DECADAL SCALE CLIMATIC WARMING AND ITS IMPACTS ON ECOLOGICAL REGIME OF THE BLACK SEA DURING 1990S

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Abstract

The Black Sea is shown to experience intensive warming of its surface waters during 1990s at a rate of ~0.25 °C per year. Following a strong cooling phase in early1990s, the most intense warming event with ~2 °C increase in the SST took place during winters of the 1994-1996 period. This event was accompanied by 4 cm yr-1 net sea level rise in the basin, and two-fold increase of the annual mean net fresh water flux, as well as a gradual depletion of the Cold Intermediate Layer (characterized by T<8 °C) throughout the basin. Consequently, from 1996 onwards, upward nutrient supply to surface waters was reduced substantially, giving rise to bottom-up limited unfavorable phytoplankton growth, and reduced stocks of mesozooplankton, gelatinous macrozooplankton and pelagic fishes. The climate-induced changes therefore had a strong impact on dramatic reduction of pelagic fish stocks observed during the second half of 1990s.

Key words: Black Sea, climatic warming, ecological changes

Changes in large scale atmospheric pressure and precipitation patterns cause interannual-to-multidecadal scale climatic variations both locally and in remote areas via teleconnection patterns in the form of the quasi-periodic sea level changes, warming and cooling cycles of the sea surface temperature, and ultimately impose significant impacts on ecology and economical wellfare of societies. Even it is an isolated and relatively small sea, far from direct impacts of major oceans, the Black Sea is found to possess a strong climatic signature at interannual-to-multidecadal scales. The most recent example of such climatic effects emerges in the form of a warming cycle of the entire upper layer waters since 1994 (1).

The basin-averaged winter (December-March)-mean and annual-mean sea surface temperature (SST) data, derived from 9 km monthly, gridded NOAA/NASA AVHRR Oceans Pathfinder data set, reveal an intense cooling period of the early 1990s, evident by the minimum winter-mean SST of 6.8 °C in 1993 followed by an equally strong winter warming phase characterized by an almost 2 °C rise during 1994-1996. The winter warming phase is maintained during the rest of the 1990s by a more gradual temperature variations by retaining at least their 1997 level of warming, and occasionally having values as high as ~10 °C in 2001. These warmer winter SSTs were correlated with milder winters characterized by relatively higher air temperatures, weaker heat loss to the atmosphere and weaker wind stress forcing exerted on the sea surface . The warming trend is also well-pronounced in the annual-mean data in the form of linear SST rise by about 2°C from 1993 to 2001. The annual-mean tended to increase linearly SSTs from 14.2 °C in 1993 at a rate of 0.25 °C per year, with the highest annual mean value of ~16.4 °C measured during 2001. The subsurface signature of the warming can be traced from the structure of the Cold Intermediate Layer (CIL), characterized traditionally by temperatures colder than 8 °C. This cold water mass, convectively generated every winter within the upper 50-75 m of the water column, preserves its identity between the seasonal and permanent thermoclines during rest of the year. As shown for a station along the northeastern coast, off Gelendzhik, the average winter CIL temperature shows a linear trend of increase from its minimum value of 6.2 °C in 1993 to around 7.7 °C during the winters of 2000 and 2001. This trend follows quite closely the air temperature variations at the same site. Moreover, approximately 5-10 m rise of the anoxic interface level during the second half of 1990s might reflect destabilization of the permanent pycnocline as a consequence of warming of the surface waters.

As pointed out by Stanev and Peneva (2), the warming period may well be teleconnected to changes in the North Atlantic Oscillation (NAO) cycle, and the climatic warming trend of the Northern Hemisphere. Their analysis has indicated that the constant sea level rise of ~12 cm in the Black Sea from 1993 to 1996 is correlated with the increased net fresh water flux into the basin, which in turn is correlated with the dramatic decrease of the NAO index (from +2 to –2) during the same period. These changes in the physical climate of the sea imply disintegration of the prevailing basinwide cyclonic circulation cell (3), and weakening of the associated upward motion within the interior part of the basin after 1995.

The intimate relationship between climatic warming and form of the annual phytoplankton production can be inferred by the composite ocean color data set representing the monthly mean chlorophyll contcentrations since 1996 onwards. It indicates steady winter values of about 0.5 mg m^{-3} in contrast to a well-pronounced peak of ~2.0 mg m^{-3} in the data set prior to the mid-90s. Weaker turbulent mixing and stronger stratification during mild winters of all these years should be responsible for more limited nutrient supply from the nutricline, and consequently erosion of the late winter-early spring peak of the annual surface chlorophyll distribution by more than half after the mid-90s. Such a poor new production-based biological activity in February-March is followed by equally poor regenerated production during rest of the spring season. The annual structure acquires only a weak autumn peak of about 0.75 mg m^{-3} comparable to its counterpart in the former data set.

The measurements also reveal similar adverse changes in the annual mesozooplankton biomass distributions after 1995. The early-spring mesozooplankton bloom is no longer a dominant feature of their annual structure due to the bottom-up resource limitations in the spring primary production. The autumn mesozooplankton biomass distributions after the mid-1990s are also somewhat lower than those of the early 1990s. These changes are reflected at higher trophic levels in the form of decreasing trends in both the gelatinous carnivore biomass and the anchovy catch data during the second half of the 1990s. As warming prevails longer, both mesozooplankton and pelagic fish stocks are expected to decline further due to stronger bottom-up limitation associated with continual loss of nutrients from the euphotic zone against their more limited supply from subsurface levels. From the fishery perspective, a closer look at future evolution of plankton community structure is therefore of critical economical importance, and may ultimately serve for predicting timing of the forthcoming shift of the present warming cycle by a cooling cycle and subsequent increase in fish stocks.

References

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