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Relationship Between Biological Parameters and Fish Catch Ratio of *Rutilus kutum* Kamensky, 1901 and *Cyprinus carpio* in the Southeast of the Caspian Sea (Mazandaran-Goharbaran)

Mohammadali Afraei Bandpei*, Aboulghasem Roohi, Hassan Nasrollahzadeh Saravi, Nourbakhsh Khodaparast, Reza Daryanabard, Asieh Makhlogh, Fatemeh Tahami, Mojgan Rowshantabari, Abdolah Hashemian, Alireza Keihansani

Caspian Sea Ecology Research Center, Iranian Fisheries Science Research Institute, Agricultural Research Education and Extension Organization (AREEO), Sari, Iran

Email address:
mafraei@yahoo.com (M. A. Bandpei)
*Corresponding author

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Abstract: This study was conducted in the southeastern part of the Caspian Sea in Mazandaran (Goharbaran) from a project [#4-76-12-95101] during 2013 -2014. Samples were collected monthly at 8 stations. The aim of this study was to evaluate the density and biomass of biological parameters at different months and their relationships with fish catch ratio such as *Cyprinus carpio* and *Rutilus kutum* Kamensky, 1901. Overall, 157 species of phytoplankton were identified which belonged to 8 phyla among them Bacillariophyta comprised to 48% of the highest species frequency. A total of 11 species of zooplankton, and 24 species of macrobenthos were found. There was a significant differences between density and biomass of biological parameters at different stations ($p<0.05$). The results showed that the density of phytoplankton in winter was the highest value at all stations. In contrast, the density of zooplankton decreased at the same time. This could be due to the lack of grazing animal *e.g.* zooplankton which grazing on phytoplankton. Based on Principal component analysis (PCA) the maximum value of similarity coefficient for *C. carpio* were in November and December (0.997) and for *R. kutum* Kamensky, 1901 in February and April (0.998), respectively. This could be due to the data of sampling stations which located to the inshore water and the substrate feeding behavior of carp and approaching the spawning season and spend the reproductive period in the river for Kutum.

Keywords: Plankton, Macrobenthos, Carp, Kutum, Caspian Sea, Iran

1. Introduction

The Caspian Sea is famous for possessing valuable species of sturgeon and bony fishes which assume for more economical and ecological importance [18]. Compared to the open sea, fish fauna of the Caspian Sea is less due to its small size but more resources which is extremely vulnerable [31]. There are about 123 species and subspecies in the Caspian Sea and its adherents waters that has fishes which belong to 53 genera and 17 families [53]. Among them, Cyprinidae fish account for about 40 percent and Kutum *(R. kutum* Kamensky, 1901) alone, more than 50 percent of bony fish catch in the Caspian Sea that comprise more than 90 percent of the fishermen income. Common carp (*Cyprinus carpio*) is also economically valuable species fish and consist the third place of fish catch in Guilan and Mazandaran provinces and also the first rank in fishermen income in Golestan province [8, 10, 17, 20]. Since the Caspian Sea ecosystem was changed consistently in recent years due to some reasons such as the comb jelly

(*Mnemiopsis leidyi* Agassiz, 1865) invasion [12, 30, 35, 36, 38] and also some changes in zooplankton biodiversity, introduction of exotic species e.g. *Acartia tonsa* that we noticed a reduction in the number of zooplankton species from 75 species in 1996 to less than 20 species in 2012 [28, 40] and the presence of some toxic and harmful species of phytoplankton [33], the presence of some non-native fish like anchovies (*Hemiculter leucisculus*) and Gastroidae fish [2], dominance of some macrobentic such as *Streblospio gynobranchiata* after the jelly fish introduction as a non-native species [27, 43]. These all changes can affect the ecosystem of the Caspian Sea because in recent years the sea was witnessed with high volatility in catch of bony fish, sturgeon and Clupeidae. All would be due to the presence of non-native species and their impact on the fish population. Fishing off the coast of the Caspian Sea such as Kilka shows that during the years 1992 to 1999, its catch increased to its highest level (85 and 95 thousand tonnes) in 1998 and 1999, but after the arrival of invasive species *M. leidyi* the catch of Caspian Kilka dropped sharply in 2000 and 2003 to 15 thousand tonnes [21]. However, phytoplankton and zooplankton communities are primary producers and also consumers, respectively, but nowadays a non-native species *M. leidyi* was introduced into the Caspian Sea which changes the ecosystem biodiversity which monitoring study, distribution, density and biomass of phytoplankton and zooplankton and the comb jelly seems necessary. At the southern shores of the Caspian Sea, feeding behavior of fish are different, *e.g.* detrivorous behavior in Mullet fish, Planktivorous feeding in the Clupeidae, carnivorous in Kutum, and Omnivorous in common Carp [4]. Therefore, aware of the relationship between the density, distribution of fishes and environmental parameters including plankton and macrobentic groups are very important. On the other hand, to be aware of the benthic invertebrates, phytoplankton and zooplankton and comb jelly to determine the density and biomass of different of them in stations and months and also to study the relationship between environmental parameters as well as their relationship with the Kutum and Carp are necessary. In fact, the aim of this study was to evaluate the density and biomass of biological parameters at different months and also their interrelations with Kutum and Carp fishes.

2. Material and Methods

This study was conducted in the southeastern part of the Caspian Sea in Mazandaran (Goharbaran) and was based on the data from a project [#4-76-12-95101] during 2013 -2014. Samples were collected at 8 stations, four stations at a depth of 5 m (#1-4), two stations at a depth of 10 m (#5-6) and two stations at a depth of 15 m (#7-8). Sampling was conducted monthly from May 2013 to April 2014. Phytoplankton was gathered by Ruttner water sampler [51].

Phytoplankton samples were collected with 0.5-L dark bottles from the surface waters and preserved using buffered formaldehyde at a final concentration of 2.5% [44]. Samples were concentrated to a volume of ~20 ml by the sedimentation method, after keeping the samples stagnant for at least two weeks. The microphytoplankton present in a subsample of 1 ml, taken from the ~20 ml sample, was counted using a Sedgwick–Rafter cell under a phase-contrast binocular microscope. For nanoplankton analysis, 0.01-ml subsamples were scanned on a slide. The volume of each cell was calculated by measuring its diameter, length and width. Volumes were converted to biomass assuming μm^3 to be equal to 1 pg. For species identification available identification phytoplankton keys were used [25, 26]. Phytoplankton weight was measured by their size and calculated using the geometric forms [25, 26, 34]. Then according to the geometric shape of the volume was calculated. Finally, with regard to the dilution factor, density and biomass were calculated in cubic meters [11].

Non-gelatinous zooplankton samples were taken using a Juday net (mesh size 100 µm, mouth opening 0.1 $m^{2)}$ from different layers (from bottom to 50 m, 50–20 m and 20 m to the surface) [52]. Samples were preserved with neutral formaldehyde with 4–5% final concentration for analyses in the laboratory. They were sub-sampled using a 1-ml Hensen–Stempel pipette and transferred to a Bogorov tray for counting. An inverted microscope was used for identification of non-gelatinous zooplankton. At least 100–150 individuals were counted per sample [16].

For Sampling of comb Jelly a plankton net with a mesh size of 500 µm with a diameter of 50 cm was used. Jelly comb and zooplankton samples were gathered at similar stations and layers [37]. Macrobenthos were collected with the Van veen Don Grab having a mouth opening of 0.1 m2; wash separately with seawater from the sieve with a diameter of 500µm mesh size net using sea water and immediately fixed to have a final neutral formaldehyde solution of ~10% for taxonomic analysis (until genus or species level) and enumeration under binocular microscope [14, 19, 49].

Biological parameters analysis such as Kutum (*R. kutum*) and common carp (*C. carpio*) were used based on commercial catch data belonged to the four Pareh-fishing (Beach seine) cooperatives such as: Jahannama, Shahid Ghorbani, Goharbaran and Noozarabad fish cooperatives [29]. Table 1 shows the geographical coordinates of stations and figure 1 shows the sampling area in southeast of the Caspian Sea in Mazandaran province.

Table 1. *Geographic coordinates of the stations and depth of sampling area.*

Geographic coordinates		Depth (m)	Stations
Longitude	Latitude		
53º15'15″	36º82'93″	5	1
53º18'08″	36º83'56″	5	2
53º21'27″	36º84'14″	5	3
53º24'56″	36º84'89″	5	4
53º17'66″	36º85'02″	10	5
53º24'14″	36º86'24″	10	6
53º17'26″	36º86'50″	15	7
53º 20'34″	36º87'02″	15	8

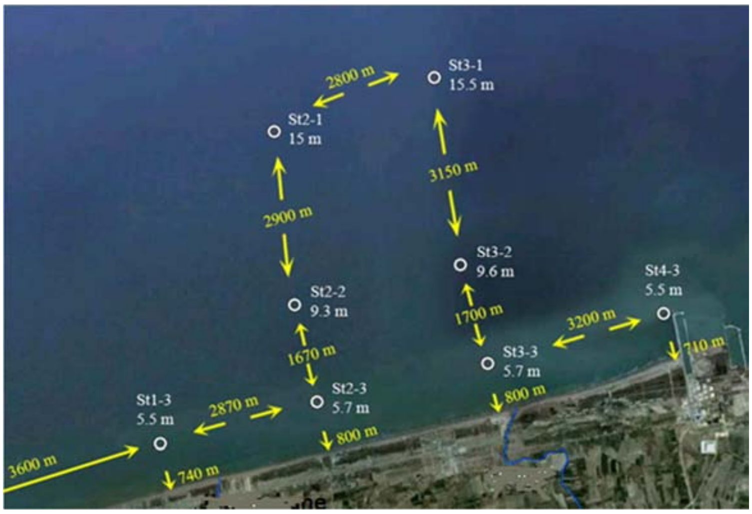


Figure 1. *Sampling area in the Southeast of the Caspian Sea (Mazandaran-Goharbaran).*

For statistical analysis, Excel and SPSS software were used for comparison test between means using analysis of variance (ANOVA) and all statistical tests were performed at the level of 5% [15]. MVSP software was used for the comparison of ecological relations of parameters.

3. Results

3.1. Phytoplankton

A total of 157 species of phytoplankton were determined which belonged to 8 phyla including Bacillariophyta (75 species), Cyanophyta (23 species), Pyrrophyta (26 species), Chlorophyta (19 species), Euglenophyta (10 species), and Chrysophyta, Chryptophyta and Haptophyta with 1, 1 and 2 species, respectively. The lowest and highest density belonged to Chryptophyta with 67000±5000 cell.m^{-3}, Chlorophyta with an average of 18751000±2441420 cell.m^{-3}, and the lowest and highest biomass of Chryptophyta with a mean of 0.02±0.03 mg.m^{-3} and Bacillariophyta of 35.64±1.65mg.m^{-3}, respectively (Figure 2). The density and biomass of phytoplankton among months and stations showed the highest density of 38000000±13455588cell.m^{-3} in February in the depth of 10 m (station #6) and the lowest was recorded with 10500±6004 cell.m^{-3} in January in the depth of 15m (station #7), respectively (Figure 3). The lowest biomass was reported with an average of 0.26±0.1mg.m^{3} for the month of July and the station #7and the depth of 15 M and the highest biomass with a mean of 177±1.5mg.m^{3}at the depth of 10 M in January in station #6 (Figure 3). According to Duncan test (ANOVA) the results showed that the density in different months could be divided into 5 groups: group 1 included early July, June, May and October, October and April in Group 2, Group 3 consisted of November, December, January, and September and in group 4 and group 5 were September - December and December – March, respectively. Also based on Duncan test the results showed that the biomass in various month were divided into 4 groups, the first group could be July, August, September and October, June, September and May in the group 2, the Group 3 included of April, October, November, December and January, and in Group 4 was only March. Data showed significant differences in terms of density and biomass at different months (p<0.05).

3.2. Zooplankton

A total of 4 holozooplankton included Copepoda, Cladocera, Protozoa and Rotifera and 2 mesozooplankton such as Bivalvia and Cirripedia were identified in whole study period. Generally, 11 species of zooplankton were identified that Copepoda *Acartia tonsa* was dominant with 72% of zooplankton population. The results showed that the highest density and biomass of Copepoda were 4281±149 ind.m^{-3} and 31.03±1.1mg.m^{-3}, respectively (Figure 4). Maximum density and biomass of Bivalvia were 584.2±214.5 ind.m^{-3} and 2.73±1.5 mg.m^{-3}. Copepoda *Acartia tonsa*, Cladocera *Podon polyphemoides*, Rotifera *Asplanchna priodonta* and Protozoa *Tentinopsis priodonta* were dominant zooplankton during the study period. The results showed the highest density and biomass was recorded in September and October, with an average of 16776±95.7 ind.m^{-3} in station 2 and 20.8±2.1 mg.m^{-3} in station 5, respectively (Figure 5). There was significant difference in terms of density at different stations (p<0.05). According to Duncan test (ANOVA) the results showed that the density at different months could be divided into 5 groups in which March, February, April and July in first group, February, April, July and December in second, group 3 included April, June, July, October, November, December and January, fourth group consisted of July, October, November, December, January and, May, finally May and September included in fifth group. There was also a significant difference between biomass in various stations (p<0.05). Duncan test (ANOVA) on biomass showed the same results as well as zooplankton density at different months, although the density and biomass of zooplankton in months of April to March showed a decreasing trend.

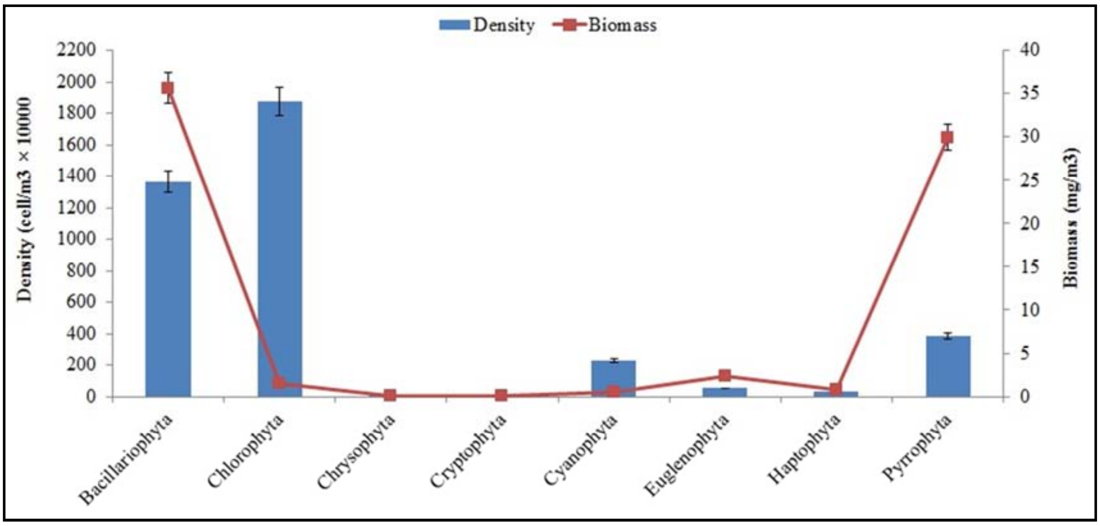
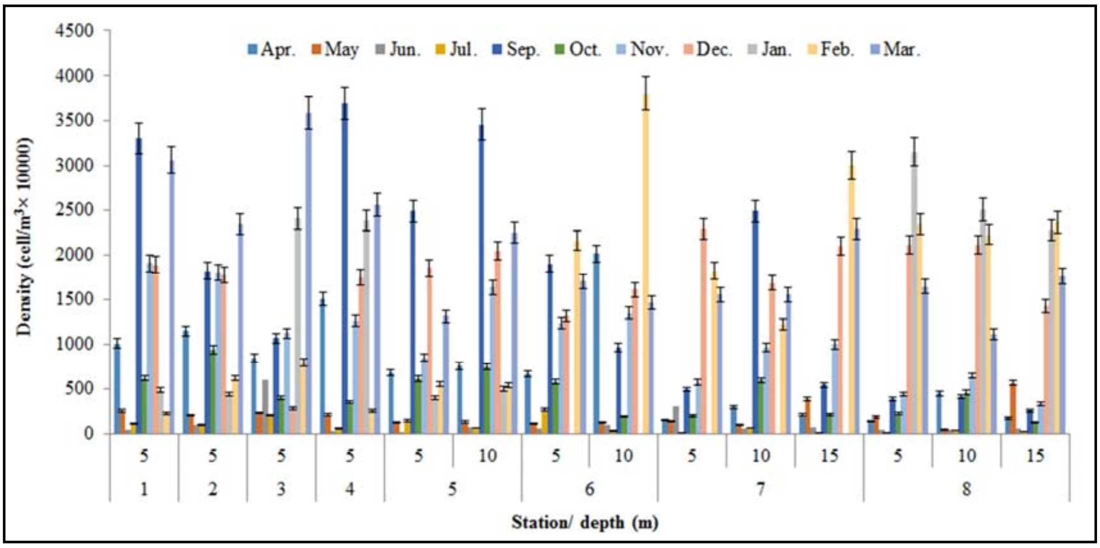


Figure 2. *Average changes of Phytoplankton density and biomass at different phyla in the southeast of the Caspian Sea (Mazandaran-Goharbaran).*



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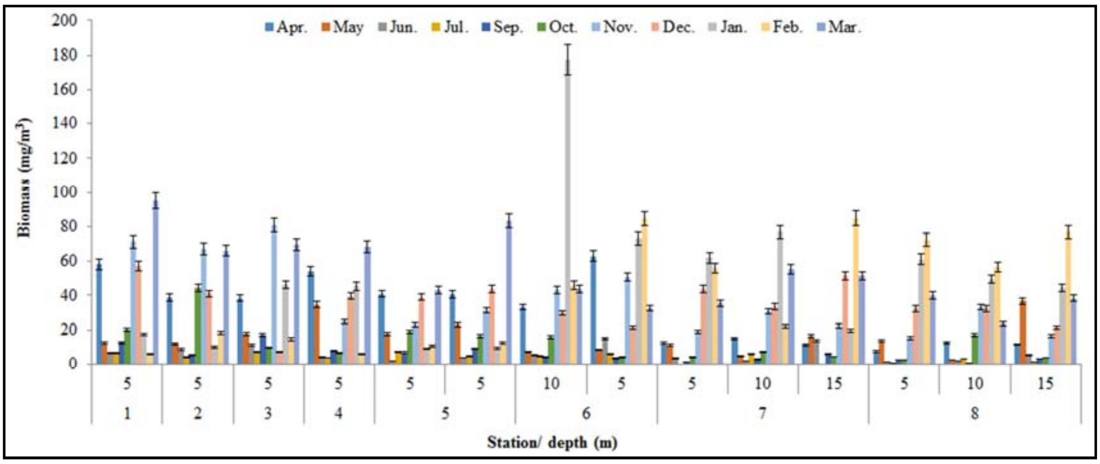

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Figure 3. *Monthly changes of Phytoplankton (A) density and (B) biomass at different stations and water column in the southeast of the Caspian Sea (Mazandaran-Goharbaran).*

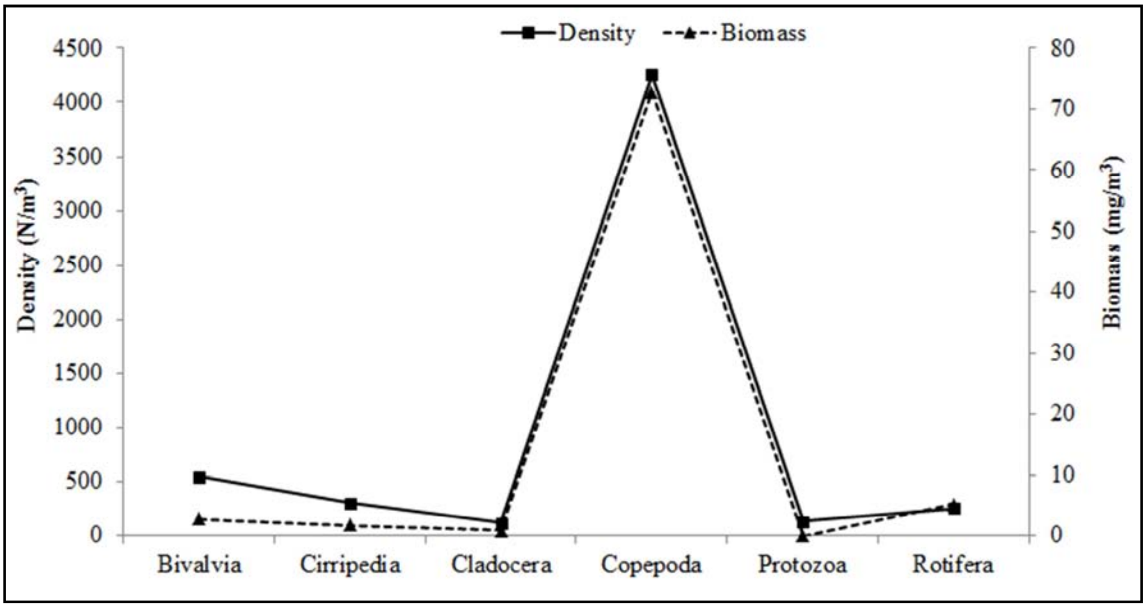
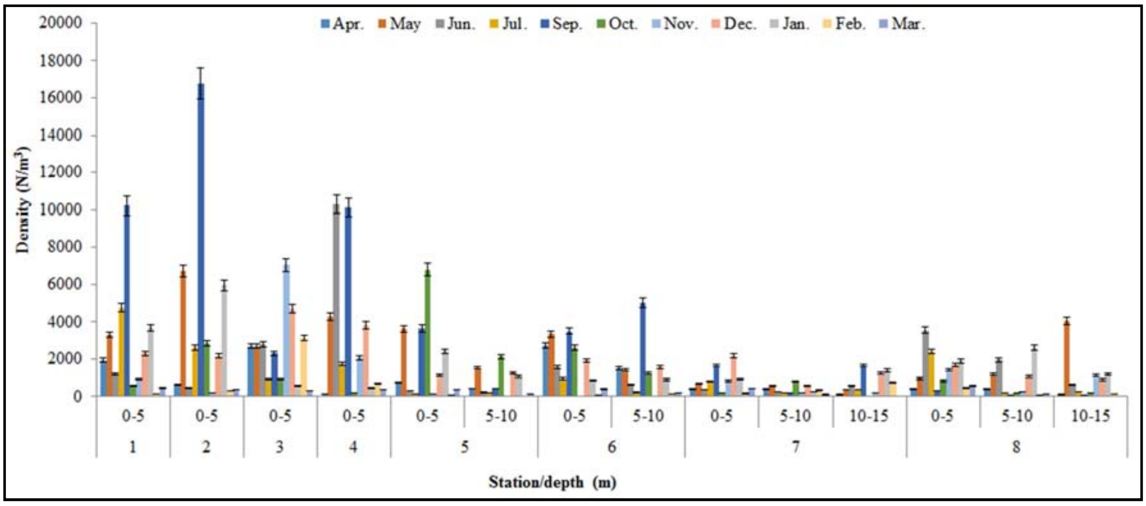


Figure 4. *Average density and biomass of Zooplankton in the southeast of the Caspian Sea (Mazandaran-Goharbaran).*



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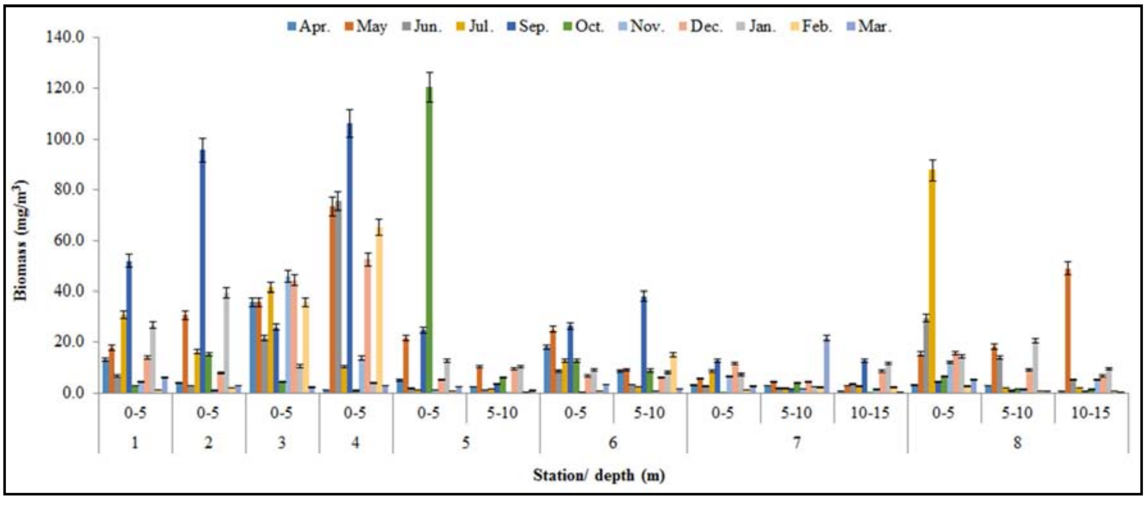


B

Figure 5. *Monthly changes of zooplankton (A) density and (B) biomass at different stations and water column in the southeast of the Caspian Sea (Mazandaran-Goharbaran).*

The density of phytoplankton and zooplankton in different seasons showed that relations between them have fluctuations in different stations (Figure 6). Phytoplankton had the highest density in winter at the all stations whereas zooplankton showed the lowest density except in 1 and 2 stations.

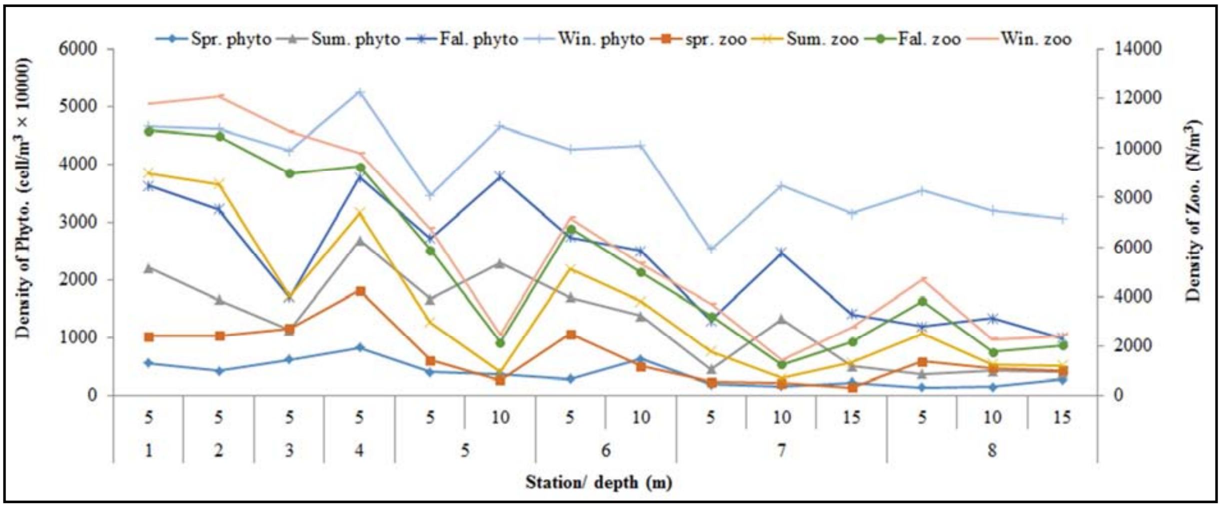
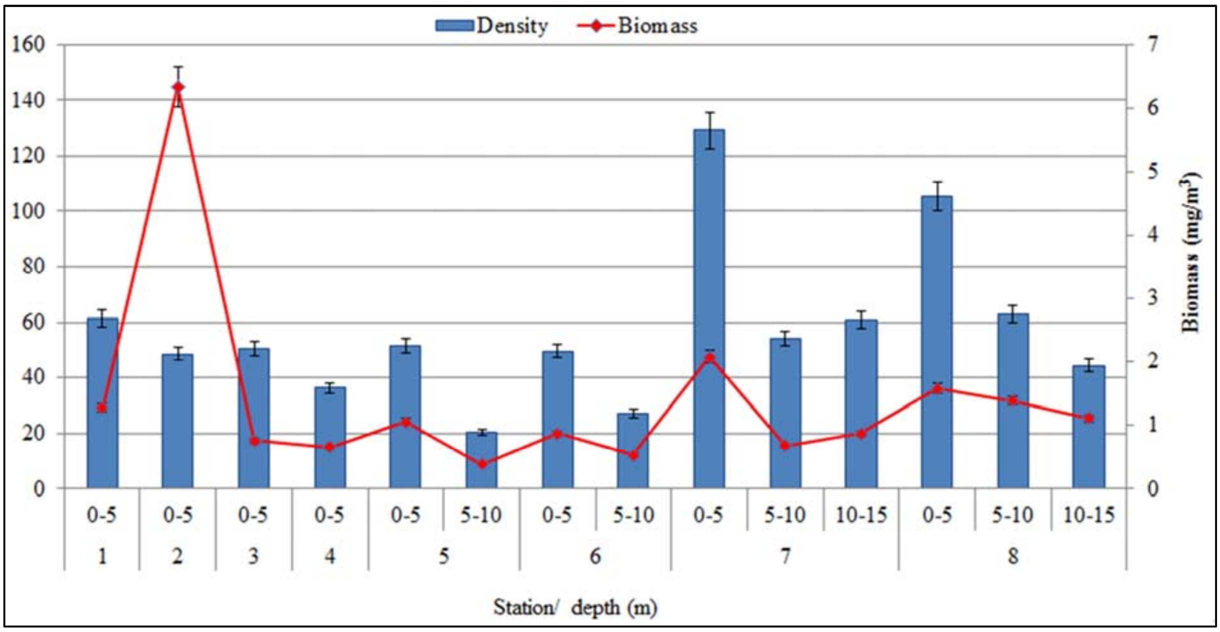


Figure 6. *Seasonally changes of phytoplankton and zooplankton density in different stations and water column in the southeast of the Caspian Sea (Mazandaran-Goharbaran).*

spr.phyto= spring phytoplankton; sum. phyto= summer phytoplankton; fal.phyto= fall phytoplankton; win. phyto= winter phytoplankton; spr.zoo=spring zooplankton; sum.zoo=summer zooplankton; fal.zoo=fall zooplankton; win.zoo= winter zooplankton

3.3. Comb Jelly (Mnemiopsis leidyi)

The *M. leidyi* density and biomass at different stations showed that the highest was recorded in 0-5 m with 129.1±48.5 ind.m^{-3} in station 7 and the highest biomass in station 2 with 6.4±5.1 mg.m^{-3}, respectively (Figure 7a). Significant differences were found in terms of *Mnemiopsis* density and biomass at different stations ($p<0.05$). The highest abundance of comb jelly was recorded in November with an average of 154.1±136.3 ind.m^{-3} and the lowest in January with 7.4±6.7 ind.m^{-3} (Figure 7b). maximum biomass of comb Jelly was measured in October with 4.7±1.5 mg.m^{-3} and the lowest in January with a mean 0.04±0.02 mg.m^{-3}. There was a significant difference between density and biomass in different months ($p<0.05$). By the Duncan test (ANOVA) the *M. leidyi* density at different months were divided into 3 groups: the first was seen in January, March, April, May, June, September, October, December and second group included June and October and the third group could be included of November and December.



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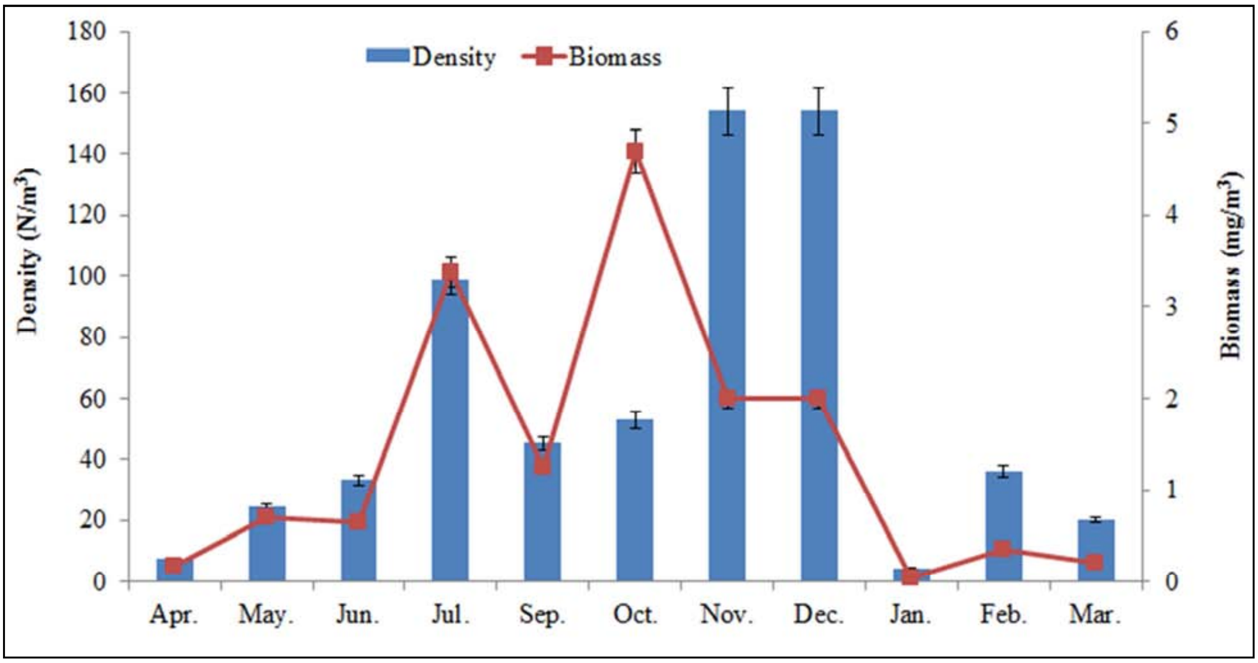


B

Figure 7. *Mean abundance and biomass of comb Jelly among months (B) and water column at different stations (A) of the southeast of the Caspian Sea (Mazandaran-Goharbaran).*

3.4. Macrobenthos

A total of 24 species were identified belonged to 4 classes including Polychaeta (4 species), Bivalvia (1 species), Crustacean (18 species) and Oligochaeta. The results showed that *Streblospio gynobranchiata* was the highest frequency with a mean of 1247±58.5 ind.m^2 in which crustacean consisted of 75% of species diversity and Polychaeta with 17% and other ranks each with 4% of species richness. There was fluctuations trend in benthic invertebrate density at different months. The results stated that the highest and lowest density of macrobenthos was recorded in April in station #5 with an average of 1680.3±689.3 ind.m^{-2} and December with 28.8±12.1 ind.m^{-2} in the station #8, respectively (Figure 8). Based on the comparative test between density in various months it was noticed that the lowest was in May with a mean 209±113 ind.m^{-2} and the highest in January with an average of 890±94 ind.m^{-2}. By Duncan test (ANOVA) the results on the density at different months showed that there were 4 groups: the first group includes May, July, September, December and the second group was noticed during March, July, October and the third group in February, March, April, June, October, December and the fourth group consisted of February, April, June, July, November. There was also significant difference between the density of benthic invertebrates at different month ($p<0.05$).

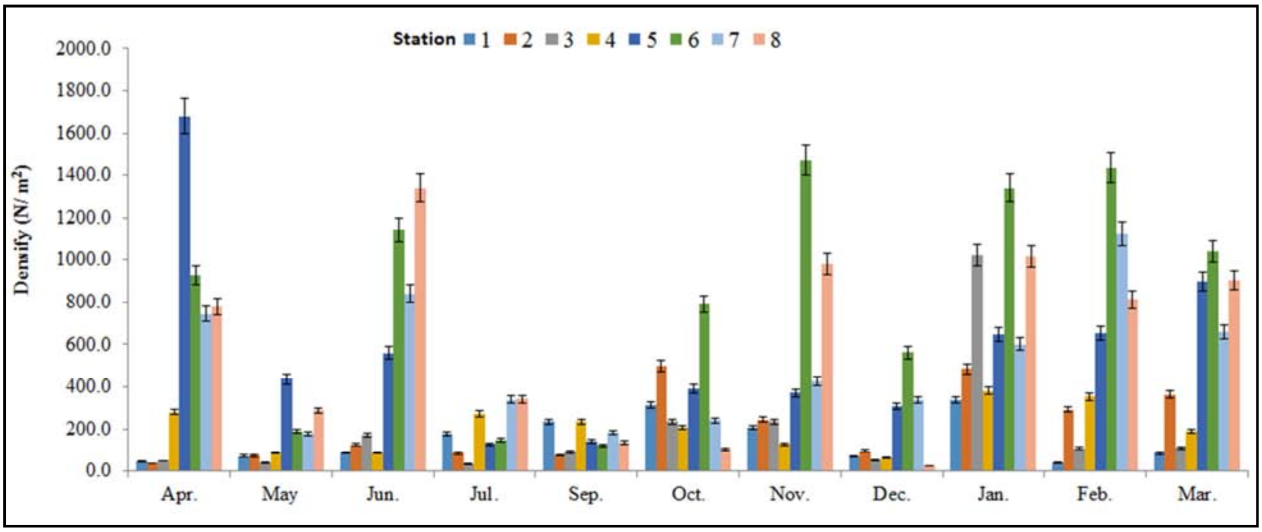
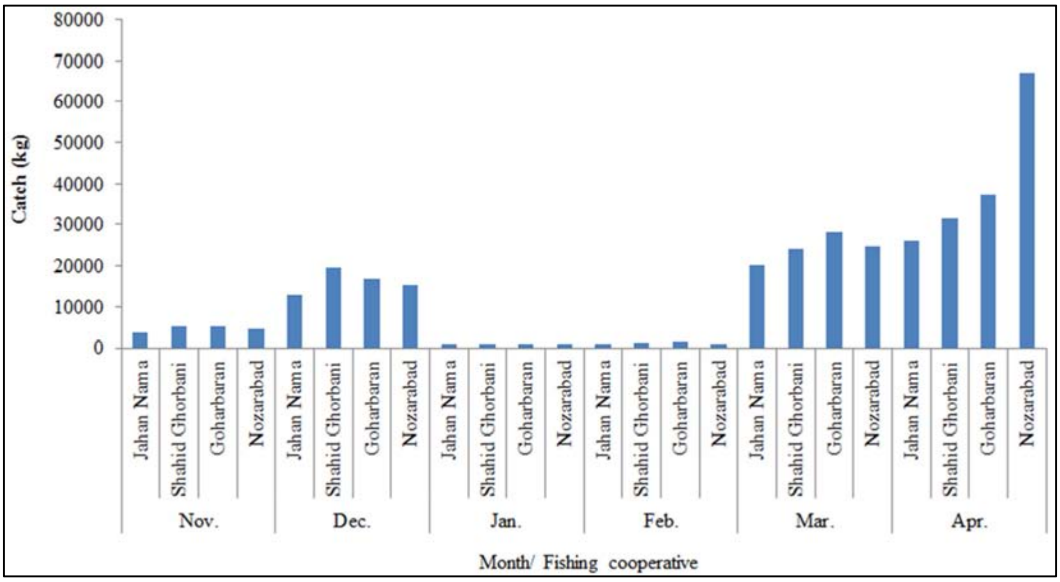


Figure 8. *Monthly changes of macrobenthos density at different stations in the southeast of the Caspian Sea (Mazandaran-Goharbaran).*

3.5. Fish

The results showed that the *R. kutu*m catch accounted for the highest rate in April with an average of 67142 kg in Nozarabad cooperative Co. and the lowest was in the Jahannama Co. in January with 784 kg (Figure 9a). There was a significant differences between Kutum catching at different months ($p<0.05$). The maximum and minimum catch ratio of common carp *Cyprinus carpio* was in October belonged to Nozarabad, though in February did not catch fish (Figure 9b) where it could be because of fish wintering and migrating toward the offshore depths. There was a significant differences between Carp catch at different months ($p<0.05$). Based on Principal Component Analysis (PCA) and comparison between kutum catch with other biological parameters it was revealed that the similarity coefficient Pearson test formed four groups, first included zooplankton-comb jelly; Phytoplankton in second class, third in class comprised to third class -Kutum and fourth class were Benthos and third class. Compare the catches of carp with other biological parameters based on PCA analysis revealed that the similarity coefficient of Pearson test was common at different months of the same Kutum that it would be because of migration of the fish and ecological niche (Figure 10).



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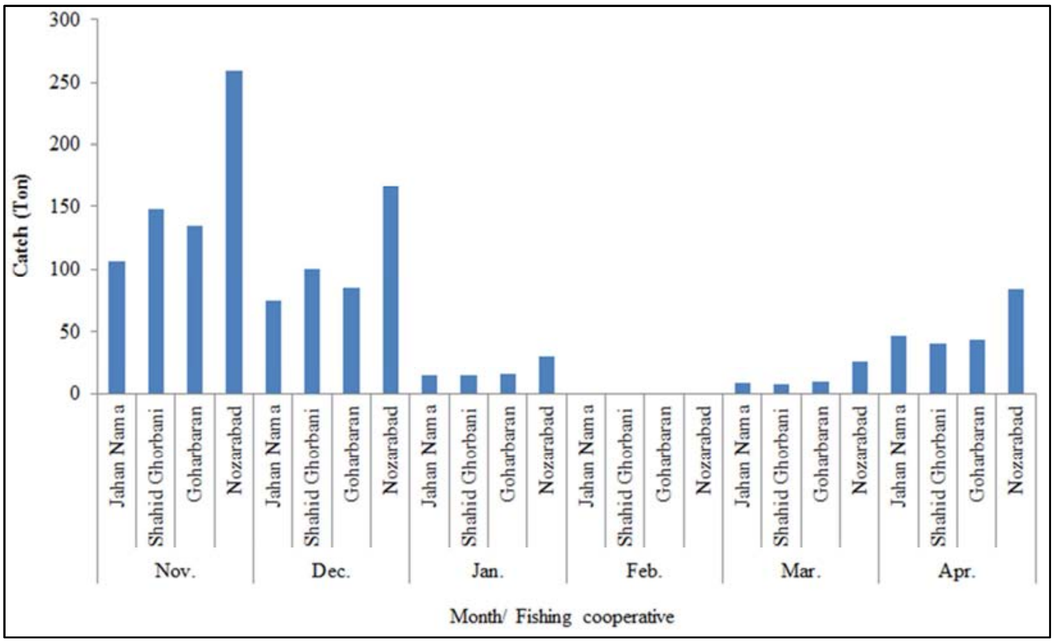
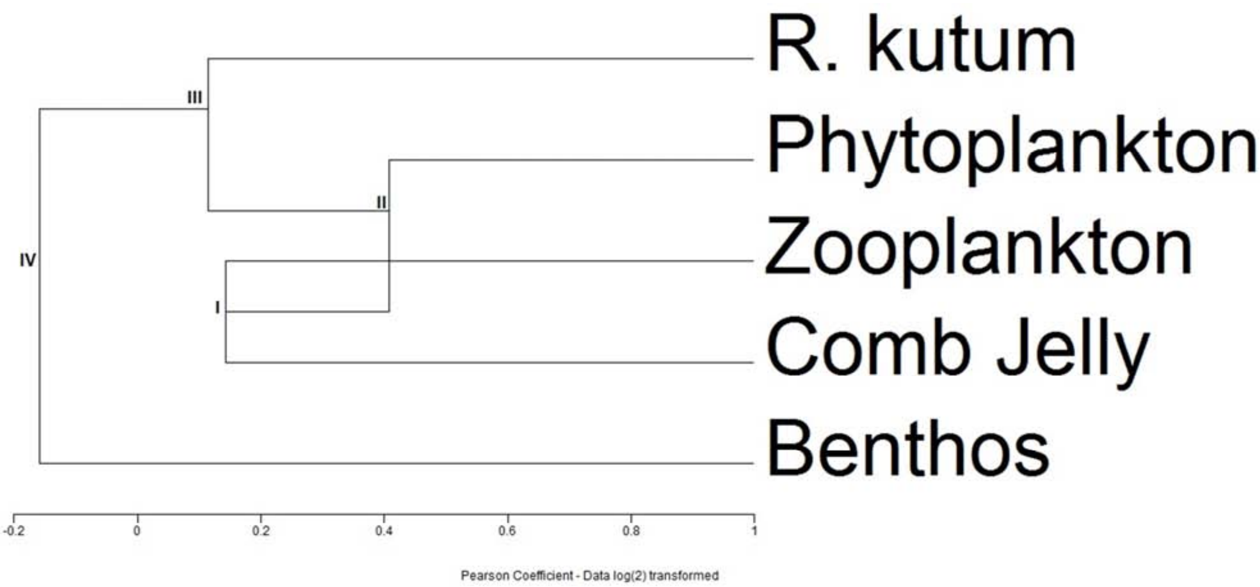


B

Figure 9. *Monthly catch of Rutilus kutum (A) and Cyprinus carpio (B) in different fishing cooperatives in the Southeast of the Caspian Sea (Mazandaran-Goharbaran).*



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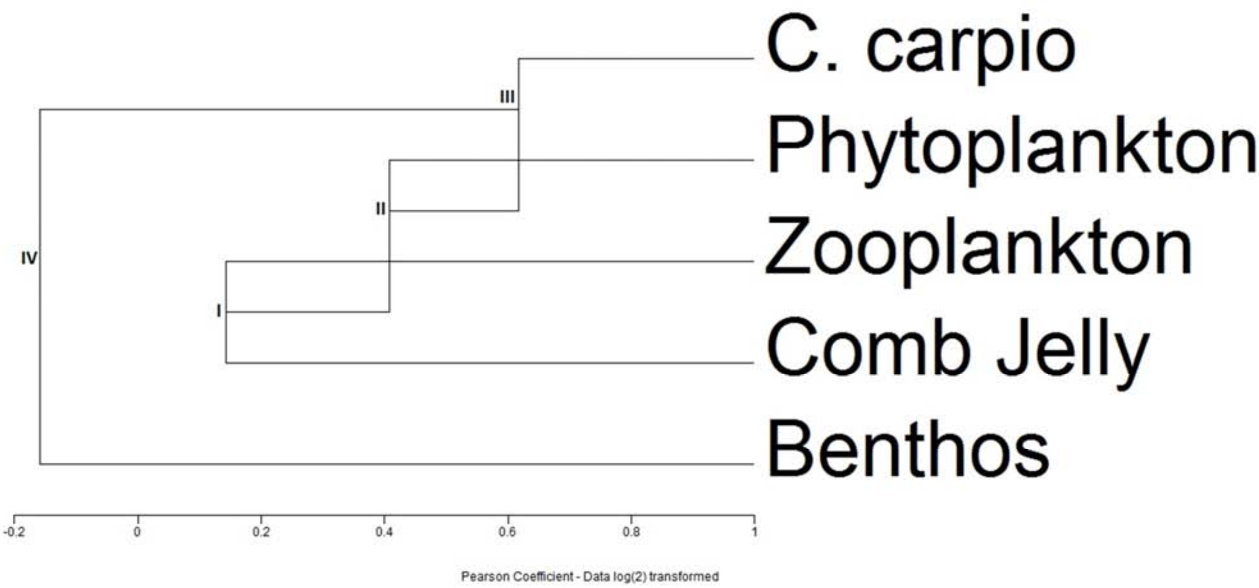

B

Figure 10. *The dendrogram of cluster analysis of biological groups and Rutilus kutum (A) and Cyprinus carpio (B) in the southeast of the Caspian Sea (Mazandaran-Goharbaran).*

4. Discussion

The long term monitoring of previous investigation performed in the southern coast of the Caspian Sea showed that so far 335 species of phytoplankton were identified in which Bacillariophyta, Pyrrophyta, Cyanophyta, Chlorophyta and Euglenophyta was the main phyla and three other phyla with less diversity including Chrysophyta, Xanthophyta and Chryptophyta [3, 21, 22, 28, 32, 45]. In the present study, a total of 157 phytoplankton species were identified that the most abundance phyla was Bacillariophyta. The species number of phytoplankton in the southern coast of the Caspian Sea was fluctuation *e.g.* in 2008, 191 species were recorded [23], in 2009, 195 species [32], in 2010, 181 species [45], and 38 species in Kelarabad [7] in which Bacillariophyta was the most frequency species in previous studies. In the present study, Bacillariophyta had the highest species diversity with 75 species (48%) compared to other phyla accounted for the highest frequency which is confirmed with previous studies. In the present study, the Chlorophyta was noticed with the highest density but Pyrrophyta biomass was shown with lower than it could be because of the geometric shape, size and material of the shell depend. Some studies have shown that only a small sized Pyrrophyta and no capsules are fed by zooplankton but because encapsulated and have a thick shell less used in digestion and absorption of zooplankton [24, 48].

At the present study, the abundance and biomass of phytoplankton at the different seasons increased from spring to winter, in contrast the density and biomass of zooplankton decreased in which this could be due lots of parameters such as phytoplankton grazing by zooplankton, presence and the absence of zooplankton as primary consumers, increased nutrients and environmental pollution. The amount of phytoplankton and zooplankton density and biomass at different stations showed that an inverse relationship occurred between them [1] and it is because of grazing of phytoplankton by zooplankton as well. In the present study, in winter, the density of zooplankton reduced from station #1 to #8 in contrast the phytoplankton density increased in which this could be due to the zooplankton population decreased as a predator. Comparing between phytoplankton and zooplankton density in winter showed that the relationship can be inverse in some stations, particularly in stations 1 to 3 that phytoplankton abundance decreased with increasing zooplankton population. In station 5 (10 m depth) it is quite clear and in stations 6 to 8 by reducing the amount of zooplankton the phytoplankton increased in which by informing corresponded past. In this study, the density and biomass of comb Jelly in autumn was more than other seasons this could be due to changes in reproductive behavior, high water temperature and because of the small-sized majority. Roohi *et al.,* [38, 39] reported that the maximum density of comb Jelly was recorded in autumn in the southern Caspian Sea which the biggest group were 0-5 m and the length of more than 10 m less and more frequent. The abundance comparison of the comb Jelly from 2008 to 2009 showed that less than 20 m water column the most dominant, 20-50 M and 50-100 m were in the later stages which can be due to proper conditions of food, temperature and increase nutrients [6, 36]. The density and biomass of *M. leidyi* from 1991 to 2010 show the decreasing trend in the southern Caspian Sea *e.g.* the density decreased from 674.1 ind.m^3 in 1991 to 11.2 ind.m^{-3} in 2010 with coefficient of variation of 98.3% and biomass from 48.4 g.m^{-3} to 0.6 g.m^{-3} with a coefficient of variation of 98.7% [36]. Other factors reduce the population of the *M. leidyi* in the Caspian Sea could be due to a decrease in fertility and fecundity of *M. leidyi* and reduced the food resources [35, 38, 39].

Earlier studies showed that the fecundity of *M. leidyi* decreased about 88% from 2005 to 2011 in the Caspian Sea that could be due to adverse conditions such as reducing available food items [41, 42]. In this study, the density and biomass of comb Jelly was 57.3 ± 80.6 ind.m^{-3} (range 1-437 ind.m^{-3}) and 1.4 ± 4.8 g.m^{-3} (range 57.7 -0.01 g.m^{-3}), which has confirmed with studies of Roohi *et al.,* [38]; Shiganova *et al.,* [41], and Afraei Bandpei *et al.,* [6].

At the present study, 24 species of benthic invertebrates were identified in which Polychaeta abundance was confirmed 50% that accounted for the highest frequencies but based on biodiversity crustacean has the highest frequency with 75%. Hashemian *et al.*, [27] reported that a total of 29 macrobentic species in the southern Caspian Sea in which crustacean on the formed macrobentic dominant and the dominant species was introduced species Polychaeta *Streblospio gynobranchiata*. In the present study, *S. gynobranchiata* was also the dominant benthic invertebrate population. This can be due to its behavior as exotic species and power associated related that has confirmed with reported by Hashemian *et al.,* [27]. Macrobenthos community Changes in different areas and times were due to some parameters as a function of several factors including: biological aspects, the structure of the seabed, food abundant, fish nutrition and the chemical and physical properties [5, 13]. Among different groups of macrobentic invertebrates, Polychaeta *S. gynobranchiata* was the dominant group in all seasons and sampling stations. This could be due to the invasion of Polychaeta in the Caspian Sea and the competition for food and habitat with others [9, 47].

Comparative study of ecological relationships between biological parameters (Phytoplankton, zooplankton-comb Jelly and macrobentic fauna) with Kutum and carp fishes showed that exposure they have been in the same class as the zooplankton-comb Jelly in the first class, of the second class of phytoplankton-first class, and third class Kutum fish and carp with second class correlation coefficient that this could be due to anadromous strategy and ecological niche similarity. Based on principal component analysis (PCA) the results of the comparison between catch of Kutum and biological groups showed that Kutum was the most consistent with the first and second classes. At the present study, the results showed the greatest similarity in March and April and the lowest was in the months of December and January. This could be due to approaching the period of reproduction, spawning season and migration to the river. Afraei Bandpei [4] reported that the most of Kutum catch was in March and April, and common carp was in November and December, respectively. So, the most of the fishermen income in the southern coast of the Caspian Sea was the sale of Kutum and share of income of Kutum in Guilan, Mazandaran and Golestan was 74%, 85.8% and 26%, respectively [8].

The status of bony fish catch in the Caspian Sea in a decade (2005-2014) showed that most of the catches were of the three species including Kutum, Carp and Mugil, respectively [6] in which corresponded with the results of present study. Fazli *et al.,* [20] noted that in 2013-2014; years of exploitation, the first rank belonged to Kutum (80.1%) among the whole of bony fish catch in the southern of the Caspian Sea although the highest catches were obtained in spring. Principal component analysis (PCA) for comparing relationships between biological parameters and common carp showed that these changes were similar with Kutum catch where this could be due to equal reproduction behaviors and similar immigration strategy (Anadromous fish) to fresh water for breeding while the results show that the highest similarity coefficient was in November and December. This can be explained by the presence of this species in the catch. In this study, the results showed that catch of common carp in 2006-2007 exploitation was highest in November and December in Guilan and Mazandaran provinces with an average of 9 and 102 tons, respectively, in which the highest catch ratio was in March and April with a mean of 152 tons in Golestan province. This could be due to regional topography, ecological niche, bed slope, temperature, rivers and fishing efforts [10]. Fazli *et al.,* [20] noted that in 2013-2014, Carp with 3.2% of whole of bony fish catch consisted third rank in the southern of the Caspian Sea whereas for the highest catches in the autumn. In the present study, based on Principal component analysis (PCA) the highest similarity coefficient of carp was in the months of November and December (0.997) and for Kutum in March and April (0.998), respectively. This could be due to the approaching the beach and the feeding period for carp and inshore spend the reproductive period, spawning season for Kutum and migration to the rivers.

In conclusion, the ecological relationships between biological parameters could be depend to an increase or decrease in density, increase or decrease of the biomass, the presence or absence of species, environmental parameters, and physiological structure of the species, Predators, seasonal changes, feeding behavior and environmental pollution. Therefore, for accurate study of the relationship between biological parameters, especially planktonic groups with different fish species it is needed to investigate further monitoring survey as well as more samples of fishes and their nutrition for a proper interpretation.

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