Major modifications of the Black Sea benthic and planktonic biota in the last decades

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Increasing eutrophication as well as other man-made activities have considerably changed the structure and functionning of the Black Sea ecosystems, mainly in its NW corner, affecting both the qualitative and the quantitative state of the benthic and planktonic phyto- and zoo-communities.

We attribute this change to the more rapid acceleration of changing interrelationships between anthropogenic influence and biota in this nearly enclosed basin during the last three decades.

The marked decline of the ecological health has induced marked changes especially in the structure of littoral ecosystems.

The **macrophytobenthos** has shown a gradual, but continuous, decline approximately since 1945-1950 due to both natural (e.g. occasional massive frosts) and anthropogenic factors (silting of the rocky bottom, increased turbidity, diminution of light penetration).

The previously large belts of *Cystoseira barbata*, a perennial brown alga, along the western coast have practically disappeared as have numerous other associated and/or epiphytic algal and animal species.

The present algal flora, which displays a reduced species diversity, is uniform. Generally it is dominated by *Enteromorpha intestinalis, E. linza, Ceramium elegans and C. arborescens*. These newly dominant species with short and nearly seasonal life cycles show considerable production but, nevertheless, they do not reach the levels attained by *Cystoseira* during previous decades.

The evolution of **zoobenthos** communities is marked by a qualitative impoverishment, expressed by the reduction of species number by 50-60% at the present in comparison with the 1960 period, as well as by the numerical reduction of numerous species which formerly were omnipresent in the communities.

The qualitative structure of the communities was altered by the diminution of those species which were prevailing and characteristic formerly (*Spio filicornis, Corbula mediterranea, Syndesmia fragilis, Spirula subtruncata, Mytilus galloprovincialis*) and by the proliferation and autoacclimation of some opportunistic species (*Neanthes succinea, Polydora limicola, Mellina palmata, Mya arenaria, Scapharca inaequivalvis*).

Increases in populations of opportunistic species did not compensate for the reduction of general biomass and density, which are lower by 35-84 % than those measured 25 years ago. The zoobenthic communities become more and more homogenous as a result of mass proliferation of a few species. Their community structure is unstable owing to permanent disturbance generated by blooms and related benthic mass mortalitites.

Following the more intense eutrophication, the biomass of the **phytoplankton** surpasses that of the past. Some essential structural changes have occurred and new quantitative and qualitative characteristics have been recorded.

The increase in the amplitude and frequency of algal blooms is a significant ecological consequence of the accumulation of nutrients in sea water. Since1970, blooms are no longer exceptional phenomena. For example, in the 1980's alone, 46 blooms due to 15 algal species were recorded in the Romanian littoral waters.

Besides the species producing the blooms, other numerous mass species are remarkably developped. During the 1980's, 79 species reached densities of more than 100,000 cells/l, as compared to 57 species in the 1970's and only 38 species in the 1960's.

From the 1960's up to the 1980's, the proportion of nondiatoms in the numerical density of the phytoplankton increased from below 8% of the total, up to 62% with a corresponding decrease of the diatoms. The changes of the quantitative proportions of the main algal groups are due to the changes in the nutritive basis. Theses changes include :

(1) the reduction of the ratios Si : N and Si : P (which is detrimental to diatoms), and (2) the increase of organic matter (which favors the phytoplankters with mixotrophic affinities belonging to Dinoflagellata, Euglenida, and Chrysophyta).

Between 1983 and 1990 the average biomass of phytoplankton in Romanian littoral waters was more than 8 times higher than that assessed between 1959 and 1963.

The evolution of the **zooplankton** communities was marked by simplification of structure and decline of the species diversity, especially in the shore areas. Besides the total disappearance of some species (three species of the copepods belonging to the family Pontellidae), the populations of some holoplanktonic species have diminished greatly, as for example *Centropages Kroyeri, Penelia avirostris, Evadne tergestina and E. spinifera.*

The population of the meroplanktonic component of the zooplankton (the planktonic larval stages of benthic biota) have also diminished as a consequence of the mortalities produced in the benthic fauna.

In contrast the density of a small number of opportunistic species (e.g. *Acartia clausi* and *Pleopis polyphenoides*) increased, the species becoming dominant in the communities.

Another characteristic feature is the explosive development of *Noctiluca scintillans*, especially during the summer, following a significant algal bloom (in the summer of 1986 and 1987, this species represented 91-99% of the entire zooplankton biomass). Massive accumulation of the jellyfish *Aurelia aurita* has also been recorded.

Between 1980 and 1987 the total zooplankton increased in mean values of density and biomass of up to 10 times as compared to the mean values in the decade 1960-1970, because of large populations of *Noctiluca* in the summer.

The trophic zooplankton has experienced a substantial decline of the population (especially during 1990-1991) and a decrease of the planktonophagous fish catches concomitently with the appearance in the Black Sea waters of *Mneniopsis leidyi* (a big consumer of plankton and fish juveniles). For the ecosystem components of the Black Sea as a whole, the inseparable relationship between the dynamics of community structure with space and time, as well as the variable character of dynamic processes at the community level, have become particularly obvious during the last thirty years.

Hydrology and water circulation in the Black Sea

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In the course of a century-long exploration of the Black Sea, oceanographers have managed to determine the major regularities of its hydrologic regime and water dynamics. However, until today we are faced with a host of questions of utmost importance, for which no coherent response has yet been provided. Amongst these is the problem of seasonally-varying water circulation, formation of the vertical structure, the active layer response to external forcing, primarily, to wind. Naturally, all these issues are related to the cardinal problem of water circulation in the basin.

It is well known that the Black Sea cyclonic circulation is composed of two basin scale gyros in the western and eastern parts of the deep central section. However, there exist a variety of contrary views of seasonal variability, position, configuration and intensity of these dynamic features. Summarizing the data from a series of studies, one may infer that the water circulation in the Black Sea becomes most intensive in winter and feeble in summer. On the other hand, analysis of the historical data on surface circulation of geostrophic lows in the upper Black Sea during late summer shows that in summer cyclonic circulation in the northwestern section of the basin frequently transforms into its opposite, when the recurrence of southerly and south-westerly winds increases.

All studies of the Black Sea current vertical structure point out that current velocities rapidly decrease with depth. Some investigators hold that an opposite-sign, that is anticyclonic circulation is likely at depths below 300 m, whereas other researchers adduce proofs to the effect that the water circulation in the deep section of the sea is one-layered. During the late autumn/winter period, the vertical current variability in the northwestern shelf area is relatively insignificant, with the exception of the thin near-bottom layer, being 1 to 2 m thick at most. in spring and summer, diverse dynamical situations are likely to occur, including an absolute disparity between the horizontal patterns of currents in the upper layer and the bottom one. Those phenomena, obviously, are the result of the water circulation's sign alternating in the area.

In the course of the 1980's, oceanographers were seeking to elaborate and validate the current views on the variable water circulation through the use of contemporary techniques of research, specifically, the monitoring of currents by moored buoys, numerical diagnostic computations of water circulation from density fields with the wind field and bottom relief taken account of, and the numerical calculations of circulation evolution under the impact of external forcing mechanisms (wind, heat and volume fluxes through the sea surface).

The investigations carried out in recent years have shown that alongside the quasi-stationary dynamic features and geostrophic water circulation in the Black Sea, there occur mesoscale nonstationary disturbances of planetary/wave character. The horizontal scales and the accessible potential energy of both modes of general circulation are comparable between them, which is consistent with the known theoretical concepts. Notwithstanding the seeming absurdity of the implication that mesoscale eddies and rim current meanders, travelling with the planetary (Rossby) wave velocity, are present in Black Sea climatic fields, physically, this conclusion appears to be more valid than the traditional views on the Black Sea pattern of currents.

In fact, a restricted size of the basin does not contribute to the formation of a baroclinic layer with thickness sufficient for the accumulation of accessible potential energy comparable with the oceanic one. This shows off in the relatively small intensity of the quasi-stationary elements of circulation, the latter's velocity being not larger than 10 to 11 cm. s-1. On the other hand, intense nonstationary external forcings, primarily, in the form of verticity induced by wind with a pronounced seasonal variability, with maxima occuring during transition seasons and minima during summer and mid-winter, cause the generation of planetary/wave mesoscale disturbances.

The relatively stable annual recurrence of specific atmospheric forcings adds to the likelihood of the repeatability of the Black Sea's typical nonstationary response, which is manifest even in the climatic (mean multi-annual) fields. The basin's being limited in size also facilitates the waters' regular dynamic response to the external forcing, since the related nonstationary motions are expected to have parameters of the confined basin's proper oscillations. Only such motions (both gravitational and planetary quasi-geostrophic) may have considerable energy for a sufficiently long time.

Analysis of the energetics of climatic nonstationary disturbances of water circulation has revealed that these occur mainly in the central deep-water part of the Black Sea. Here, the energetics of the process is largest. Its reduction in the coastal zone is equivalent, on the average, to 20 to 30 percent. Climatic disturbances are likely to generate less consistent synoptic fluctuations. Their energy is concentrated in the coastal zone. The principal mechanism behind these disturbances seems to be related to the Black Sea rim current's hydrodynamic instability. All these mesoscale motions in the open sea can give rise to the eddies and coastal trapped waves, alongside the local wind forcing.

The various types of mesoscale, nonstationary waves exist in the Black Sea and are permanently interacting. A result is the complex structure of water circulation retrieved from all quasi-synoptic surveys accomplished in various Black Sea areas. A goal of future research is to identify the different types of dynamic disturbances and to study their properties in detail. This will allow us to gain an insight into the major mechanisms responsible for the formation, transformation and variability of the thermohaline barrier. It should be anticipated that the entire Black Sea ecosystem is functioning in the same mesoscale nonstationary regime. Thus, a study of the latter may be of significant relevance in terms of various practical implications designed to improve management and control of the diverse activities in the Black Sea waters and its shores.