Chapter 2

Bloom Dynamics of *Emiliania Huxleyi* (Lohmann) Hay & Mohler, 1967 in the Sea of Marmara: A Review

Muhammet Turkoglu

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/62907

Abstract

Coccolithophores have had an effect on global climate change for a few million years. The marine phytoplankton group is responsible for approximately 20% of the total carbon fixation in marine systems. They can form blooms spreading hundreds of thousands of square kilometers, are recognized by elegant coccolith structures formed from calcium carbonate exoskeletons, and are visible from space. Although carbon is transferred to the sediments in organic matter and calcite form by coccolithophores, carbon dioxide (CO_2) is released by the calcification process. Therefore, they have a complex effect on the carbon cycle due to their activity regarding CO_2 production and consumption. This review represents the first attempt to present temporal and vertical distributions of *Emiliania huxleyi* (Lohmann) Hay & Mohler, 1967 (*Ehux*), which is one of the most important species of the coccolithophores in the bloom periods and the interaction of this species with other phytoplankton groups in the Sea of Marmara. This study may also indicate the advance of this species from the Black Sea region through the Sea of Marmara and the Dardanelles under favorable conditions.

Keywords: Phytoplankton, coccolithophore, *Emiliania huxleyi*, bloom dynamics, Sea of Marmara

1. Introduction

The Sea of Marmara is a very important water passage between the Aegean Sea and the Black Sea via the Dardanelles and the Bosphorus. It has two current systems that run in opposite directions. Deep water high in density (38.0 ppt) coming from the Aegean Sea flows into the Black Sea. Surface water low in density (18.0 ppt) coming from the Black Sea flows into the Aegean Sea. Therefore, Marmara is affected by both neighbor systems [1–3].

Coccolithophores are marine haptophyte phytoplankton. They are one of the most important groups of phytoplankton in today's oceans and contain about 300 species. *Emiliania huxleyi* (*Ehux*) is one of the most abundant coccolithophores found globally in all oceans, except polar ones. Although some coccolithophores produce toxins, *Ehux* does not produce any. However, *Ehux* has received considerable attention because of its capacity to produce massive blooms under favorable conditions [4–8]. This species also blooms to excess in the Sea of Marmara as a result of the system's unique character not only in summer periods but also in winter periods due to climate change and eutrophication [1, 9–11].

The coccolithophore *Ehux* has captured the attention of various scientists—especially those working in marine biology, geology, biogeography, and paleoclimatology. As a result of its coccolith structure—its remains can be traced back millions of years—this species carries important hints on climate change and oceanic conditions during geological time periods [12]. It is known that massive blooms of *Ehux* provide a chemical balance between the hydrosphere, geosphere, and atmosphere in the context of the carbon cycle. The blooms are known to exceed tens of thousands of square kilometers in area and can be detected by remote sensing due to its reflective calcite form. In addition to its important role in the global carbon cycle, *Ehux* also plays an important role in the global sulfur cycle [12, 13].

The main phytoplankton groups in the Sea of Marmara are dinoflagellates, diatoms, coccolithophores, and cyanobacteria. Although there are many different phytoplankton species—more than 150 in the Sea of Marmara—the blooms tend to be extremely rich in a single, or only a few, predominant species such as *Ehux* and *Noctiluca scintillans* [9–11, 14]. The Sea of Marmara has a three- or four-phase phytoplankton bloom sequence which changes year to year. Diatoms tend to predominate in March–April, dinoflagellates in April–May, the dramatically colorful blooms of *Ehux* predominate in May–June, and diatoms in July–August [1, 9–11, 14–16].

This study looks at *Ehux* from the unique character of the system in that there are blooms not only in summer but also in winter due to climate change and eutrophication in the Sea of Marmara.

2. Methodology

The methodology adopted by this review study on the bloom dynamics of the coccolithophore *Ehux* in the Sea of Marmara has as its aim to expose both similar and specific bloom behaviors as well as differences from any other system. The bloom dynamics of the key species—not only in summer but also in winter—are discussed in light of their associations with other phytoplankton groups (such as diatoms and silicoflagellates) and physicochemical variables such as temperature, salinity, and nutrients under the unique character of the Sea of Marmara and under the pressure of climate change and eutrophication (**Fig. 1**).

http://dx.doi.org/10.5772/62907

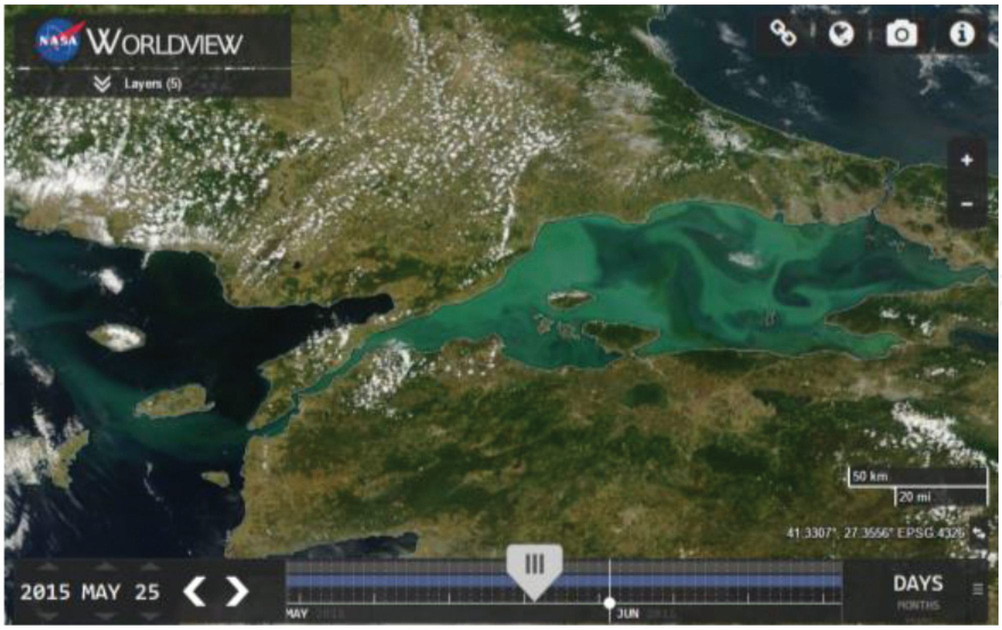

Fig. 1. Sea of Marmara under pressure from climate change and eutrophication [17].

3. *Emiliania huxleyi* (Lohmann) Hay & Mohler, 1967

3.1. General characters

Ehux does not produce any toxin; Thomas Huxley and Cesare Emiliani pointed this out in their study of marine deep sediment. *Ehux* is a coccolithophore species with a worldwide distribution from tropical waters to subarctic waters. It is one of thousands of photosynthetic phytoplankton that live freely in the euphotic ocean zone, forming the first step of all ocean food webs. *Ehux* is a single-celled phytoplankton covered with coccoliths, which are uniquely ornamented calcite disks [18, 19]. The coccoliths are frequently colorless and transparent, but they are formed of calcite which refracts light very efficiently. *Ehux* emits more carbon dioxide (CO_2) and hence has a greater effect on climate change than other phytoplankton species as a result of calcium carbonate ($CaCO_3$) accumulations in their coccoliths [7, 12, 13].

3.2. Global distribution and abundance

Ehux is the most abundant coccolithophore species found in the oceans. It has a worldwide distribution, the exception being the polar regions. During comprehensive blooms, sometimes covering areas of 100,000 km^2, *Ehux* cell densities can exceed all other phytoplankton densities in the region combined, accounting for 75% or more of the total number of phytoplankton in the region. These massive blooms can be shown through satellite imagery because of the large amount of light backscattered from the ocean water column, which provides a method to assess their biogeochemical importance on both basin and global scales [4–8].

3.3. Climate change and harmful algal blooms

It is predicted that climate change will seriously impact aquatic ecosystems, both freshwater and marine. Together with nutrient pollution, these climatic impacts might bring about increases in the densities and field effects of harmful algal blooms (HABs). Climate change might affect HABs in many ways as a result of increased water temperature, higher CO_2 values, changes in rainfall and salinity, coastal upwelling, rise in sea levels.

As waters warms more than usual due to climate change, HABs will increase both in number and area. HABs usually occur in warm summer periods. Warm waters favor the formation of HABs in a number of ways. For example, nanoplankton and picoplankton species such as the more toxic cyanobacteria and coccolithophores prefer warmer waters. High temperature levels at the surface prevent mixing of the water column, which allows HABs to become thicker and grow faster. It is generally accepted that warm waters favor the proliferation of tiny phytopkankton bloom species and allow them to survive much easier in the surface waters. It is known that algal blooms absorb solar radiation, which makes the water even warmer than usual and facilitates more algal blooms. On the other hand, climate change might lead to more drought seasons, making freshwater saltier. So, marine algal bloom species could spread to freshwater and brackish water ecosystems.

Phytoplankton species need dissolved CO_2 to proliferate. Higher CO_2 levels—first in the air and then water—might lead to rapid phytoplankton increase, particularly picoplanktonic species that float on the surface layer of the water. Moreover, climate change might affect precipitation dynamics, leading to alternating periods of drought and intense storms. The main source of nutrients is rain and river water discharge into aquatic ecosystems, supporting more algal blooms.

In view of current sea level rise, more scientists predict that sea levels will rise by as much as 1 m by 2100. Rising sea levels would create an increase in shallow and coastal waters—perfect conditions for the growth of phytoplankton and other algae. Another important factor is the increase in coastal upwelling events due to climate change. Coastal upwelling is a transport process from ocean deep-layer waters rich in nutrients to surface-layer waters of coastal zones due to the drifting of surface waters by offshore winds. Waters rich in nutrients delivered by upwelling lead to more algal blooms.

On the other hand, it is important to remember that this is a two-way process in which climate change affects HABs and HABs affect climate change. Looked at from the perspective of global excessive *Ehux* blooms, there are two special factors affecting global climate change. The first is that *Ehux* blooms locally act as an important source of $CaCO_3$ and dimethyl sulfide (C_2H_6S), the dense production of which can have a significant impact not only on the properties of the ocean surface mixed layer, but also on global climate change. As with all phytoplankton, *Ehux* primary production through photosynthesis is a sink of CO_2. However, the production of coccoliths through calcification is a source of CO_2. This means that coccolithophores, which include *Ehux*, have the potential to act as a net source of taking CO_2 out of the ocean. Whether they are a net source or sink in terms of CO_2 and how they will react to ocean acidification is not very clear. However, the chemical processes in **Fig. 2** are informative. The second factor is

http://dx.doi.org/10.5772/62907

that the scattering induced by *Ehux* blooms not only causes more heat and light to be pushed back up into the atmosphere more than usual, but also causes more of the remaining heat to be trapped closer to the ocean surface [20–23].

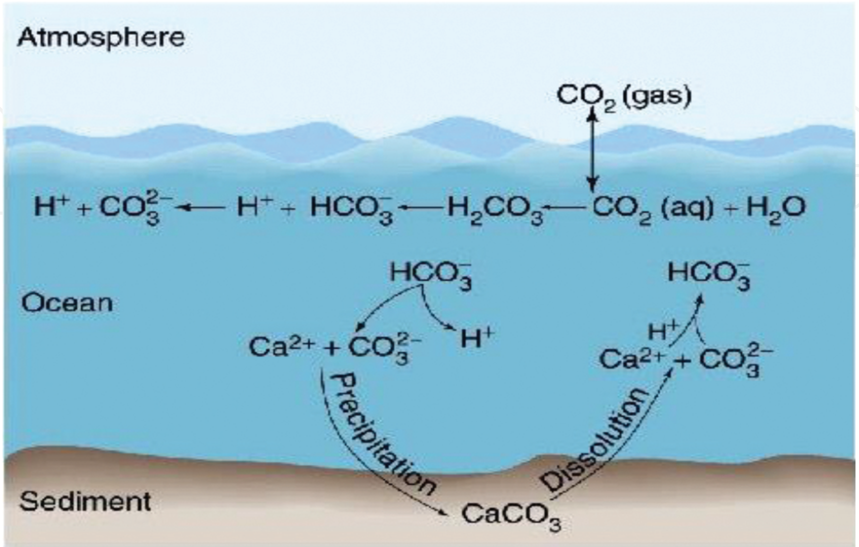

Fig. 2. Carbon cycle between atmosphere and ocean sediment.

4. Bloom dynamics of *Emiliania huxleyi* in the Sea of Marmara

4.1. Effect of temperature, salinity, and CO_2 in the Sea of Marmara

Average annual air temperature anomalies between 1981 and 2014 in Turkey (**Fig. 3**) confirm increased annual average temperature. For example, looking at temperature changes in the last 5 years the average temperature in 2014 (14.9°C) exceeds the average between 1971 and 2010 (13.5°C) (**Figs. 3 and 4**).

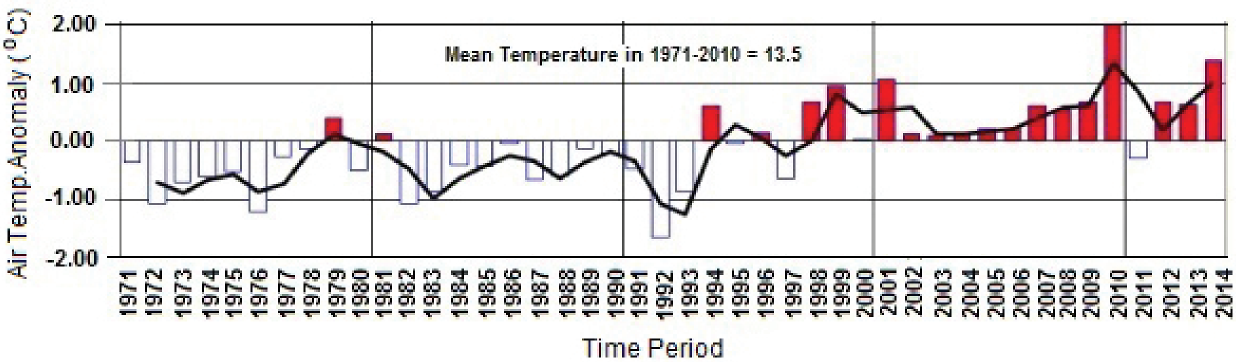

Fig. 3. Average annual air temperature anomalies between 1971 and 2014 in Turkey [24].

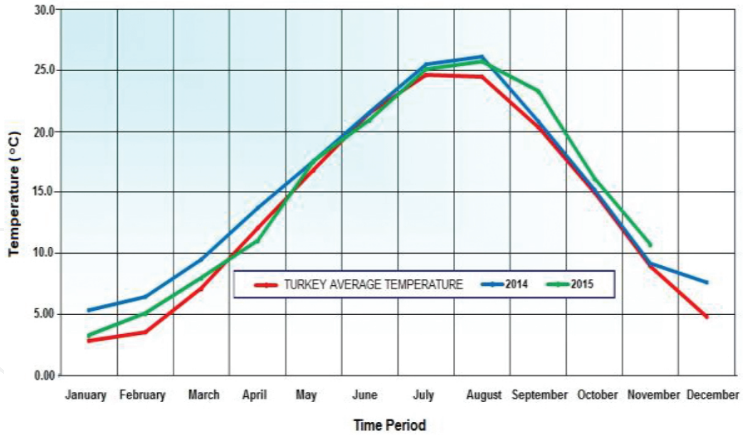

Fig. 4. Monthly average temperature variations in 2014 and 2015, and long-time temperature anomalies in Turkey [24].

The increase in average air temperature also causes an increase in surface water temperature in the Sea of Marmara and Black Sea—as is the case in other Turkish seas (**Fig. 5**). Due to the similar climatic behavior coupled with the effect of Black Sea surface waters via the Bosphorus, sea surface temperature variations in the Sea of Marmara are largely similar to the time series of basin mean winter anomalies of sea surface temperature (SSTA), surface atmosphere temperature (SATA), and the meridional component of surface wind (WA, m/s, dashed lines) for the Black Sea [25].

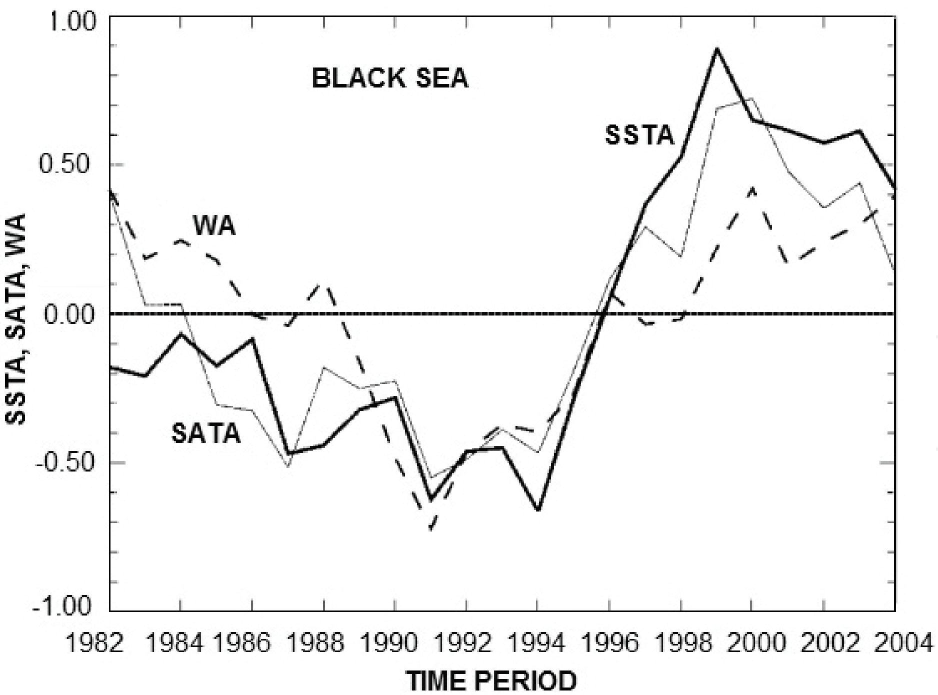

Fig. 5. Time series of basin mean winter anomalies of sea surface temperature (SSTA, °C, bold solid lines), surface atmosphere temperature (SATA, °C, solid lines), and the meridional component of surface wind (WA, m/s, dashed lines) for the Black Sea [25].

http://dx.doi.org/10.5772/62907

Ehux is one of the most abundant coccolithophores showing a global distribution in all the oceans (apart from the polar oceans), generally in late spring or early summer. This species drifts freely and prefers the surface layers of oceans. *Ehux* blooms occur not only in summer, but also in winter when the temperature does not fall below 10.0°C in the Sea of Marmara [9, 10]. Sorrosa et al. [26] show that low temperature suppresses coccolithophorid growth, induces cell enlargement, and stimulates the intracellular calcification that produces coccoliths. For example, while the coccolithophore *Ehux* tolerates a wide temperature range (10–25°C), another coccolithophore species *Gephyrocapsa oceanica* Kamptner, 1943 tolerates a narrow temperature range (20–25°C) when cell sizes are correlated with temperature in a negative manner [26]. On the other hand, increased global CO_2 emissions (**Fig. 6**) coupled with other favorable factors are behind the massive blooms of *Ehux* in the Sea of Marmara, as is the case in the rest of the world. *Ehux* has received considerable attention since it tends to produce massive blooms under favorable temperature and high CO_2 emission conditions [4–10, 27, 28]. On the other hand, **Fig. 6** illustrates what is claimed to be a causal correlation between CO_2 and temperature[29].

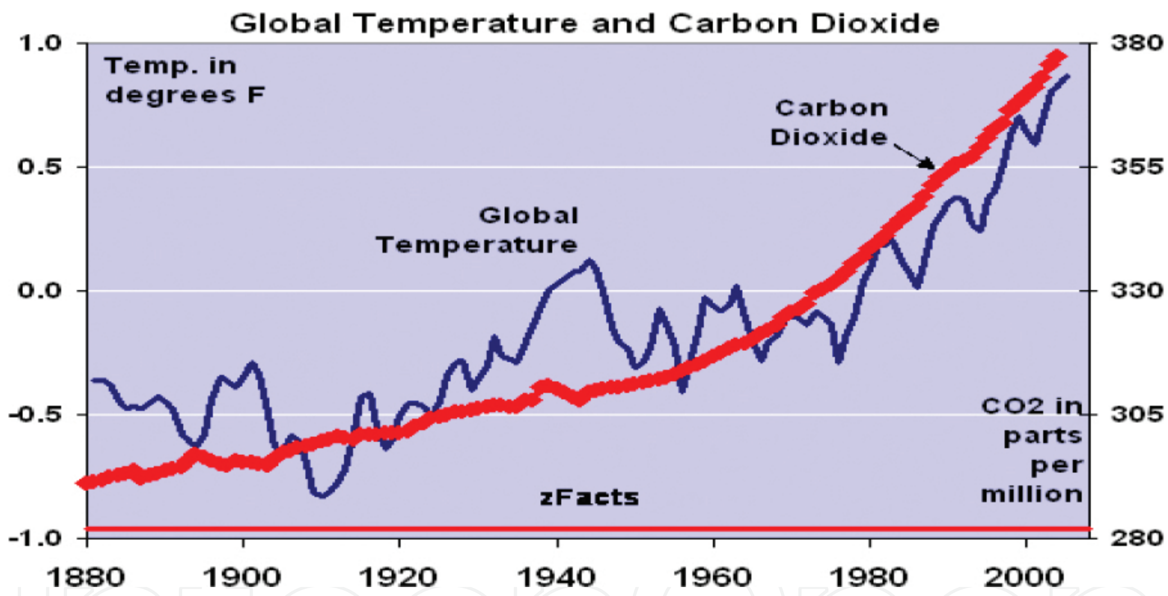

Fig. 6. Worldwide temperature and carbon dioxide anomalies [29].

The Sea of Marmara has two current systems that flow in opposite directions: upper-layer water that originates from less salty Black Sea surface water (18.0 ppt) and lower-layer water that originates from very salty Mediterranean water (39.0 ppt). Therefore, there is stratification in terms of both temperature and salinity during the year. However, the stratification in temperature in summer and winter in the Sea of Marmara is reversed, but the stratification in salinity is not. Hence, surface waters are consistently cold in winter (8–12°C) and hot in summer (20–25°C) irrespective of temperature during the year. When it comes to minimum and maximum temperature variations the Sea of Marmara provides the most favorable conditions for massive *Ehux* blooms during the year. As mentioned earlier, it is known that *Ehux* tolerates a wide temperature range between 10 and 25°C [9, 10, 26].

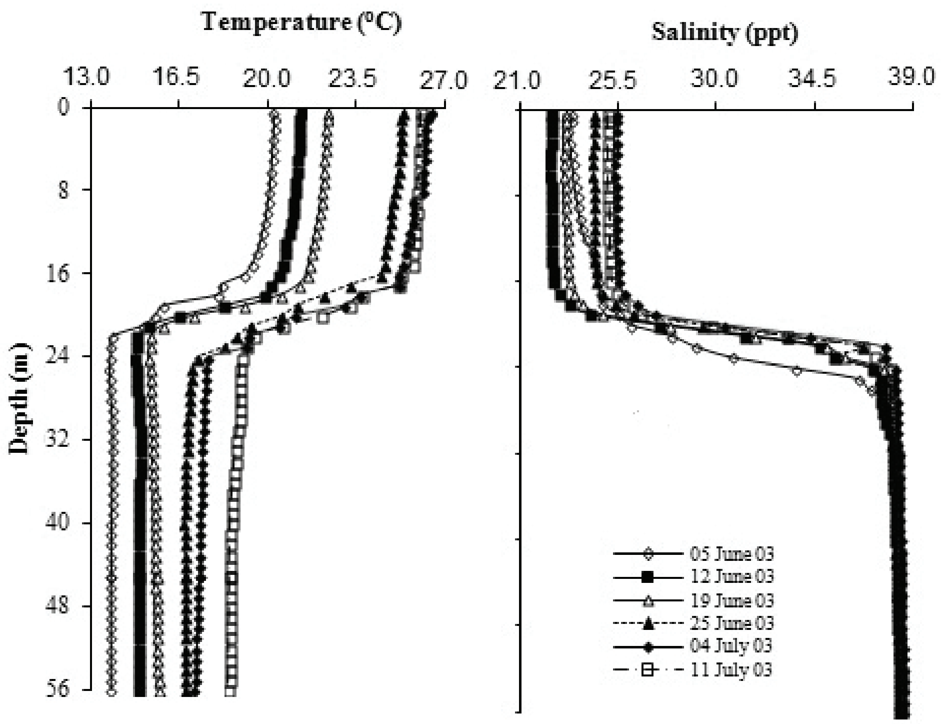

Fig. 7. Vertical distribution of temperature and salinity during the summer 2003 *Ehux* bloom in the Dardanelles [9].

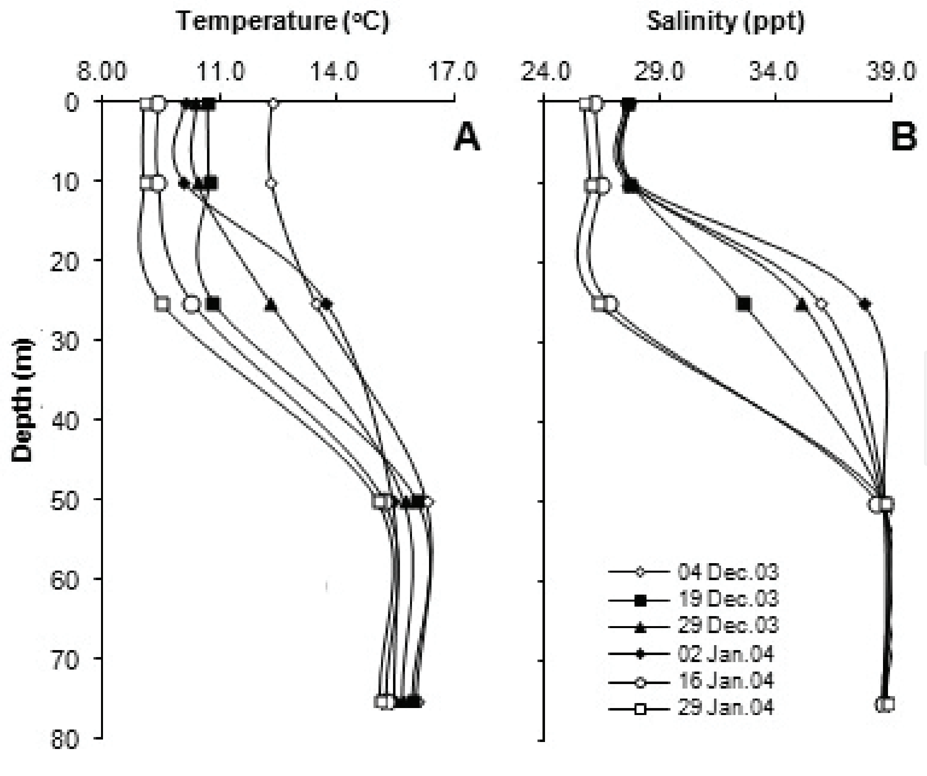

Fig. 8. Vertical profiles of temperature (A) and salinity (B) during the winter 2003/2004 bloom of *Ehux* in the Dardanelles [10].

In the summer *Ehux* bloom period [9], whereas the upper layer (0–15 m) has low salinity values (22.3–25.4 ppt) the much thicker lower layer (25–60 m) has high salinity values (36.5–38.5 ppt). However, temperature variations in both the upper layer (19.1–26.48°C) and lower layer (13.8–18.98°C) were more variable than variations in salinity. The seasonal thermocline and halocline interfaces are clear and form between 15 and 25 m during algal blooms (**Figs. 7 and 8**).

4.2. Effect of nutrient and nutrient ratios on *Emiliania huxleyi* blooms in the Sea of Marmara

There is experimental and natural evidence for the exceptional competitive ability of *Ehux* when the nitrate:phosphate (N:P) ratio is high. In multispecies competition experiments, Riegman et al. [30] found that *Ehux* isolated from the North Sea, along with some diatom species such as *Chaetoceros socialis*, outcompeted other species when the N:P was 100. With an N:P ratio of 1.50, although other species outcompeted *Ehux, Ehux* still maintained a relatively high population in the assay medium. In another study, Riegman et al. [31] demonstrated that *Ehux* had an incredibly high affinity for phosphate under phosphorus stress (N:P=300). Further, Riegman et al. [31] showed that *Ehux* has two cell surface–bound alkaline phosphatase enzymes enabling it to utilize organic phosphate at nanomolar concentrations, supporting the findings of a previous study [32]. Therefore, *Ehux* would be expected to be particularly competitive at low phosphate concentrations and high N:P ratios. Mesocosm studies in a Norwegian fjord support this idea [33, 34].

However, another examination of mesocosm experiments over several years showed that *Ehux* also grows well in mesocosms where the N:P ratio is low [33]. In many experiments the N:P ratio immediately before *Ehux* bloom is lower than the initial ratio. Clearly, there are other environmental factors in addition to high N:P ratios that are critical for *Ehux* blooms. The various findings of these experiments suggest that *Ehux* can still gain an advantage under a wide range of nitrate and phosphate ratios and concentrations in mesocosms even when the nutrient environment is artificially changed.

Turkoglu [9, 10] demonstrated that N:P ratios are significantly lower than the assimilatory optimal of the Redfield ratio (16:1) in the Sea of Marmara during *Ehux* bloom periods not only in summer (**Fig. 9**), but in winter *Ehux* bloom periods as well (**Fig. 10**). On the other hand, it is observed that N:P ratios are lower (<10) and silicate:phosphate (Si:P) ratios are higher (>10) in *Ehux* bloom periods in the upper layer under bloom conditions (**Figs. 9 and 10**). However, due to nitrogen scarcity Si:N ratios are over 1.00 (average: 3.07 ± 2.16) both in the upper layer and in the lower layer (average: 2.89 ± 1.93) during *Ehux* blooms in the Dardanelles, which is a part of the Turkish Straits System (**Figs. 9 and 10**).

On the other hand, vertical profiles of inorganic nutrients in bloom periods show that both nitrogen and phosphate concentrations in the Sea of Marmara are higher (**Figs. 10 and 11**) than any other marine system, even its neighbor the Black Sea [10, 11, 14, 16, 35–39]. As a result of heavy eutrophication, nutrient concentrations in the Sea of Marmara have gradually increased since 1960 (**Fig. 12**).

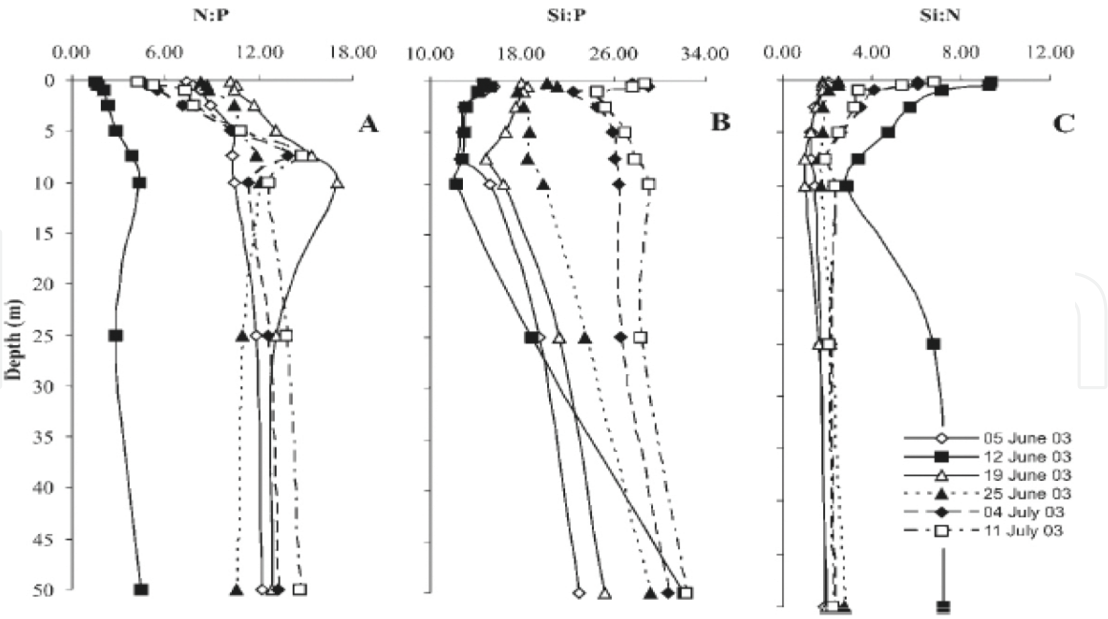

Fig. 9. Vertical distribution of some nitrogen ratios in the winter bloom period in the Sea of Marmara (Dardanelles) [9].

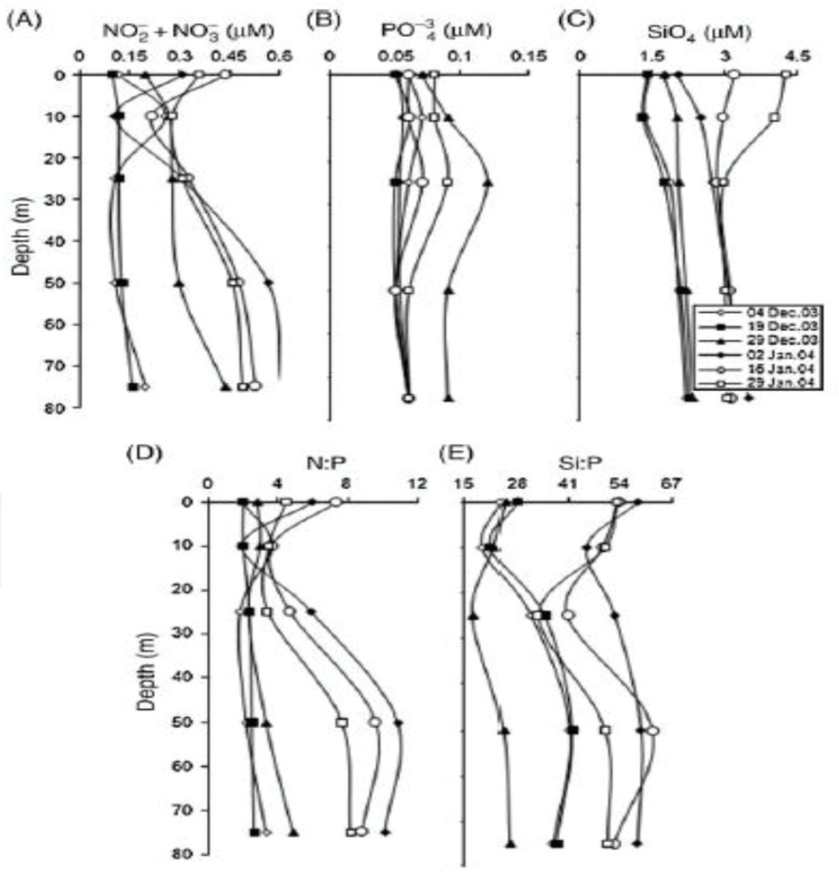

Fig. 10. Vertical distribution of nutrients and nitrogen ratios in the summer bloom period in the Sea of Marmara (Dardanelles) [10].

http://dx.doi.org/10.5772/62907

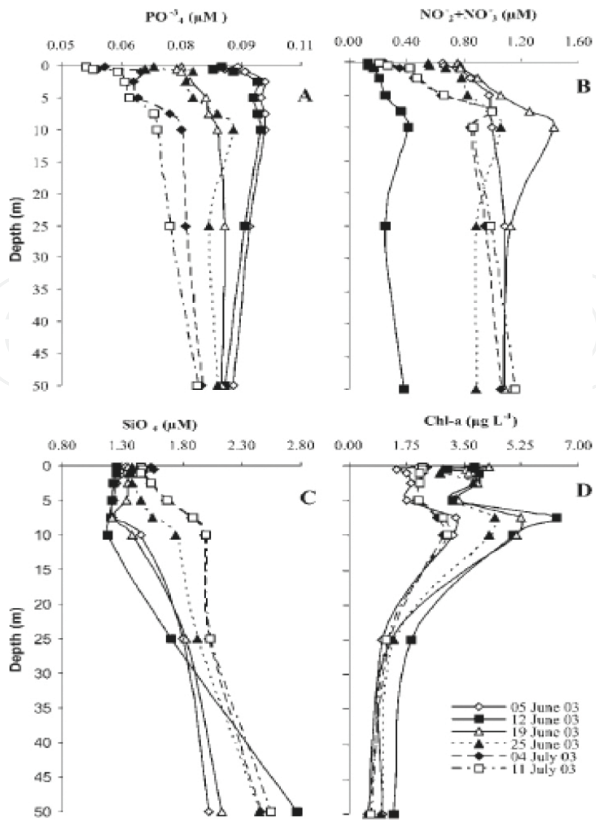

Fig. 11. Vertical distribution of nutrient concentrations in the summer bloom period in the Sea of Marmara (Dardanelles) [9].

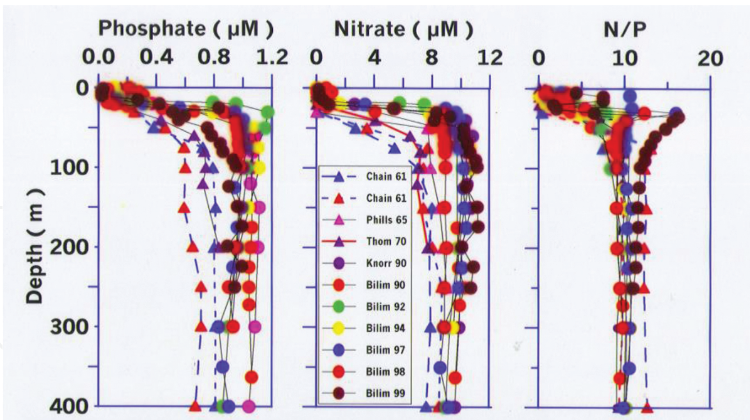

Fig. 12. Vertical variations of phosphate, nitrate, and N:P ratio in the long term in the deep basin of the Sea of Marmara (METU-IMS Data).

In actuality, what triggers *Ehux* blooms in the Sea of Marmara cannot be attributed to nutrient concentration levels or nutrient ratios such as N:P, Si:P, and Si:N on their own. Since this species proliferates under both low/high nutrient concentration levels and low/high N:P ratios, *Ehux* blooms are probably dependent on other phytoplankton blooms such as diatoms. In other words, competition between other phytoplankton groups, especially diatoms, may well be critical. The concentration of silicates and phosphates in the system plays a major part in competition between *Ehux* and diatoms. *Ehux* blooms follow the blooms of diatoms in different marine systems (9, 10, 37–44).

In *Ehux* bloom periods, one of the probable causes of insufficient nutrient concentrations, especially silicate (<2.00 mm) and phosphate concentrations (<0.05) in the surface layer, is the utilization of nutrients by early diatom blooms. In other words, low phosphate and silicate concentrations favor *Ehux* blooms [6, 8, 33, 45]. In actuality, *Ehux* blooms are not stimulated by low phosphate or low silicate concentrations. *Ehux* predominates in the absence of diatoms due to the low phosphate and silicate concentrations. The proliferation or bloom of diatoms almost stops when the silicate concentration falls below 2.00 μM in marine systems, bringing the competition between diatoms and *Ehux* to an end. Subsequent to the very high diatom density in spring, there begins the excessive bloom of *Ehux* some time in late spring (second half of May), some time in early summer (June and July), and again some time in early/middle winter periods which varies year to year in the Sea of Marmara [9, 10].

Merico et al. [46] showed low N:P ratios in the southeastern Bering Sea during the *Ehux* bloom years 1997–2000 as a result of nitrogen scarcity, not phosphate abundance. This is unlike the Sea of Marmara where phosphate exceeds nitrogen due to domestic waste water rich in phosphate [9, 10]. In fact, in most bloom studies to date, nitrogen levels are lower than phosphate and hence N:P ratios are low. For example, the limiting factor for *Ehux* blooms is generally nitrogen rather than phosphate in the Sea of Marmara. N:P ratios cannot be trusted to reflect nutrient conditions at the initiation of *Ehux* blooms if there is prior preferential phosphate or nitrate utilization by other blooms, especially diatoms in the Sea of Marmara [9, 11].

On the other hand, inorganic N:P ratios may not be good indicators of phosphorus stress if organic forms of nitrogen and phosphorus are available to phytoplankton. Organic forms of nitrogen and phosphorus are used by many phytoplankton and may be important in their nutrition, but data on organic nutrient forms, bioavailability, and species-specific abilities to use them are still limited [47, 48]. *Ehux* is able to use some amino acids, amides, purines, and urea [49]. In the few studies that have examined the uptake of nonnitrate nitrogen during blooms, *Ehux* primarily used NH^{+}_{4} and urea. At the very least, *Ehux* has a superior ability to use regenerated nitrogen. It is perhaps the combined ability of *Ehux* to use nonnitrate nitrogen in addition to its exceptional phosphorus procurement capacity that grants it competitive success in nutrient-depleted waters exposed to high solar radiation such as the Sea of Marmara, which is nitrogen limited [1, 9–11, 14, 16].

4.3. Phytoplankton chlorophyll *a* levels in the Sea of Marmara

Turkoglu (2008) revealed that, in the summer *Ehux* bloom period, chlorophyll *a* concentrations range from 1.5 to 6.5 μg L^{-1} in the upper layer where there are massive *Ehux* blooms (**Fig. 11**). In contrast, Turkoglu [10] showed that, in the *Ehux* winter bloom period, chlorophyll *a* concentrations are lower (min–max:1.23–2.32 μg L^{-1}; average: 1.94 ± 0.43 μg L^{-1}) than summer bloom periods in the upper layer. However, chlorophyll *a* maxima were also observed in the subsurface layer (10 m) due to diatom and other blooms at this depth during the bloom period

[10, 11]. The system is so productive that the annual average phytoplankton chlorophyll *a* level is 2.78 ± 3.21 μg L^{-1}. On the other hand, chlorophyll *a* levels reach 20.0 μg L^{-1} in some spring and late summer periods (**Fig. 13**) [50, 51].

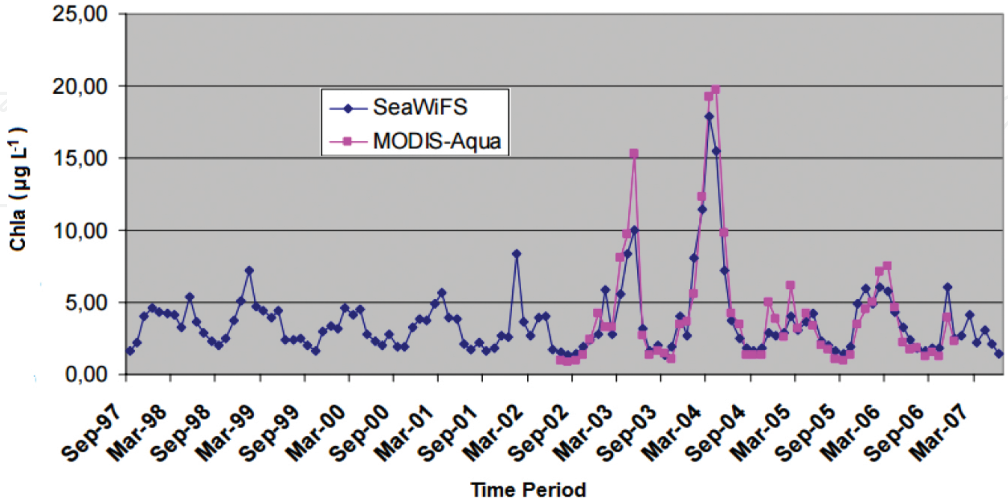

Fig. 13. Variations of MODIS and SeaWiFS chlorophyll a in the Sea of Marmara [50].

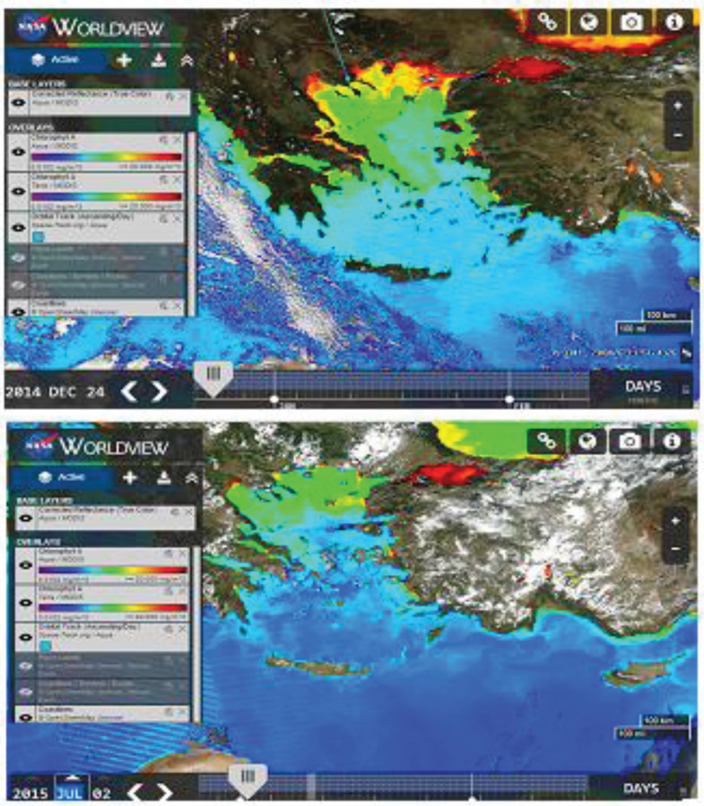

Fig. 14. SeaWiFS satellite images of chlorophyll a concentrations in winter (upper image) and summer (lower image) in the Sea of Marmara [17].

SeaWiFS (Sea-Viewing Wide Field-of-View Sensor) satellite images for chlorophyll *a* concentrations show that high concentrations are found not only in summer but also in winter in the Sea of Marmara (**Fig. 14**).

5. *Emiliania huxleyi* bloom characters of the Sea of Marmara

5.1. Interactions of *Emiliania huxleyi* and other phytoplankton

Various scientists studying phytoplankton taxonomy have listed over 150 different types of phytoplankton in the Sea of Marmara [1, 52]. However, the blooms tend to be extremely rich in a single, or only a few, predominant species. This sea has a three-phase phytoplankton bloom sequence. Diatoms tend to predominate in March, dinoflagellates in April, and the dramatically colorful blooms of *Ehux* predominate in the second half of May. The phytoplankton bloom colors the system with brilliantly coloured swirls of various shades of green in late spring and early summer.

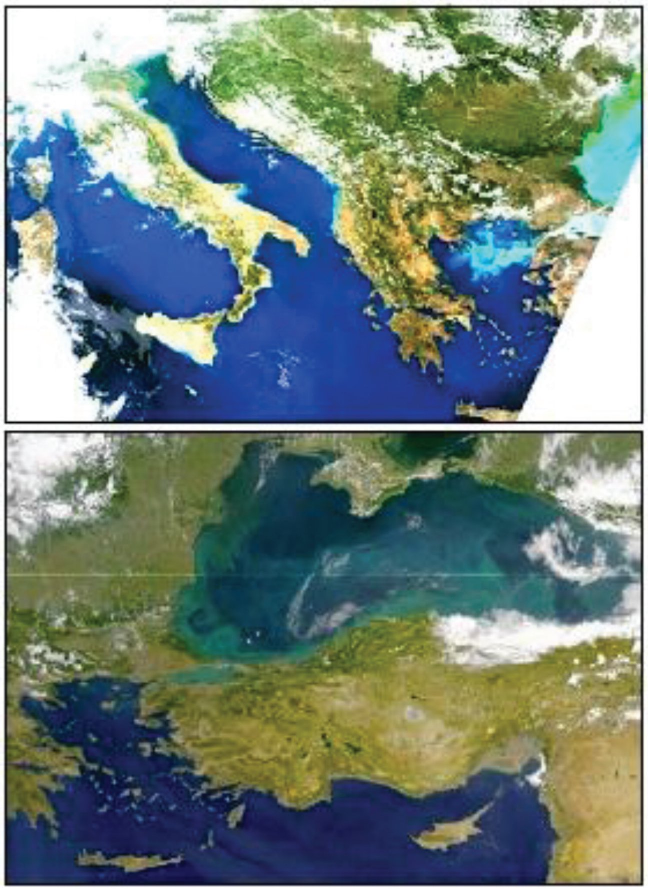

Fig. 15. SeaWiFS true-color satellite images showing the effect of toxins from the Black Sea on the Sea of Marmara and the North Aegean Sea on June 21, 1997 (upper image) and June 16, 1998 (lower image) (SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE).

http://dx.doi.org/10.5772/62907

Ehux is one of the most abundant coccolithophores found globally in all oceans (except the polar ones) in late spring, early summer, and even in early winter. In the bloom periods, factors such as high surface irradiance, shallow stratification with a mixed layer depth of about 0–20 m, anomalies in salinity and temperature, and low phosphate and silicate concentrations come together to create favourable conditions for *Ehux* blooms in the Sea of Marmara [9–11]. The system is so eutrophic that, following the massive summer bloom of *Ehux* in June and July 2003 [9], a winter bloom was observed between late December 2003 and early January 2004 in the Dardanelles [9–11]. However, the population density of *Ehux* was small in early January 2004 (5.03×10^7 cells L^{-1}) in the superficial layer compared with the summer *Ehux* bloom period (2.55×10^8 cells L^{-1}). In bloom periods, *Ehux* is the dominant species and represents about 90% of the phytoplankton in the Sea of Marmara [9–11]. The relatively strong bloom potential of *Ehux* in winter and in summer period testifies to the fact that the Sea of Marmara is suffering severe hypereutrophication due to the transport of toxins from the Black Sea (**Fig. 15**).

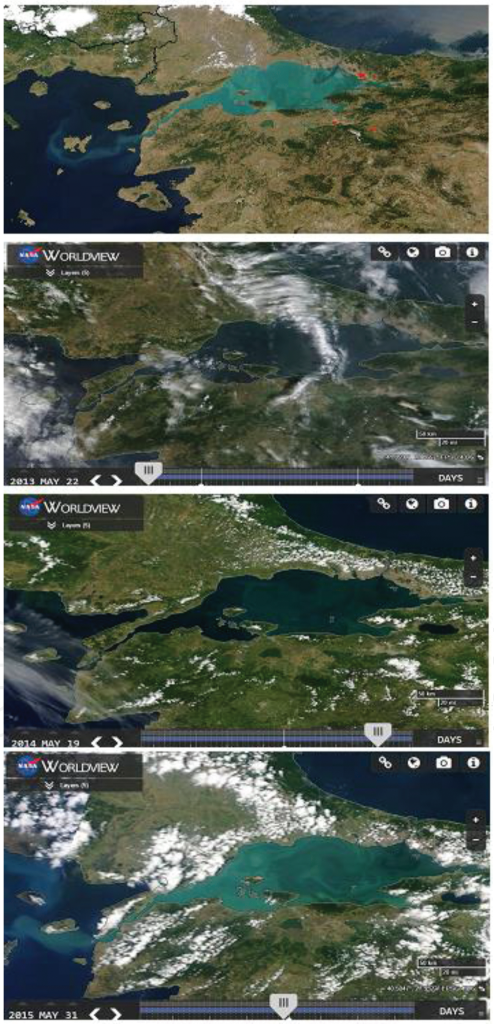

Fig. 16. SeaWiFS true-color satellite images showing algal blooms on different dates (the top image was taken on July 25, 2003) in the Sea of Marmara [17].

The Moderate Resolution Imaging Spectroradiometer (SeaWiFS/MODIS) produced true-color images of the extensive bloom events of *Ehux* on June 25, 2003; May 22, 2013; May 19, 2014; and May 31, 2015 (**Fig. 16**).

The abundance of *Ehux* during bloom periods in the Sea of Marmara is higher [9–11] than previous bloom densities in the entire Atlantic Ocean [27, 53, 54]. It is little surprise then that the albundance of *Ehux* is higher than previous bloom densities in the Aegean Sea [1, 55], the Black Sea [37, 40, 43, 44], and the Bering Sea [46].

MODIS images (**Figs. 15 and 16**) reveal how the Sea of Marmara and hence the Aegean Sea are affected by the biophysicochemical character of the Black Sea. The images exhibit turquoise water discharge flowing from the Black Sea into the Sea of Marmara and then into the North Aegean Sea (**Figs. 15 and 16**). The effect of the *Ehux* bloom in the Sea of Marmara is clearly seen in the North Aegean Sea, demonstrating the influence of the surface current emptying from the Dardanelles. Thus, some biogenic organic matter such as bacterioplankton and phytoplankton in the Black Sea are naturally exported to the Sea of Marmara and then reach the eastern Mediterranean via the Dardanelles (**Fig. 15**).

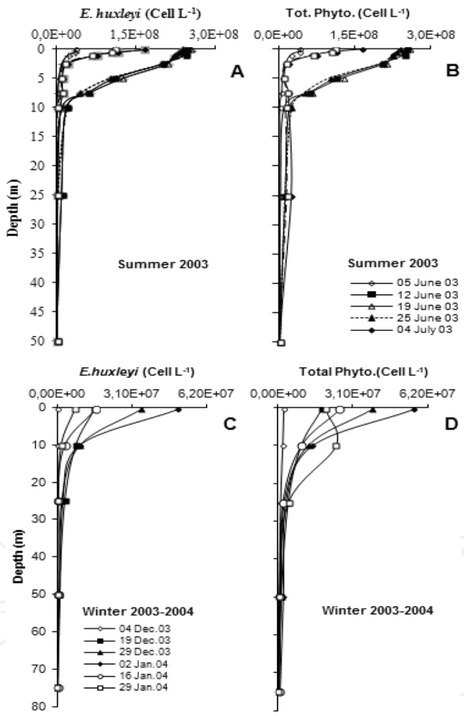

Fig. 17. Vertical variations of *Ehux* and total phytoplankton in the *Ehux* summer and winter bloom periods in the Dardanelles (Sea of Marmara) [1, 9, 10].

The sea level in these bodies of water is in equilibrium—were it not the surface of these seas would be rising or falling. The flow of water into one is counterbalanced by an approximately equal flow of water out of another. The flow of surface water out of the Black Sea and the Sea of Marmara into the Aegean Sea is approximately 600 km^3 y^{-1}. The water flow is balanced by annual freshwater discharge of about 300 km^3 from rivers, especially from the Danube River,

http://dx.doi.org/10.5772/62907

which discharges into the Black Sea, and by annual saline water input of about 300 km^3 coming from the Mediterranean Sea via the Bosphorus. Black Sea surface-layer water is substantially less saline than Mediterranean water due to the freshwater discharge of rivers [28, 56, 57]. Input of less saline water from the Black Sea and the Sea of Marmara, accompanied by the clouds of coccoliths, is very important to the physicochemical oceanography of the Aegean Sea. The movement of the turquoise water, which stays in the surface layer due to its lower density, can be tracked through the Aegean Sea (**Figs. 15 and 16**).

During both the *Ehux* summer and winter bloom periods the vertical profiles of *Ehux* (**Fig. 17**) reveals that, whereas the cell density of *Ehux* increases from 3.58×10^7 to 2.55×10^8 cells L^{-1} in the surface layer in summer, there is also an increase from 1.60×10^4 to 5.03×10^7 cells L^{-1} in the upper layer. Again, whereas the cell density of *Ehux* exceeds 2.0×10^8 cells L^{-1} in the surface layer in summer, it also exceeds 5.00×10^7 cells L^{-1} in middle winter in the upper layer in winter period. The very high bloom density in the surface layer both in summer and winter dramatically decreases with depth and almost all of the bloom density is lost at a depth of 10 m in both periods [1, 9, 10].

6. Management of HABs and *Emiliania huxleyi* blooms

HABs can be managed in three ways: (1) prevention, (2) mitigation, and (3) control efforts. Prevention involves reducing the incidence and extent of HABs by controlling or decreasing the input of anthropogenic waste water, rich in nutrients and other pollutants, and ballast water, rich in invasive species, before HAB onset. HAB mitigation generally involves monitoring for blooms and their toxins, public communication programs, and the transfer/removal of fish cages from critical areas to less critical regions. HAB control involves a number of methods: biological, chemical, ultrasonic, ozonation, chemical and clay flocculation.

Nature dictates that all organisms are controlled by other organisms. There are many host-specific viruses, predators, parasites, and pathogens involved in the biological control of many HAB species. To date, the control mechanisms on the distribution of *Ehux* blooms are little known; however, there is evidence that viruses are linked to sudden crashes of *Ehux* blooms [58, 59]. Viruses are found in all marine environments and are a very important control mechanism over populations of bacteria and phytoplankton, affecting biodiversity, nutrient, and biogeochemical cycles [60, 61]. Although much work here is related to viruses that infect *Micromonas pusilla* [62–64] and *Heterosigma akashiwo* populations [65], scientific understanding of the effects of viruses on *Ehux* population dynamics is still limited. Some studies have revealed that the number of viruses dramatically increase following the death of massive *Ehux* blooms [66–69, 13]. *Ehux* viruses (EhVs) isolated from some dense *Ehux* blooms [70, 71] have recently been assigned to a new genus, *Coccolithovirus* [72], in the family Phycodnaviridae [71].

Recently, amplified segments of the major capsid protein (MCP) gene from viruses that infect *Ehux* were cloned and sequenced by Schroeder et al. [72] using denaturing gradient gel electrophoresis (DGGE). Schroeder et al. [73] distinguished many virus genotypes—such as

EhV84, EhV86, EhV88, EhV163, EhV201, EhV202, EhV203, EhV205, and EhV207. This led to elimination of an *Ehux* bloom in a mesocosm experiment off western Norway.

7. Conclusion

The overutilization of nutrients by summer and winter diatom blooms immediately before *Ehux* blooms leads to insufficient inorganic nutrients (especially inorganic phosphate) that could lessen the impact of such blooms. Coupled with high irradiance, two stable temperature structures at the surface (due to two thermocline formations in summer and winter that result from two currents that run in opposite directions to each other), and a stable water column in terms of vertical mixing following the establishment of the seasonal thermocline in summer and reverse thermocline (due to the two currents running opposite to each other in winter) are the main characteristics of *Ehux* summer and winter blooms in the Sea of Marmara [9–11, 14, 16], confirming previous studies, especially on summer *Ehux* blooms in the North Sea and northeast Atlantic [6, 8, 45]. It is known that coccolithophore *Ehux* summer blooms follow the dense blooms of diatoms in spring in many different marine systems [37, 38, 40–44, 74]. Furthermore, *Ehux* forms extensive and intensive blooms in many cold coastal and oceanic regions [10, 75].

Because of their potential impact on global carbon and sulfur cycles [41], *Ehux* blooms attract a lot of attention. The environmental factors involved in triggering *Ehux* blooms are incompletely known. Some physicochemical factors—such as strong temperature stratification, high solar radiation, phosphate limitation, and low N:P ratios—and some biological factors—such as reduced grazing ratios and competition between phytoplankton groups—seem to be prerequisites for intense *Ehux* blooms [9, 10, 54]. However, there is conflict about whether the evidence supports the universality of high N:P ratios as a controlling factor for *Ehux* blooms. Almost all researchers studying nutrient ratios in the Sea of Marmara show that the N:P ratios are lower than the Redfield ratio not only during *Ehux* blooms, but also during the rest of the year in the Sea of Marmara [9–11, 14, 16, 39, 51, 57, 76–80].

However, there is general agreement that—in light of the high levels of nutrients, changing nutrient ratios, chlorophyll *a*, and successive algal blooms—the Sea of Marmara is subject to heavy pollution as a consequence of urban and domestic waste water from Istanbul and northwestern Black Sea surface waters where pollutants are discharged by the Danube River.

Author details

Muhammet Turkoglu

Address all correspondence to: mturkoglu@comu.edu.tr

Canakkale Onsekiz Mart University, Marine Sciences and Technology Faculty, Hydrobiology Department, Marine Biology Section, Terzioglu Campus, 17100 Canakkale, Turkey

References

[1] Turkoglu M, Unsal M, Ismen A, Mavili S, Sever TM, Yenici E, Kaya S, Coker, T. Dynamics of lower and high food chain of the Dardanelles and Saros Bay (North Aegean Sea). Tubitak Project Final Report, TUBITAK-YDABÇAG-101Y081; 2004a. 314 p.

[2] Turkoglu M, Baba A, Ozcan H. Determination and evaluation of some physicochemical parameters in the Dardanelles (Canakkale Strait-Turkey) using multiple probe system and geographic information system. Hydrology Research (previously: Nordic Hydrology). 2006; 37 (3): 293–301. DOI: 10.2166/nh.2006.012.

[3] Baba A, Deniz O, Turkoglu M, Ozcan H. Investigation of discharge of fresh water in the Çanakkale Strait (Dardanelles-Turkey). In: Linkov I, Kiker GA, Wenning RJ, editors. Environmental Security in Harbors and Coastal Areas. NATO Science for Peace and Security Series C: Environmental Security, Springer, Netherlands; 2007. p. 421–427. DOI: 10.1007/978-1-4020-5802-8_30.

[4] Balch WM, Holigan PM, Ackleson SG, Voss KJ. Biological and optical properties of mesoscale coccolithophore blooms in the Gulf of Maine. Limnology and Oceanography. 1991; 36: 629–643.

[5] Balch WM, Holigan PM, Kilpatrick KA. Calcification, photosynthesis and growth of the bloom-forming coccolithophore, *Emiliania huxleyi*. Cont. Shelf Res. 1992; 12: 1353–1374. DOI: 10.1016/0278-4343(92)90059-S.

[6] Nanninga HJ, Tyrrell T. The importance of light for the formation of algal blooms by *Emiliania huxleyi*. Marine Ecology Progress Series. 1996; 136, 195–203.

[7] Hattori H, Koike M, Tachikawa K, Saito H, Nagasawa K. Spatial variability of living coccolithophore distribution in the Western Subarctic Pacific and Western Bering Sea. Journal of Oceanography. 2004; 60: 505–515. DOI: 10.1023/B:JOCE.0000038063.81738.ab.

[8] Smyth TJ, Tyrrell T, Tarrant B. Time series of coccolithophore activity in the Barents Sea, from twenty years of satellite imagery. Geophysical Research Letters. 2004; 31: L11302. DOI: 10.1029/2004GL019735.

[9] Turkoglu M. Synchronous blooms of the coccolithophore *Emiliania huxleyi* (Lohmann) Hay & Mohler and three dinoflagellates in the Dardanelles (Turkish Straits System). Journal of the Marine and Biological Association of the United Kingdom. 2008; 88 (3): 433–441. DOI: doi:10.1017/S0025315408000866.

[10] Turkoglu M. Winter bloom and ecological behaviors of coccolithophore *Emiliania huxleyi* (Lohmann) Hay & Mohler, 1967 in the Dardanelles. Hydrology Research. 2010a; 41 (2): 104–114. DOI: 10.2166/nh.2010.124.

[11] Turkoglu M. *Emiliania huxleyi* bloom in winter period in the Dardanelles, Turkey. Rapp. Comm. Int. Mer Médit. 2010b; 39: 410–410.

[12] Fabry VJ. Calcium carbonate production by coccolithophorid algae in long-term carbon dioxide sequestration. San Marcos (US): California State University; 2003. 20 p. DOI: DE-FC26-01NT41132.

[13] Dacey JWH, Wakeham S. Oceanic dimethylsulfide: Production during zooplankton grazing on phytoplankton. Science. 1986; 233 (4770): 1314–1316. DOI: 10.1126/science.233.4770.1314.

[14] Turkoglu M. Red tides of the dinoflagellate *Noctiluca scintillans* associated with eutrophication in the Sea of Marmara (The Dardanelles, Turkey). Oceanologia. 2013; 55 (3): 709–732. DOI: 10.5697/oc.55-3.709.

[15] Unsal M, Turkoglu M, Yenici E. Biological and physicochemical researches in the Dardanelles. Tubitak Project Final Report, TUBITAK-YDABÇAG-100Y075; 2003. 133 p.

[16] Turkoglu M, Oner C. Short time variations of winter phytoplankton, nutrient and chlorophyll-a of Kepez harbor in the Dardanelles (Çanakkale Strait, Turkey). Turkish Journal of Fisheries and Aquatic Sciences. 2010; 10 (4): 537–548.

[17] NASA 2015. National Aeronautics and Space Administration, US. Available from: https://earthdata.nasa.gov/labs/worldview/ [Accessed: 2015-06-15].

[18] Hay WW, Mohler HP, Roth PH, Schmidt RR, Boudreaux JE. Calcareous nanoplankton zonation of the Cenozoic of the Gulf Coast and Caribbean–Antillean area, and transoceanic correlation. Transactions of the Gulf Coast Association of Geological Societies, 1967; 17: 428–480.

[19] Schaechter M. Eukaryotic Microbes. 1st ed. Amsterdam: Academic Press and Elsevier; 2012. 479 p. DOI: 10.1111/j.1550-7408.2012.00637.x

[20] Tyrell T, Holligan PM, Mobley CD. Optical impacts of oceanic coccolithophore blooms. Journal of Geophysical Research. 1999; 104: 3223–3241. DOI: 10.1029/1998JC900052.

[21] Kinkel H, Baumann KH, Cepek M. Coccolithophores in the equatorial Atlantic Ocean: response to seasonal and Late Quaternary surface water variability. Marine Micropaleontology. 2000; 39 (1–4): 87–112. DOI: 10.1016/S0377-8398(00)00016-5.

[22] Beaufort L, Probert I, De Garidel-Thoron T, Bendif EM, Ruiz-Pino D, Metzl N, Goyet C, Buchet N, Coupel P, Grelaud M, Rost B, Rickaby REM, De Vargas C. Sensitivity of coccolithophores to carbonate chemistry and ocean acidification. Nature. 2011; 476 (7358): 80–83. DOI: 10.1038/nature10295.

[23] Beatrice G. 2015. What's fueling the rise of coccolithophores in the oceans? [Internet]. 2015. Avaliable from: www.csmonitor.com (The Christian Science Monitor). [Accessed: 2015-11- 30].

[24] OSIB-MGM 2015. Seasonal temperature analysis (Mevsimlik Sıcaklık Analizi). Turkish Ministry of Forestry and Water Affairs (T.C. Orman Su İşleri Bakanlığı), Turkish State

Meterological Service (Meteoroloji Genel Müdürlüğü) [Internet]. Available from: http://www.mgm.gov.tr/veridegerlendirme/sicaklik-analizi.aspx?s=m/[Accessed: 2015-12-01].

[25] Kazmin AS. Zatsepin AG, Kontoyiannis H. Comparative analysis of the long-term variability of winter surface temperature in the Black and Aegean Seas during 1982–2004 associated with the large-scale atmospheric forcing. International Journal of Climatology. 2009; 30 (9): 1349–1359. DOI: 10.1002/joc.1985.

[26] Sorrosa JM, Satoh M, Shiraiwa Y. Low temperature stimulates cell enlargement and intracellular calcification of coccolithophorids. Mar. Biotech. 2005; 7 (2), 128–133. DOI: 10.1007/s10126-004-0478-1.

[27] Tyrrell T, Taylor AH. A modelling study of *Emiliania huxleyi* in the NE Atlantic. Journal of Marine Systems. 1995; 9: 195–203. DOI: doi:10.1016/0924-7963(96)00019-X.

[28] Oguz T, Ducklow HW, Malanotte-Rizzoli P, Murray JW, Shushkina EA, Vedernikov VI, Unluata U. A physical-biochemical model of plankton productivity and nitrogen cycling in the Black Sea. Deep Sea Research Part I. 1999; 46 (4): 597–636. DOI: 0.1016/S0967-0637(98)00074-0.

[29] Watts A. A study: The temperature rise has caused the CO_2 increase, not the other way around [Internet]. 2010. Available from: http://wattsupwiththat.com/2010/06/09/a-study-the-temperature-rise-has-caused-the-co2-increase-not the-other-way-around/ [Accessed: 2015-12-01].

[30] Riegman R, Noordeloos GC, Cede AA. 1992. *Phaeocystis* blooms and eutrophication of the continental coastal zones of the North Sea. Mar. Biol., 112: 479–484. DOI: 10.1007/BF00356293.

[31] Riegman R, Stolte W, Noordeloos AAM, Slezak D. Nutrient uptake and alkaline phosphatase (EC 3:1:3:1) activity of *Emiliania huxleyi* (Prymnesiophyceae) during growth under N and P limitation in continuous cultures. J. Phycol. 2000; 36: 87– 96. DOI: 10.1046/j.1529-8817.2000.99023.x.

[32] Kuenzler EJ, Perras JP. Phosphatases of marine algae. Biol. Bull. 1965; 128: 271–284.

[33] Egge JK, Heimdal BR. Blooms of phytoplankton including *Emiliania huxleyi* (Haptophyta). Effects of nutrient supply in different N:P ratios. Sarsia. 1994; 79: 333–348. DOI: 10.1080/00364827.1994.10413565.

[34] Aksnes DL, Egge JK, Rosland R, Heimdal BR. Representation of *Emiliania huxleyi* in phytoplankton simulation models. A first approach. Sarsia. 1994; 79: 291–300. DOI: 10.1080/00364827.1994.10413561.

[35] Eker E, Georgieva L, Senichkina L, Kideys AE. Phytoplankton distribution in the western and eastern Black Sea in spring and autumn 1995. ICES Journal of Marine Science. 1999; 56: 15–22. DOI: 10.1006/jmsc.1999.0604.

[36] Eker-Develi E. Distribution of phytoplankton in the southern Black Sea in summer 1996, spring and autumn 1998. Journal of Marine Systems. 2003; 39 (3–4): 203–211. DOI: 10.1016/S0924-7963(03)00031-9.

[37] Turkoglu M, Koray T. Phytoplankton species succession and nutrients in the Southern Black Sea (Bay of Sinop). Turk J Bot. 2002; 26 (4): 235–252.

[38] Turkoglu M. Succession of picoplankton (coccoid cyanobacteria) in the Southern Black Sea (Sinop Bay, Turkey). Pak J Bio Sci. 2005; 8 (9), 1318–1326.

[39] Turkoglu M, Erdogan Y. Diurnal variations of summer phytoplankton and interactions with some physicochemical characteristics under eutrophication of surface water in the Dardanelles (Çanakkale Strait, Turkey). Turk J Bio. 2010; 34 (2): 211–225. DOI: 10.3906/biy-0807-7.

[40] Turkoglu M, Koray T. Algal blooms in surface waters of the Sinop Bay in the Black Sea, Turkey. Pak J Bio Sci. 2004; 7 (9): 1577–1585.

[41] Holligan PM, Viollier M, Harbour DS, Camus P, Champagne-Philippe G, Muller K. A biogeochemical study of the coccolithophore, *Emiliania huxleyi*, in the North Atlantic. Global Biogeochemical Cycles. 1993; 7: 879–900. DOI: 10.1029/93GB01731.

[42] Broerse ATC, Tyrrell T, Young JR, Poulton AJ, Merico A, Balch WM, Miller PI. The cause of bright waters in the Bering Sea in winter. Continental Shelf Research. 2003; 23, 1579–1596. DOI: 10.1016/j.csr.2003.07.001.

[43] Cokacar T, Kubilay N, Oguz T. Structure of *Emiliania huxleyi* blooms in the Black Sea surface waters as detected by SeaWiFS imagery. Geophys. Res. Letters. 2001; 28(24): 4607-4610. DOI: 10.2001GL013770.

[44] Oguz T, Merico A. Factors controlling the summer *Emiliania huxleyi* bloom in the Black Sea: A modeling study. Journal of Marine Systems. 2006; 59 (3–4): 173–188. DOI: 10.1016/j.jmarsys.2005.08.002.

[45] Zeichen MM, Robinson IS. Detection and monitoring of algal blooms using SeaWiFS imagery. International Journal of Remote Sensing. 2004; 25: 1389-395. DOI: 10.1080/01431160310001592346.

[46] Merico A, Tyrrell T, Lessard EJ, Oguz T, Stabeno PJ, Zeeman SI, Whitledge TE. Modelling phytoplankton succession on the Bering Sea shelf ecosystem: Role of climate influences and trophic interactions in generating *Emiliania huxleyi* blooms 1997–2000. Deep-Sea Research. I. 2004; 51: 1803–1826. DOI: 10.1016/j.dsr.2004.07.003.

[47] Palenik B, Dyrhman S. Recent progress in understanding the regulation of marine primary productivity by phosphorus, p. 26–38. In: Lynch JP, Deikman J. editors. Phosphorus in plant biology: Regulatory roles in molecular, cellular, organismic and ecosystem processes. American Society of Plant Physiologists, Rockville, MD, 1998. pp. 26–38.

[48] Berman T, Bronk DA. Dissolved organic nitrogen: A dynamic participant in aquatic ecosystems. Aquat. Microb. Ecol. 2003; 31: 279–305. DOI: 10.2003/31/a031p279.

[49] Palenik B, Henson SE. The use of amides and other organic nitrogen sources by the phytoplankton *Emiliania huxleyi*. Limnol. Oceanogr. 1997; 42: 1544–1551. DOI: 10.4319/lo.1997.42.7.1544.

[50] Ikis D. Temporal and spatial changes of primary productivity in the Sea of Marmara obtained by remote sensing. Middle East Technical University, Graduated School of Natural and Applied Sciences, Biology Section, Master Thesis, 2007. 49 p.

[51] Turkoglu M, Tugrul S. Long time variations of chlorophyll a and nutrients in the coastal waters of the Sea of Marmara. Rapp. Comm. Int. Mer Medit. 2013; 40: 900–900.

[52] Balkis N. List of phytoplankton of the Sea of Marmara. J. Black Sea/Mediterranean Environment. 2004; 10: 123–141.

[53] Tyrrell T, Taylor AH. A modelling study of *Emiliania huxleyi* in the NE Atlantic. J. Mar. Syst. 1996; 9: 83–112. DOI: 10.1016/0924-7963(96)00019-X.

[54] Tyrrell T, Merico A. *Emiliania huxleyi*: Bloom observations and the conditions that induce them. In: Thierstein HR, Young JR. editors. Coccolithophores: from molecular processes to global impact. Berlin, German: Springer; 2004. 75–97 p.

[55] Aubert M, Revillon P, Aubert J, Leger G, Drai C, Arnoux A, Diana C. Transfert de pollutants entre la Mer Noire, la Mer de Marmara et la Mer Egée. Mers D'Europe. Etudes hydrobiologiques, chimiques et biologiques, Volume 3, Nice: CERBOM, Rev. Int. Ocean. Méd., 1990. 57 p.

[56] Besiktepe S, Sur HI, Ozsoy E, Latif MA, Oguz T, Unluata U. The circulation and hydrography of the Marmara Sea. Progress in Oceanography. 1994; 34: 285–334. DOI: 10.1016/0079-6611(94)90018-3.

[57] Polat SC, Tugrul S. Chemical exchange between the Mediterranean and Black Sea via the Turkish strait. Bull. Inst. Oceanography. 1996; 17: 167-186.

[58] Jacquet S, Heldal M, Iglesias-Rodriguez D, Larsen A, Wilson W, Bratbak G. Flow cytometric analysis of an *Emiliania huxleyi* bloom terminated by viral infection. Aquat. Microb. Ecol. 2002; 27:111–124. DOI: 10.3354/ame027111.

[59] Wilson WH, Tarran GA, Schroeder D, Cox M, Oke J, Malin G. Isolation of viruses responsible for the demise of an *Emiliania huxleyi* bloom in the English Channel. J. Mar. Biol. Assoc. U.K. 2002; 82:369–377. DOI: 10.1017/S0305004102005534.

[60] Fuhrman JA. Marine viruses and their biogeochemical and ecological effects. Nature. 1999; 399: 541–548. DOI: 10.1038/21119.

[61] Wommack KE, Colwell RR. Virioplankton: viruses in aquatic ecosystems. Microbiol. Mol. Biol. Rev. 2000; 64:69–114. DOI: 10.1128/MMBR.64.1.69114.2000.

[62] Cottrell MT, Suttle CA. Genetic diversity of algal viruses which lyse the photosynthetic picoflagellate *Micromonas pusilla* (Prasinophyceae). Appl. Environ. Microbiol. 1995; 61:3088–3091.

[63] Cottrell MT, Suttle CA. Widespread occurrence and clonal variation in viruses which cause lysis of a cosmopolitan, eukaryotic marine phytoplankter, *Micromonas pusilla*. Mar. Ecol. Prog. Ser. 1991; 78:1–9.

[64] Short SM, Suttle CA. Sequence analysis of marine virus communities reveals that groups of related algal viruses are widely distributed in nature. Appl. Environ. Microbiol. 2002; 68:1290–1296. DOI: 10.1128/AEM.68.3.1290-1296.2002.

[65] Tarutani K, Nagasaki K, Yamaguchi M. Viral impacts on total abundance and clonal composition of the harmful bloom-forming phytoplankton *Heterosigma akashiwo*. Appl. Environ. Microbiol. 2000; 66:4916–4920. DOI: 0.1007/978-0-387-95919-1_208.

[66] Bratbak G, Egge JK, Heldal M. Viral mortality of the marine alga *Emiliania huxleyi* (Haptophyceae) and termination of algal blooms. Mar. Ecol. Prog. Ser. 1993; 93:39–48.

[67] Bratbak G, Wilson W, Heldal M. Viral control of *Emiliania huxleyi* blooms? J. Mar. Syst. 1996; 9:75–81.

[68] Brussaard CPD, Kempers RS, Kop AJ, Riegman R, Heldal M. Virus-like particles in a summer bloom of *Emiliania huxleyi* in the North Sea. Aquat. Microb. Ecol. 1996; 10:105–113.

[69] Castberg T, Larsen A, Sandaa RA, Brussaard CPD, Egge JK, Heldal M, Thyrhaug R, van Hannen EJ, Bratbak G. Microbial population dynamics and diversity during a bloom of the marine coccolithophorid *Emiliania huxleyi* (Haptophyta). Mar. Ecol. Prog. Ser. 2001; 221:39–46.

[70] Castberg T, Thyrhaug R, Larsen A, Sandaa RA, Heldal M, Van Etten JL, Bratbak G. Isolation and characterization of a virus that infects *Emiliania huxleyi* (Haptophyta). J. Phycol. 2002; 38:767–774. DOI: 10.1046/j.1529-8817.2002.02015.x.

[71] Van Etten JL, Graves MV, Muller DG, Boland W, Delaroque N. Phycodnaviridae—large DNA algal viruses. Arch. Virol. 2002; 147:1479–1516. DOI: 10.1007/s00705-002-0822-6.

[72] Schroeder DC, Oke J, Malin G, Wilson WH. Coccolithovirus (Phycodnaviridae): characterisation of a new large dsDNA algal virus that infects *Emiliania huxleyi*. Arch. Virol. 2002; 147:1685–1698. DOI: 10.1007/s00705-002-0841-3.

[73] Schroeder DC, Oke J, Hall M, Malin G, Wilson WH, Virus succession observed during an *Emiliania huxleyi* bloom. Applied and Environmental Microbiology. 2003; 69: 2484–2490. DOI: 10.1128/AEM.69.5.2484-2490.2003.

[74] Turkoglu M, Buyukates Y, Kaya S. Blooms of Coccolithophore *Emiliania huxleyi* and Some Dinoflagellates in the Dardanelles, Turkey. Turkish Journal of Aquatic Science. 2004b; 2 (3): 423–423 (in Turkish).

[75] Brown CW, Yoder JA. Coccolithophorid blooms in the global ocean. J. Geophys. Res. 1994; 99: 7467–7482. DOI: 10.1029/93JC02156.

[76] Turkoglu M. Short time variations of chlorohyll a and nutrients in the Dardanelles, Turkey. Rapp. Comm. Int. Mer Medit., 2010c; 39: 411-411.

[77] Turkoglu M. Temporal variations of surface phytoplankton, nutrients and chlorophyll-a in the Dardanelles (Turkish Straits System): A coastal station sample in weekly time intervals. Turk J Bio. 2010d; 34 (3): 319–333. DOI:10.3906/biy-0810-17.

[78] Turkoglu M. Hyper-eutrophycation and Intensive Foam Formation in the Dardanelles, Turkey. OMICS Group Conferences, Hydrology & Ground Water Expo; September 10–12, 2012, Hilton San Antonio Airport, Los Angeles, USA: 2012. p. 38–38.

[79] Turkoglu M. First bloom record of toxic dinoflagellate *Prorocentrum lima* (Ehrenberg) F. Stein, 1878 and climate change interactions in the Dardanelles (Turkish Straits Sistem). OMICS Group Conferences, 4th International Conference on Earth Science & Climatic Change; June 16–18, 2015; Alicante, Valencia, Spain: 2015. p. 40–40.

[80] Turkoglu M, Erdogan Y. Daily variations of summer phytoplankton in the Dardanelles. Rapp. Comm. Int. Mer Medit. 2007; 38: 399–399.

IntechOpen