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Research Article

Red Tide Observations along the Eastern Black Sea Coast of Turkey

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Abstract: To determine the occurrence of dominant phytoplanktonic species causing red tides along the eastern Black Sea (Trabzon) coast of Turkey, multiple samples were collected periodically between 1991 and 2001. Red tide events were observed only during the periods between February and July. Six phytoplanktonic species causing 5 red tide events detected were *Diplopsalis lenticula*, *Euglena acusformis*, *Eutreptia lanowii*, *Pyramimonas orientalis*, *Scrippsiella trochoidea*, and *Gymnodinium sanguineum*. Numeric density of species during the red tide events ranged between 0.97 x 10^6 and 356 x 10^6 cells l^{-1}. During the red tides, the highest level of chlorophyll-a biomass ranged between 4.6 and 54.87 µg l^{-1}. Effects of such ecological parameters as temperature, salinity, nitrite, nitrate, phosphate, and total Fe on the level of red tide, measured as the number of cells per litre, are also discussed.

Key Words: red tide, phytoplankton, algal bloom, Black Sea

Doğu Karadeniz Kıyıları Boyunca Red Tide Gözlemleri

Özet: Türkiye'nin Doğu Karadeniz sahillerinde red tide'a sebep olan baskın fitoplanktonik türlerin belirlenmesi amacıyla 1991 ve 2001 tarihleri arasında periodik olarak fitoplankton örneklemeleri yapılmıştır. Red tide olayları sadece Şubat ile Temmuz ayları arasında gözlenmiştir. Beş red tide'a sebep olan 6 fitoplankton türü tespit edilmiştir: *Diplopsalis lenticula*, *Euglena acusformis*, *Eutreptia lanowii*, *Pyramimonas orientalis*, *Scrippsiella trochoidea* ve *Gymnodinium sanguineum*. Türlerin red tide sırasındaki sayısal yoğunlukları 0.97 x 10^6 ve 3.56 x 10^6 hücre l^{-1} arasında olduğu tespit edilmiştir. Red tide sırasında klorofil a değerlerini 4.6 ve 54.87 µg l^{-1} arasında değiştiği gözlenmiştir. Sıcaklık, tuzluluk, nitrit, nitrat, fosfat ve toplam Fe miktarlarının litrede hücre sayısı olarak ölçülen bloom seviyesine etkisi tartışılmıştır.

Anahtar Sözcükler: Red tide, fitoplankton, alg aşırı çoğalması, Karadeniz

Introduction

The occurrence of algal blooms in estuaries and neritic environments has been increasing in recent years (Wyatt & Pazos, 1992; Buskey et al., 1997). About 300 species, 7% of the estimated 3400-4000 phytoplankton species, including diatoms, dinoflagellates, silicoflagellates, prymnesiophytes and raphidophytes, have been reported to cause red tides (Smayda, 1997). Reports on phytoplankton blooms in the Black Sea are rare, and the reports are mainly from the north-west region (Mihnea, 1987; Mihnea, 1992; Bodenau & Ruta, 1998; Velikova, 1998). Although many species of phytoplankton, including some toxic species that can cause red tide, are present in the area, no harmful effect on aquatic animals in the surrounding environment has been reported. This is mainly due to the lack of research on the impact of red tides in the area; however, our observational field studies showed that red tide could be an important event factor for the health of the ecosystem due to rapid changes in physicochemical properties of the water, as it is in other parts of the world.

A phytoplankton monitoring programme was performed between 1991 and 2001 along the eastern Black Sea coast of Turkey to determine the seasonal distribution of species in the region. Five noticeable blooms recorded during this period are herein presented. Environmental factors that might have contributed to the build-up of red tide are also discussed. This is the first report of red tides along the Turkish coast of the eastern Black Sea.

Materials and Methods

Water and phytoplankton samples were taken by 2 research vessels, the R/V KTU DENAR and R/V YAKAMOZ between 1991 and 2001 off the coast of Trabzon (Figure 1). This monitoring site was specifically selected to monitor since the area is greatly affected by such human activity as city discharge water and agricultural runoff. In addition to our periodic sampling, observations and samples taken by fishermen were considered as evidence when red tides were spotted. Phytoplankton material was collected with a 20 µm plankton net and 9 l Kahlsico water sampler bottle for qualitative and quantitative analysis, respectively. The samples collected with the plankton net were kept for live observation, and the samples collected with the bottle were fixed with borax buffered neutral formaldehyde, *in situ*, for quantitative analysis (Throndsen, 1978). Wet mounts were examined under a Nikon E600 fluorescence microscope and an Olympus BH-2 light microscope with 10x, 100x, and 400x magnifications for identification. The references used for the identification of phytoplankton species were Tregouboff and Rose (1957), Drebes (1974), and Tomas (1993, 1996). For cell counting, we used a Karl-Kaps inverted microscope with a 1 ml counting chamber (Throndsen, 1995). During the blooms, the concentrations of nutrients (NO_2^-, NO_3^-, PO_4^{-3}, and total Fe) and chlorophyll-a were measured using spectrophotometric methods (Parsons et al., 1989). Conductivity, temperature, and depth (CTD) data were obtained with a YSI Model 3800 CTD and an Aandera RJM 9 CTD current meter.

A multivariate analysis and comparison of cell counts (log transformed) and explanatory variables (phosphate and nitrate) was conducted to determine the effects of nutrients on the magnitude of the blooms. Only case data only were used in this study. The model was selected with step-by-step exclusion of the parameters. In all statistical tests, a P value less than 0.05 was considered significant. Statistica 6.0 (SAS Inc.) was used for performing the analyses.

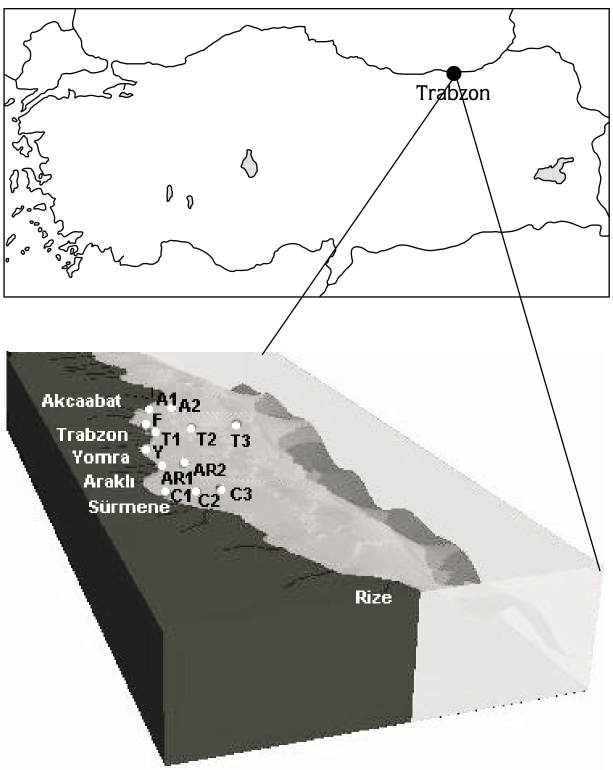

Figure 1. Study area and sampling stations.

Results

No seasonal temperature anomalies were observed during the last decade in the study area (Figure 2). The surface distribution of NO_2^-, NO_3^-, PO_4^{-3}, total Fe, salinity, temperature, and chlorophyll-a of the bloom sites are shown in Table 1. Total Fe was observed to deviate greatly from the norm during the detected blooms.

During the sampling period, 6 different species were found to cause red tides along Trabzon's coast line (Figure 3 and Table 2); 3 were Dinophyceae (*Diplopsalis lenticula* Bergh, *Gymnodinium sanguineum* Hirasaka, and *Scrippsiella trochoidea* (Stein) Balech ex Loeblich III), 2 were Euglenophyceae (*Euglena acusformis* Schiller and *Eutreptia lanowii* Steuer), and the other was

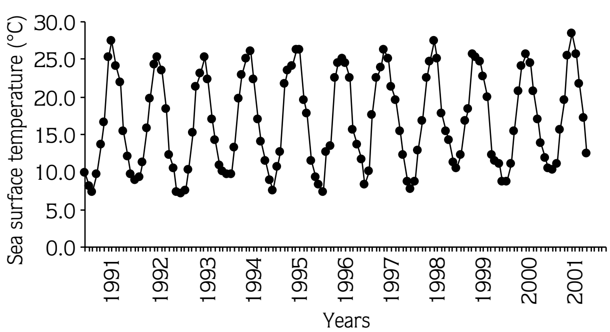

Figure 2. Annual water surface temperature changes between January 1991 and January 2001.

Table 1. Physico-chemical parameters during the red tide.

Red tide Period	N-NO_2 (mg l^{-1})	N-NO_3 (mg l^{-1})	P-PO_4 (mg l^{-1})	Total Fe (mg l^{-1})	Salinity (‰)	Temperature (°C)	Chl-a (µg l^{-1})
21st July 1993	0.002	0.8	0.180	0.001	17.1	22.8	4.6
8th March 1994	0.005	0.74	0.084	0.005	14.9	9.5	21.10
15th June 1995	0.014	0.5	0.076	0.023	16	23.2	54.87
2nd February 2000	0.2	0.2	0.091	0.021	18.8	8.7	19.23
29th June 2001	0.022	0.12	0.083	0.033	14.9	22.3	7.6

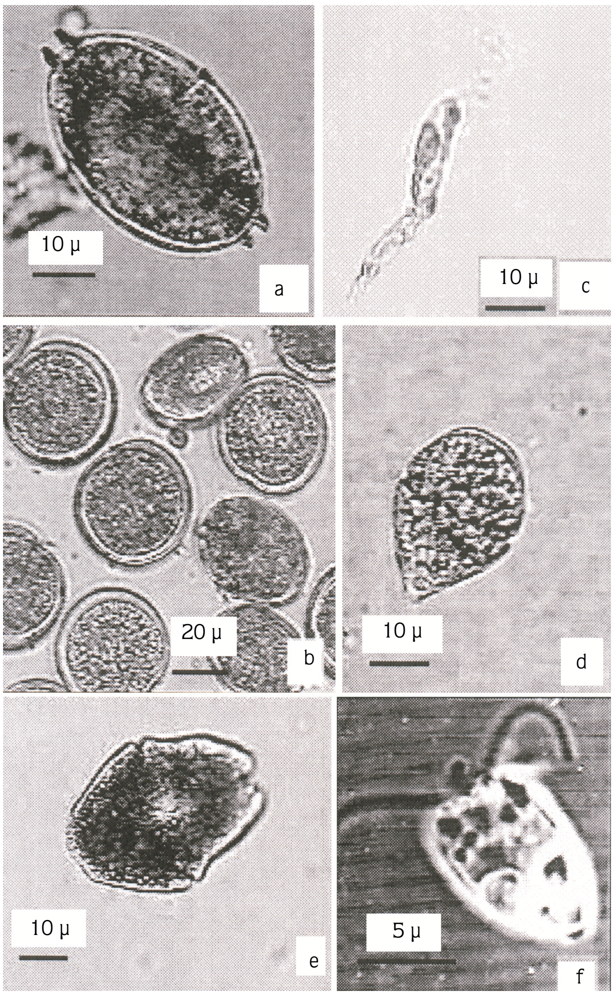

Figure 3. Images of causative organisms: A- (400x) and B- (200x) of *Diplopsalis lenticula* sample isolated from Akçaabat Bay; C- Light micrograph (400x) of *Euglena acusformis* isolated from Yomra Bay; D- Light micrograph of *Scrippsiella trochidea* (400x) isolated from Sürmene Bay; E- Light micrograph of *Gymnodinium sanguineum* (400x) isolated from Sürmene Bay; F- SEM image of *Pyramimonas orientalis*.

Table 2. Cell concentration of the species during the red tide.

Date of occurrences	Causative species	Cells l^{-1}
21st July 1993	*Diplopsalis lenticula* Bergh	0.97×10^6
8th March 1994	*Euglena acuiformis* Schiller *Eutreptia lanowii* Steuer	87×10^6
15th June 1995	*Pyramimonas orientalis* Butcher ex McFadden, Hill, & Wetherbee	356×10^6
2nd February 2000	*Scrippsiella trochoidea* (Stein) Balech ex Leoblich III	13.4×10^6
29th June 2001	*Gymnodinium sanguineum* Hirasaka	2.74×10^6

Prasinophyceae (*Pyramimonas orientalis* Butcher ex McFadden, Hill, & Wetherbee). The dates of occurrence, causative organisms, and corresponding cell numbers of observed phytoplankton species causing red tide during the study period are summarised in Table 2. During the blooms, the maximum number of cells occurred either at the surface or subsurface. Red tides, brownish or orange, occurred at a specific location of the inner portion of bays due to NNE and N wind-driven surface currents enhancing nutrient concentration. During the red tides, accumulations of cells were observed through the line of crossing coastal micro gyres. Red tides either covered an entire area, or were present as unevenly distributed patches; they lasted for about 1-4 days, and did not spread off-shore.

During the sampling period, the first red tide phenomena appeared in Akçaabat coastal waters on July

21, 1993. The causative organism was *G. lenticula*. The red tide lasted for 2 days. The mean densities of the cells were 0.97 x 10^6 cells l^{-1} (Table 2). The number of *G. lenticula* cells per unit volume was lower than those of other red tide events we observed during the course of this study. Cell size and number of organisms per millilitre were both large enough to change the colour of the water. *G. lenticula* has not been observed since that time anywhere in the sampling area.

During the second red tide event, 2 Euglenoid algae (*E acusformis* and *E. lanowii*) were observed in Yomra Bay on 8th March 1994. The number of cells per litre reached 87 x 10^6 (Table 2). A brownish-orange red tide was observed as 1 m diameter patches in the inner part of the bay. The water temperature during the bloom was 9.5 °C and salinity was 14.9‰. The bloom disappeared the day after the observation. Although species were present in the bloom area for almost a week after the red tide, concentrations never reached the level observed during the red tide.

The highest cell counts, 356 x 10^6 cells l^{-1} (Table 2) were obtained during the *P. orientalis* bloom in Sürmene Bay on 15th June 1995. The water colour was yellowish-green and its depth was measured with a secchi disc as 45 cm from the surface. A day after sampling, the colour disappeared and environmental parameters returned to initial values. During the bloom, the chlorophyll-a concentration was 54.84 mg l^{-1}, which was the highest biomass value ever measured in the region.

The bloom of *S. trochoidea* was observed as brownish-red around many horizontal lines of the inner area of Sürmene Bay from 2nd-4th February 2000. The number of cells at the water surface was 13.4 x 10^6 cells l^{-1}. It was lower (2.88 x 10^6 cells l^{-1}) at a depth of 5 m. The bloom of *S. trochoidea* was mixed with *Heterocapsa triquetra*. During the bloom, water temperature and salinity were 8.7 °C and 18.8‰.

A bloom of *G. sanguineum* (Figure 3) was observed in the entire sampling area, without any interruption, and lasted for 4 days beginning 29th June 2001. The concentration of *G. sanguineum* reached 2.74 x 10^6 cells l^{-1} and turned the water reddish-brown. During the sampling, sea water temperature and salinity were 22.3 °C and 14.9‰. The concentrations of nitrate and total Fe were higher than those of the other red tide events observed.

A significant relationship between environmental factors (NO_3^- and PO_4^{-3}) and magnitude of the red tide was detected (multivariate analysis, $P < 0.05$; $r^2 = 0.91$); Log (cell) = 9.32 + 1.37 NO_3^- – 24.85 PO_4^{-3}.

Fe and NO_2 were not found to be correlated with the blooms under the conditions observed. Moreover, when Fe was included in the model, a significant increase in P value was anticipated (P = 0.09).

Discussion

Five red tide events were recorded along Trabzon's coastal waters from 1991 to 2001. Even though the same species caused blooms at various levels before 2001, no red tide event was observed afterwards. These findings indicate that red tides do not occur annually or periodically in this region. When they occurred, it was always between late winter and early summer.

Red tides occurring seasonally indicate that certain environmental parameters, or a combination of them, trigger the blooms. In this study, NO_2^-, NO_3^-, PO_4^{-3} total Fe, salinity, and water temperature were measured during each red tide event to determine any association between these environmental factors and the magnitude of the blooms that were measured as number of cells per litre. The best multivariate model indicated that the level of red tide largely depended on NO_3^- and PO_4^{-3} concentrations (P = 0.003). When Fe was included in the model, representativeness of the model decreased (P = 0.09). Fe is known to be a limiting factor in some blooms (Brand, 1991; Chavez et al., 1991; Sunda et al., 1991); therefore, this finding was not surprising. In brief, the levels of NO_3^- and PO_4^{-3} were important environmental factors in the occurrence of the red tide events. This aspect needs to be evaluated further with more data, if new blooms occur.

Similar species caused red tide in the north-eastern and south-eastern part of the Black Sea. In addition to the species presented here, *S. trochoidea* and *E. lanowii* can also cause red tide in the north-eastern Black Sea. Moreover, *S. trochoidea* and *E. lanowii* are the most frequently encountered organism causing red tide at both locations (Bodenau and Ruta, 1998).

It is known that the concentrations of organisms in red tides range from 1 x 10^6 cells l^{-1} to 1 x 10^8 cells l^{-1}, or more than 5 x 10^4 cells l^{-1} (Koray, 1984). When *G.*

lenticula is compared to the other species, the cell number of species per litre seems to be lower; however, red tide can easily be observed at such low concentration due to the large cell size of this species.

There is no record of illnesses such as paralytic shellfish poisoning disease in the region, although dinoflagellate blooms frequently occur in the area. Two possible reasons are that species causing frequent blooms have no harmful effects on human health and the shellfishes, e.g., *Mytilus galloprovincialis* and *Anadara cornea*, are not eaten by local people for cultural reasons. However, frequent fish kills in the absence of any pathogenic agent during the same season suggest that some species of toxic algae could be responsible for unexplained mass fish kills (Ogut, unpublished results).

In brief, the results show that there are toxic algae in the region, but they never reach levels high enough to be harmful to humans or marine life. Along with increasing coastal pressures from antropogenical activity (aquaculture and discharge system), these algae could eventually lead to serious problems as in other parts of the world and, therefore, their levels should be closely monitored.

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