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# Phytoplankton distribution in the western and eastern Black Sea in spring and autumn 1995

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Species composition, abundance, and biomass of micro- (>15 μm) and nano- (<15 μm) phytoplankton were studied in the western and eastern Black Sea during March–April and October 1995. A total of 142 species were identified, of which >50% were dinoflagellates. Abundance and biomass values were lower during the March–April period (average $129 \pm 28$ thousand cells l$^{-1}$ and $330 \pm 124$ μg l$^{-1}$) than during the October period (average $364 \pm 161$ thousand cells l$^{-1}$ and $1794 \pm 515$ μg l$^{-1}$) and compared with previous investigations. Values for the north-westerly region were higher than for the southerly areas, probably owing to effects of the Danube river, but were much lower than previously reported, possibly indicating improved ecological conditions. In March–April, dinoflagellates (mainly *Heterocapsa triquetra* and *Scrippsiella trochoideum*) were the most important groups, whereas, in October, diatoms (mainly *Pseudosolenia calcar-avis*) and coccolithophores (*Emiliania huxleyi*) were dominant. Nanophytoplankton constituted 57% and 84% of total abundance and 8% and 3% of total biomass in spring and autumn, respectively. Microphytoplankton were dominant in the western Black Sea, whilst nanophytoplankton were dominant in the eastern region in spring.

Key words: abundance, biomass, Black Sea, phytoplankton.

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## Introduction

The ecosystem of the Black Sea has changed greatly over the last few decades owing to eutrophication originating from the north-western shelf (Bologa, 1985/1986; Bodeanu, 1989, 1993; Mee, 1992; Kideys, 1994; Zaitsev and Alexandrov, 1997). 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 (Nesterova, 1986). In addition, toxic algal blooms have been reported (Leppäkoski and Mihnea, 1996), Secchi disk depths have decreased, and anoxic conditions have expanded.

The Black Sea is characterized by two large cyclonic gyres in its eastern and western parts embedded in a basin-wide cyclonic boundary (rim) current (Oguz *et al.*, 1991, 1996, 1993; Sur *et al.*, 1994). A strong vertical stratification, largely determined by salinity, is maintained and a permanent pycnocline coincides with the halocline at a depth of 100–200 m. At the upper boundary of the halocline, there is a cold intermediate layer (CIL) which often coincides with the 8.5°C isotherm. Since the vertical transport of matter is strongly affected by the same mechanisms as are responsible for the stratification, an oxycline and chemocline are situated at the same depth as the CIL (Bingel *et al.*, 1993). The thin mixed surface layer above the CIL ($\simeq 30$ m) is strongly exposed to seasonal heating and cooling, and at its base a seasonal thermocline is formed during summer.

A net increase has been observed in nitrate and phosphate concentrations, the two essential nutrients controlling the overall growth of phytoplankton (Moncheva and Krastev, 1995). The annual discharge of inorganic phosphate (IP) from the Danube river, which contributes approximately 70% of total river input into

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the Black Sea, was about 18 000 t for 1980–1995, which is about 50% more than the flux in the 1960s. Annual total inorganic nitrogen (TIN) input from the Danube ranged between 500 000 and 800 000 t during 1988–1995, which is four times higher than previous estimates (Cociasu *et al.*, 1997). In the Dniester outflow, the increases in nitrate and concentration were threefold and sevenfold, respectively (Mee, 1992). There are also signs of increased nutrient concentrations in the open sea, e.g. maximum nitrate concentrations have increased between two and six times since the 1960s (Tolmazin, 1985). In contrast, Si concentration is about twofold to fourfold lower in the last 15 years compared to the 1960s, mainly due to the building of dams in the rivers (Bodeanu, 1989; Cociasu *et al.*, 1997; Humborg *et al.*, 1997).

While many phytoplankton studies have been carried out on the north-western shelf (Petrova-Karadjova, 1973; Nesterova, 1986; Bodeanu, 1989, 1993; Mihnea, 1992; Moncheva and Krastev, 1995; Moncheva *et al.*, 1998; Cociasu *et al.*, 1997; Stereva *et al.*, 1999), relatively few refer to the southern Black Sea (Karacam and Duzgunes, 1990; Feyzioglu, 1994; Uysal and Sur, 1995; Uysal *et al.*, 1998). Moreover, no data are available on the smaller species in the southern areas, because samples in previous investigations were filtered over a 55-μm mesh size, and biomass was never calculated. We present a qualitative and quantitative analysis of phytoplankton distribution in the Black Sea in relation to the ecological conditions.

## Material and methods

Samples were taken at 105 stations in March–April and at 38 stations in October 1995. In spring, the area sampled covered the north-western shelf and the southern part of both the western and eastern basin, while sampling in autumn was restricted to the southern region with emphasis on the eastern basin. Samples in March–April were taken from three different layers (84 samples from the surface, 21 samples from the mixed (homogeneous layer) and 11 samples from the CIL). In October, 38 samples were taken from the surface and 31 samples from the mixed layer. For surface sampling, a hand bucket was used and for lower depths a Rosette sampler. A sedimentation method was used for counting and species identification. Samples were fixed with buffered formaldehyde to obtain a final concentration of 2.5% and stored in 1 l dark bottles for 2 or 3 weeks. Thin hoses were plunged into the bottles and the supernatant was evacuated down to a volume of 100 ml. The remainder was gently agitated and poured into smaller bottles. A week later, the same process was repeated by using thinner and curved tubes until a ca. 20-ml sample was left. The microphytoplankton present in a 1-ml subsample was counted using a Sedgewick-Rafter cell under a phase contrast binocular microscope. For nanophytoplankton analysis, 0.01-ml subsamples were scanned using a slide. The volume of each cell was calculated by measuring morphometric characteristics (diameter or length and width). Volumes were converted to biomass assuming 1 $\mu m^3$ is equal to 1 pg.

Chemical (salinity, $PO_4$-P, $NO_3$-N, Si, and Chl *a*) and physical (temperature, density and Secchi disk depth) analyses of the sea water were also performed (see Yilmaz *et al.*, 1998 for methodology).

## Results

A total of 142 species were identified from the different layers of the water column over the two sampling periods, 121 in March–April and 108 in October. In the surface layer, dinoflagellates constituted 53% and 55% of the total species number in March–April and October, while diatoms constituted 23% and 25%, respectively.

The mean surface abundance (Fig. 1) and biomass (Fig. 2) values were higher in October (average 364 thousand cells $l^{-1}$ and 1794 μg $l^{-1}$) than in March–April (average 129 thousand cells $l^{-1}$ and 330 μg $l^{-1}$). The average Secchi disk depth was correspondingly higher in March–April (12 ± 1.6 m) than in October (6 ± 2.2 m).

There was also a difference in dominant phytoplankton groups in surface water between the two seasons. In March–April, dinoflagellates (including heterotrophs) displayed the highest relative abundance (35%; Fig. 3a) and biomass (89%; Fig. 3b), *Heterocapsa triquetra* (Ehrenberg) Balech and *Scrippsiella trochoidea* (Stein) Lemmermann being the two dominant species (together 25% of total abundance and 51% of total biomass). In October, diatoms represented 85% of the total biomass (Fig. 3d), while coccolithophores were most abundant in numbers (69%; Fig. 3c). The dominant diatom species was *Pseudosolenia calcar-avis* Sundström (*Rhizosolenia calcar-avis* Schultze) in October (78% of total biomass). *Emiliania huxleyi* (Lohmann) Hay & Mohler was the major coccolithophore species.

The ratio of dinoflagellates to diatoms in March–April in terms of abundance (13.1) and biomass (14.1) was correspondingly higher than in October (0.7 and 0.1, respectively). In addition, these ratios were higher in the western Black Sea (15.9 and 19.2) compared to the eastern (10.2 and 7.2) in March–April.

The contribution of nanophytoplankton (mainly coccolithophores) to total biomass was fairly low (8% in March–April and 3% in October) even though they represented 57% and 84% of the total abundance at the

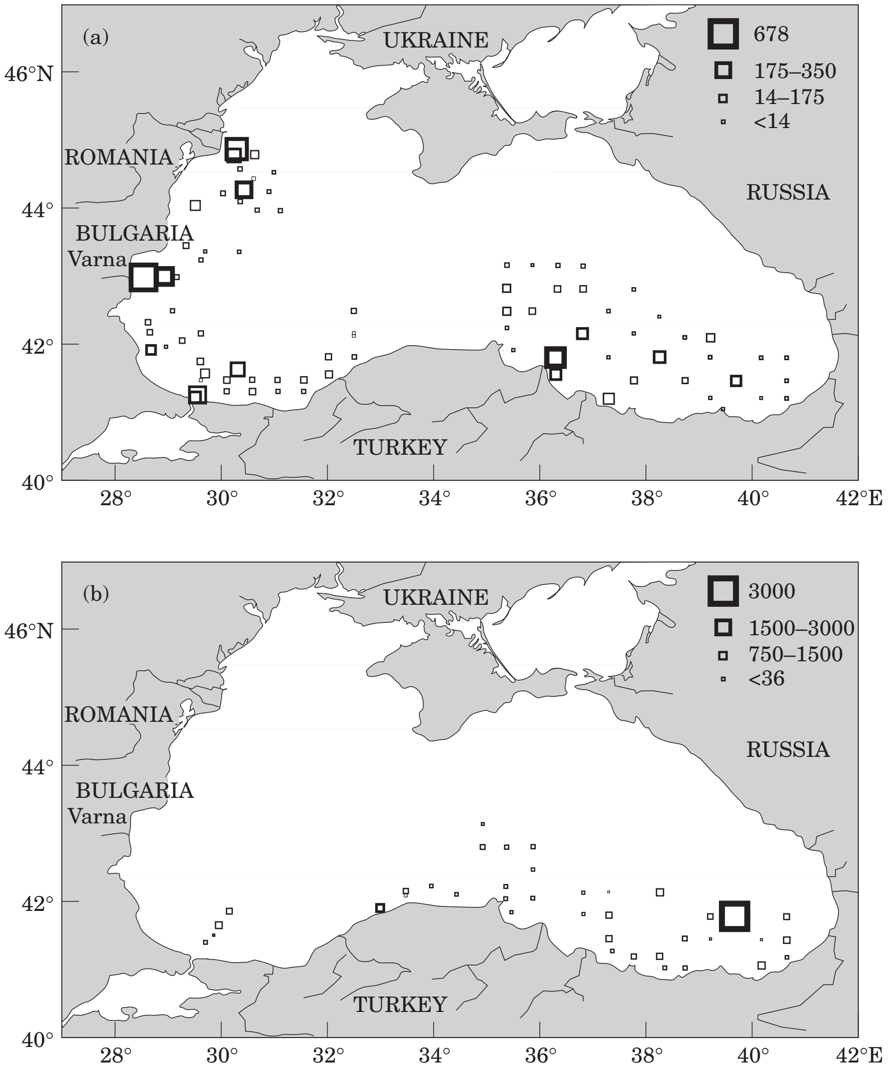

Figure 1. Abundance (thousand cells $l^{-1}$) of total phytoplankton in the surface layer by sampling station in (a) March–April and (b) October 1995.

surface, respectively. Their share increased with depth during both periods.

Since relatively few stations were sampled in the western part in October, a comparison between regions has to be restricted to March–April (Figs 1a, 2a). Maximum abundance and biomass were recorded on the north-western shelf (St 14 off Varna). Average abundance of phytoplankton at the surface was ≃50% and biomass tenfold higher in the western region than in the eastern region (Table 1). Average nutrient and Chl *a* concentrations in the western part were also higher. The abundance of nanophytoplankton was higher in the eastern Black Sea compared to the west in March–April 1995 (Fig. 4a).

## Discussion

The total number of phytoplankton species observed is within the range reported in other investigations carried out in the southern Black Sea (Table 2). According to Zaitsev and Mamaev (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 (Ivanov, 1965; Zaitsev and Mamaev, 1997; Bologa, 1985/1986), but in recent years, with proceeding eutrophication, the situation is the reverse. Also, the relative abundance and biomass of dinoflagellates

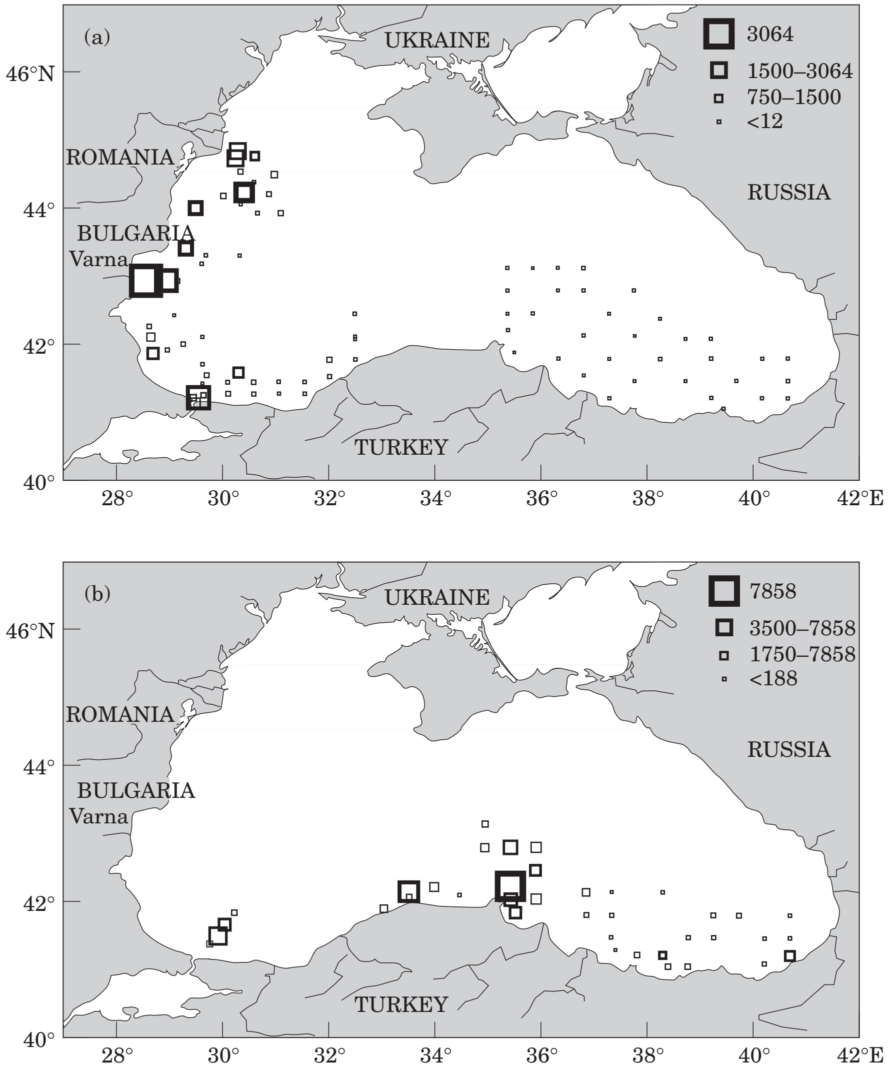

Figure 2. Biomass (µg $l^{-1}$) of total phytoplankton in the surface layer by sampling station in (a) March–April and (b) October 1995.

appears to have increased. In the western Black Sea, and especially during summer months, dinoflagellates were the dominant species group (Uysal *et al.*, 1998).

Dominant species at the surface were the dinoflagellates *Heterocapsa triquetra* and *Scrippsiella trochoidea* in March–April and the diatom *Pseudosolenia calcar-avis* and the coccolithophore *Emiliania huxleyi* in October. Humborg *et al.* (1997) also observed that *E. huxleyi* was the major coccolithophore species. The higher contribution of nanophytoplankton during autumn compared to spring agrees with the findings of Sorokin (1983).

The Black Sea shows the characteristics of typical temperate seas with two major blooms, one during winter-early spring and a less intense autumn bloom (Vedernikov and Demidov, 1993). Our sampling period started at the end of March and the relatively low abundance and biomass values in March–April compared to October suggest that the spring bloom was probably already over by then. This is also supported by the modelling study of Oguz *et al.* (1996), who show that the spring bloom starts in the first week of March and that intense phytoplankton production lasts about 7–10 d.

Compared to previous studies performed in the western Black Sea, average biomass and abundance values were quite low in the present investigation and close to those found during the 1960–1970s. The average biomass on the north-western shelf was around 650 µg $l^{-1}$ in the 1950s, 1000 µg $l^{-1}$ in the 1960s, 19 000 µg $l^{-1}$

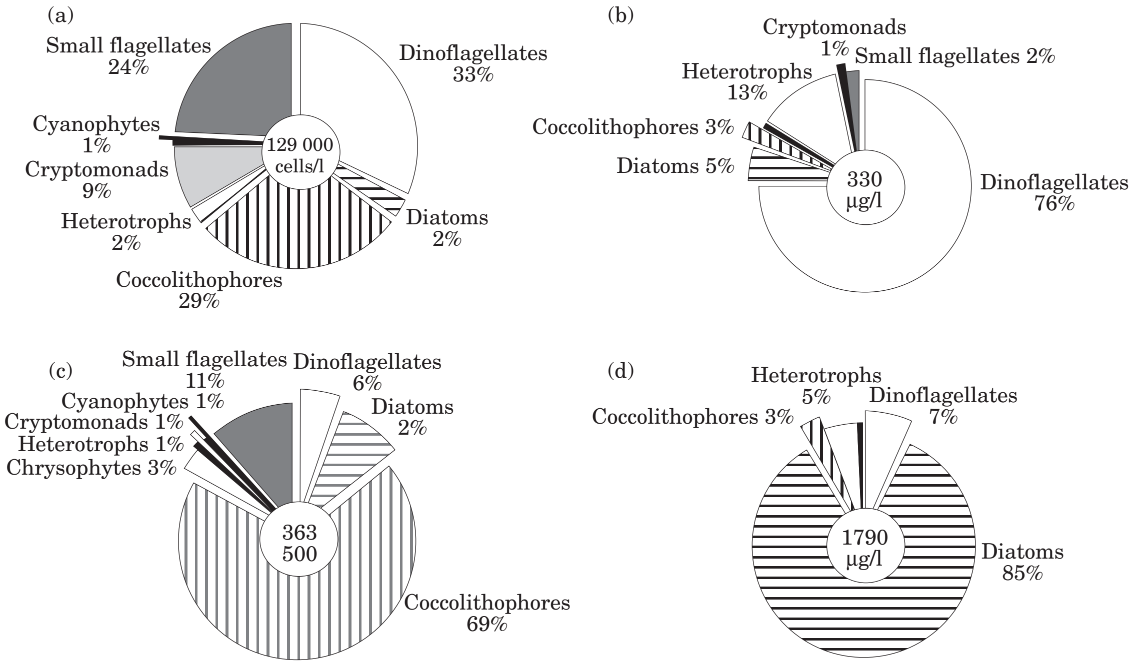

Figure 3. Average percentage composition of phytoplankton in 1995 by abundance and by biomass in the surface layer: (a) abundance March–April; (b) biomass March–April; (c) abundance October; (d) biomass October.

in the 1970s and 30 000 µg $l^{-1}$ in the 1980s (Zaitsev and Alexandrov, 1997). Our biomass values for the western Black Sea (550 µg $l^{-1}$ in March–April and 1230 µg $l^{-1}$ in October) were much lower than the averages for the periods during the 1970s and 1980s. Mihnea (1992) found abundance values in Mamaia Bay of 2.5–12 million between 1977 and 1986. The 1995 value for March April (143 000 cells $l^{-1}$) was very much lower than any of these.

According to Stereva *et al.* (1999), seasonal biomass values in Varna Bay for 1983–1988 were 24 500 µg $l^{-1}$ in winter, 56 500 µg $l^{-1}$ in spring, 42 300 µg $l^{-1}$ in summer, and 38 200 µg $l^{-1}$ in autumn. These values were also very high compared to the March–April 1995 values for this bay (3064 µg $l^{-1}$).

Table 1. Average phytoplankton, Chl a and nutrient concentrations (± s.d.) at the surface in the western and eastern Black in March–April 1995.

| | Western | Eastern |
|---|---|---|
| Abundance (thousand cells $l^{-1}$) | 143 ± 41 | 98 ± 34 |
| Biomass (µg $l^{-1}$) | 550 ± 193 | 55 ± 14 |
| Chl a (µg $l^{-1}$) | 0.49 ± 0.28 | 0.10 ± 0.05 |
| $NO_3$-N (µM) | 4.49 ± 2.83 | 1.10 ± 0.08 |
| $PO_4$-P (µM) | 0.13 ± 0.06 | 0.08 ± 0.07 |
| Si (µM) | 5.91 ± 2.62 | 4.84 ± 1.68 |

There are limited data for comparing our values for the southern Black Sea, particularly since in previous studies cells <55 µm were excluded owing to differences in methodology. Nevertheless, the abundance observed by Uysal and Sur (1995) in February 1990 (247 000 cells $l^{-1}$) was higher than ours (129 000 cells $l^{-1}$). This difference may reflect the sampling period in relation to the spring bloom.

The dinoflagellates to diatoms ratio in terms of biomass in March–April (14.1) was higher than in October (0.1). Besides, this ratio was higher in the western region (19.2) compared to the eastern part (7.2) in March–April, indicating more eutrophic conditions in the former. According to Bodeanu (1993), the biomass ratio off Romania changed from 0.2 in the 1960s to 0.6 in the 1970s and 0.4 in the 1980s. Moncheva and Krastev (1997) compared the period of 1954-1970 in Varna Bay and Cape Kaliakra with the period 1970–1990 (Petrova-Karadjova, 1973) and observed that the ratio increased from 0.2 to 1.4.

Abundance and biomass of phytoplankton, Chl *a*, and nutrient concentrations at the surface in spring were all higher in the western region than in the eastern region (Table 1). This was similar to other studies performed in the southern Black Sea (Table 3). Satellite-derived data (1979–1982) also show that average chlorophyll concentrations of 3–10 mg $m^{-3}$ were measured on the north-western shelf, while they did not exceed 0.5 mg $m^{-3}$ in the central Black Sea

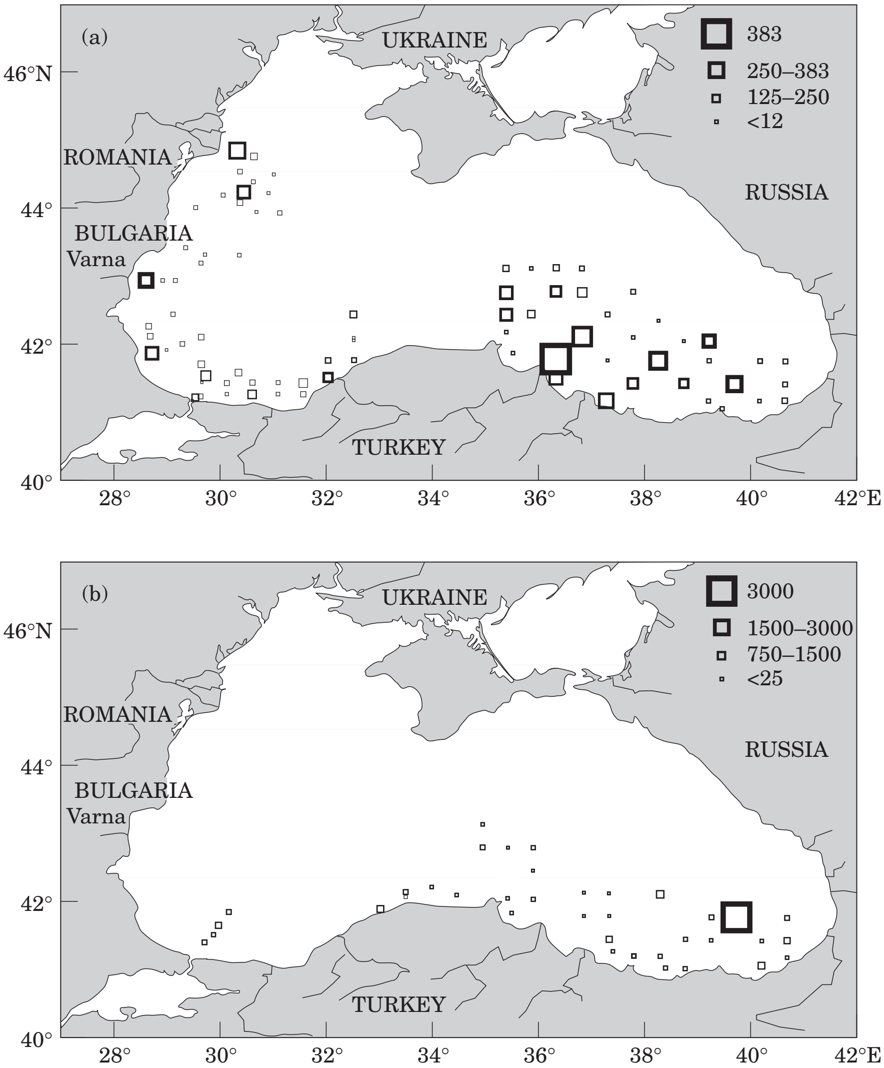

Figure 4. Abundance (thousand cells $l^{-1}$) of total nanophytoplankton in the surface layer by sampling station in (a) March–April and (b) October 1995.

Table 2. Number of species of dinoflagellates (Df) and diatoms (Diat) in the Black Sea by period and area according to different sources.

| Period | Area | Df | Diat | Total | Reference |
|---|---|---|---|---|---|
| Nov. 1987–Oct. 1988 | SE | 12 | 17 | 29 | Karacam and Duzgunes (1990) |
| Jul. 1989 | SE | 26 | 38 | 64 | Feyzioglu (1994) |
| Feb. 1990 | S | 41 | 73 | 122 | Uysal and Sur (1995) |
| Mar.–Apr. 1995 | S+NW | 64 | 28 | 121 | This study |
| Oct. 1995 | S | 59 | 27 | 108 | This study |
| Apr. 1996 | S | 33 | 26 | 73 | Uysal *et al.* (1998) |
| Jul. 1996 | S | 71 | 24 | 119 | Uysal *et al.* (1998) |

(Humborg *et al.*, 1997), indicating that intense blooms are largely restricted to nearshore areas of the north-western shelf.

In March–April, small-sized microphytoplankton species were dominant in the western Black Sea compared to the eastern side. *Heterocapsa triquetra*

Table 3. Abundance and biomass of phytoplankton by period in the western (W) and eastern (E) Black Sea according to different sources.

| Period | Abundance (thousand cells $l^{-1}$) W | E | Biomass ($\mu g\ l^{-1}$) W | E | Reference |
|---|---|---|---|---|---|
| Feb. 1990 | 470* | 23* | | | Uysal (1995) |
| Jun. 1993–Aug. 1994 | | | | | |
| Winter | | <100* | | | Feyzioglu (1996) |
| Summer | | >100* | | | |
| Mar.–Apr. 1995 | 143 | 98 | 550 | 55 | This study |
| Oct. 1995 | 257 | 347 | 1230 | 1617 | This study |
| Jul. 1996 | 113 | 87 | | | Uysal *et al.* (1998) |
| Jul. 1996 | | | 246 | 249 | Unpubl. data** |

*>55 µm.
**Institute of Marine Sciences of Middle East Technical University.

(≃2011 µm$^3$) and *Scrippsiella trochoidea* (≃2034 µm$^3$) together amounted to 53% and 10% in the two areas, respectively, of the total biomass at the surface. These percentages were 61% for the north-western area and 40% for the south-western area. Nesterova (1986) also noted that small algae (<1000–5000 µm$^3$) were predominant (71% of phytoplankton biomass) in the north-western Black Sea owing to eutrophication, whereas larger species (10 000–60 000 µm$^3$) represented 62% of total biomass in the south-western region during the summer of 1980.

The outflow of the Danube river, the most important nutrient source of the Black Sea, merges usually with the cyclonic gyre in a southerly direction and carries a significant amount of fresh water along with nutrients and other organic material towards the Anatolian shores (Tolmazin, 1985; Sur *et al.*, 1994). This explains the higher phytoplankton abundance and biomass in the western Black Sea. Moreover, the higher nitrate and phosphate to silicate ratios as well as organic material entrapped in the western region may provide competitive advantage for mixo- or heterotrophic dinoflagellates compared to autotrophic diatoms. This appears to be reflected in a high dinoflagellates to diatoms ratio in this region.

Phytoplankton dynamics in the Black Sea vary both temporally and spatially and an understanding of the full impact of eutrophication investigations covering wide areas is essential.

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