The Eastern Mediterranean as a Laboratory Basin for the Assessment of Contrasting Ecosystems

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THE BIOLUMINESCENCE FIELD AS AN INDICATOR OF THE SPATIAL STRUCTURE AND PHYSIOLOGICAL STATE OF THE PLANKTONIC COMMUNITY AT THE MEDITERRANEAN SEA BASIN.

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ABSTRACT The purpose of this work is to show the possibilities of using the characteristics of the bioluminescent fields to monitor the marine planktonic communities. The data bank contains 3500 vertical casts of bioluminescent potential and near 1000 samples of the planktonic organisms obtained at 500 oceanographic stations executed in 21 expedition to the Mediterranean Sea basin in 1970-1995. Studies were carried in different seasons in the Mediterranean and the Black Seas where different trophic conditions and considerably different species composition and abundance occurred in the phytoplankton. There are of course differences between abundance of various dinoflagellates and an intensity of measurement of bioluminescence, but the main features of these appeared to be similar, the intensity of bioluminescence increased in proportion to their number and physiological state.

Seasonal changes are also well developed and mostly in the Black Sea. Two intensive periods of bioluminescence were recorded, one in May-June and the other one, more intensive, in October-November. The bioluminescent potential was achieving 1.4 10^{-2} microwatt cm^{-2} l^{-1}, which exceeded minimum numbers in February 500 times. Seasonal cycles are weakly developed in the oligotrophic regions of the Mediterranean Sea: differences of the bioluminescent potential between summer and winter periods achieve 3.5 times only.

Macroscale trends of bioluminescence changes within the Mediterranean basin are comparable with that of the plankton spatial distribution. General trend of bioluminescence increase, from the Aegean Sea towards the west and from Algerian coast to Spain, was evaluated on the scale of the whole basin. Bioluminescence in the central part of the Black Sea is 3 times weaker than that in the Alboran Sea. However, it is one order higher than that in the central part of the Mediterranean Sea.

As we have stated there are regions of «clean» and «polluted» waters in both neritic and open sea waters. For example, in the Mediterranean Sea the sentral regions of the Alboran, Ionian and Aegean Seas, and the central part of the western gyre and Karadag marine reserve of the Black Sea were all considered to have relatively good water quality while the regions of the intensive shipping (straits, southern part of the Ionian Sea, near-Bosphorus region, Black Sea north-western part) and densely inhabited riparian zones (Crimean southern coast) were considered to be regions of «ecological risk». There are considerable differences between the parameters of the regression lines from the studied regions. For example, to obtain the same bioluminescence intensity in the 0-100 m layer, the quantity of dinoflagellates in polluted regions of the Mediterranean Sea would have been twice as abundant as those from «clean» waters. Similarly the numbers of bioluminescent algae in the Black Sea would have increased 3-4 times to obtain the same bioluminescent intensity. As the anthropogenic pressure in the Black Sea is higer, due to the population density in the river drainage areas and to the low water exchange the differences are more apparent. It can be presumed, that an organism's metabolic state (and hence its bioluminescence) could serve as an indicator for the levels of pollution in the environment.

Key words: bioluminescence, plankton, spatial structure, anthropogenic pollution

The purpose of this work is to show the possibilities of using the characteristics of the bioluminescent fields to monitor the marine planktonic communities. The characteristics of bioluminescence of marine organisms are used in fisheries around the world [3,12], in studies of the macro- and mesoscale plankton communities spatial structure [9,20], in taxonomy [13], in investigations of the temporal plankton variability [8]. In laboratory experiments we have shown the high sensitivity of bioluminescent systems of marine organisms, of different taxa, to the influence of different physical and chemical fields of anthropogenic origin [6,18]. Those approaches were initiated in the studies of planktonic communities of the Mediterranean basin seas.

MATERIALS and METHODS

The instrumental measurements of bioluminescence in the Mediterranean basin were started by the Laboratory of Biophysical Ecology, IBSS in 1965 [2,5]. The submersible bathyphotometers, created in the laboratory have been used [4,19]. Together with bioluminescence measurements, temperature of the studied layer, speed of drift of the vessel, force and direction of wind were taken. Normally, measurements of bioluminescence were carried out 2 hours after sunset. This permitted the exclusion of the influence of daylight on the rhythm of light emission of plankton bioluminescents and their vertical migration.

Phytoplankton were sampled with a rosette of 5-l water bottles, fixed 1 m higer than the bathyphotometer, from intense bioluminescence layers and standard horizons. Zooplankton sampling was carried out in the upper 20m layer, using a Juday Net (36 cm mouth diameter, mesh size 116 micrometers). The total plankton biomass (wet weight) caught by net sampling was determined back in the laboratory and certain of the samples were processed to species level.

The data bank contains 3500 vertical casts of bioluminescent potential and near 1000 samples of the planktonic organisms obtained at 500 oceanographic stations executed in 21 expedition to the Mediterranean Sea basin in 1970-1995.

RESULTS and DISCUSSION.

The well developed vertical stratification of bioluminescent field might be noted as its typical feature on the scale of 1-100m (Fig.1,2). The minimal thickness of layers consist from 3 to 7 m. The degree of development of such a stratification increases in waters with enhanced biological productivity. However, almost in all cases, one might notes the upper low-bioluminescent layer (8-15 m thick), the quazistacionaric layer of the enhanced bioluminescence in the thermocline (Fig.1,2).

General trend of bioluminescence increase, from the Aegean Sea towards the west (Fig.3), was evaluated on the scale of the whole basin. Maximal numbers of bioluminescence were noted within zones where the Atlantic and Mediterranean water masses do interact, within cyclonic eddies and the divergent zones. For instance, bioluminescence recorded within this local dynamic zones exceed its average number in the Ionic Sea 30 times. Bioluminescence in the central part of

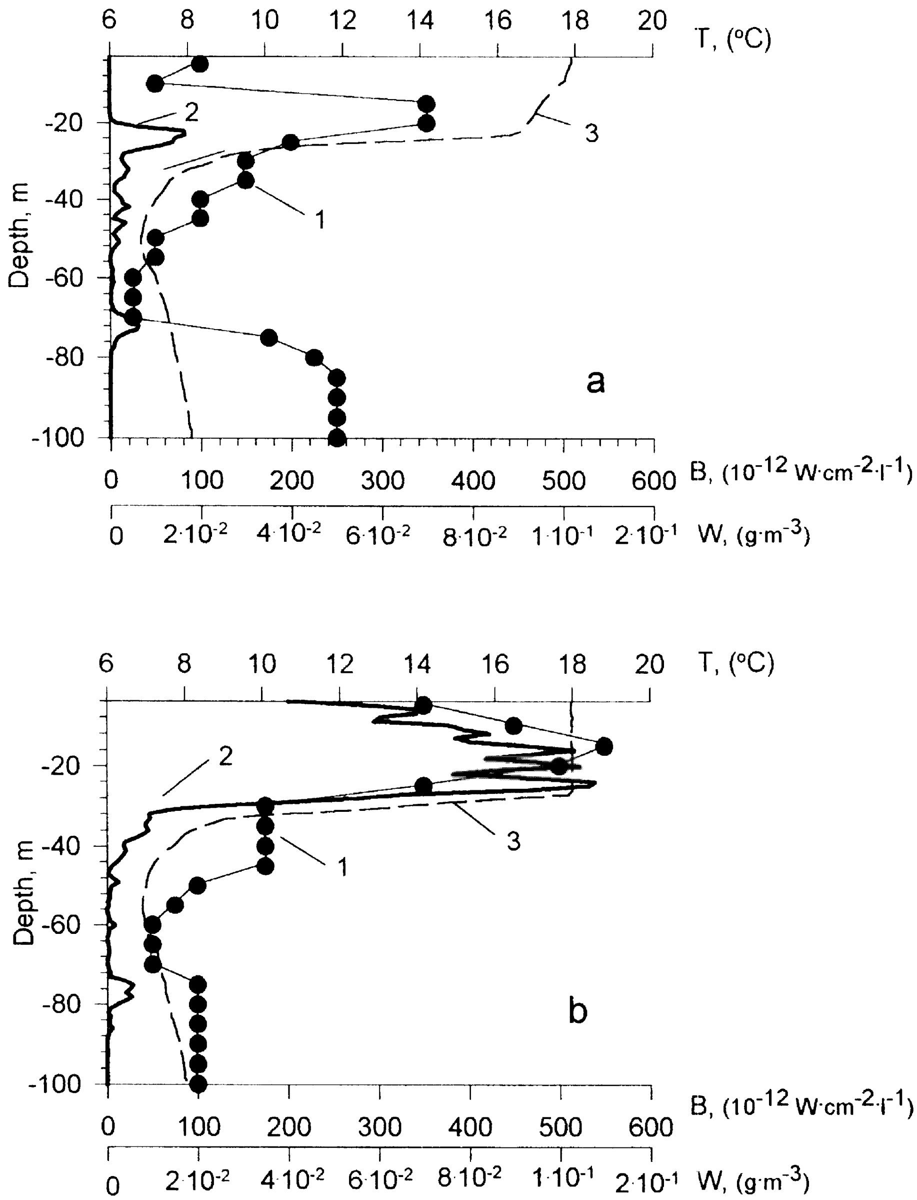

Fig. 1. The typical vertical structure of plankton biomass (1), bioluminescence (2) and temperature (3) in the Black Sea photic layer at day (a) and night (b) time

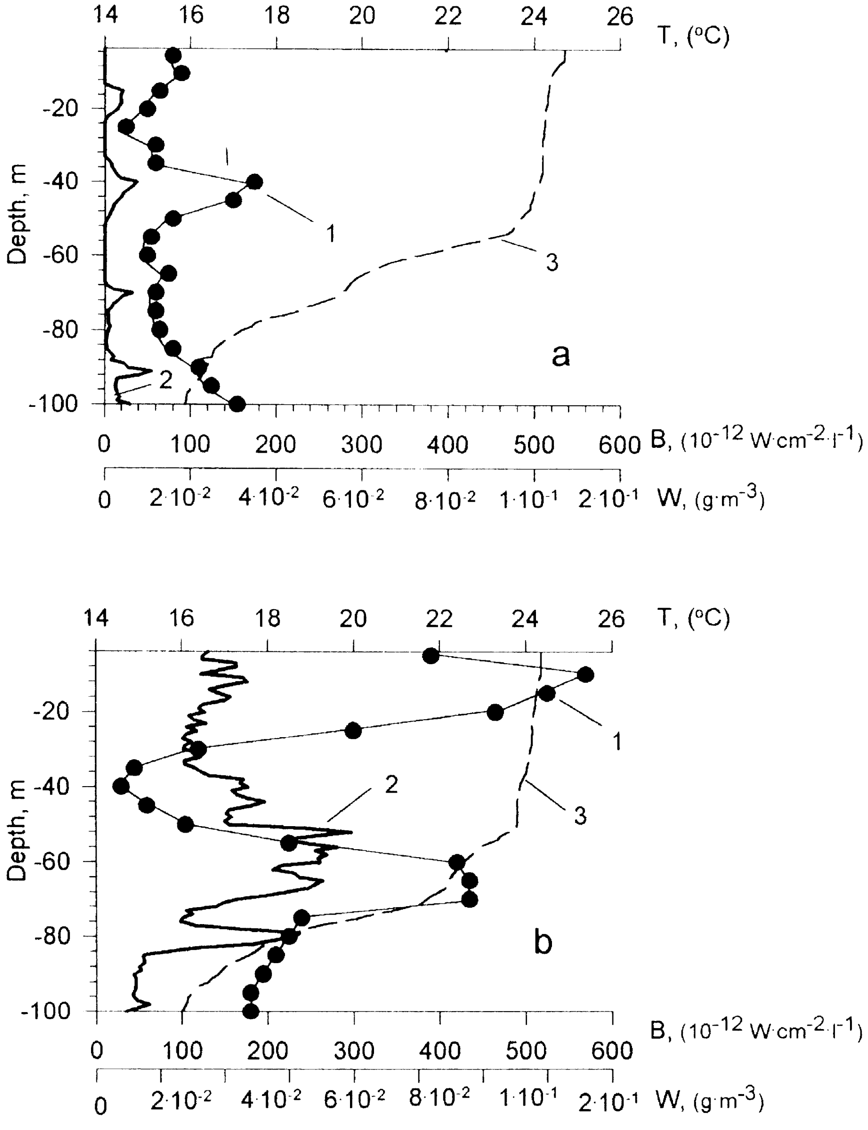

Fig. 2. The typical vertical structure of plankton biomass (1), bioluminescence (2) and temperature (3) in the Ionian Sea photic layer at day (a) and night (b) time

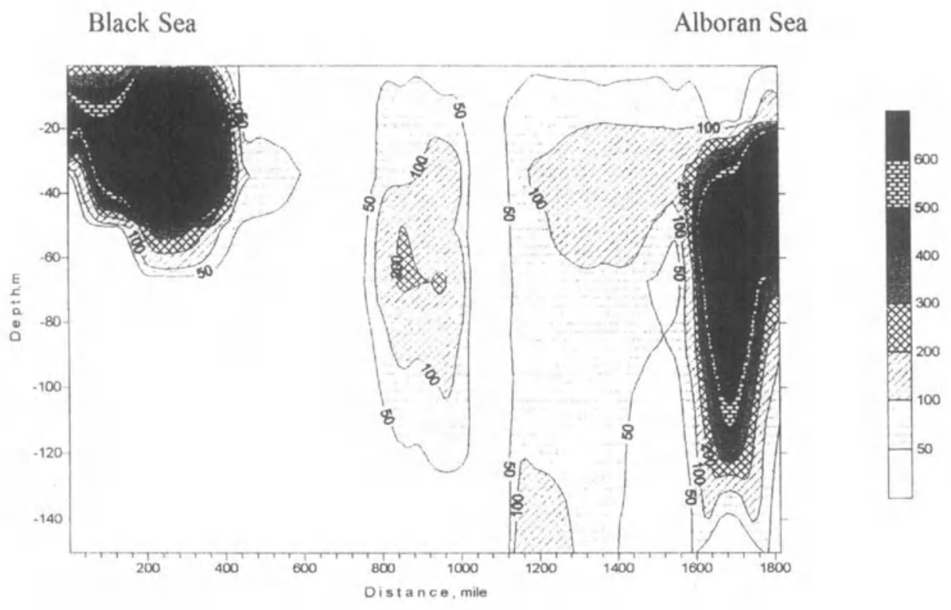

Fig.3 General trend of bioluminescence from the Black Sea to the Alboran Sea.

the Black Sea is 3 times weaker than that in the Alboran Sea. However, it is one order of magnitude higher than that in the central part of the Mediterranean Sea.

Macroscale trends of bioluminescence changes within the Mediterranean basin are comparable with that of the plankton spatial distribution [10]. Zones of the intensive bioluminescence are related to the position of the enhanced plankton biomass zones. This tendency is partly mirrored in the statistical relationship between abundance of Dynophyta algae and the bioluminescent potential found for non-polluted waters of the basin (Fig.4). A strong correlation between Dynophyta algae and bioluminescence, revealed for all regions of the Mediterranean Sea, was quite unexpected, because such a strong bioluminescent organisms as copepods, numerous in the plankton, should have contribute considerably into the total bioluminescent potential [7]. This means that the models where Dinoflagellata play the dominant role in the formation of bioluminescent field [17] should be more applicable for the Mediterranean Sea basin.

Regions of "ecological risk" are as a rule neritic near shore waters under industrial influence and the "relatively satisfactory" waters are well offshore and in the open sea. For example, in the Mediterranean Sea the sentral regions of the Alboran, Ionian and Aegean Seas, and in the central part of the central part of the western gyre and Karadag marine reserve of the Black Sea were all considered to have relatively good water quality while the regions of the intensive shipping (straits, southern part of the Ionian Sea, near-Bosphorus region, Black Sea north-western part) and densely inhabited riparian zones (i.e., Crimean southern coast) were considered to be regions of "ecological risk". Evidence for this simple classification is present universally in the literature [1,11,14,16] for the neritic zones of the world's oceans and the Mediterranean Sea, Table 1.

Data from such areas of our studied regions are given in Table 2 in the form of the squares of the correlation coefficients and the values of the regression coefficients. In column "a" regression parameters are given for comparatively clean waters, in column "b" - those in polluted waters. In column "c" these coefficients change when the two curves from each region are united. There are considerable differences between the parameters of the regression lines from the studied regions. For example, to obtain the same bioluminescence intensity in the 0-100 m layer, the quantity of dinoflagellates in polluted regions of the Mediterranean Sea would have to be twice as abundant as those from "clean" waters. Similarly the numbers of bioluminescent algae in the Black Sea would have to increase 3-4 times to obtain the same bioluminescent intensity (Fig.4).

Indeed, resistance of any organisms to environmental influence depends on the metabolic state of the intracellular systems. How quickly the organisms are able to adapt to anthropogenic pollutants is determined primarly by the energetic needs of the organism [15]. It can be presumed, that an organism's metabolic state (and hence its bioluminescence) could serve as an indicator for the levels of pollutants in the environment. These conclusions have been repeatedly confirmed in our

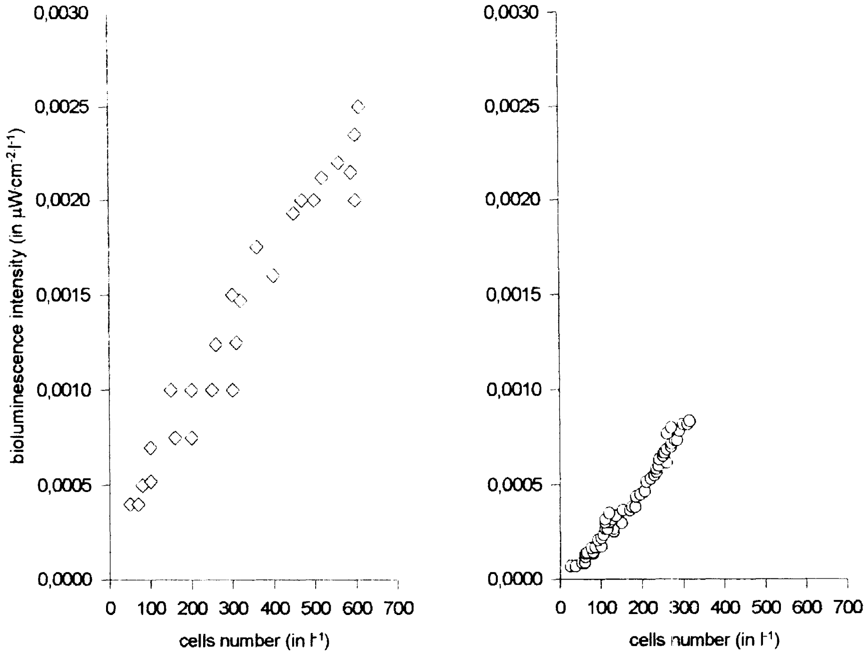

Fig.4. Regressions between bioluminescence intensity and numbers of dinophyte algae in the upper 100-m.

TABLE 1. Anthropogenic levels (μg/l) of some toxic materials in the euphotic layer and their toxic threshold for phytoplankton (from PATIN, 1977; BENZHITSKY, 1979; IZRAEL,1984).

Toxin	Anthropogenic levels		Toxic threshold
	Open waters	Neritic zones	
Petrogenic hydrocarbons	10	10^{2} - 10^{4}	10^{2}
Polychlorobiphenyls	10^{-2}	10^{-1} - 10^{0}	10^{1}
Pb	10^{-1} - 10^{0}	10^{1} - 10^{4}	10^{-1}
Hg	10^{-2}	10^{-1} - 10^{0}	10^{-1}
Pesticides (DDT)	10^{-2}	10^{0}	10^{-1}

TABLE 2. Regression equations between bioluminescence intensity and number of the dinophyte algae. Explanation in text.

Parameter	Mediterranean Sea			Black Sea		
	«a»	«b»	«c»	«a»	«b»	«c»
n	58	21	79	29	20	49
a	9.2E-06	4.3E-06	9.3E-06	1.9E-05	1.1E-05	5.3E-05
b	0.2E-03	0.1E-03	0.4E-03	0.1E-02	0.3E-02	0.3E-02
r^2	0.983	0.853	0.830	0.950	0.864	0.284

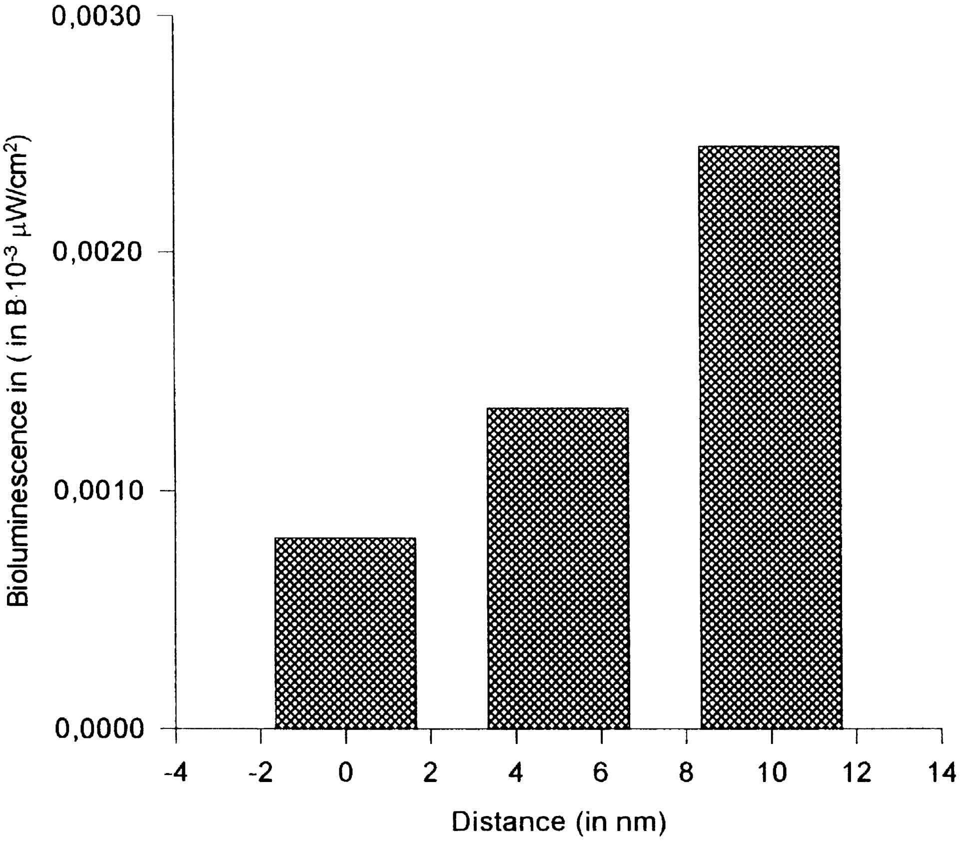

Fig.5 Reaction of the *Noctiluca miliaris* to electric stimulation from regions within Sevastopol Bay.

bioluminescence of plankton organisms [6]. From studies of the bioluminescent characteristics of Noctiluca miliaris, where samples were collected from regions of different anthropogenic impact (i.e., centre of Sevastopol Bay and from 5 and 10 nm) it was established that even these small spatial differences in sampling were responsible for marked differences in the levels of bioluminescence, Fig.5. Thus, the level of anthropogenic impact on a marine ecosystem can be assessed by monitoring the bioluminescence field of the dinoflagellates in that region.

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