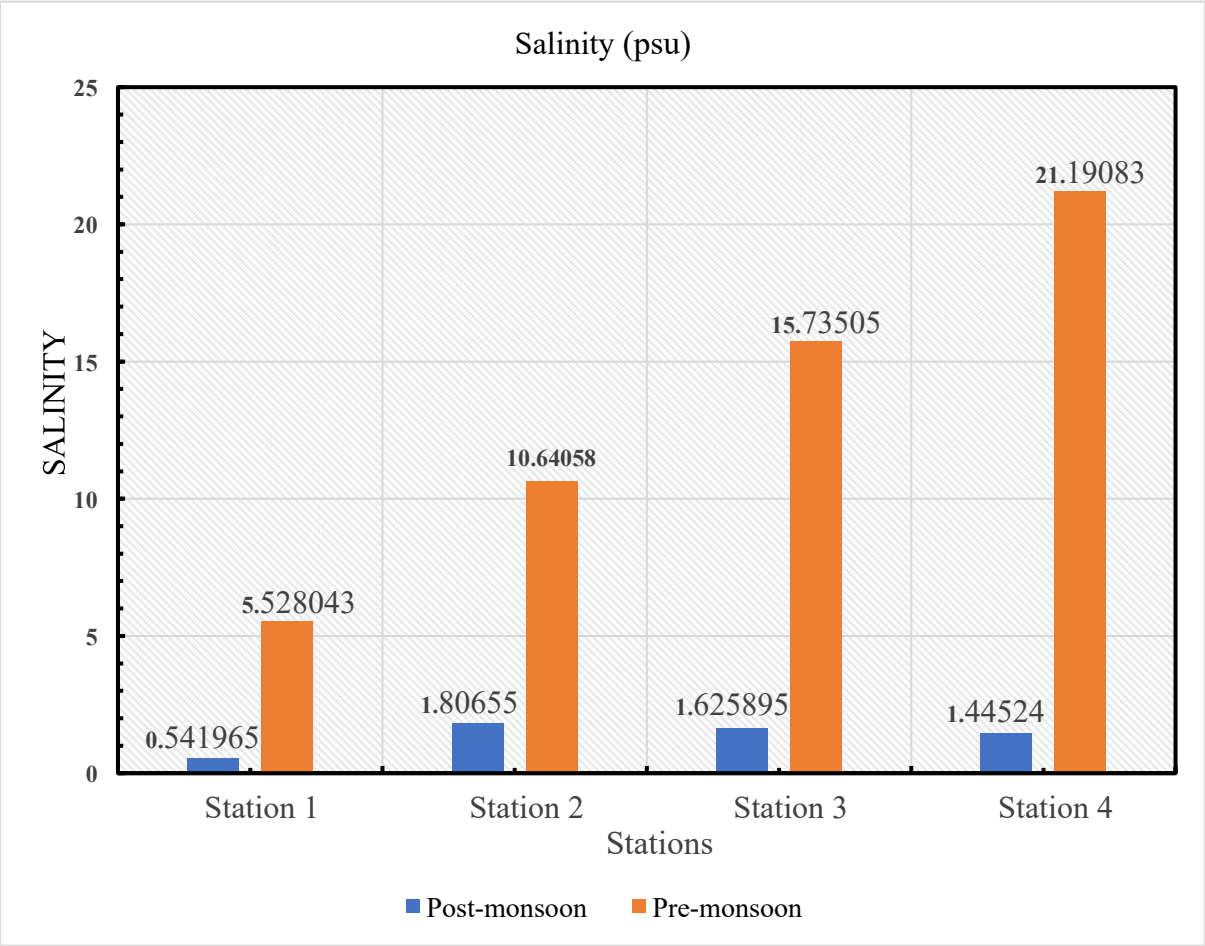
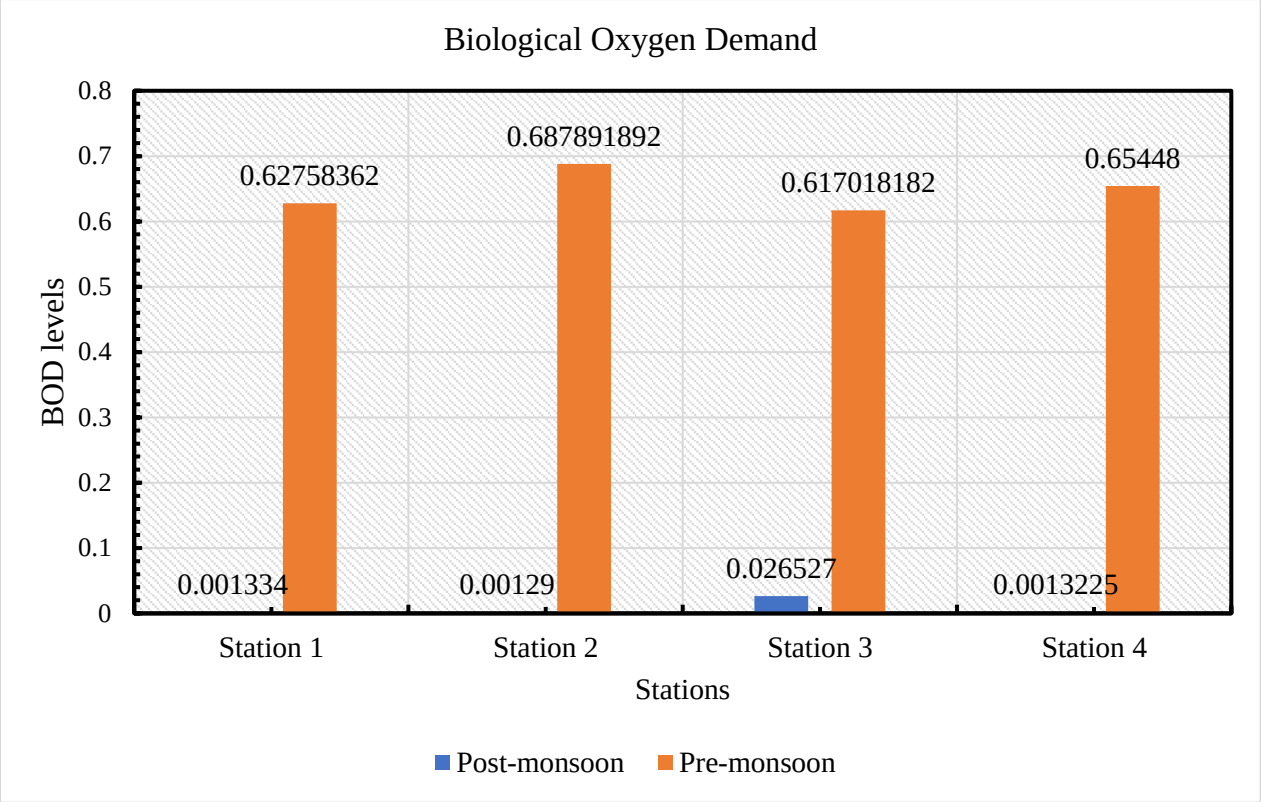


Table 4.1.h: Variations in Biological Oxygen Demand at sampling sites

Station	BOD in mg/L	
	Post-Monsoon (Winter)	Pre-Monsoon (Summer)
1	0.001334	0.62758362
2	0.00129	0.687891892
3	0.026527	0.617018182
4	0.0013225	0.65448

Figure 6: Seasonal Variations in Biological Oxygen Demand at the sampling sites



4.2 The morphometric analysis of the fish species from the Curtorim region gave insights to the growth pattern of the aquatic vertebrates among the seasonal study conducted during post-monsoon and pre-monsoon of 2023 and 2024 respectively.

The presence of the *Genidens* species in the estuarine system coincides with the research study observation carried out by Maciel, Avigliano., *et al.,* (2020) who reported that the species occurrence is not well defined, however is reported to have an estuarine habitat. The growth observed during the present study reports a negative growth pattern for the species.

Another species found in the catch namely the *Megalops cyrinodes* indicates a growth parameter of less than 1, which can be interpreted to be no well-defined growth, however, the study by Harahap *et al*., (2020) in Indonesia reported a negative growth parameter, and a study done by Renjithkumar *et al.,* (2023) recorded the growth of the species from the Southwest coast of India, had an isometric growth pattern. Additionally, *Nibea soldado* also showed a growth parameter of less than 1 whereas species like *Solea solea* (figure 8) *Tetraodon nigroviridis*,(figure 9a) *Escualosa thoracata* (figure 9b) *Nuchequula nuchalis,*(figure 9c) reported a negative growth parameter.

Figure 7: Length-Weight relationships of *Genidens barbus*.

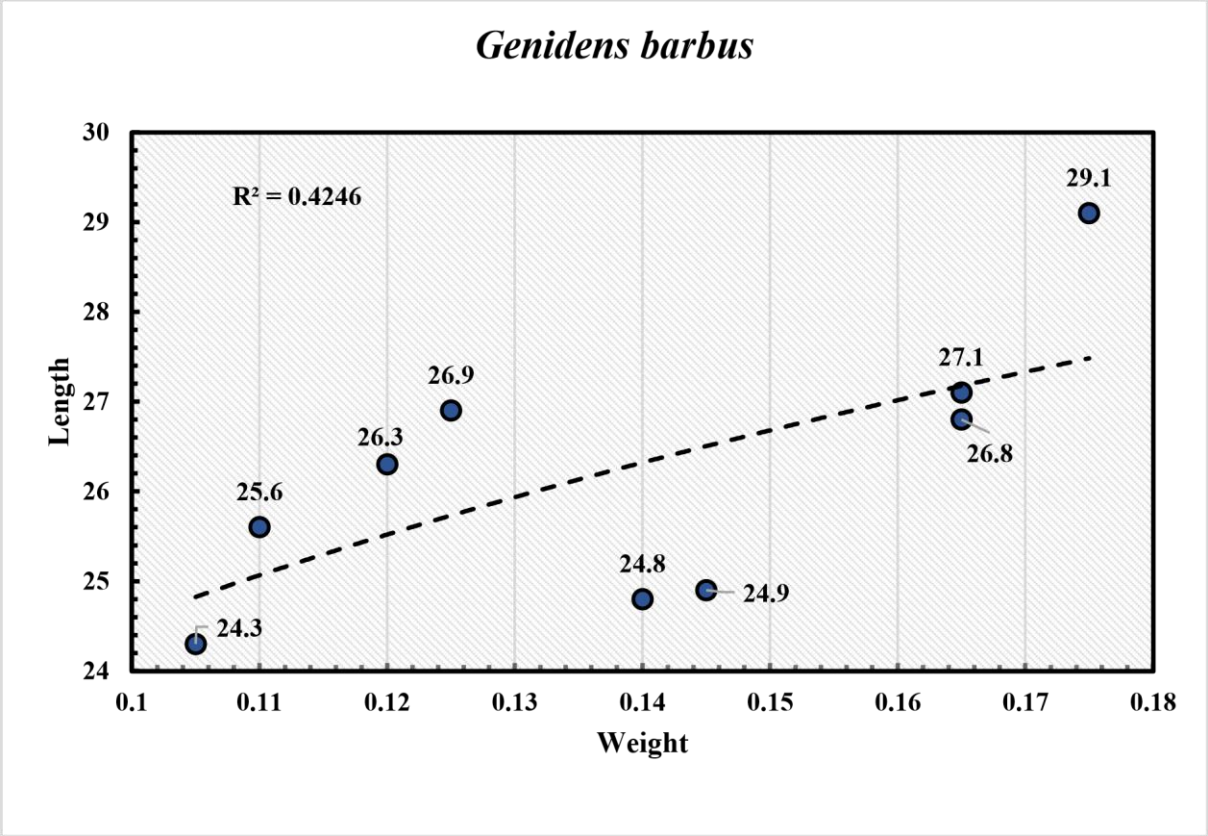


Figure 8: Length-Weight relationships of *Solea solea*

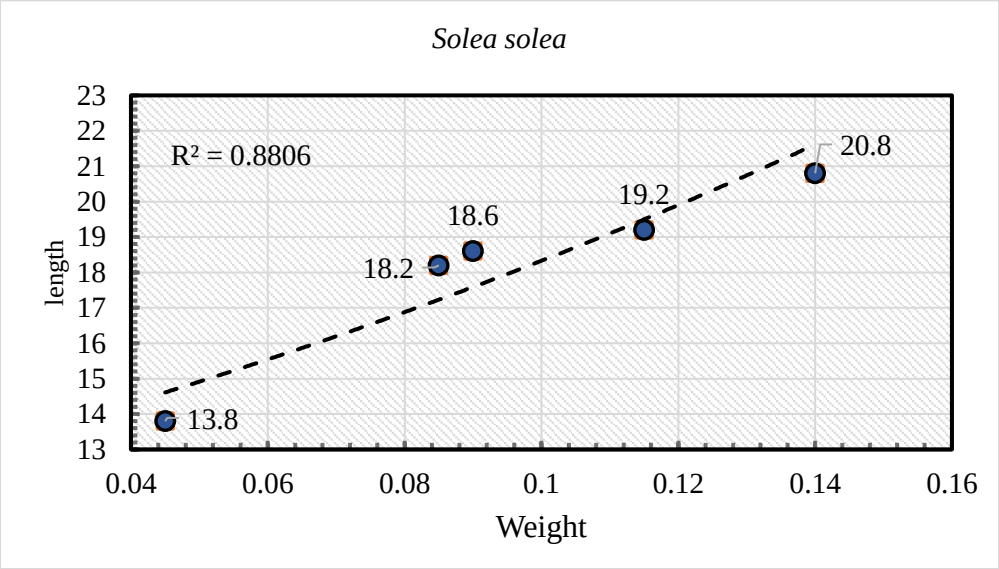


Figure 9a: Length-weight relationships of *Tetraodon nigrovirids*

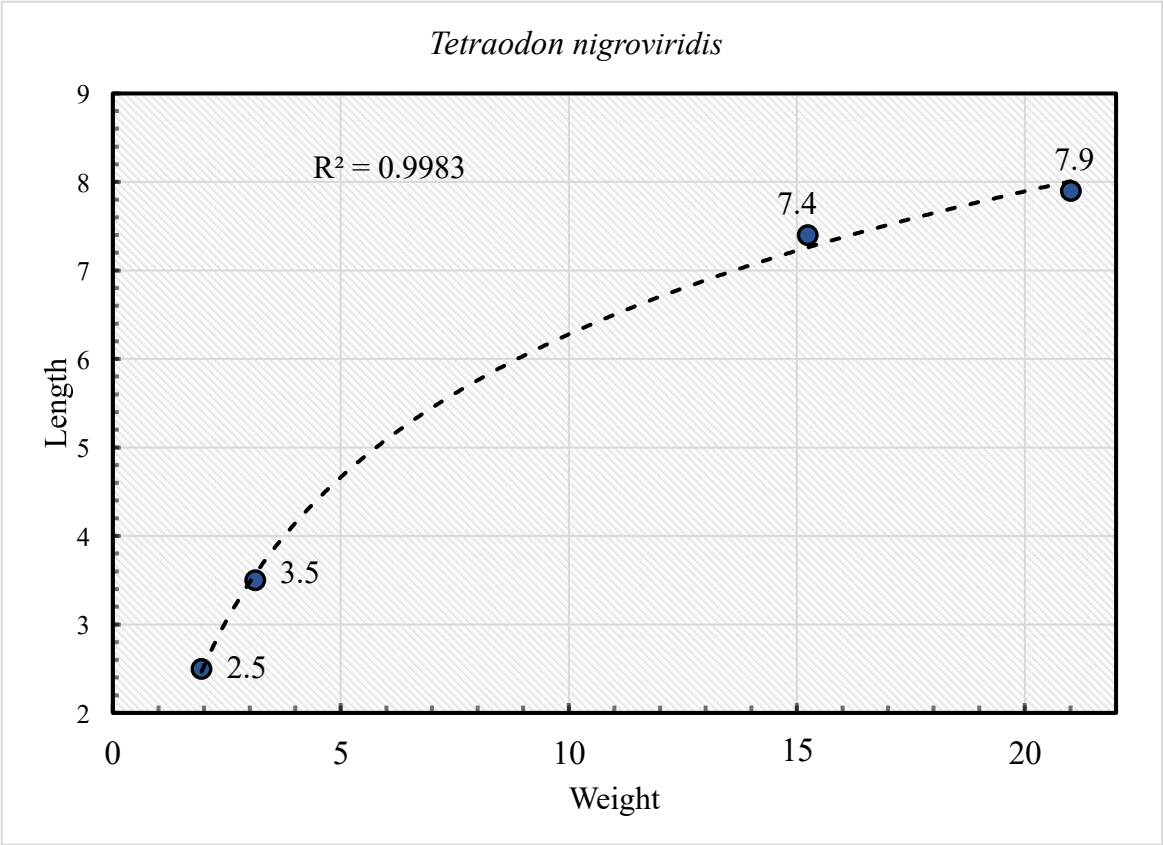


Figure 9b: Length-weight relationships of *Escualosa thoracata*

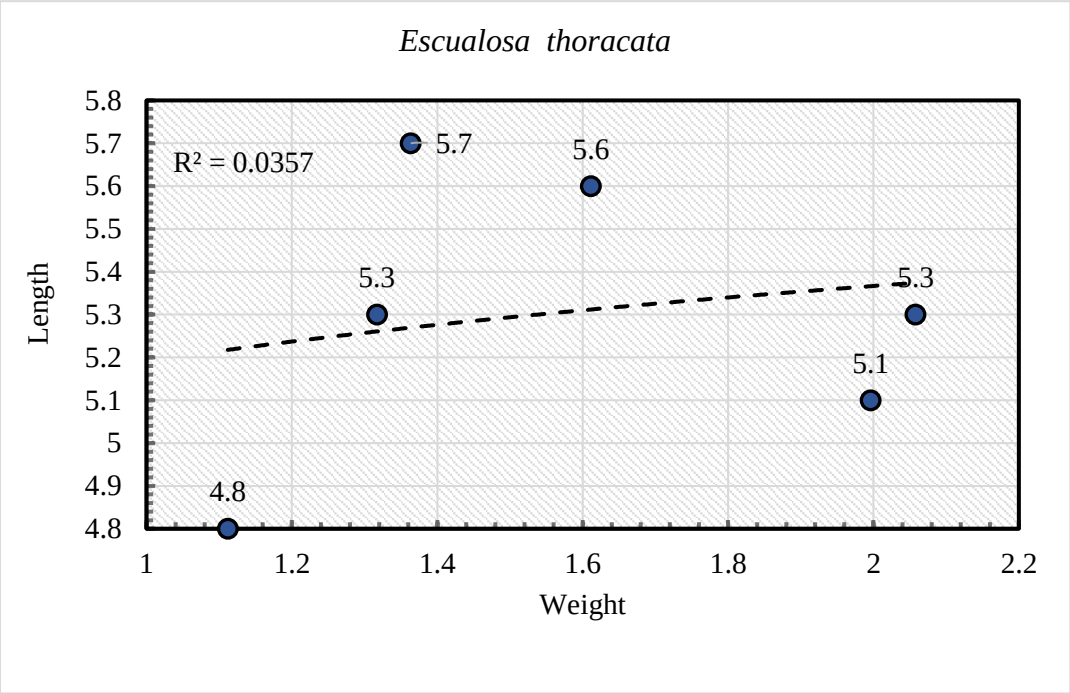
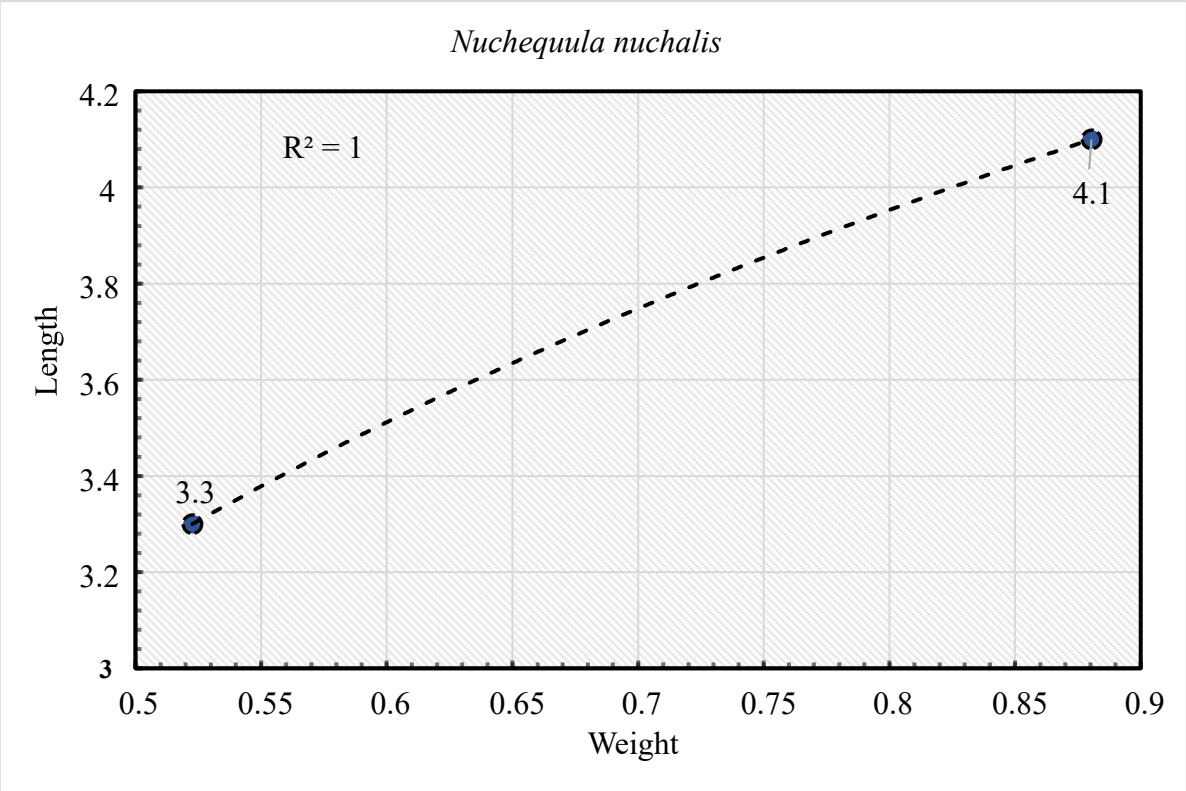


Figure 9c: Length-weight relationships of *Nuchequula nuchalis*



The values were ideal for growth according to Carlander (1969), who said that the fish tends to grow in thickness as they continue to grow with the ‘b’ values that ranged from 2.7 to 3.4, wherein all the recorded growth patterns in the present study was reported to be in negative, with values ranged from 0.2979 and the highest values to be 1.21338.

4.3 Another factor called the condition factor (K), was proposed by Fulton to understand the well-being of the fish and to understand the conditions of the environment the fish grow, and governs the growth of fish individually. The observed condition factor in the present study was recorded less than 1 for *Megalops cyrinoides, Genidens barbus, , Nibea soldado* that reported 0.00137, 0.000869577, 0.00139 respectively, indicating a poor condition of the environment for the fishes to grow in, except for *Escualosa thoracata, Nuchequula nuchalis* reporting 1.070707 and 1.365 and the highest value of 6.9 was recorded for *Tetraodon nigrovirdis* respectively, and the species *Solea solea* recorded the condition factor with a value 0.001519 and 0.00077413 for *Genidens barbus* collected form the pre-monsoonal period with a value of 7.71 of indicating a poor conditional growth of the fish.

The possible reason for the poor condition factors observed aligns with the area which is a land that has residents by the shore of the waterbody, which is a contributing factor of anthropogenic activities.

4.4 The factor R^2 also called the coefficient of determination, tells us about the measure of quality, and about variations of a dependent variable (weight) from an independent variable(length),(Shaun Turney, 2022). From the present study, the variations were observed high in *Escualosa thoracata* followed by *Solea solea, and Genidens barbus*, whereas, the R^2 is least for *Nuchequula nuchalis and Tetraodon nigroviridis* giving an interpretation that the *Nuchequula nuchalis and Tetraodon nigroviridis* species are not

much dependent (weight) on the independent variable (length) for growth, whereas, the others have a dependency on lengths for the growth in weight.

4.3 Conclusions

- The study focuses on the morphometric characteristics of the fish species found in the Zuari estuary, in the Curtorim region.
- The acquired information in the study provides information on the selected fish species, Genidens barbus and other fish species on their respective Length-weight relationships.
- The fish species Genidens barbus dominated the fish catch which was a total of 10 individuals from both seasons, followed by *Solea solea* and *Tetraodon nigroviridis*, with 5 and 4 individuals for each of the species respectively.
- The condition factor observed for all the fish species had the values reported as less than 1 for three species from the post-monsoonal period however, was observed at 1.0717 for *Escualata thoracata* and 1.365 for *Nuchequula nuchalis*.
- The coefficient of determination or the measure of quality was a good fit for *Nuchequula nuchalis* and *Tetraodon nigroviridis.*

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