The Qualitative and Quantitative Distribution in Phytoplankton and Zooplankton of Southern Black Sea of Cape Sinop, Turkey in 1999-2000

Levent Bat, Fatih Sahin, Funda Ustun, Ahmet E: Kideys and Hasan H. Satilmis

***Abstract*—In the present study, seasonality and composition of phytoplankton and zooplankton were comparatively studied at two stations (one inshore and one offshore) off Sinop, in southern Black Sea during January-May 1999 and March -October 2000. A total 76 genera including 149 species and varieties were identified, of which 46% were dinoflagellates and 34% were diatoms in phytoplankton. Abundance of the genera Emiliana (in January-May 1999), Pseudosolenia and Ceratium (in March-October 2000) were higher than that of the other genera in almost every sampling period. Increased dinoflagellate to diatom ratio reflects more fertile conditions in the southern Black Sea.**

Abundance and biomass of the total fodder zooplankton the highest values were recorded in February 1999; March 2000. Cladocera and Appendicularia abundance and biomass values were higher in 1999 than 2000. *Noctiluca scintillans* was the most abundant of zooplankton group with a share of 43% (maximum: 416,925 ind.m^{-2} in May) in 1999. The second abundant group was Copepoda with 42% (172,981 ind.m^{-2} in February).Copepods with 78% of abundance and 73% of biomass (maximum: 372,330 ind.m^{-2} and 15,253 mg.m^{-2} in March) were the dominant group in 2000. They were followed by the dinoflagellate *Noctiluca scintillans* with 4.8% (maximum: 24,500 ind.m^{-2} in June).

***Key Words*—Black Sea, phytoplankton, zooplankton.**

I. INTRODUCTION

The ecosystem of the Black Sea has changed greatly over the last decades owing to eutrophication originating from the north-western shelf [1], [2], [3]. Phytoplankton abundance and biomass has increased in relation to a net increase in nutrient concentrations, the species composition has changed–with a relative increase in species number, abundance and biomass of dinoflagellates compared to diatoms – and there has been a trend towards small-sized phytoplankton groups [4]. In addition, toxic algal blooms have been reported [5]. Secchi disk depths have decreased, and anoxic conditions have expanded.

The Black Sea receives 87 % of the fresh water volume from its north-western part which is shallow. The rivers reduce surface salinity and contribute large amounts of nutrients and detritus. These factors create a displaceable extensive freshened region, with reduced transparency and an increased phytoplankton crop in north-western part of the Black Sea [6]. In the open waters and the southern part of the basin, hydrobiological properties are more stable than other areas and the phytoplankton crop is much smaller [7].

Phytoplankton, primary food source of the sea must constitute an indispensable part of the research programs since increasing pollution initially affect phytoplankton by increasing the frequency of plankton blooms causing to changes in food chain structure.

Zooplankton not only acts as a secondary producer within the food chain but also as prey for larger marine organisms of economic value such as fish and shrimps. Meanwhile, their abundance and occurrence is not only associated with changes in the food supply (phytoplankton) but also with a combined effect exerted by hydrographic conditions and pollution stress. Consequently, in recent years some zooplankton species have either disappeared from or substantially decreased in number at different sampling sites of the Black Sea. Some other species have flourished and reach huge numbers (e.g. *Mnemiopsis*).

The comprehensive biweekly studies in this region are made. In the present study, we present abundance, biomass and species composition of phytoplankton and zooplankton in two stations in the southern Black Sea during January-May 1999 and March-October 2000.

II. MATERIAL AND METHODS

The monthly samples were collected from the two stations (Fig.1) near the Sinop Peninsula in the Black Sea by the R.V. 'Arastirma I' within the framework of TUBITAK (The Scientific and Technical Research Council of Turkey) project during January-May 1999 and March-October 2000. While the total depth of station A (35° 09' 32"E-42° 00' 21"N) was 70 m,

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L. B. Author is with the Sinop Fisheries Faculty, 57000 Sinop TURKEY (corresponding author to provide phone: +90-368-2876263; fax: +90-368-2876255; e-mail: leventb@omu.edu.tr).
F. S. Author is with the Sinop Fisheries Faculty, 57000 Sinop TURKEY (author e-mail: fsahin@omu.edu.tr).
F.U. Author is with the Sinop Fisheries Faculty, 57000 Sinop TURKEY (author e-mail: fundau@omu.edu.tr).
A.E.K. 1. Institute of Marine Sciences, Middle East Technical University, Erdemli 33731, Turkey
2. European Commission Joint Research Center Institute for the Protection and Security of the Citizen Agriculture and Fisheries Unit. TP051 Via Enrico Fermi 1, Ispra I-21020 (VA), ITALY (author e-mail: ahmet.kideys@jrc.it)
H.H.S. Fisheries Faculty, 17100 Canakkale TURKEY (author e-mail: hhsatilmis@yahoo.com)

it was 300 m at station B (35° 15' 00"E-42° 04' 05"N) which is 4 miles far from shore. Station A and Station B show coast and offshore characteristics, respectively.

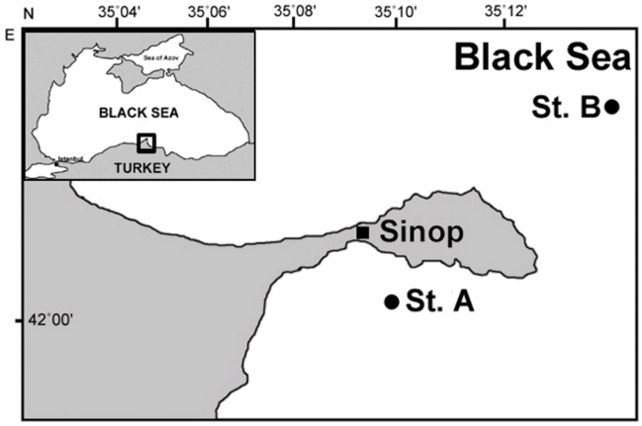

Fig. 1. Sampling area.

Phytoplankton samples were collected in two stations from the different layers of the water column (0, 10, 20, 30, 40, 50 and 75 m). For the surface sampling a hand bucket, for lower depths a Hydro-Bios Universal Water Sampler was used. Zooplankton samples were taken vertical haul at each station by using plankton net of 50 cm diameter mouth opening and 112 µm mesh size. Physical and chemical parameters of environment which includes temperature, salinity, pH, chl -*a* and nitrite were determined.

III. Results

A. Physical Parameters

During the January-May 1999 period, the first detectable increase in the temperature in the surface water was in April (16.06 ºC). The temperatures in the surface water varied between 8.5 ºC and 16.06 ºC.

In March-October 2000 period, the lowest temperature degree was found as 8.24 ºC at the shallow station in April 2000. The highest temperature degree was found as 25.58 ºC at the same station in July 2000.

During the January-May 1999 period, the highest salinity measured at the deep station was 18.33 psu (May 12). The lowest salinity was measured in March 23 at the shallow station 15.35 psu. In March-October 2000, the highest salinity measured at the deep station was 18.93 psu. The lowest salinity was measured in April 20 at the shallow station 15.06 psu .

The mean of measured Secchi disc depths (SDD) was 11.75±2.2 m in March-October 2000. The lowest SDD was 7.4±1.7 m (St. A), while the highest one (14.1±2.3 m) situated at the offshore (St. B).

Maximum concentration of the Chl-*a* in January-May 1999 and March-October 2000 was measured 1.01 µg/l at Station B in February 1999 (40 m) and 6.99 µg/l at Station A in August 2000 (10 m) respectively.

Maximum nitrite concentration in January-May 1999 and March-October 2000 was measured as 0.2 µM at Station B (10m) in February 1999 and 0.199 µM at Station B (10 m) in March 2000 respectively.

B. Phytoplankton

In January-May 1999 and March-October 2000, a total of 149 species were identified from both stations. Representatives from all phytoplankton groups were found during the whole study period.

In terms of species composition, dinoflagellates were the dominant group with 50% proportion, diatoms took the second rank while silicoflagellates were at third place (Table 1).

Among the dinoflagellates, the following genera are richest in species: *Gyrodinium* spp (8 taxa), *Gymnodinium* spp (6 taxa), *Prorocentrum* spp (5 taxa), *Protoperidinium* spp (5 taxa), *Dinophysis* spp (4 Taxa), *Ceratium* spp (3 taxa) and among diatoms; *Chaetoceros* spp (7 taxa), *Nitzschia* spp (5 taxa) and *Coscinodiscus* spp (4 taxa) were determined in sampling periods.

According to data; dinoflagellates (*Gymnodinium sanguineum*, *Gyrodinium fusus*, *Heterocapsa triquetra*, *Prorocentrum compressum*, *Prorocentrum cordatum*, *Ceratium furca*, *Ceratium tripos*, *Dinophysis acuta*, *Dinophysis fortii*, *Prorocentrum micans*), diatoms (*Thalassiosira eccentrica*, *Cerataulina bergonii*, *Chaetoceros affinis*, *Ditylum brightwellii*, *Pseudosoloenia calcar avis*, *Thalassionema nitzschioides*, *Skeletonema costatum*), coccolithophores (*Emiliania huxleyi*) and silicoflagellates (*Dictyocha speculum*) were the most important groups in both sampling years. Abundance of the genera Emiliana (in January-May 1999), Pseudosolenia and Ceratium (in March-October 2000) was higher than of the other genera in almost every sampling period.

Table 1. Species composition of the total phytoplankton groups during January-May 1999 and March- October 2000.

	Station A		Station B		TOTAL		%	
Species	1999	2000	1999	2000	1999	2000	1999	2000
Dinoflagellates	58	32	46	22	64	35	50	50
Diatoms	37	24	28	19	45	27	35	39
Silicoflagellates	3	3	5	2	5	3	4	5
Euglenoids	1	2	1	2	1	2	1	3
Cyanophytes	1	1	1	1	2	1	2	1
Coccolithophores	7	1	5	1	6	1	5	1
Chlorophytes	1	1	1	1	1	1	1	1
Criptomonads	5	-	1	-	5	-	4	
Total					129	70	100	100

In terms of species number, the diatoms were more abundant in spring (March, April) than in the other periods. However, dinoflagellates were more abundant in summer (May and June) and autumn. Maximum and minimum species numbers were recorded in January 1999 (74 taxon) and October 2000 (29 taxon) respectively.

Cyanophyteits were more abundant (~ %75 of the whole species number) than the other groups in January-May 1999 period.

The decline in diatoms was followed by increase in dinoflagellates. Dinoflagellates began to increase in late spring (May) and than they reached a maximum in June and gradually decreased towards October. Dinoflagellate blooms were shown in summer. Diatoms were dominated in spring and their blooms were in mid spring.

During the January-May 1999 period, the mean surface abundance and biomass values were higher in May (average 943 thousand cell l^{-1} and 141 µg l^{-1}) than the other sampling periods. The mean surface abundance and biomass values were higher in June (average 340 thousand cell l^{-1} and 234 µg l^{-1}) and October 2000 (average 289 thousand cell l^{-1} and 197 µg l^{-1}) than in March-May 2000 (average 76 thousand cell l^{-1} and 98.5 µg l^{-1}). Correspondingly, the average Secchi disc depth was higher in March-May (13 ± 1.2) than in June (11 ± 2.1) and October (7 ± 1.9).

In sampling periods, there was also a difference in dominant phytoplankton groups in the surface waters. In March and April, diatoms displayed the highest relative abundance (53%) and biomass (67%); the dominant species was *Chaetoceros affinis* Lauder. In May, coccolithophores and silicoflagellates display the highest relative abundance (95%) and biomass (together 89%), the dominant species were *Distephanus speculum* Lemmermann and *Emiliana huxleyi* (Lohmann). In June, dinoflagellates represented 40% of total biomass and 32% of relative abundance with *Protoperidinium steinii* Jörgensen. In August and October, dinoflagellates represented 82% of total biomass and 86% of total abundance, the dominant species was *Ceratium tripos* (Müller) Nıtzsch in both months. The dominant diatom species were *Pseudosolenia calcar-avis* Schultze in October (75% of diatom biomass in surface layer) (Fig. 2).

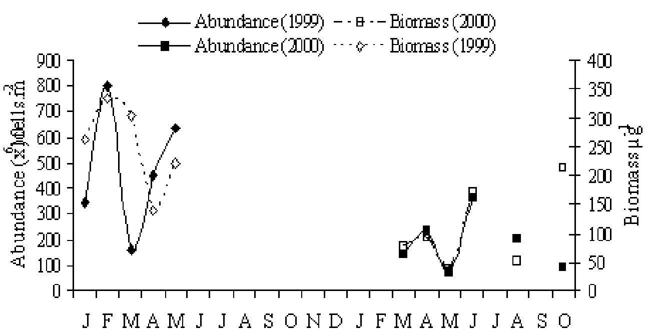

Fig. 2 . Contribution of different phytoplankton groups in the total abundance and biomass in the stations during January-May 1999 and March-October 2000 period period..

In monthly samples, maximum total phytoplankton abundance ($163x10^6$cell.m^{-2}) was detected on 15 June 2000 in coastal station and maximum biomass (480 µg.l^{-1}) was detected on 30 October 2000 in the costal station too. Minimum total phytoplankton abundance ($27x10^6$cell.m^2) and biomass (50µg.l^{-1}) were found on 24 May 2000 in the offshore station.

C. Zooplankton

The mesozooplankton abundance (ind.m^{-2}) and biomass (mg.m^{-2}) off Sinop displayed remarkably different patterns between the inshore and the offshore waters. The values of the inshore station displayed 4 peaks with large fluctuations, whereas those of the offshore station showed 3 main peaks. The inshore station almost always reached its peak value about a month earlier than the offshore station. Both the total abundance and the biomass reached their maximum values in May and July, and to their minimum values in November and January 1999 (Fig.3).

The abundance values for the inshore station ranged between 37,800-282,500 ind.m^{-2}, whereas those of the offshore station ranged between 39,800-242,260 ind.m^{-2}, the ranges being remarkably similar in quantity in 1999.The ranges for the biomass values for the inshore and offshore stations also came to be similar, which were between 1,236-22,806 mg.m^{-2} and 2,221-20,715 mg.m^{-2}, respectively. Both the abundance and biomass values showed a decreasing trend towards winter, and the lowest values were obtained in early January. The peak values of total zooplankton biomass were observed in May (11,871 mg.m^{-2}, inshore) and in April (12,496 mg.m^{-2}, offshore) in 2000. The abundance values for the inshore station ranged between 37,843 (June) and 293,830 ind.m^{-2} (March), whereas those of the offshore station ranged between 40,775 (May) and 163,490 ind.m^{-2} (March). The biomass values of inshore and offshore waters were calculated between 1,075 (October)-11,871 mg.m^{-2} (May) and 1,412 (October)-12,496 mg.m^{-2} (April), respectively (Fig.3).

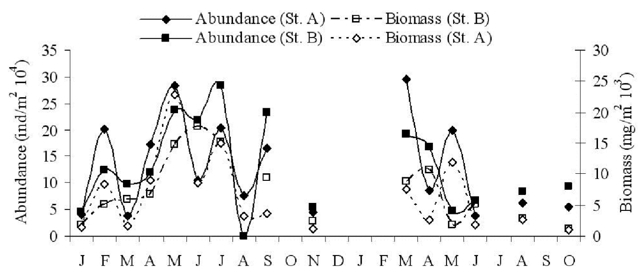

Fig. 3. Seasonal changes of mesozooplankton (in terms of m^2) off Sinop in 1999 and 2000.

N. scintillans had a mass dominance over the other mesozoplankton groups for about two months between May and July in 1999. Copepods showed no preference between the inshore and offshore stations and were identified to be abundant throughout the year, except for the period of *Noctiluca* abundance. Cladocerans existed during warm months, appearing in plankton in May at the inshore station and in June at the offshore station. Meroplankton showed a higher preference for the inshore station, reaching peak values in February. The contribution of *Sagitta* was almost negligible throughout the year, only remarkable existence being recorded during summer months. It is especially interesting to note the dramatic decline in the abundance of all the other zooplankton groups in the period of peak *Noctiluca* abundance between May and early July in 1999 (Fig. 4).

Copepoda played the major role in the formation of zooplankton abundance in 2000. They showed no preference between both stations and were identified to be abundant throughout the year. A peak of Copepoda abundance was observed in March both inshore (229,865 ind.m^{-2}) and offshore stations (142,465 ind.m^{-2}). Both stations Cladocera consists of total zooplankton 0.72% and 0.33%, respectively. While Cladocera reached highest values in August (3750 ind.m^{-2}) at the inshore waters, at the offshore waters it highest value reached in October (750 ind.m^{-2}). At the each station, this group was not observed in April. *Sagitta setosa* was observed density all the months of sampling period. This species maximum abundance value was showed at the inshore waters in May (265 ind.m^{-2}), at the offshore waters in October (720 ind.m^{-2}). In the offshore waters its abundance values were higher than inshore waters all sampling period in 2000. Meroplankton showed a higher preference for the inshore station, reaching maximum values in March. *Noctiluca scintillans* was available highest values at the inshore station in August (93,250 ind.m^{-2}) and at the offshore station in June in 2000 (19,250 ind.m^{-2}) (Fig. 4).

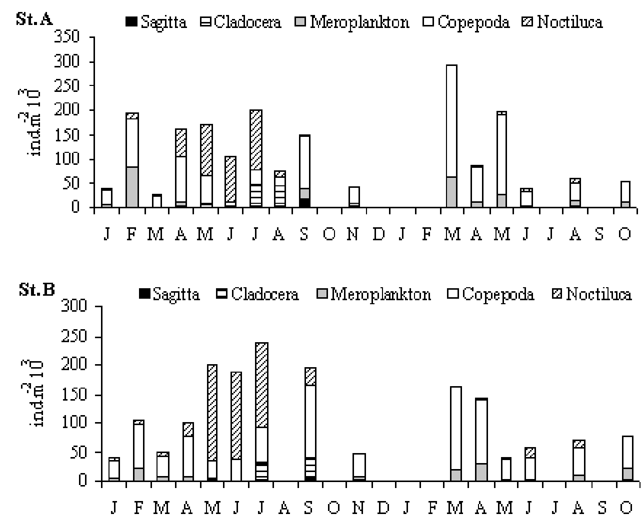

Fig. 4. Seasonal changes of mesozooplankton (in terms of m^2) off Sinop in 1999 and 2000.

IV. Conclusion

Total species number of phytoplankton (149) of 8 classes (*Chlorophyceae*, *Diatomophyceae* (*Bacillariophyceae*), *Dictyochophyceae*, *Dinophyceae*, *Euglenophyceae*, *Cyanophyceae* (*Nostocophyceae*), *Prasinophyceae* (*Micromonadophyceae*), *Prymnesiophyceae* (*Haptophyceae*)) were distinguished during sampling period. The total number of phytoplankton species observed is within the range reported in other investigations carried out in the southern Black Sea. According to Reference [8] (1997, 746 species and varieties (including freshwater and estuarine species) occur in the Black Sea, 46% of which belong to diatoms and 27% to dinoflagellates. In previous years, the number of dinoflagellate species was usually lower than of diatoms [6], [8], [9]. Likewise, Reference [10] and Reference [11] reported that the proportion of the diatoms in the total community progressively decreased, while dinoflagellates and other non-diatom groups increased. We also found higher number of dinoflagellate species compared to diatoms (Table 2).

Dinoflagellate to diatom ratio in terms of species number differs with season and region as well. In summer season and in the eutrophic regions species number of dinoflagellates was relatively higher than in the other seasons and regions. For example, while the percentage of dinoflagellates in the total species number was as low as 20.65% in April 1989 [12] and it increased (46.4%) in August 1995- July 1996 [13] and in our study that it was 50% in summer 2000.

According to Reference [13] the diatoms were more abundant in winter (January and February) and early spring (March) than in other periods. However, dinoflagellates were more abundant in summer (May, June and July) in their study. Similarly, diatoms were more abundant in spring (March, April) than in other periods while dinoflagellates were more abundant in summer (May and June) and October in the present study.

Similar to the ratio of diatoms: dinoflagellates in terms of species number the analysis of the diatoms: dinoflagellates biomass ratio during spring-summer has revealed a dramatic inversion since 1970 [14]. Despite the oscillations in the inter-annual variability this inversion trend is stable during the 80`ies. The average share of diatoms in the total biomass up to 1970 is 86% (versus 14% of Dinophyta), decreasing during 1970/90 to 42% [15]. The comparison of the taxonomic structure (by biomass) of phytoplankton communities in seasonal terms during the 90`ies to that of the 80`ies in contrast reveal a decrease in the dominance of diatoms species, on the account of an increase in the share of diatoms more apparent in winter and autumn and an increase in the taxonomic diversity (summer and autumn), which most likely could be attributed to the shift of the nutrient ratios (N:P, Si:N and Si:P) during the two periods [16].

Reference [17] indicated that peaks in the primary productivity of the Black Sea were known to occur twice a year, with a major bloom generally composed of diatoms in early spring, followed by a secondary bloom mainly comprising coccolithophorids in autumn. Extensive blooms of coccolithophorids and dinoflagellates occurred mainly in coastal areas of the Black Sea. Additional summer blooms with a predominance of dinoflagellates and coccolithophorids have been increasingly observed in the region in recent years [7], [18], [19]. Similar to recent observations summer abundance and biomass maxima in the present study show the changed seasonal bloom characteristic of phytoplankton.

Table 2. Number of dinoflagellate and diatom species in the Black Sea by period and area according to different sources (SE: South-Eastern, S: Southern, NW: North-Western)..

Area (Black Sea)	Dinoflagellates	Diatom	Total	Reference
SE	12	17	29	[28]
SE	26	38	64	[12]
S	41	73	122	[29]
S	33	26	73	[30]
S	71	24	119	[30]
S+NW	64	28	121	[20]
S	59	27	108	[20]
S	64	45	50	This study 1999
S	35	27	70	This study 2000

Reference [20] reported that the mean surface abundance and biomass values were higher in October (average 364 thousand cell l^{-1} and 1794 µg l^{-1}) than in March-April 1995 in the southern Black Sea (average 129 thousand cell l^{-1} and 330 µg l^{-1}). Similarly, in the present study March-May values (average 76 thousand cell l^{-1} and 98,5 µg l^{-1}) were lower than

October 2000 (average 289 thousand cell l^{-1} and 197 µg l^{-1}).

Dinoflagellate to diatom ratio in terms of species number differs with season and region as well. In summer season and in the eutrophic regions species number of dinoflagellates was relatively higher than the other seasons and regions. For example, while the percentage of dinoflagellates in the total species number was as low as 20.65% in April 1989 it increased to 51% in April 1999. Even respective ratios from summer also appeared to increase to 50% in 2000, from 46.4% in August 1995- July 1996. Such finding indicated more fertile conditions in the Black Sea and is in accordance with the rise in fish landings.

The offshore station is possibly situated along the rim current where nutrient injection to surface waters is significant. Moreover, off Sinop region was often regarded as an upwelling area during different sampling periods (July 1992, August 1993, June-July 1996) and was concluded to be a consistent feature of the Black Sea hydrographs [21] since it was also present during the 1957 and 1992 egg surveys [22]. Therefore there must be a higher primary productivity and hence secondary productivity in this region.

The omnivorous mesozooplankton was previously (in 1978) known to possess two major peaks during mid-March and towards mid-August [23], which took place right after the late winter and spring phytoplankton blooms. The simulation made by Reference [23] for the time period between Januarys - December at an offshore station off Gelendzhik (Caucasian coast) reproduced the observed planktonic food web structure reasonably well. The maximum value of about 5.75 $gC.m^{-2}$ was obtained in March as compared to the relatively smaller peak of about 2.5 $gC.m^{-2}$ in August. However, the situation in 1989-1991 was quite different with the introduction of *Mnemiopsis* into the ecosystem. The simulation of the conditions in late 1980s revealed that the second mesozooplankton peak appeared somewhat earlier, towards mid-June and did not significantly differ from the March peak in magnitude (being about 5.0 $gC.m^{-2}$). This situation arises due to an additional phytoplankton bloom, making up a total of three distinct blooms in February, late April and August. The appearance of mesozooplankton bloom in June was thus explained to have arisen following the April phytoplankton bloom [26]. The situation in our case was quite different, resulting in 4 distinct peaks (in winter, spring, summer and autumn) in 1999, instead of two. Another striking difference from the previously obtained values is that the autumn peak was much more pronounced than the winter peak.

The maximum inshore fodder zooplankton biomass obtained in this study in February 1999 and May 2000 (7.3 $g.m^{-2}$ and 18 $g.m^{-2}$, respectively) was more than 3-7.5 times higher than that obtained by Reference [24]. However it must be noted that the stations were very shallow (max. 12 m) in their study. On the other hand, identified that the mean annual biomass values of 2000-2001 was more than 2 times higher than the ones in 1995 (0.42 ± 0.38 g/m^2) which was connected with the positive impact of *Beroe ovata* feeding on *Mnemiopsis leidyi* [24]. The indirect impact of *Beroe ovata* on zooplankton is also clear from the comparison of 1998 and 2000 data by Reference [25]. *Beroe ovata* is believed to arrive to the Black Sea in 1997 [26]. The result of this predation on *Mnemiopsis* must be a decreased predation pressure on zooplankton as can be seen from the data presented by Reference [25], where crustaceans and meroplankton abundance was a few fold higher in 2000 compared to 1998.

Reference [27] studied the seasonal and inter-annual fluctuations of species composition abundance values ($ind.m^{-3}$) of copepod species and major taxa of the Sevastopol Bay during 1976 – 1996. As compared with the period of 1976 – 1989, the total zooplankton abundance values dramatically decreased by a factor of 6 during the period of 1989 - 1996 to values of 1,547 $ind.m^{-3}$, the main change occurring in 1989 - 1990 period. Our total zooplankton abundance value of 128,348 $ind.m^{-2}$ in 1999 and 133,544 $ind.m^{-2}$ in 2000 will be 7 times higher than the respective values obtained for Sevastopol Bay since 1990's (18,564 $ind.m^{-2}$). The fodder zooplankton abundance also increased to almost 5-7 fold (68,925 $ind.m^{-2}$ in 1999 and 129,562 $ind.m^{-2}$ in 2000) as compared to the Sevastapol Bay in 1990's (14,196 $ind.m^{-2}$). The reason for this increase can be largely attributed to the magnitude differences between the particular groups, such as copepods, *N. scintillans* and meroplankton. In Sinop region in 1999, the former two groups displayed much higher biomass values than those in Sevastapol Bay since 1990's. On the other hand, the meroplankton species such as Decapoda, Polychaeta and Bivalvia larvae became more important in the Sevastopol Bay in 1995 - 1996, being the most dominant group of the total zooplankton with an abundance contribution of 46%. However, in the Sinop region in 1999, the meroplankton share in terms of abundance was less than half of its share obtained in Sevastapol Bay, constituting 15% of the total mesozooplankton at the inshore station.

In this study the southern Black Sea (Cape Sinop) phytoplankton and zooplankton biomass, abundance and species composition were investigated in two stations and compared with limited previous data from the same region. Monthly variations of phytoplankton and zooplankton biomass were never reported in the southern Black Sea so far. In this regard, the present study could give a basis for future studies in this region.

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L. Bat Samsun, Turkey, 20.02.1964.. B.Sc.of Sinop Fisheries Faculty, Turkey, 1984-1988 (in Fisheries Science); MSc.of Sinop Fisheries Faculty, Turkey. 1990-1992 (in Marine Biology); Ph. D. University of Aberdeen, Scotland. 1993-1996 (in Marine Biology). Main field Marine Biology, other fields Aquatic Toxicology & Marine pollution.

He worked as a Research Assistant in University of Ondokuz Mayis between 1989 and 1997; as an Assistant of Prof. Dr. in University of Ondokuz Mayis, Sinop Fisheries Faculty between 1997 and 1998; as an Assoc. Prof. Dr. in University of Ondokuz Mayis, Sinop Fisheries Faculty between 1999 and 2004; as a Prof. Dr. in University of Ondokuz Mayis, Sinop Fisheries Faculty since 2004.

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