DYNAMICS AND TRENDS OF BASIC HYDROLOGICAL AND HYDROCHEMICAL PARAMETERS OF THE BLACK SEA IN FRONT OF THE BULGARIAN COAST IN THE BEGINNING OF XXI CENTURY

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Abstract

During 2001-2003, an investigation was done on the dynamics of basic hydrological and hydrochemical parameters in the 30-mile zone in front of the Bulgarian Black Sea coast, down to 100/150-metre isobath, as well as in the Varna Bay. The research has covered sea temperature, sea salinity, dissolved oxygen and oxygen saturation. Sea temperature and sea salinity are critical parameters that need to be investigated to meet climate research goals. Dissolved oxygen is important indicator for ecosystem state assessing. The research has had social and public aspects as well. Trends of these parameters were established in the beginning of XXI Century.

Keywords: Black sea, hydrological parameters, hydrochemical parameters, concentrations, dynamics, trends

INTRODUCTION

Marine life needs a stable environment in order to survive. Temperature, salinity and dissolved oxygen are important parameters of sea water (Rozhdestvensky, 1954; Keondzhyan and Terekhin, 1990; Ryabinin et al., 1991; Sapozhnikov, 1992) that influence life forms (Bolshakov, 1970; Sorokin, 1982; Rozhdestvensky, 1986). Each of these is discussed below along with how it develops in the condition of climate change in the beginning of XXI Century.

Climate change is altering the world’s water resources (Permesan, 2006; Sutton, Dong and Gregory, 2007), as evidenced through changing precipitation patterns, severe drought and floods, snowpack amount, evaporation, streamflow, and rising sea levels. Climate change impact assessment refers to research and investigations designed to find out what effect changes in climate cause on the natural world.

Sea temperature and sea salinity are critical parameters that need to be investigated to meet climate research goals. Dissolved oxygen (Bogdanova, 1959) is important indicator for ecosystem state assessing. Reduction in the dissolved oxygen content in sea water to relatively low levels can cause the death of fishes and other animals and can also make them more sensitive to disease and to toxic agents in the sea water (Topping, 1976).

In fact, water quality is a very complex subject, in part because water is a complex medium intrinsically tied to the ecology of the Earth. Natural water bodies vary in response to environmental conditions.

The research has social and public aspects as well, as humans use sea water for many recreational purposes, as well as for exercising and for sports. Some of these include swimming, waterskiing, boating, surfing and diving.

MATERIAL AND METHODS

During 2001-2003, the Black Sea in front of the Bulgarian coast was surveyed (Dineva, 2002; Dineva, 2003; Dineva, 2004 a; Dineva, 2004 b) along Capes Kaliakra, Galata and Emine, with sampling at 1, 3, 10, 20 and 30 miles, up to 100/150 m depth (Figure 1 B.). Research in the Varna Bay was done at Control Station B5 (Figure 1 A.).

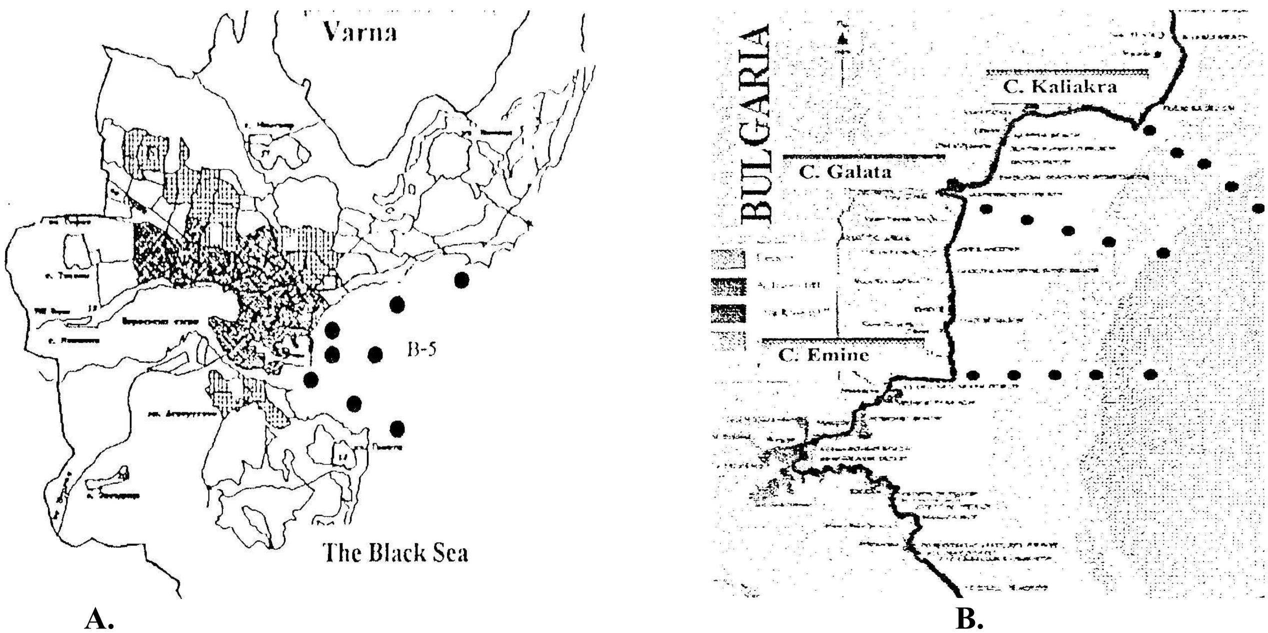

Figure 1. Maps of sampling stations: (A) Varna Bay – Control St. B5. (B) in front of the Bulgarian Black Sea coast along Capes Kaliakra, Galata and Emine.

CTD measurement (CTD 60, 2001) of temperature, salinity, dissolved oxygen and oxygen saturation was done in the Black Sea coastal and open waters.

CTD60 is a high quality, high accuracy multi-parameters probe for oceanographic measurements of physical and chemical parameters, with calculations according to UNESCO formulas.

RESULTS AND DISCUSSION

During 2001-2003, annual temperature minimums were in February. In 2001 (Dineva, 2008), winter sea surface temperatures (SST) were 2.17°C above the 1992-2000 mean (Dineva, 2005; Dineva, 2007) and the temperatures were above the long-term average throughout the 150 m layer, with anomalies in excess between 2.25 °C at 10 m depth and 0.17°C at 150 m. Over 2002 (Dineva, 2010), in the 30-mile zone (coastal and open sea waters) the winter SST was 1.39°C above the 1992-2000 mean and temperatures were above the long-term average throughout 100-150 m layer. The winter Black Sea warming in front of the Bulgarian coast was 0.66°C at 100 m depth and approached 0.21°C at 150 m depth in the southern zone.

The April vertical temperature gradients were low.

The warming in May was mostly in the surface waters. In May 2003, sea temperature vertical range was 7.35 ˚C - 14.79 ˚C - lower than the long-term (1992-2000) average.

In June, in front of the Bulgarian Black Sea coast still there was not a typical thermocline - it was in process of formation. For some zones, the temperature jump was through thin layer, with a spatially changing depth.

The sea waters in front of the Bulgarian Black Sea coast were warmest in July – August (Figure 2). The warming was throughout the whole layer in the 10-mile zone, while in the deep waters there was a temperature jump, with some differences of the set-up - in the thickness and depth of situation. The temperature maxima were between 25 and 27 ˚C. Summer was hot, and temperatures were above the long-term (1992-2000) average in the 30-mile zone. In 2001 (Dineva, 2008), sea surface temperatures reached its annual maximum in August – 26.23 – 26.82 ºC, and throughout the 150 m sea layer were higher than the long-term (1992-2000) average. In 2002 (Dineva, 2010), the annual sea surface temperature maximum was in July, and the year's absolute SST maximum was recorded in the surface waters at 10 miles in front of Cape Galata – 26.78 °C, above the 1990s maximum (Dineva, 2007) and almost identical as 2001 maximum (Dineva, 2008). The annual sea bottom temperature maximum in the coastal waters was a month late - in August.

In September, the thermocline was already disappearing.

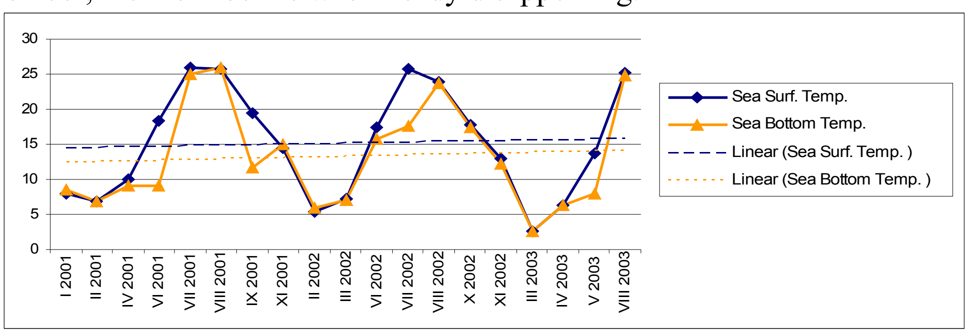

Figure 2. Dynamics and trends of sea surface temperature (ºC) and sea bottom temperature (ºC) at 3 miles in front of Cape Galata during 2001-2003.

In October there was a relative homothermia in the coastal waters.

In the autumn, surface temperatures in the open sea vary between 12.68 ˚C and 14.73 ˚C, and in the Varna Bay they were between 12.47 ˚C and 14.63 ˚C. In 2001, autumn temperatures were above the long-term (1992-2000) average throughout the 100 m layer of the 30-mile zone in front of the Bulgarian Black Sea coast (coastal and open sea waters).

Figure 2 shows both sea surface and sea bottom temperature increasing trends, as well as annual increasing amplitudes in 2001-2003.

Mostly, there were similar changes of annual salinity variability both in the open-sea and bay waters.

In February 2002, salinity was above the long-term (1992–2000) average (Dineva, 2005; Dineva, 2007) throughout the 150-metre layer, with a positive sea surface salinity (SSS) anomaly of 0.63 psu and greatest positive anomaly of 0.92 psu at 100 m depth (Dineva, 2010).

In March 2003, there was a low Danube influence onto Bulgarian Black Sea.

Unusually high salinity was registered in April 2003. At 10 miles in front of Cape Galata there was a slightly Danube influence and the surface water salinity was 16.93 psu, with an increase towards the coast, up to 17.39 psu. The salinity was greatest and abnormal in the Varna Bay – 17.98 psu in the surface waters and 18.13 psu in the bottom layer.

In May 2003, SSS sharply decreased. The stream of Danube transformed waters was at 10 miles in front of Cape Galata. The whole layer was influenced but the refreshing was strongest in the 10-metre layer. Salinity was 15.08 psu in the surface waters and 15.80 psu on 10 m depth. In the Varna Bay, only the surface waters were influenced, and annual minimum of 15.45 psu was formed.

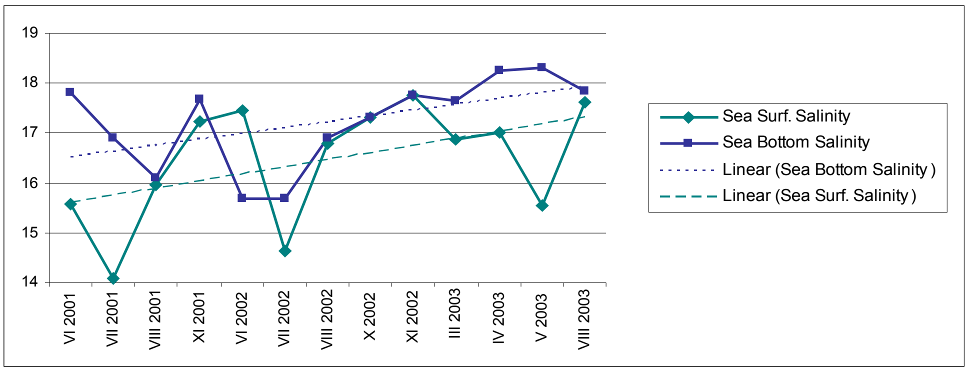

Figure 3. Dynamics and trends of sea surface salinity (psu) and sea bottom salinity (psu) at 3 miles in front of Cape Galata during 2001-2003.

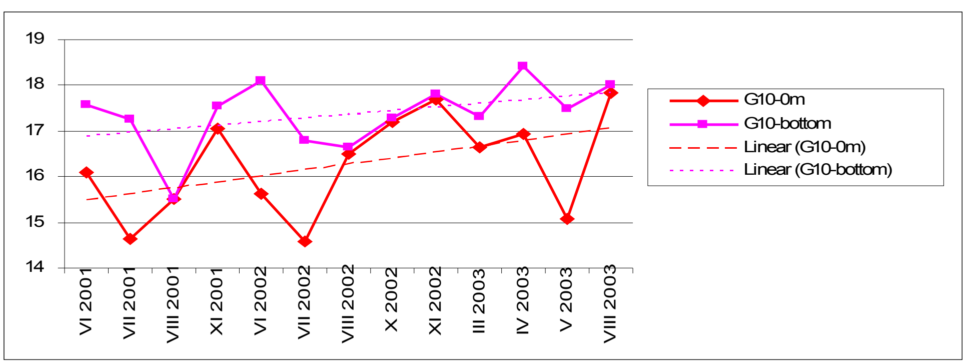

Figure 4. Dynamics and trends of sea surface salinity (psu) and sea bottom salinity (psu) at 10 miles in front of Cape Galata during 2001-2003.

Salinity, lower than 17 psu, was registered in the 30-mile zone in front of Cape Galata in June 2001 and 2002. In front of Cape Kaliakra, Danube transformed waters have changed their position, and they can be up to 3 miles or up to 20 miles in front of the coast. The most difficult is to predict their location in front of the Cape Emine – they can be located from 3 to 30 miles in front of the coast or to be in the 10- mile zone. The maximum depth of the refreshed layer was up to 10 m, and in front of the Cape Kaliakra - only 5 m.

The annual minimum of salinity was in July. In front of Cape Galata it was at 3 or at 10 miles offshore. The greatest decrease was over 2001 in the surface waters at 3 miles in front of Cape Galata – 14.09 psu. The annual minimum of 14.58 psu was at 10 miles in front of Cape Galata in 2002, and in the Varna Bay it was 14.22 psu in 2001 and 15.46 psu in 2002.

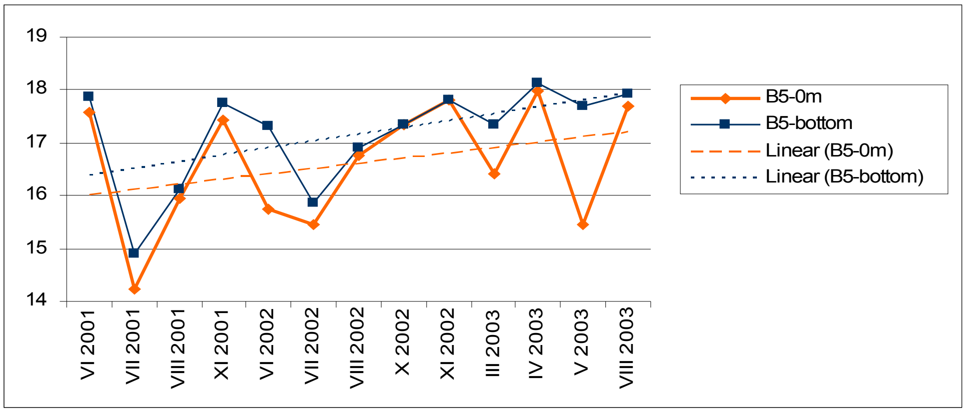

Figure 5. Dynamics and trends of sea surface salinity (psu) and sea bottom salinity (psu) in the Varna Bay during 2001-2003.

Salinity variations in August were great, with an upward trend. In 2001, the refreshed layer was located at 10 miles along the coast. In 2002, the most Danube influence was up to 3 miles in front of the Cape Kaliakra, at 10-20 miles in front of Cape Galata, and at 3 miles in front of the Cape Emine. In 2003, salinity was higher than long-term (1992–2000) average, with about 1 psu in the 50 m layer.

In the coastal and bay waters, salinity was higher than 17 psu and almost vertically identical in October 2002.

In 2001, autumn sea salinity was higher than the long-term (1992-2000) average (Dineva, 2005; Dineva, 2007) throughout the 150-metre layer (Dineva, 2008). Sea salinity of the 30-mile zone in front of the Bulgarian coast again was above the long-term (1992–2000) average up to 100-metre isobath in November 2002, with a positive SSS anomaly of 0.49 psu and greatest positive anomaly of 1.02 psu at 100 m depth (Dineva, 2010).

During 2001–2003, salinity dynamics at 3 miles (Figure 3) and 10 miles (Figure 4) in front of Cape Galata, where the influence of the Danube transformed waters was great, and in the Varna Bay (Figure 5) has formed upward trends in the whole layer.

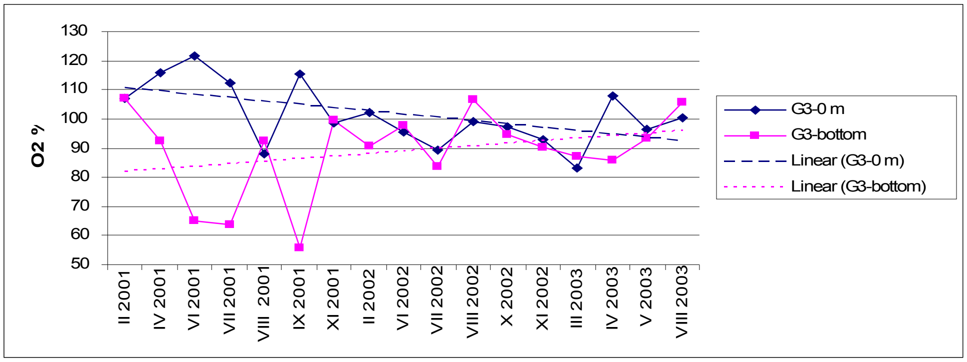

Figure 6. Dynamics and trends of oxygen saturation of sea surface and sea bottom waters at 3 mile in front of Cape Galata during 2001-2003.

Dissolved oxygen

The oxygen setting was comparatively good in front of the Bulgarian Black Sea coast (Figure 6 and Figure 7), with mostly variations around the normal, and without hypoxic situations. There were more deviations in 2001.

Even sea surface waters were with oxygen deficit in the winter of 2003. Oxygen super-saturation of the sea water was recorded in the closest coastal zone – at 1 mile in front of Cape Galata – 126.49 % in the layer.

The oxygen saturation of the bay waters was 90 – 94 % in April 2003. With an increase of the Danube flow in May, the highest oxygen super-saturation of the sea water again was at 1 mile in front of Cape Galata – 120.48% (5m), while the oxygen deficit has increased to 82 – 88 % saturation in the Varna Bay.

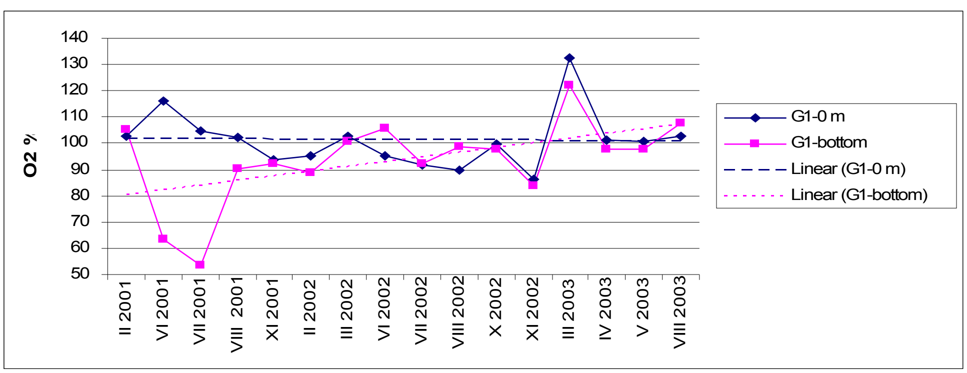

Figure 7. Dynamics and trends of oxygen saturation of sea surface and sea bottom waters at 1 mile in front of Cape Galata during 2001-2003.

At 3 miles in front of Cape Galata, the maximal saturation was 121.82 % (surface) in June 2001. The depth of the oxygen super-saturated waters has mostly reached 10 m. In 2002, oxygen super-saturation of surface waters was recorded only along Emine slash in June, and it was vertically widespread up to 25 m. Oxygen super-saturation peak, like as in 2001, was again repeated but this time at 1 mile in front of the Cape Emine on 25 m depth – 121.84 %. There was no hypoxic situation in the coastal waters. The highest oxygen deficiency was in the bottom layer at 1 mile in front of Cape Kaliakra – 76.77 % - a state far from hypoxic.

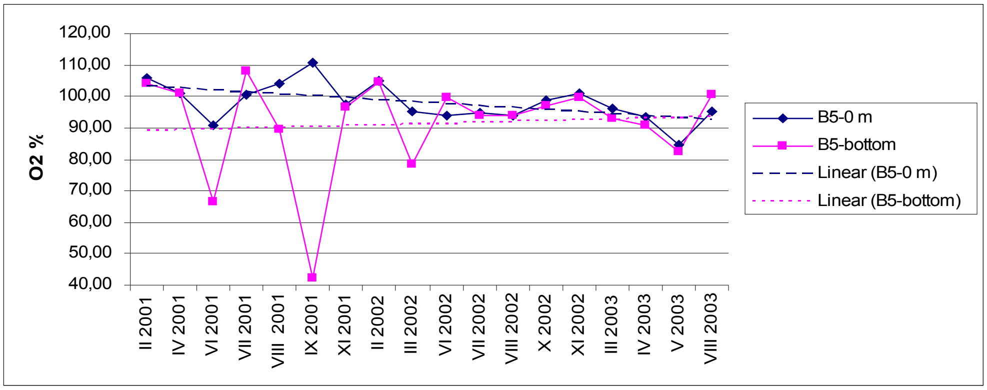

Figure 8. Dynamics and trends of oxygen saturation of sea surface and sea bottom waters in the Varna Bay during 2001-2003.

In August 2003, the 50-metre sea layer along Galata and Emine slashes was oxygen super-saturated, with maximum on 25 m depth – 127.07 %, and super-saturation has reached 75 m depth at 20 miles and 30 miles in front of Cape Kaliakra. During 2001–2003, the absolute oxygen saturation maximum was exactly in the summer of 2003 – at 3 miles in front of Cape Kaliakra on 25 m depth – 176.05 %.

The oxygen deficiency in the bottom layer of Varna Bay (Figure 8) was considerable – 42.37 % in September 2001, but there was no hypoxic situation.

There was oxygen deficiency even in the sea surface waters in the autumn of 2002. The sea waters were super-saturated with oxygen in the closest coastal zone – 152.33 % in the layer at 1 mile in front of Cape Kaliakra.

CONCLUSIONS

During 2001–2003, the annual temperature dynamics was similar, but with increasing temperature amplitudes. The waters were warmest in July – August. The temperature maxima were between 25 and 27 ˚C. A thermocline has formed in June, and it has disappeared in September. Over 2001–2003 in the conditions of climate change, both sea surface and sea bottom temperature increasing trends were established, along with mostly higher temperature than over 1990s in the 30-mile zone.

Due to the strong upwelling of the sea water, salinity was abnormally high in April 2003. During 2001-2003, the annual salinity minima were at 3 miles or at 10 miles in front of the Bulgarian Black Sea coast in July. The greatest salinity decrease was recorded in the surface waters at 3 miles in front of Cape Galata - 14.09 psu in 2001, while in the Varna Bay it was respectively 14.22 psu. In 2001–2003, salinity at 3 and 10 miles in front of Cape Galata, where the influence of the Danube transformed waters was strongest, and in the Varna Bay, has formed increasing trends throughout the whole layer. Due to severe drought in the beginning of XXI Century, increased evaporation, reduced precipitation, decreased river flow, and upwelling, salinity was mostly higher than over 1990s in the 30-mile zone.

During 2001–2003, the oxygen setting was comparatively good in the open sea, with mostly variations around the normal, and without hypoxic situations. There were more deviations in 2001. The absolute oxygen saturation maximum was in the summer of 2003 at 3 miles in front of Cape Kaliakra on 25 m depth – 176.05 %. The oxygen deficiency in the bottom layer of Varna Bay was considerable in September 2001– 42.37 %, but there was no hypoxic situation. Generally, the oxygen tendencies were towards a near to normal state over 2001–2003.

ACKNOWLEDGEMENTS:
The results presented stem from the project “Nutrient Management in the Danube Basin and its Impact on the Black Sea” (daNubs) supported under contract EVK1-CT-2000-00051 by the Energy, Evironment and Sustainable Development (EESD) Programme of the 5th EU Framework Programme. Details on the project can be found on the project homepage: http://danubs.tuwien.ac.at/.

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