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Availability of Fish Species in Relation to Plankton Abundance Throughout the South Bengal Coast Over Three Distinct Seasons

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A B S T R A C T

To clarify the area's fertility as a new fishery ground, an intra-seasonal study on phytoplankton, zooplankton, and fish availability was conducted in the Bay of Bengal. In three different locations in the Bay of Bengal, the composition, abundance, and distribution of phytoplankton and zooplankton were to be ascertained as part of this study. Petuaghat, Junput, and Sankarpur are points A, B, and C respectively. All samples were obtained from these three distinct locations using oblique towing and a hand-net with a mesh size of 20 m. 16 species from 3 families make up the phytoplankton ecosystem that is now in existence. The most prevalent phytoplankton in this area is Chlorophyta, followed by Bacillariophyta, while Cyanophyta is the least accessible. Euglena sp. and Volvox sp. are widely distributed in Chlorophyta. The 18 species that make up the zooplankton population. When it came to both the number of species and their abundance, Copepoda dominated the landscape. Copepods, protozoan zooplankton, arrow worms, larvaceans, cnidarians, ostracods, and liaceans were also widely distributed groups in these areas. According to the fish diversity survey, there are primarily 25 species of fish in this area that are significant for commerce. In all sampling points, fish are more readily available in the winter and during the monsoon. Additionally, compared to the winter season, the summer season has the lowest fish diversity. *Harpodon nehereus* exhibits the highest percentages of fish diversity out of all the sampled species.

***Key words*:** Phytoplankton, Zooplankton, Bay of Bengal, Species composition, Abundance, Distribution

Understanding the distribution and fluctuations of the organism that makes up the dietary component of a species is essential to gaining a full appreciation of the relevance of food and feeding habits of economically important fishes as well as the research of their biology [1]. At the tail end of the 20th Century, a select group of ichthyologists were interested in the studies on the food that fishes eat, and ever since that time, a number of examinations along these lines have been carried out in a variety of locations across the globe. Fishermen have access to a beneficial tool in the form of information on the feeding grounds of commercial fish populations, which enables them to expand their fishing operations in an easy and profitable manner. The importance of doing exploratory research in India, both for the purpose of determining the size of the existing fish stock and of locating unexplored but potentially fruitful fishing sites, has been brought up on multiple occasions in recent years. Numerous types of fish that live in freshwater, estuarine, and marine environments have all been subjected to research on their diets and the ways in which they consume food. There is a significant body of research on the food that demersal and benthic fishes of the East and West coasts of India consume as well as their feeding behaviors. Rao [2] conducted research on the diets and feeding behaviors of fishes that were caught using trawls in the Bay of Bengal. He discovered the diurnal fluctuation in the composition of the feed and worked on these topics. Since the beginning of this century, numerous methodically structured surveys have been carried out in the waterways of India, and numerous researchers have evaluated these surveys at various points over the course of the most recent few years. It is common knowledge that the study of a fish's diet and eating patterns is essential to gaining an understanding of its behavior with regard to migration, growth, and reproduction. This is a fact that has been well established.

In his thesis from the year 1996, Venkatraman investigated the food sources and feeding habits of the inshore fish that live in the waters off of Calicut on the Malabar coast. Kagwade [3] participated in the collection of prawns in the trawling grounds of Bombay and Saurashtra. In the region that we are researching, we have discovered that the abundance of plankton is significantly lower during the summer months as compared to other seasons following the monsoon. The availability of plankton is at its highest point during the winter.

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Additionally, following the monsoon and summer, the diversity of fish is at its highest during the winter months.

MATERIALS AND METHODS

Station 1: (Petuaghat) It is located about 3.7 km from the shore at 10 to 20 m depth (21°47'03.9"N 87°54'00.1"E).

Station 2: (Junput) It is located (21°42'21.8"N 87°50'00.2"E) about 3.9 km from the shore at 10 to 20 m depth and it is an important potential fishing ground for pelagic fishes such as sardine, anchovy, Indian mackerel, seer fishes and *Lates calcarifer*.

Station 3: (Sankarpur) It is located (21°37'35.9"N 87°35'08.6"E) about 4.1 km from the shore at 10 to 20 m depth.

Fig 1 Three sampling stations namely Petuaghat, Junput, and Sankarpur

The current investigation was conducted on the South Bengal coast of the Bay of Bengal, India, between April 2019 and March 2021. Using GPS (Garmin) fixed locations, sampling was done at three transect points (point A: Petuaghat, point B: Junput, and point C: Sankarpur), starting from the shore and going three kilometers out to sea. In the winter, summer, and monsoon seasons of 2019-21, surface water samples were taken at these locations. Using a Niskin water sampler, surface water samples from 0.5 m of water depth were taken for various biological parameter analyses. Standard analytical techniques were used to analyze biological (plankton) parameters. Using a plankton net, samples of phytoplankton and zooplankton were taken from the shoreline to three kilometers out into the sea (mesh size 0.03-0.04 mm, mouth area 0.3 m^2). The water sample was divided into two halves, with one component used for physicochemical parameter study and the other for species identification. The samples were fixed in 3% Lugol's solution before being added to 4% buffered formaldehyde for taxonomic identification. Using a light microscope, researchers made observations at the microscopic level and then used the images to create a final product (Magnus MLX with a camera at 40x magnification). Identification of the zooplankton group was done using the accepted identification process [4-7]. Fish samples were taken from the Behundi net's catch, which is managed by a straightforward mechanized boat. This program was completed within 10 kilometers of the seashore. After that, the stomach's contents are directly examined, dissected, or evacuated.

At monthly intervals, zooplankton samples were taken from the water's surface using a horizontal tow of a plankton net with a mesh size of 158 mm and a mouth diameter of 0.35 meters manufactured of bolting silk (No. 10). (General Oceanics Inc., Florida). Following that, samples of zooplankton were stored in 4% formalin in filtered seawater for qualitative analysis and species-level identification using established techniques [8-10]. Samples were concentrated to 5–10 ml prior to microscopic analysis by siphoning away the top layer using a tube protected with a 10 mm Nytex filter on one end. The necessary sample concentrates were transferred to a Sedgwick-Rafter counter with a 1 ml capacity, and their concentrations were determined using a Zeiss Binocular Dissection Microscope at a 100-x magnification. The total figure of zooplankton existent in the collected sample was estimated by the following formula:

$$N \quad \frac{n \times v}{V}$$

Where N is the total figure of zooplankton entities per liter of water filtered, n is an average number of zooplankton individuals in 1 ml of sample, and v is the volume of zooplankton concentrates, V is the volume of total water filtered. Species diversity index [11], species richness [12], and evenness index [13] of phytoplankton were worked by using the following respective formulae.

a. Shannon - Wiener diversity index (H')

$$(H') = \sum_{i=1}^{S} Pi \log_2 Pi$$

where S is the total number of species, Pi is the ni/N for the I the species, ni is the number of individuals of a species in the sample, and N is the total number of individuals of all species in the sample. H' is the species diversity in bits of information per individual, where the value of H' is dependent upon the number of species present, their relative proportions, sample size (N), and the logarithmic base. The choice of the base of the logarithm is very important. In the present study, log2 has been used as per the practice in India.

b. Species richness

$$(SR) = \frac{(S-1)}{\log N}$$

where S is the number of species representing a particular sample, and N is the natural logarithm of the total number of individuals of all the species within the sample.

c. Species evenness or equality

$$(J') = \frac{H'}{\log_2 S}$$

where J' = species evenness, H' = species diversity in bits of information per individual (observed species diversity), and S = total number of species.

Statistical analysis

Using the statistical software SPSS, the Pearson's correlation matrix was created to examine the link between zooplankton population density and pelagic fish catch, as well as with various physico-chemical characteristics (version 16.0). Using the statistical program SPSS (version 16.0), two-way analyses of variance (ANOVA) for zooplankton population density for stations 1-3 were computed to assess the significance of changes in biodiversity indices across temporal and geographic variations. to comprehend the similarities between the zooplankton community structure.

RESULTS AND DISCUSSION

(Table 1) lists the frequent and abundant phytoplankton species that were observed at station-l during the study period. The present study has found a total of 16 genera of phytoplankton that are members of the groups Chlorophyta, Bacillariophyta, and Cyanophyta. Chlorophyta are the most frequently encountered during the study period, followed by Bacillariophyta and Cyanophyta. (Table 2) lists the numerous and frequent species that were observed at Station-ll during the study period. The present study found a total of 16 genera of phytoplankton that are members of the groups Chlorophyta, Bacillariophyta, and Cyanophyta. The Chlorophyta family includes the species *Euglena sp., Volvox sp., Cladophora sp., Spirogyra sp., Closterium sp*., and *Ulothrix sp*. The most frequent group seen throughout the study period included *Anbaena sp., Oscillatoria sp., Microcystis sp*., and *Nostoc sp.* that belong to the family Cyanophyta and *Bacillaria sp., Cyclotella sp., Pinnularia sp., Navicula sp., Gomphonema sp.*, and *Pleurosigma sp.* etc. The species of phytoplankton that were prevalent and plentiful at station III during the study period are listed in (Table 3). The present study found a total of 16 genera of phytoplankton that are members of the groups Chlorophyta, Bacillariophyta, and Cyanophyta. Here, *Navicula* species are more prevalent than *Euglena sp.* and *Anbaena sp*. *Cladophora sp., Spirogyra sp.*, and *Bacillaria sp.* are sporadic species found in 2021.

Table 1 Season wise available phytoplanktons at station l in the year 2019 to 2021

Season wise available phytoplankton at Station-l (% by number)													
S. No.	Family	Species name	Summer				Monsoon				Winter			
			2019	2020	2021	Mean	2019	2020	2021	Mean	2019	2020	2021	Mean
1.	Chloro	*Euglena* sp.	13	9	9	10.33	9	10	9	9.33	11	10	9	10
2.		*Volvox* sp.	12	10	8	10	8	3	2	4.33	8	4	3	5
3.		*Cladophora* sp.	7	6	7	6.66	6	12	13	10.33	5	3	8	5.33
4.		*Spirogyra* sp.	8	9	8	8.33	5	10	9	8	9	8	10	9
5.		*Closterium* sp.	8	8	9	8.33	12	7	8	9	9	12	11	10.66
6.		*Ulothrix* sp.	2	7	8	5.66	7	8	9	8	7	12	13	10.66
7.	Bacillariophyta	*Bacillaria* sp.	3	2	0	1.66	2	5	0	2.33	6	5	0	3.66
8.		*Cyclotella* sp.	3	5	4	4	0	6	7	4.33	0	4	7	3.66
9.		*Pinnularia* sp.	8	5	6	6.33	6	4	8	6	6	5	6	5.66
10.		*Navicula* sp.	7	10	7	8	7	5	5	5.66	5	7	5	5.66
11.		*Gomphonema* sp.	3	4	6	4.33	7	4	6	5.67	6	5	4	5
12.		*Pleurosigma* sp.	4	2	4	3.33	6	5	3	4.66	5	2	6	4.33
13.	Cyanophyta	*Anbaena* sp.	8	9	6	7.66	5	8	7	6.66	5	6	7	6
14.		*Oscillatoria* sp.	7	8	9	8	9	6	6	7	6	8	7	7
15.		*Microcystis* sp.	5	4	5	4.66	6	5	7	6	7	7	6	6.66
16.		*Nostoc* sp.	2	2	3	2.33	3	3	3	3	4	2	2	2.66

Table 2 Season wise available phytoplanktons at station ll in the year 2019 to 2021

Season wise available phytoplankton on Station-ll (% by number)													
S. No.	Family	Species name	Summer				Monsoon				Winter			
			2019	2020	2021	Mean	2019	2020	2021	Mean	2019	2020	2021	Mean
1.	Chloro	*Euglena* sp.	9	8	8	8.33	8	10	8	8.66	10	11	8	9.66
2.		*Volvox* sp.	8	2	7	5.66	11	8	12	10.33	9	10	11	10
3.		*Cladophora* sp.	8	8	11	9	8	9	7	8	6	9	9	8
4.		*Spirogyra* sp.	10	9	12	10.33	4	5	5	4.66	6	7	8	7
5.		*Closterium* sp.	8	9	7	8	9	9	8	8.66	9	10	9	9.33
6.		*Ulothrix* sp.	7	12	5	8	8	9	10	9	10	3	6	6.33
7.	Bacillariophyta	*Bacillaria* sp.	4	3	0	2.33	2	4	0	2	6	7	0	4.33
8.		*Cyclotella* sp.	6	7	6	6.33	0	7	7	4.66	0	3	4	2.33
9.		*Pinnularia* sp.	5	6	3	4.66	7	5	4	5.33	5	7	7	6.33
10.		*Navicula* sp.	6	4	5	5	6	5	4	5	5	4	5	4.66
11.		*Gomphonema* sp.	4	6	7	5.66	7	4	7	6	4	4	7	5
12.		*Pleurosigma* sp.	3	4	6	4.33	6	3	6	5	7	4	6	5.66
13.	Cyanophyta	*Anbaena* sp.	7	7	8	7.33	6	10	7	7.66	6	7	6	6.33
14.		*Oscillatoria* sp.	7	8	8	7.66	6	7	6	6.33	7	6	6	6.33
15.		*Microcystis* sp.	6	5	4	5	8	3	5	5.33	5	8	8	7
16.		*Nostoc* sp.	3	3	3	3	3	4	5	4	5	2	3	3.33

Table 3 Season wise available phytoplanktons at station lll in the year 2019 to 2021

Season wise available phytoplankton on Station-lll (% by number)													
S. No.	Family	Species name	Summer				Monsoon				Winter			
			2019	2020	2021	Mean	2019	2020	2021	Mean	2019	2020	2021	Mean
1.	Chloro	*Euglena* sp.	10	7	9	8.66	7	11	10	9.33	10	11	9	10
2.		*Volvox* sp.	0	4	8	4	0	4	3	2.33	0	3	2	1.66
3.		*Cladophora* sp.	9	2	0	3.66	7	5	0	4	5	3	0	2.66
4.		*Spirogyra* sp.	4	2	0	2	3	9	0	4	9	8	0	5.66
5.		*Closterium* sp.	6	8	8	7.33	8	8	6	7.33	6	2	2	3.33
6.		*Ulothrix* sp.	4	2	0	2	2	4	0	2	4	2	0	2
7.	Bacillariophyta	*Bacillaria* sp.	4	2	0	2	2	5	0	2.33	7	5	0	4
8.		*Cyclotella* sp.	7	5	6	6	0	5	11	5.33	0	10	10	6.66
9.		*Pinnularia* sp.	10	10	10	10	7	6	6	6.33	7	7	6	6.66
10.		*Navicula* sp.	10	10	12	10.66	9	4	7	6.66	7	9	10	8.66
11.		*Gomphonema* sp.	7	7	6	6.66	8	6	7	7	6	8	12	8.66
12.		*Pleurosigma* sp.	6	6	7	6.33	4	10	6	6.66	7	7	6	6.66
13.	Cyanophyta	*Anbaena* sp.	5	9	9	7.66	9	12	6	9	7	5	4	5.33
14.		*Oscillatoria* sp.	9	9	6	8	6	6	8	6.66	6	9	6	7
15.		*Microcystis* sp.	6	4	7	5.66	7	5	4	5.33	4	7	7	6
16.		*Nostoc* sp.	2	3	2	2.33	2	1	2	1.66	3	1	2	2

Table 4 Shannons-Weiner and Simpson(phytoplanktons) Index in different seasons at station-l (Petuaghat)

S. No	Seasons	Shannons-weiner Index		Simpson Index
		(H)	(E)	
1.	Summer Season	2.68063	0.966833	0.93641
2.	Monsoon Season	2.708593	0.976918	0.939196
3.	Winter Season	2.699302	0.973567	0.937382

*H = Shannon-weiner index, E = Evenness, D = Simpson Index

Table 5 Shannons-Weiner and Simpson (phytoplanktons) Index in different seasons at station-ll (Junput)

S. No	Seasons	Shannons-weiner Index		Simpson Index
		(H)	(E)	
1.	Summer Season	2.71115	0.977841	0.939556
2.	Monsoon Season	2.711585	0.977998	0.939534
3.	Winter Season	2.714956	0.979213	0.939855

*H = Shannon-weiner index, E = Evenness, D = Simpson Index

Table 6 Shannons-Weiner and Simpson(phytoplanktons) Index in different seasons at station-lll (Sankarpur)

S. No	Seasons	Shannons-weiner Index		Simpson Index
		(H)	(E)	
1.	Summer Season	2.71115	0.977841	0.933471
2.	Monsoon Season	2.711585	0.977998	0.937935
3.	Winter Season	2.714956	0.979213	0.935566

*H = Shannon-weiner index, E = Evenness, D = Simpson Index

We discovered a total of 18 zooplanktons during the study period. The species of zooplankton that were seen at station 1 are listed in (Table 7). Here, there is significant seasonal variance. Only during one season are certain species in great abundance. The monsoon season is when you can mostly find *Acrocalanus sp.*, *Amphorellopsis sp.*, *Clausocalanus sp.*, *Candacia sp.*, *Ctenocalanus sp*., and *Euchaeta sp*. In our study period we find total 18 zooplanktons. In station-II the recorded zooplanktons species are given in (Table 8). Some species like Veligerlarvae, *Eutintinnus*sp., *Leprotintinnus* sp. are found only winter season.

During the time of our study, station-III found a total of 18 zooplankton species; the species documented are listed in (Table 9). Here, seasonal variation is very strong. Some species, such as *Microsetella sp.* can be found both in the summer and the winter. Copepod nauplii are abounding here all year round. (Table 13) lists the frequent and abundant fish species that were seen at station-l during the study period. Nine orders contain a total of 25 different fish species. After those in the monsoon and summer, the fish production peaked in the winter. The entire year is when *Harpodon nehereus*, often known as Babla, is most plentiful. The abundant and common species of fish recorded during the study period at station-II are presented in (Table 14). Totally 25 fish species belong to 9 orders. In winter season the fish production is the highest after those in monsoon and summer. In monsoon season *Hilsa toil* locally known as Chandani (7.6±0.5) and *Hilsa ilisha* commonly known Ilish (6.3±0.5) are found in good numbers. (Table 15) lists the many and frequent fish species that were observed at Station III during the study period. Nine orders contain a total of 25 different fish species. Summertime is a time of abundance for *Eleutheronema tetradactylum*, also known as Karua, and year-round for *Rhinomugil corsula*, also known as Kanua. In monsoon season *Hilsa toil* locally known Chandani (7.6±0.5) and *Hilsa ilisha* commonly known Ilish (6.3±0.5) are found in good numbers. In winter *Thryssa polybranchialis* (8.6±1.2) and *Trichiurus lepturus* (12±0.8) found in large numbers.

(Table 1) lists the frequent and abundant phytoplankton species that were observed at station-l during the study period. The present study found a total of 16 genera of phytoplankton

that are members of the groups Chlorophyta, Bacillariophyta, and Cyanophyta. The Chlorophyta family includes the species *Euglena sp.*, *Volvox sp.*, *Cladophora sp.*, *Spirogyra sp.*, *Closterium sp.*, and *Ulothrix sp.* The most frequent group seen throughout the study period included *Anbaena sp.*, *Oscillatoria sp.*, *Microcystis sp.*, and *Nostoc sp.*, which are members of the Cyanophyta family. *Bacillaria sp.*, *Cyclotella sp.*, *Pinnularia sp.*, *Navicula sp.*, *Gomphonema sp.*, and *Pleurosigma chlorophyta* are the most frequently encountered during the study period, followed by Bacillariophyta and Cyanophyta. *Euglena* sp. (10.33±2.30) are found in summer in higher volume than those in monsoon (9.33±0.57) and winter (5±2.64). Phytoplankton are abundant in the Summer, Monsoon and Winter seasons at Petuaghat station. (Table 2) lists the numerous and frequent species that were observed at Station-ll during the study period. The present study found a total of 16 genera of phytoplankton that are members of the groups Chlorophyta, Bacillariophyta, and Cyanophyta. The Chlorophyta family includes the species *Euglena sp.*, *Volvox sp.*, *Cladophora sp.*, *Spirogyra sp.*, *Closterium sp.*, and *Ulothrix sp.* The most prevalent group seen throughout the study period were *Anbaena sp.*, *Oscillatoria sp.*, *Microcystis sp.*, and *Nostoc sp.* from the family *Cyanophyta sp.*, *Bacillaria sp.*, *Cyclotella sp.*, *Pinnularia sp.*, *Navicula sp.*, *Gomphonema sp.*, and *Pleurosigma sp.* from Chlorophyta are the most frequently encountered during the study period, followed by Bacillariophyta and Cyanophyta. In this area, *Bacillaria sp.* and *Cyclotella sp.* are always very few, but *Volvox sp.* are most prevalent [14].

Table 7 Season wise available zooplanktons at station l in the year 2019 to 2021

Seasonal availability of zooplankton at Station-l (% by number)													
S. No	Species name	Summer				Monsoon				Winter			
		2019	2020	2021	Mean	2019	2020	2021	Mean	2019	2020	2021	Mean
1.	*Acrocalanus sp.*	0	0	0	0	10	11	10	10.5	0	0	0	0
2.	*Amphorellopsis sp.*	0	0	0	0	15	11	10	12	0	0	0	0
3.	Veliger larvae	0	0	0	0	0	0	0	0	1	2	2	1.6
4.	*Candacia sp.*	0	0	0	0	10	9	7	8.6	0	0	0	0
5.	*Clausocalanus sp.*	0	0	0	0	8	11	9	9.3	0	0	0	0
6.	*Copepod nauplii*	26	28	27	27	14	12	16	14	21	21	20	20.6
7.	*Ctenocalanus sp.*	0	0	0	0	8	9	8	8.3	0	0	0	0
8.	*Euchaeta sp.*	0	0	0	0	7	8	7	7.3	0	0	0	0
9.	*Euterpina sp.*	17	18	17	17.3	0	0	0	0	0	0	0	0
10.	*Eutintinnus sp.*	0	0	0	0	0	0	0	0	3	3	4	3.3
11.	*Favella sp.*	3	5	3	3.6	5	4	4	4.3	6	6	5	5.6
12.	*Globigerina sp.*	0	0	0	0	4	5	4	4.3	0	0	0	0
13.	*Leprotintinnus sp.*	0	0	0	0	0	0	0	0	6	7	8	7
14.	*Metacylis sp.*	2	2	1	1.6	0	0	0	0	16	16	15	15.6
15.	*Microsetella sp.*	14	15	15	14.6	0	0	0	0	13	10	10	11
16.	*Oncaea sp.*	12	13	13	12.6	0	0	0	0	0	0	0	0
17.	*Paracalanus sp.*	12	12	10	11.3	7	6	7	6.6	9	10	9	9.3
18.	*Tintinnopsis sp.*	9	11	10	10	8	8	7	7.6	26	26	26	26

Table 8 Season wise available zooplanktons at station ll in the year 2019 to 2021

Seasonal availability of zooplankton at Station-II (% by number)													
S. No	Species name	Summer				Monsoon				Winter			
		2019	2020	2021	Mean	2019	2020	2021	Mean	2019	2020	2021	Mean
1.	*Acrocalanus sp.*	0	0	0	0	12	14	15	13.6	0	0	0	0
2.	*Amphorellopsis sp.*	0	0	0	0	15	11	13	13	0	0	0	0
3.	Veliger larvae	0	0	0	0	0	0	0	0	1	1	3	1.6
4.	*Candacia sp.*	0	0	0	0	10	12	7	9.6	0	0	0	0
5.	*Clausocalanus sp.*	0	0	0	0	12	10	9	10.3	0	0	0	0
6.	*Copepod nauplii*	27	28	26	26	16	12	14	14	20	20	21	20.3
7.	*Ctenocalanus sp.*	0	0	0	0	8	9	8	8.3	0	0	0	0
8.	*Euchaeta sp.*	0	0	0	0	7	8	7	7.3	0	0	0	0
9.	*Euterpina sp.*	17	18	18	18	0	0	0	0	0	0	0	0
10.	*Eutintinnus sp.*	0	0	0	0	0	0	0	0	4	4	4	4
11.	*Favella sp.*	3	6	3	3	5	3	4	4	6	6	5	5.6
12.	*Globigerina sp.*	0	0	0	0	4	6	4	4.6	0	0	0	0
13.	*Leprotintinnus sp.*	0	0	0	0	0	0	0	0	7	8	6	7
14.	*Metacylis sp.*	2	2	3	2.3	0	0	0	0	16	17	15	16
15.	*Microsetella sp.*	14	16	16	16	0	0	0	0	13	12	10	11.6
16.	*Oncaea sp.*	12	14	13	13	0	0	0	0	0	0	0	0
17.	*Paracalanus sp.*	12	12	10	10	7	6	7	6.6	9	10	9	9.3
18.	*Tintinnopsis sp.*	11	11	11	11	8	8	7	7.6	26	28	27	27

Table 9 Season wise available zooplanktons at station lll in the year 2019 to 2021

Seasonal availability of zooplankton at Station-III (% by number)													
S. No	Species name	Summer				Monsoon				Winter			
		2019	2020	2021	Mean	2019	2020	2021	Mean	2019	2020	2021	Mean
1.	*Acrocalanus sp.*	0	0	0	0	10	12	9	10.3	0	0	0	0
2.	*Amphorellopsis sp.*	0	0	0	0	15	10	13	12.6	0	0	0	0
3.	Veliger larvae	0	0	0	0	0	0	0	0	2	3	2	2.3
4.	*Candacia sp.*	0	0	0	0	11	9	8	9.3	0	0	0	0
5.	*Clausocalanus sp.*	0	0	0	0	8	10	9	9	0	0	0	0
6.	*Copepod nauplii*	26	27	28	27	14	14	16	14.6	21	23	20	21.3
7.	*Ctenocalanus sp.*	0	0	0	0	8	9	8	8.3	0	0	0	0
8.	*Euchaeta sp.*	0	0	0	0	7	8	7	7.3	0	0	0	0
9.	*Euterpina sp.*	17	18	18	17.6	0	0	0	0	0	0	0	0
10.	*Eutintinnus sp.*	0	0	0	0	0	0	0	0	3	5	4	4
11.	*Favella sp.*	3	5	5	4.3	4	5	4	4.3	6	5	5	5.3
12.	*Globigerina sp.*	0	0	0	0	4	5	5	4.6	0	0	0	0
13.	*Leprotintinnus sp.*	0	0	0	0	0	0	0	0	6	7	7	7.6
14.	*Metacylis sp.*	2	2	2	2	0	0	0	0	16	18	15	16.3
15.	*Microsetella sp.*	14	14	16	14.6	0	0	0	0	13	10	11	11.3
16.	*Oncaea sp.*	11	12	11	11.3	0	0	0	0	0	0	0	0
17.	*Paracalanus sp.*	12	12	10	11.3	7	6	7	6.6	9	10	9	9.3
18.	*Tintinnopsis sp.*	12	12	10	11.3	8	8	7	7.6	26	31	27	28

Table 10 Shannons-Weiner and Simpson Index in different seasons at station-I (Petuaghat)

S. No	Seasons	Shannons-weiner Index		Simpson Index
		(H)	(E)	
1.	Summer Season	1.772069	0.543897	0.842768
2.	Monsoon Season	1.772069	0.543897	0.842768
3.	Winter Season	1.772069	0.543897	0.842768

*H = Shannon-weiner index, E = Evenness, D = Simpson Index

Table 11 Shannons-Weiner and Simpson Index in different seasons at Station-II (Junput)

S. No	Seasons	Shannons-weiner Index		Simpson Index
		(H)	(E)	
1.	Summer Season	1.9729	0.605538	0.847677
2.	Monsoon Season	1.9729	0.605538	0.847677
3.	Winter Season	1.9729	0.605538	0.847677

*H = Shannon-weiner index, E = Evenness, D = Simpson Index

Table 12 Shannons-Weiner and Simpson Index in different seasons at station-III (Sankarpur)

S. No	Seasons	Shannons-weiner Index		Simpson Index
		(H)	(E)	
1.	Summer Season	1.970511	0.604804	0.846275
2.	Monsoon Season	1.970511	0.604804	0.846275
3.	Winter Season	1.970511	0.604804	0.846275

*H = Shannon-weiner index, E = Evenness, D = Simpson Index

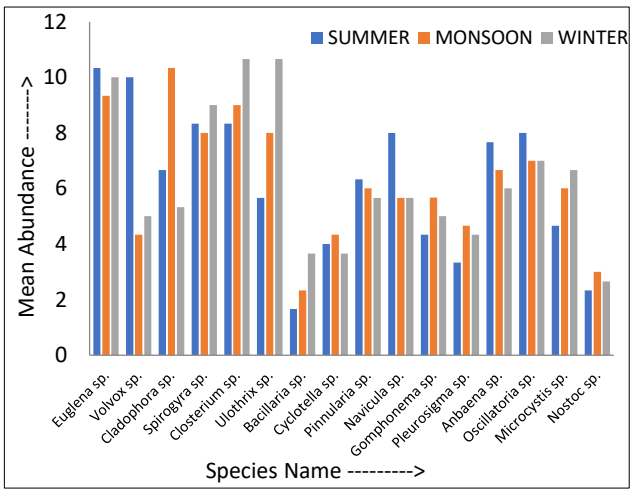

Fig 1 Phytoplankton abundance in the summer, monsoon and winter season at Petuaghat station

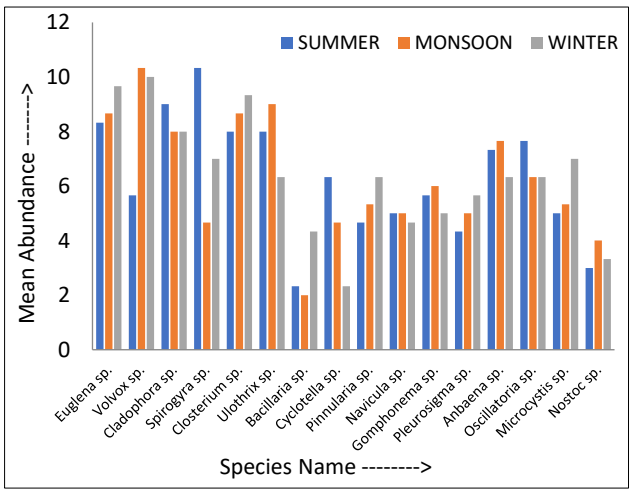

Fig 2 Phytoplankton abundance in the summer, monsoon and winter season at Junput station

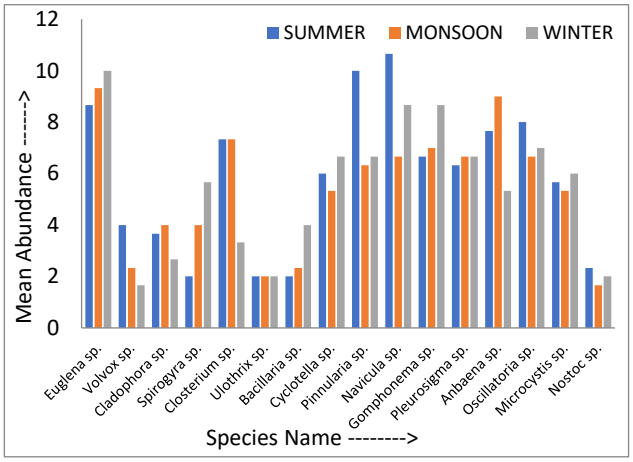

Fig 3 Phytoplankton abundance in the summer, monsoon and winter season at Sankarpur station

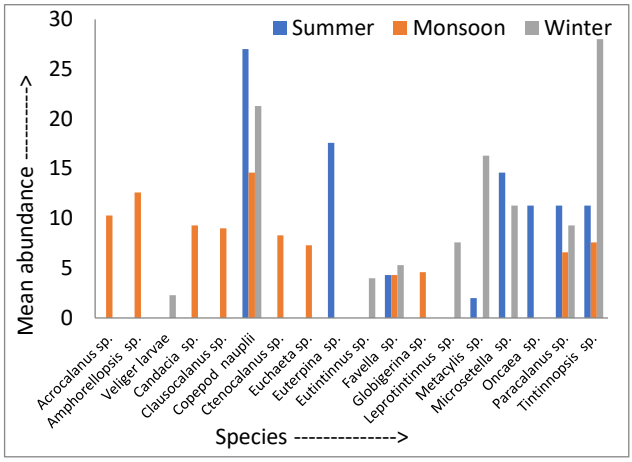

Fig 4 Zooplankton abundance in the summer, monsoon and winter season at Petuaghat station

The species of phytoplankton that were prevalent and plentiful at station III during the study period are listed in (Table 3). The present study found a total of 16 genera of phytoplankton that are members of the groups Chlorophyta, Bacillariophyta, and Cyanophyta. The Chlorophyta family includes the species *Euglena sp., Volvox sp., Cladophora sp., Spirogyra sp., Closterium sp., Ulothrix sp. Bacillaria sp., Cyclotella sp., Pinnularia sp., Navicula sp., Gomphonema sp.*, and *Pleurosigma sp.* are members of the family Bacillariophyta, while *Anbaena sp., Oscillatoria sp., Microcystis sp*., and *Nostoc sp*. are members of the family Cyano Chlorophyta are the most frequently encountered during the study period, followed by Bacillariophyta and Cyanophyta. Here, Navicula species are more prevalent than Euglena species and Anbaena species. *Cladophora sp., Spirogyra sp*., and *Bacillaria sp.* are sporadic species found in 2021 [14]. Because of the substantial amount of nutrients provided by land runoff water during the post-monsoon season across the entire study period, we discover that phytoplankton production increases at this time [15]. We discovered a total of 18 zooplanktons during the study period. The species of zooplankton that were seen at station 1 are listed in (Table 7). Here, there is significant seasonal variance. Only during one season are certain species in great abundance. The monsoon season is when you can mostly find *Acrocalanus sp., Amphorellopsis sp., Clausocalanus sp., Candacia sp., Ctenocalanus sp.*, and *Euchaeta sp*. Some species, such as veliger larvae, *Eutintinnus species*, and *Leprotinnus species*, are only present during the winter. There are several species that can be found all year round, including *Tintinnopsis sp., Favella sp*., Copepod nauplii, and *Paracalanus sp*. [16]. Some species, such as *Microsetella sp*., can be found both in the summer and the winter. Copepod nauplii are abounding here all year round.

Table 13 Season wise available fishes at station l in the year 2019 to 2021

Seasonal availability of fish by Mean volume (%) of fish per sampling from station -l												
S. No.	Species name	Summer				Monsoon				Winter			
		19	20	21	Mean	19	20	21	Mean	19	20	21	Mean
1.	*Harpodon nehereous* (Babla)	12	13	14	13	7	6	6	6.3	7	9	8	8
2.	*Johnous sina* (Bhola)	6	6	7	6.3	6	7	5	6	5	5	3	4.3
3.	*Coilia dussumieri* (Ruli)	7	7	6	6.6	6	7	6	6.3	4	4	2	3.3
4.	*Thryssapolybranchialis* (Tapra)	0	0	0	0	1	1	2	1.3	11	11	10	10.6
5.	*Trichirus lepturus* (Patiya)	2	4	3	3	5	4	4	4.3	13	14	12	13
6.	*Eleutheronema tetradactulum* (Karua)	10	12	13	11.6	5	6	5	5.3	2	1	1	1.3
7.	*Hilsa toli* (Chandani)	0	1	0	0.3	8	8	7	7.6	1	0	0	0.3
8.	*Chirocentrous nedus*	0	0	0	0	3	3	4	3.3	8	7	10	8.3
9.	*Mugil cephalus* (Khosla)	4	3	4	3.6	4	4	5	4.3	8	8	6	7.3
10.	*Rastrelliger kanagurta* (Patal)	6	6	7	6.3	0	0	0	0	1	1	3	1.6
11.	*Setipinna phasa (Fesa)*	2	4	3	3	3	3	4	3.3	1	1	1	1
12.	*Polynemus paradiseus* (Tupsi)	1	2	5	2.6	0	1	1	0.6	6	9	11	8.6
13.	*Pampus argenteus* (White pomfret)	5	3	6	4.6	6	5	7	6	1	1	3	1.6
14.	*Pampus chinensis* (Chinese silver pomfret)	0	0	0	0	8	8	7	7.6	2	1	2	1.6
15.	*Parastromateus niger* (Black pomfret)	6	7	5	6	3	5	3	3.6	0	1	1	0.6
16.	*Scatophagus* sp. (Bhajatali)	0	1	2	1	5	2	4	3.6	1	1	0	0.6
17.	*Hilsa ilisha* (Ilish)	0	0	0	0	6	8	6	6.6	1	0	0	0.3
18.	*Rhinomugil corsula* (Kanua)	8	9	6	7.6	3	2	2	2.3	3	4	3	3.3
19.	*Llisha elongate* (Damrachokhiya)	0	0	0	0	4	5	5	4.6	3	4	4	3.6
20.	*Otolithes birutas* (Silamuri)	5	3	4	4	7	6	6	6.3	8	5	9	7.3
21.	*Sardinella tawilis* (Hurhuri)	0	1	3	1.3	3	4	3	3.3	2	3	4	3
22.	*Arius caelatus* (Small nonatangra)	3	3	3	3	1	1	2	1.3	6	4	3	4.3
23.	*Arius thalassinus* (Large non tangra)	3	6	5	4.6	2	0	1	1	3	3	2	2.6
24.	*Cyanoglossus* sp. (Flat fish)	3	2	5	3.3	1	1	2	1.3	1	1	0	0.6
25.	*Terapon jarbua* (Kunkuni)	5	5	7	5.6	2	2	1	1.6	0	0	1	0.3
26.	Others	2	2	2	2	1	1	2	1.3	2	2	1	1.6

Table 14 Season wise available fishes at station ll in the year 2019 to 2021

Seasonal availability of fish by Mean volume (%) of fish per sampling from station -ll													
S. No.	Species name	Summer				Monsoon				Winter			
		19	20	21	Mean	19	20	21	Mean	19	20	21	Mean
1.	*Harpodon nehereous* (Babla)	11	13	12	12	7	6	7	6.6	7	7	8	7.3
2.	*Johnous sina* (Bhola)	8	6	7	7	6	6	5	5.6	5	4	3	4
3.	*Coilia dussumieri* (Ruli)	9	8	6	7.6	6	7	5	6	3	3	2	2.6
4.	*Thryssapolybranchialis* (Tapra)	0	0	0	0	2	1	2	1.6	10	11	12	11
5.	*Trichirus lepturus* (Patiya)	2	3	3	2.6	5	3	4	4	13	13	12	12.6
6.	*Eleutheronema tetradactulum* (Karua)	14	13	13	13.3	5	4	5	4.6	2	1	0	1
7.	*Hilsa toli* (Chandani)	0	1	0	0.3	8	8	7	7.6	3	0	0	1
8.	*Chirocentrous nedus*	0	0	0	0	3	4	4	3.6	8	7	10	8.3
9.	*Mugil cephalus* (Khosla)	6	4	4	4.6	4	3	5	4	8	8	5	7
10.	*Rastrelliger kanagurta* (Patal)	5	6	7	6	0	0	0	0	1	2	3	2
11.	*Setipinna phasa (Fesa)*	2	3	3	2.6	3	4	4	3.6	1	1	2	1.3
12.	*Polynemus paradiseus* (Tupsi)	2	2	5	3	0	2	1	1	6	9	12	9
13.	*Pampus argenteus* (White pomfret)	3	5	3	3.6	6	7	7	6.6	1	2	3	2
14.	*Pampus chinensis* (Chinese silver pomfret)	0	0	0	0	8	7	7	7.3	3	3	2	2.6
15.	*Parastromateus niger* (Black pomfret)	6	4	4	4.6	4	3	3	3.3	0	0	1	0.3
16.	*Scatophagus* sp. (Bhajatali)	0	1	1	0.6	3	3	4	3	1	2	0	1
17.	*Hilsa ilisha* (Ilish)	0	0	0	0	6	7	6	6.3	1	0	0	0.3
18.	*Rhinomugil corsula* (Kanua)	9	7	7	7.6	3	3	2	2.6	3	3	3	3
19.	*Llisha elongate* (Damrachokhiya)	0	0	0	0	4	4	5	4.3	2	4	4	3.3
20.	*Otolithes birutas* (Silamuri)	3	4	4	3.6	7	8	6	7	8	7	9	8
21.	*Sardinella tawilis* (Hurhuri)	0	1	3	13	3	4	3	3.3	2	3	4	3
22.	*Arius caelatus* (Small nonatangra)	4	3	3	3.3	1	2	2	1.6	6	5	3	4.6
23.	*Arius thalassinus* (Large non tangra)	5	7	5	5.6	2	1	2	1.6	3	4	4	3.6
24.	*Cyanoglossus* sp. (Flat fish)	3	1	1	1.6	1	2	2	1.6	1	0	1	0.6
25.	*Terapon jarbua* (Kunkuni)	6	7	7	6.6	2	1	1	1.3	0	0	1	0.3
26.	Others	2	1	2	1.6	1	2	1	1.3	2	1	1	1.3

Table 15 Season wise available fishes at station lll in the year 2019 to 2021

Seasonal availability of fish by mean volume (%) of fish per sampling from station -lll													
S. No.	Species name	Summer				Monsoon				Winter			
		19	20	21	Mean	19	20	21	Mean	19	20	21	Mean
1.	*Harpodon nehereous* (Babla)	13	11	12	12	6	8	7	7	7	9	8	8
2.	*Johnous sina* (Bhola)	6	5	7	6	7	4	5	5.3	5	6	3	4.6
3.	*Coilia dussumieri* (Ruli)	9	7	6	7.3	6	8	5	6.3	3	1	2	2
4.	*Thryssapolybranchialis* (Tapra)	0	0	0	0	1	1	2	1.3	10	7	9	8.6
5.	*Trichirus lepturus* (Patiya)	2	4	3	3	5	2	4	3.6	13	11	12	12
6.	*Eleutheronema tetradactulum* (Karua)	14	12	13	13	5	3	5	4.3	2	3	0	1.6
7.	*Hilsa toli* (Chandani)	0	0	0	0	8	3	7	6	3	1	0	1.3
8.	*Chirocentrous nedus*	0	0	0	0	3	2	4	3	8	5	6	6.3
9.	*Mugil cephalus* (Khosla)	3	3	4	3.3	4	2	5	3.6	8	3	5	5.3
10.	*Rastrelliger kanagurta* (Patal)	5	8	7	6.6	0	0	0	0	1	1	3	1.6
11.	*Setipinna phasa (Fesa)*	4	2	3	3	3	5	4	4	1	1	2	1.3
12.	*Polynemus paradiseus* (Tupsi)	2	1	5	2.6	0	2	1	1	8	6	12	8.6
13.	*Pampus argenteus* (White pomfret)	3	5	4	4	4	3	7	4.6	2	2	3	2.3
14.	*Pampus chinensis* (Chinese silver pomfret)	0	0	0	0	5	6	6	5.6	3	3	2	2.6
15.	*Parastromateus niger* (Black pomfret)	6	5	4	5	5	3	3	3.6	0	1	1	0.6
16.	*Scatophagus* sp. (Bhajatali)	0	1	2	1	3	2	4	3	1	1	0	0.6
17.	*Hilsa ilisha* (Ilish)	0	0	0	0	4	4	6	4.6	1	0	0	0.3
18.	*Rhinomugil corsula* (Kanua)	8	7	5	6.6	3	4	2	3	3	5	3	3.6
19.	*Llisha elongate* (Damrachokhiya)	0	0	1	0.3	4	6	5	5	2	3	4	3
20.	*Otolithes birutas* (Silamuri)	5	2	4	3.6	5	9	6	6.6	8	5	9	7.3
21.	*Sardinella tawilis* (Hurhuri)	0	1	3	1.3	3	4	3	3.3	2	3	4	3
22.	*Arius caelatus* (Small nonatangra)	4	2	1	2.3	1	2	2	1.6	6	4	3	4.3
23.	*Arius thalassinus* (Large non tangra)	5	7	6	6	2	1	2	1.6	3	5	4	4
24.	*Cyanoglossus* sp. (Flat fish)	3	1	1	1.6	1	2	2	1.6	1	0	2	1
25.	*Terapon jarbua* (Kunkuni)	6	5	7	6	2	1	2	1.6	0	0	1	0.3
26.	Others	2	1	2	1.6	1	2	1	1.3	2	2	1	1.6

Table 16 Shannons-Weiner and Simpson Index in different seasons at station-l (Petuaghat)

S. No	Seasons	Shannons-weiner Index		Simpson Index
		(H)	(E)	
1.	Summer Season	2.836801	0.870693	0.941235
2.	Monsoon Season	3.055805	0.937911	0.957666
3.	Winter Season	2.863914	0.879015	0.939012

*H = Shannon-weiner index, E = Evenness, D = Simpson Index

Table 17 Shannons-Weiner and Simpson Index in different seasons at station-ll (Junput)

S. No	Seasons	Shannons-weiner Index		Simpson Index
		(H)	(E)	
1.	Summer Season	2.801847	0.859964	0.938025
2.	Monsoon Season	3.07801	0.944727	0.958781
3.	Winter Season	2.887071	0.886122	0.940701

*H = Shannon-weiner index, E = Evenness, D = Simpson Index

Table18 Shannons-Weiner and Simpson Index in different seasons at station-lll (Sankarpur)

S. No	Seasons	Shannons-weiner Index		Simpson Index
		(H)	(E)	
1.	Summer Season	2.806493	0.86139	0.938195
2.	Monsoon Season	3.098787	0.951104	0.961217
3.	Winter Season	2.941073	0.902697	0.945669

*H = Shannon-weiner index, E = Evenness, D = Simpson Index

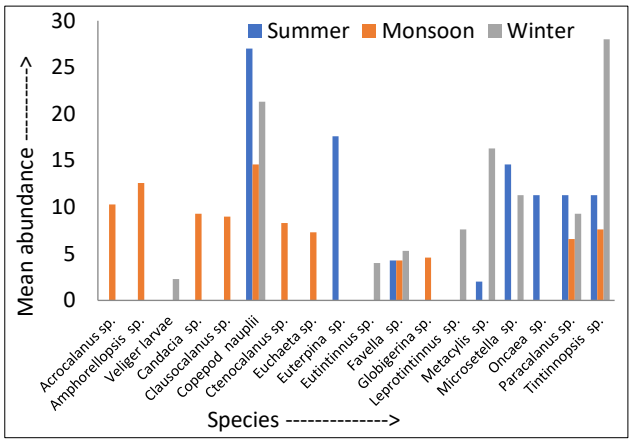

Fig 5 Zooplankton abundance in the summer, monsoon and winter season at Junput station

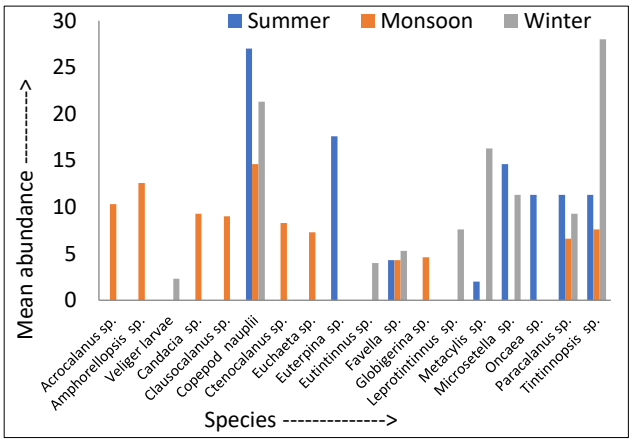

Fig 6 Zooplankton abundance in the summer, monsoon and winter season at Sankarpur station

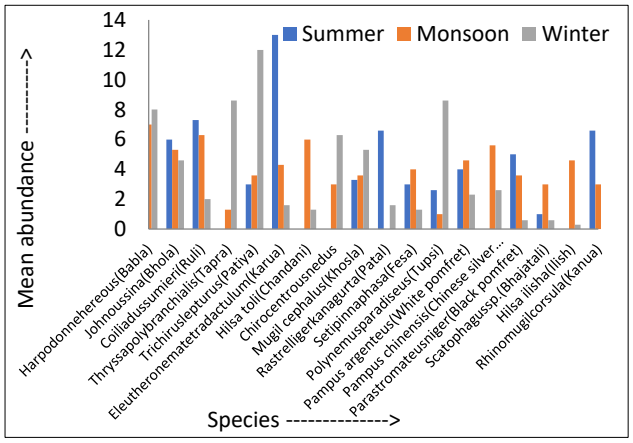

Fig 7 Fish abundance in the summer, monsoon and winter season at Petuaghat station

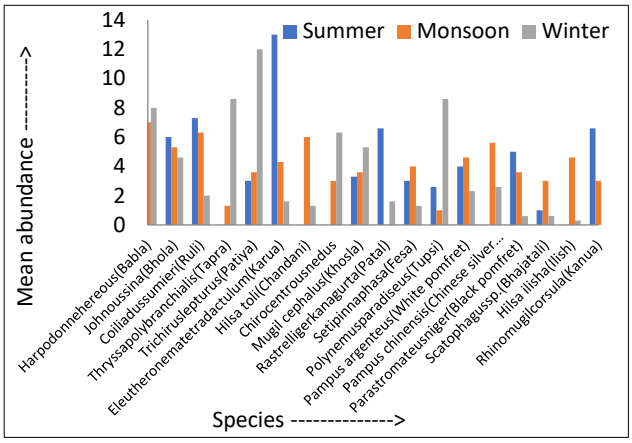

Fig 8 Fish abundance in the summer, monsoon and winter season at Junput station

In our study period we find total 18 zooplanktons. In station-II the recorded zooplanktons species are given in (Table 8). Here heavily seasonal variation occurs. Some species are abundantly found only in one season. *Acrocalanus* sp., *Amphorellopsis* sp., *Clausocalanus* sp., *Candacia* sp., *Ctenocalanus* sp., *Euchaeta* sp., are found mainly in monsoon season. Some species like Veligerlarvae, *Eutintinnus* sp. *Leprotintinnus* sp. are found only winter season. Some species like *Tintinnopsis* sp. *Favella* sp., Copepodnauplii, *Paracalanus* sp., found throughout the year [16]. Some species like *Microsetella* sp., are found in summer and winter season. Here Copepodnauplii are found abundantly all-round the year. In our

study period we find total 18 zooplanktons in station-III, the recorded zooplanktons species are given in (Table 9). Here heavily seasonal variation occurs. Some species are abundantly found only in one season. *Acrocalanus* sp., *Amphorellopsis* sp., *Clausocalanus* sp., *Candacia* sp., *Ctenocalanus* sp., *Euchaeta* sp., are found mainly in monsoon season. Some species like Veliger larvae, *Eutintinnus* sp., *Leprotintinnus* sp. are found only winter season. Some species like *Tintinnopsis* sp. *Favella* sp., Copepodnauplii, *Paracalanus* sp., found throughout the year [16]. Some species like *Microsetella* sp., are found in summer and winter seasons. Here Copepodnauplii are found abundantly all-round the year. The abundant and common species of fish recorded during the study period at station-l are presented in (Table 13). Totally 25 fish species belong to 9 orders. In winter season the fish production was highest after those in monsoon and summer. *Harpodon nehereus* locally known as Babla is most abundant throughout the year, after that *Eleutheronema tetradactylum* locally known as (Karua) *Rhinomugil corsula* locally known as Kanua, are abundant. In monsoon season *Hilsa toil* locally known as Chandani (7.6±0.5%) and *Hilsailisha* commonly known Ilish (6.6±0.9%) are found in good number. The abundant and common species of fish recorded during the study period at station-II are presented in (Table 14). Totally 25 fish species belong to 9 orders. In winter season the fish production is the highest after those in monsoon and summer. *Harpodon nehereus* locally known as Babla is most abundant throughout the year. *Eleutheronema tetradactylum* locally known as Karua are abundant in summer season and *Rhinomugil corsula* locally known as Kanua are abundant throughout the year. In monsoon season *Hilsa toil* locally known as Chandani (7.6±0.5) and *Hilsa ilisha* commonly known Ilish (6.3±0.5) are found in good numbers. The abundant and common species of fish recorded during the study period at Station-III are presented in (Table 15). Totally 25 fish species belong to 9 orders. In winter season the fish production was the highest after those in monsoon and summer [17-20]. *Harpodon nehereus* locally known as Babla is most abundant in round of the year. *Eleutheronema tetradactylum* locally known as Karua are abundant in summer season and *Rhinomugil corsula* locally known as Kanuaare abundant in year-round. In monsoon season *Hilsa toil* locally known Chandani (7.6±0.5) and *Hilsa ilisha* commonly known Ilish (6.3±0.5) are found in good numbers. In winter *Thryssa polybranchialis* (8.6±1.2) and *Trichiurus lepturus* (12±0.8) found in large numbers [21-22].

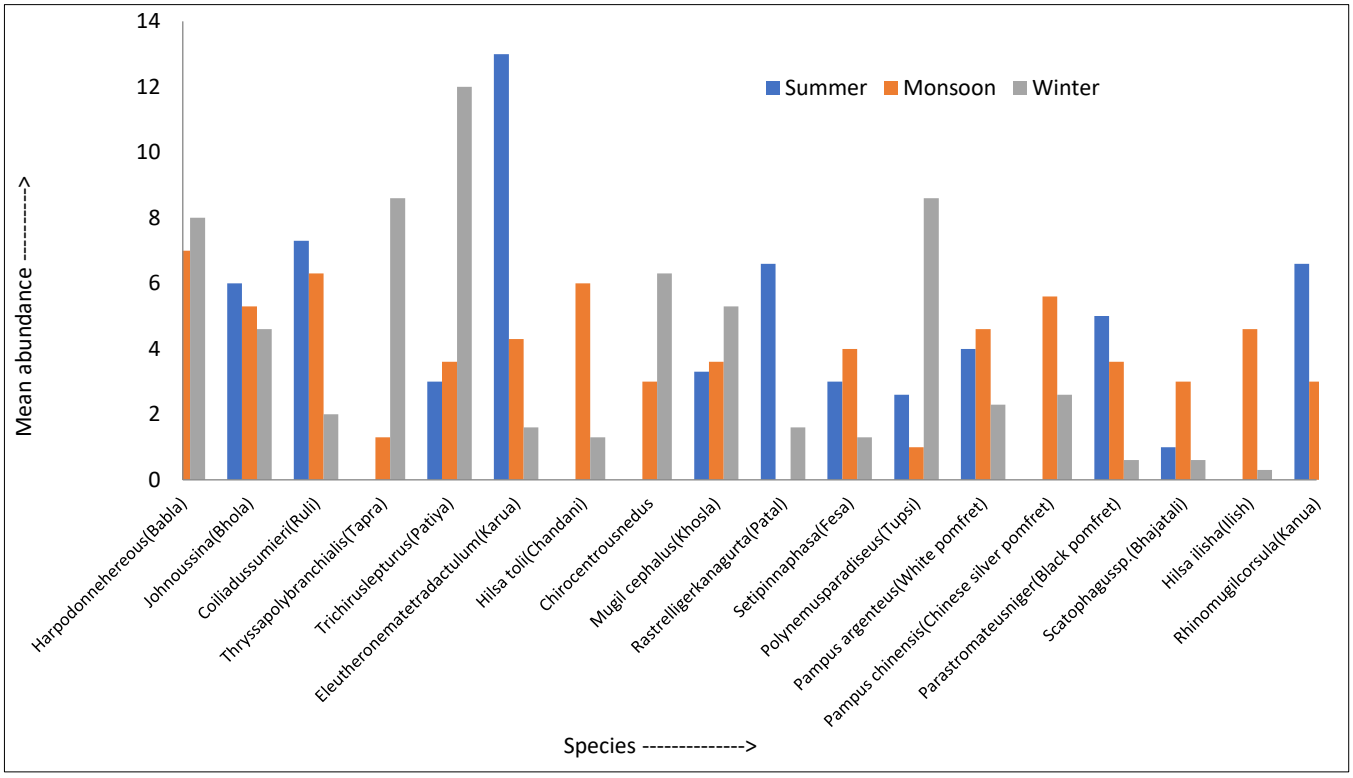

Fig 9 Fish abundance in the summer, monsoon and winter season at Sankarpur station

CONCLUSION

There is a clear seasonal pattern in the variety of phytoplankton found at the three study sites, with the greatest diversity appearing during the winter months, followed by the monsoon and the summer. *Euglena sp.* is the most common plant. The Shannon-weiner and Simpson indices exhibit the most fluctuation from station to station and from season to season, with the highest index of abundance occurring during the winter. Three separate sites exhibit seasonal differences in zooplankton availability, with winter having the greatest variety of zooplankton species available, followed by the monsoon and summer. Copepod nauplii are the most numerous species. The Shannon-weiner-Simpson index shows no statistically significant differences between the three locations. It's clear from looking at data from three distinct sites that the abundance of fish species varies greatly from one to the next, with winter having the greatest variety of species available, followed by the monsoon and summer. *Harpodon nehereus* is the most common variety. The Shannon-weiner and Simpson indices exhibit the most fluctuation from station to station and from season to season, with the highest index of abundance occurring during the winter. There appears to be a fundamental difference in the mechanisms that drive habitat choice, as seen by the varying vertical fish distributions found between seasons and years. The coastal sections of Digha cost are characterized by seasonal changes in water temperatures, the formation and destruction of a thermocline, and the cultivation of various foods.

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