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LIGHT ATTENUATION CHANGES IN THE MIDDLE AND SOUTHERN ADRIATIC

PROMJENE SLABLJENJA DNEVNE SVJETLOSTI U MORU SREDNJEG I JUŽNOG JADRANA

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Irradiance attenuation measurements performed occasionally from 1962-1990 in the Adriatic Sea were used to estimate euphotic zone depth in the middle and southern Adriatic Sea and to determine approximately optical water types.

The time span between the data at some stations allowed us to observe the reduced euphotic zone as a consequence of decreased transparency through years.

Changed light conditions: intensity and spectral composition could cause environmental changes in the euphotic zone.

INTRODUCTION

The knowledge of irradiance attenuation in surface layer is a very important subject for optical and biological oceanography but in the Adriatic Sea it was one of the least measured parameters. Irradiance attenuation measurements have some requirements as stable light conditions and relatively calm sea which are not always present at sea.

The most frequent optical measurements in the Adriatic sea were those of the Secchi disk. Irradiance measurements mostly were not spectral but irradiance of complete photosynthetically active radiation was measured. Only recently some spectral measurements have been performed.

The relation of irradiance attenuation and Secchi disc depth is not unique but it is often taken that 1% irradiance level is equal to triple Secchi disc (Strickland, 1958). Relations are different for different seas and especially between coastal and open sea. This relation is not the subject of this article but it should be said that changes in both parameters were in accordance although statistically significant relationship was not found between these parameters.

Generally the Adriatic Sea counts among the most transparent world seas. Forty years ago in the southern Adriatic it was possible to find transparency of 60 m (B u l j a n and Z o r e - A r m a n d a , 1966, 1979) which is the highest transparency ever measured in any sea. Recently the highest transparency measured at the open Adriatic has not exceeded 40 m. Transparency has decreased in the coastal area as well and euphotic zone depth consequently decreased too.

In order to distinguish water types in optical sense J e r l o v (1968) has defined three oceanic and nine coastal water types. They were defined in terms of irradiance attenuation for surface waters.

Transmittance per meter of downward irradiance in the surface layer, according to Jerlov, is given for different optical water types in the Fig. 1. It is seen that optical water types differ in transmittance of shorter wavelengths rather than longer.

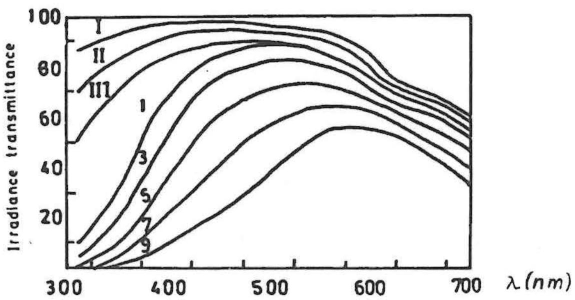

Fig. 1. Relative transmittance per meter of downward irradiance in the surface layer for optical water types, after Jerlov 1968.

Depth profiles of percentage of surface downward irradiance for the whole photosynthetically active radiation from wavelength interval of 350-700 nm for different water types is given in the Fig. 2. From the figure it is seen that depth of 1 % irradiance ranges between more than 120 m for oceanic type I to only 7 m for coastal water type 9.

Different depth levels in the sea receive different intensities and spectral composition of light. For completely clean water spectrum changes with depth as seen in Fig.3. In turbid water spectrum should decrease faster with depth but as there are differences between different water types in maximal transmission wavelength there could arise differences in maximal intensity wavelength received at different levels. For turbid waters maximal intensity wavelength tends towards greater wavelengths.

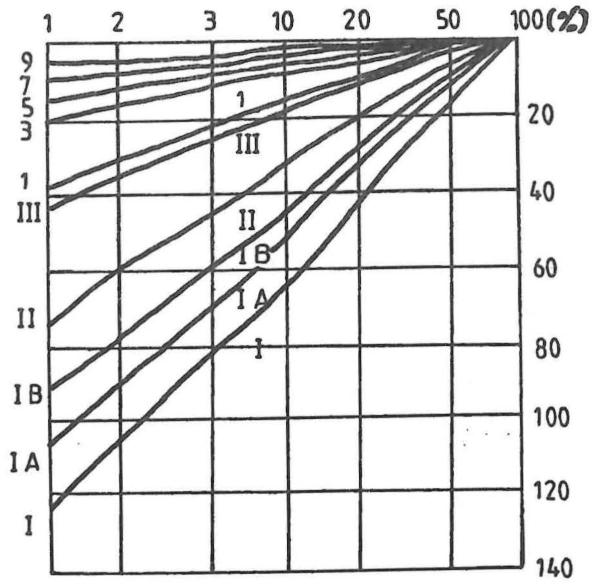

Fig.2. Percentage of surface irradiance for optical water types, after Jerlov 1968.

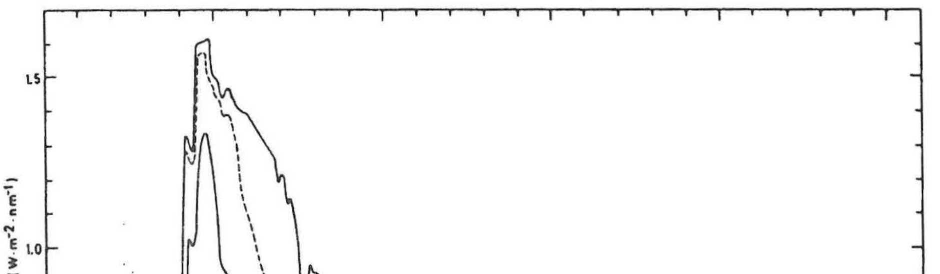

Fig.3. The complete spectrum of downward irradiance in the sea, after Jerlov 1968.

MATERIALS AND METHODS

We have used data from 36 stations of the middle and southern Adriatic Sea from both open sea and coastal regions to draw spatial distribution of euphotic depths and optical water types. Station map, Fig.4, shows contribution of both institutes, Institute of Oceanography and Fisheries and Hydrographic Institute, at measurements. The periods in use where those when data were most dense in time.

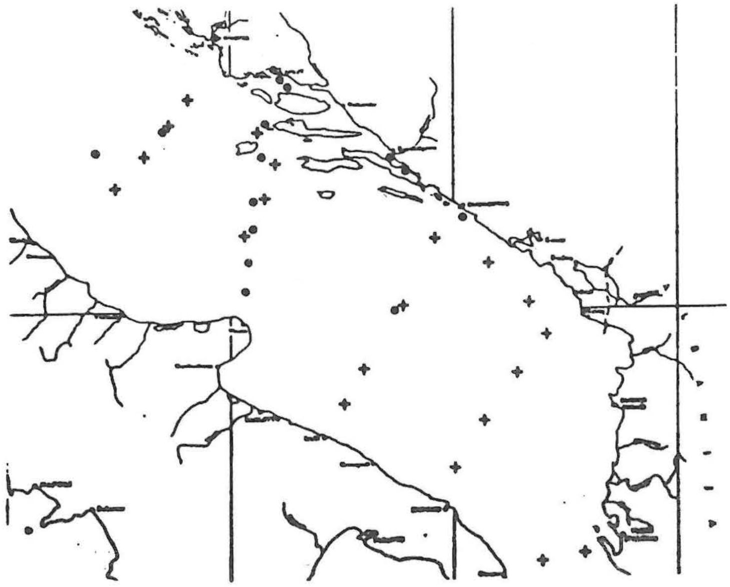

Fig.4. Station map on + stations of the Hydrographic Institute., - stations of Institute of Oceanography and Fisheries.

In all measurements a simple irradiance meter provided with photo voltaic cell and diffuse filter were used. For particular spectral irradiance measurements special filters for different wave bands were used.

Even though different instruments were used in different times they always covered most of the photosynthetically active radiation between 350-700 nm.

There were four photometers in use, two C14-centralen-factory photometers from the Institute of Oceanography and Fisheries and two Kahlsico photometers which belonged to the Hydrographic Institute.

All photometers used consisted of selenium photocell generating current when exposed to light, all having maximal spectral response for green light around 570 nm. Opaque filter was always used as the topmost while in some recent measurements colored filters were introduced lowermost. Table 1 shows band widths for filters and cell sensitivity for different instruments used.

Table. 1.

type of photometer & filters	band width (nm)	measured range (nm)
C14-Agency	275	375-650
Kahlsico-268WA305	240	425-665
red	50	615-665
green	65	490-555
blue	65	420-480
Kahlsico-268WA320	238	430-670
red	59	620-680
green	84	490-570
blue	65	420-480h

Jerlov's classification was used for optical water type determination for the whole photosynthetically active radiation.

Only the data from summer cruises were used to estimate euphotic zone depths. Data from other seasons were used only for illustration of seasonal changes.For each of the two periods for stations with more data means were calculated while for other stations a single measurements from the chosen time period sometimes represent the station.

Description of the investigated area

The Fig. 5 shows the bathymetry of the Adriatic Sea. South Adriatic Pit is a very deep slope region. It is surrounded by a narrow shelf towards the coast and towards the middle Adriatic. Shelf region is wide in the middle Adriatic and also towards Albanian coast while very narrow against Dubrovnik.

The southern Adriatic is the most oligotrophic part of the whole Adriatic Sea. It is supplied from waters of the Mediterranean Sea by a constant water input in the surface layer through the Otranto Strait. Incoming water flows along the eastern side in the Adriatic while outgoing water goes along the western side of the coast. Cyclonic circulation of the Adriatic forms sometimes several cyclonic gyres. The southernmost gyre closes across the Palagruža Sill.

Fig.5. Bathymetry (in meters) in the southern and the middle Adriatic Sea

RESULTS

Seasonal changes in the light attenuation

Irradiances measured at stations of the transect Split-Gargano in different seasons have shown at all stations seasonal maximum of irradiance transmittance in the summer and minimal transmittance in the winter or autumn. Fig.6. shows how relative irradiance changed seasonally during 1963/64 at coastal station Kaštela bay, Pelegrin and open sea station Stončica.

Euphotic zone depth

Euphotic zone depths obtained as 1 % irradiance level for the whole photosynthetic radiation for 350-750 nm were calculated from measurements during summer time. The data from earlier period 1963-1969 represent the first set of data from which euphotic

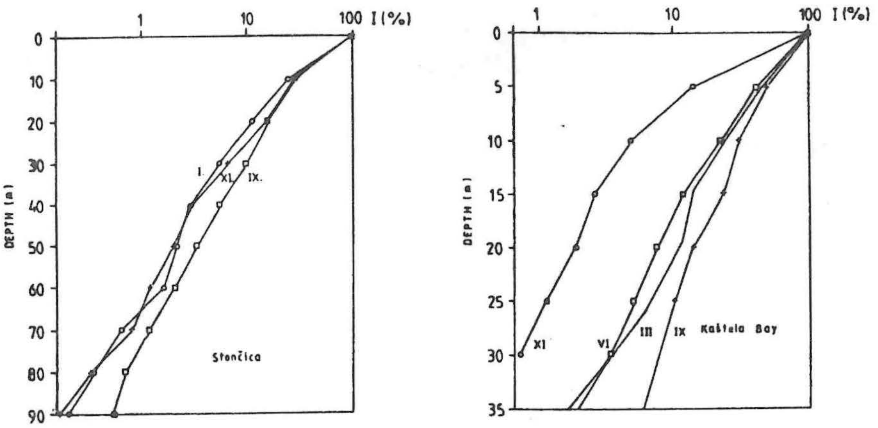

Fig.6. Seasonal change in relative irradiance at different stations of the middle Adriatic.

zone depths were determined. In the Fig. 6 euphotic depths were differently shaded for the lowest to the deepest zone depths. Obtained values of euphotic depths were from 40 in the coastal zone of the middle Adriatic to more than 160 m in the open sea but values from 80-100 m were predominant for the open Adriatic Sea at that time.

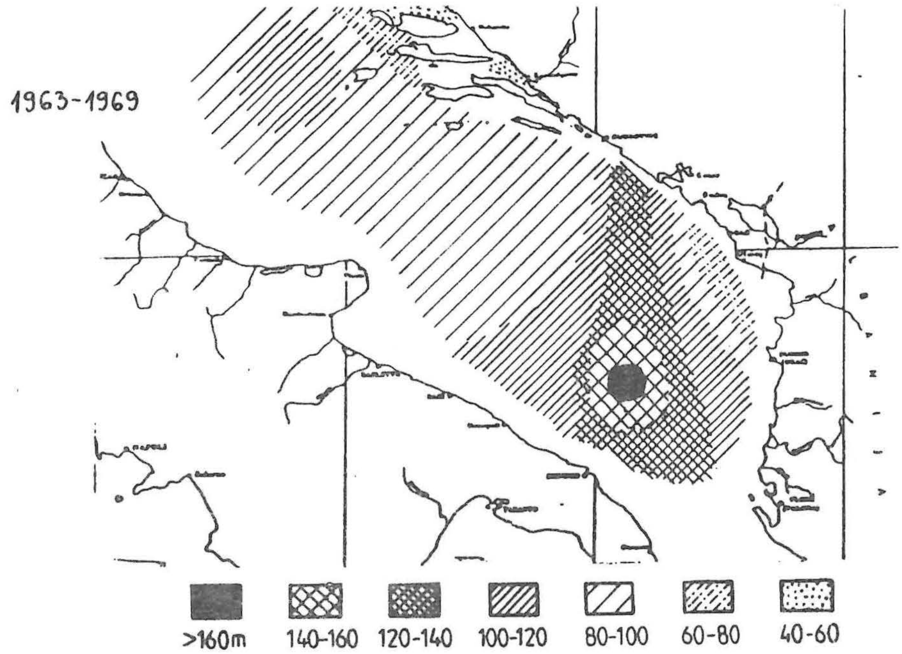

Fig.7.Euphotic zone depths from 1963-1969 .

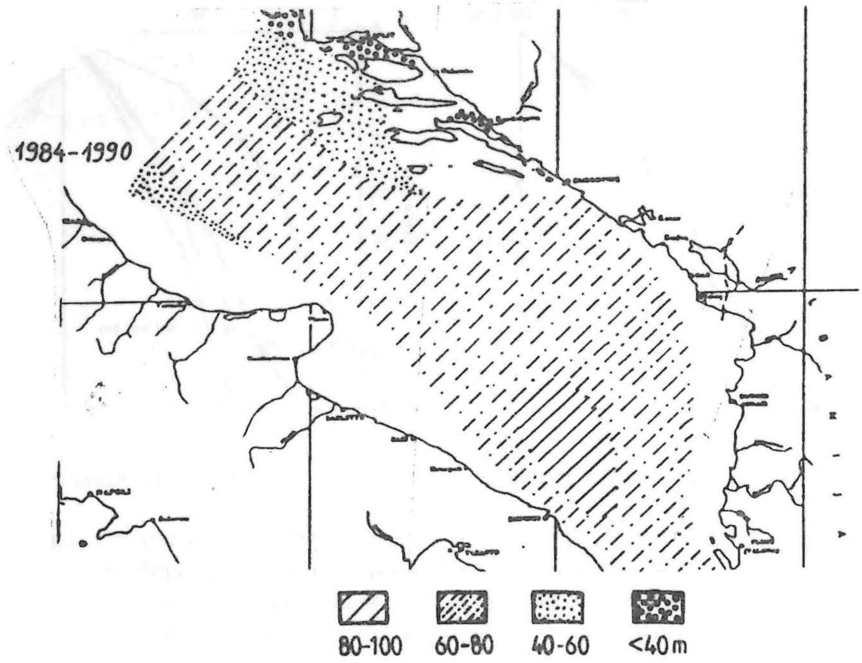

Fig.8.Euphotic zone depths from 1984-1990

The area of the deepest euphotic depth was found in the open southern Adriatic Sea from which it has decreased towards northern Adriatic. In the Jabuka Pit it has increased somewhat while towards the middle Adriatic coast it has decreased considerably relative to the open sea. In addition euphotic depths were lower against Albanian coast. Area against Dubrovnik had the deepest euphotic depth near the coast while in the area against northern Albanian coast euphotic depth considerably decreased towards the coast. The narrowest shelf area in the southern Adriatic is the shelf near Dubrovnik (see Fig. 5) and for that reason it has the deepest euphotic zone so near the coast. Albanian coast has much wider shallow shelf. There is a permanent water inflow which enriches the sea with nutrients causing higher production and reducing light penetration. Italian coast has narrow shelf and deep euphotic depths near the coast.

Obtained euphotic zone depths from more recent time period 1984-1990 are shown in Fig. 8. They ranged from values of less than 40 m in the coastal area to more than 80 m in the open southern Adriatic. The most predominant values for the open Adriatic were between 60 and 80 m for that time period. From Figs. 5 and 8 it may be seen that 100 m isobath resembled the margins of area of 60-80 m euphotic zone depths. In Fig. 8 euphotic depths decreased towards coast in the middle Adriatic and the deepest euphotic depth was found in the same region in the southern Adriatic. Only now the distribution is smoothed and decrease of euphotic depth towards Albanian coast fell within interval between 60-40 m.

Optical water types

Optical water types obtained according to Jerlov's classification are shown in Fig. 9 for the earlier period. The optical water types varied from type I to the type II for oceanic waters, showing that water types in the coastal region of the Adriatic at that time were as transparent as oceanic water types. Fig. 10 shows that recently euphotic depths ranged from IA to III for the open sea waters while in the coastal regions waters reached the type I for coastal waters.

Figs. 6 and 8 correspond to Figs. 9 and 10 to a great extent while differences were caused by different intervals of euphotic depths covering each degree of optical water types .

It is obvious that optical water types from the period 1963-69 even in the coastal areas according to Jerlov's classification all belong to oceanic water types. That is due to the fact that the Adriatic Sea is an oligotrophic sea. This was in accordance with very high transparency of the Adriatic Sea. The overall picture of irradiance attenuation and transparency has changed so that transparency decreased, as seen from Figs. 11 and 12. Level of 1 % irradiate decreased as well and optical water types changed in every region for at least one degree towards higher optical water types number.

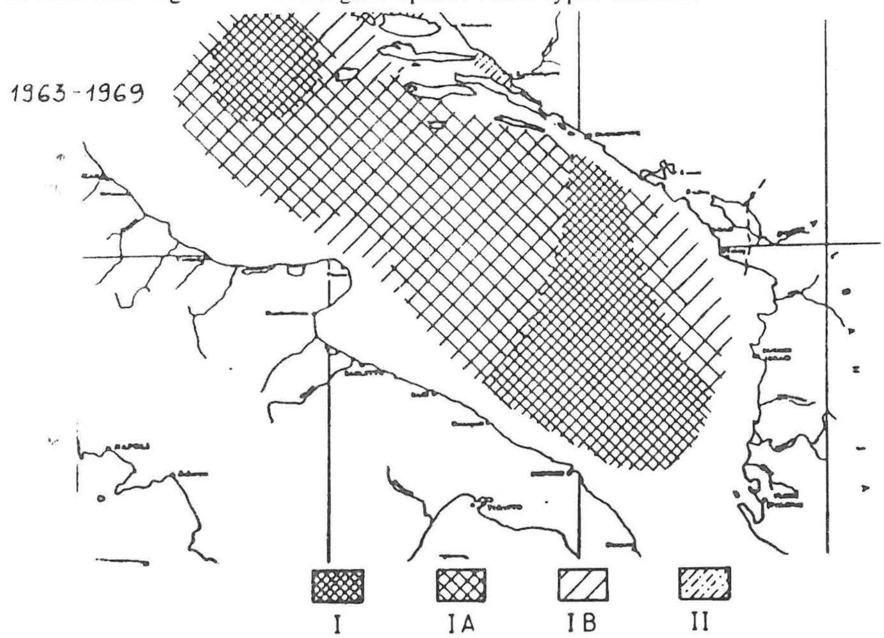

Fig. 9. Optical water types from 1963-1969

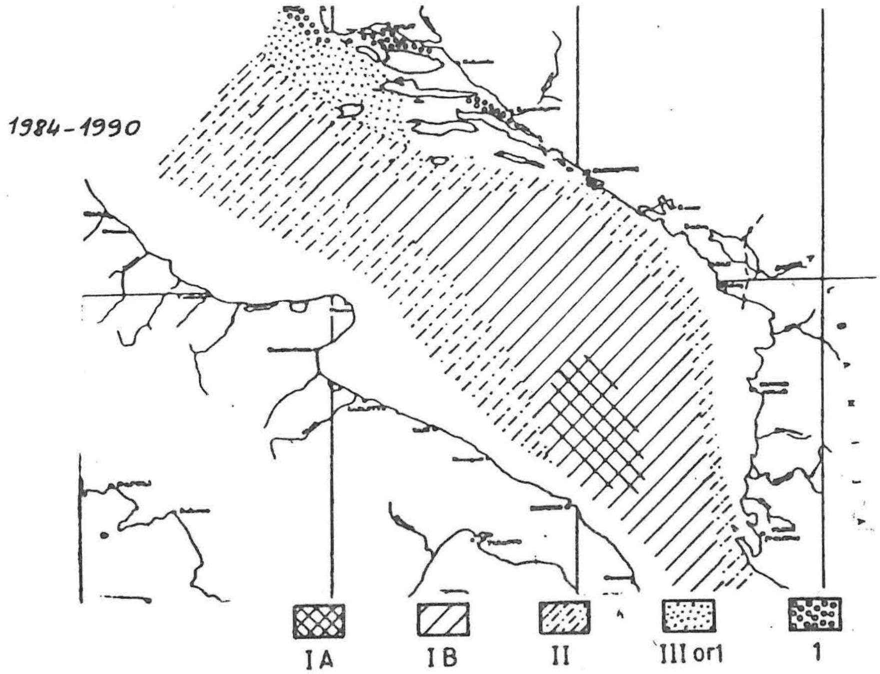

Fig. 10. Optical water types from 1984-1990

Transparency

Sea water transparency was measured with the 30 cm diameter Secchi disc. Transparency from the same time periods as irradiance data were presented in Figs. 11 and 12.

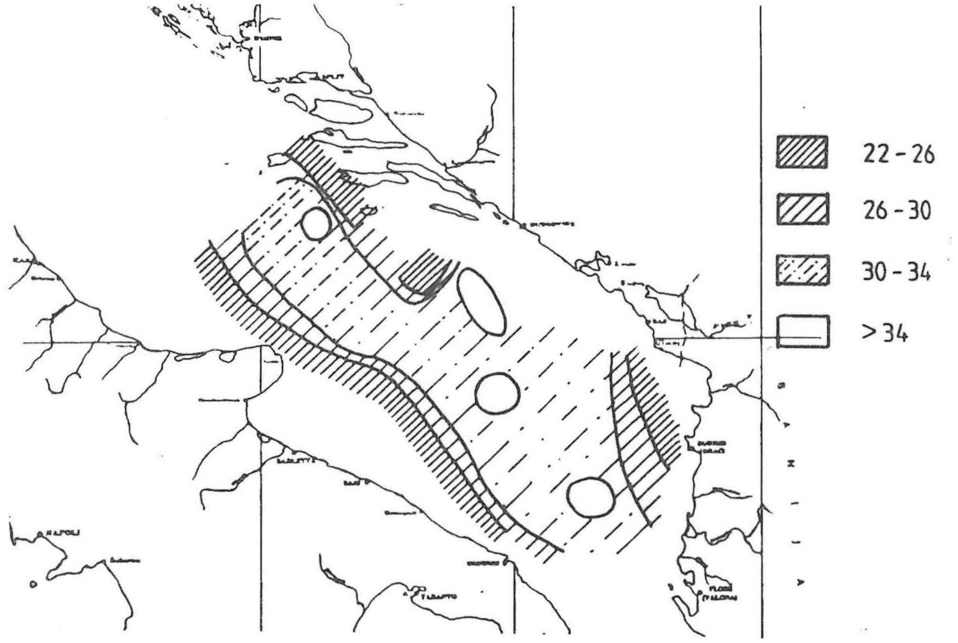

Fig.11.Transparency measured from 1963-1969

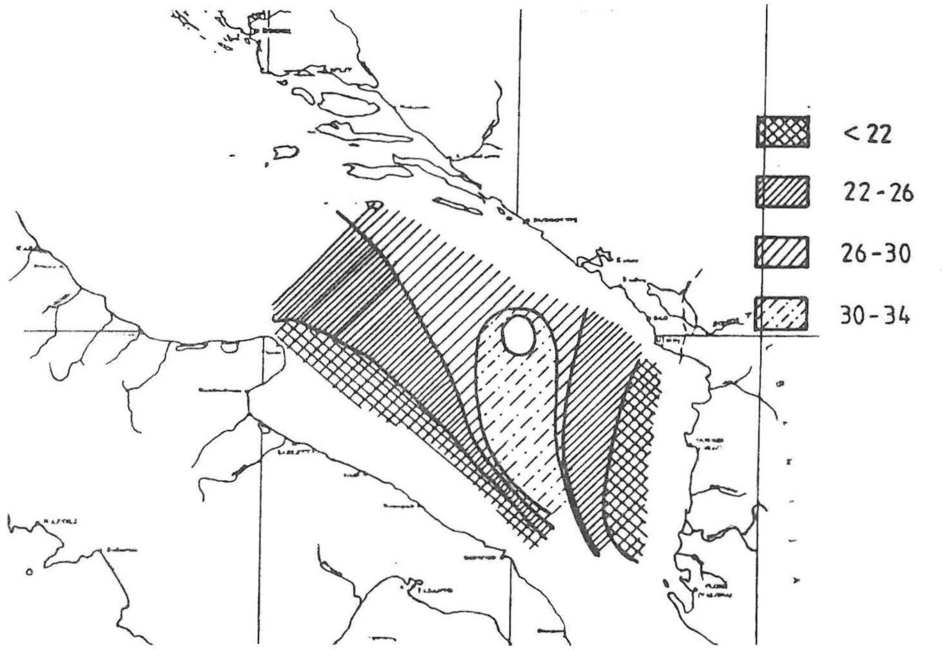

Fig.12.Transparency measured from 1984-1990

DISCUSSION

The striking result of this presentation is the remarkable decrease in the euphotic layer thickness.

Lower irradiance transmission is the result of the increased phytoplankton production observed all over the Adriatic (M a r a s o v i ć , 1989). Higher phytoplankton concentrations in the coastal areas could be attributed to the pollution influence. Pollution caused decreased euphotic layer depth in the coastal area directly by a stronger particles input and indirectly by nutrient input which favored phytoplankton production. As pollution started in the early sixties its influence could be spread in the second measurements period even to the open sea. It is also possible that the open sea exhibited influence from input of the eastern Mediterranean water. It was found earlier that transparency decreased in the years of stronger inflow of this water (M o r o v i ć , 1983). Mediterranean waters were richer in nutrients than the open Adriatic waters. In the second measurements period Adriatic productivity increased considerably and it is possible that eastern Mediterranean water was no longer considerably richer than the Adriatic water (M a r a s o v i ć , 1989). There are year to year differences in this inflow probably induced by climatic changes which influence the regime of exchange of the water through the Otranto Strait but due to insufficient irradiance attenuation data it was not possible to observe these changes.

Attenuation coefficients (Table 2) give better measure of excessive amounts of phytoplankton and/or other particles responsible for euphotic layer thickness decrease.

Table 2. Euphotic zone and attenuation coefficient change within the two periods

	Brač channel		Stončica		Adriatic Pit	
PERIOD	euphotic zone	attenuation coefficient	euphotic zone	attenuation coefficient	euphotic zone	attenuation coefficient
1963-69	50	0.020	90	0.010	160	0.006
1984-90	30	0.030	50	0.020	90	0.010

Stronger change in the attenuation coefficients occurred in the coastal area of the middle Adriatic than at Stončica but Stončica changed more than South Adriatic Pit .

Observed changes probably resulted in a change of maximal transmission from 470 nm to a longer wavelength especially in the coastal area. Reduced light intensities, less blue light in the spectrum and consequently shorter day duration at deep levels may have some consequences. The higher phytoplankton concentrations were found in the layers within the new limits of the euphotic zone. As it has become shallower than before the concentrations decreased in deeper layers. The trend of increase in oxygen saturation for Stončica (P u c h e r - P e t k o v i ć *et al.*, 1987) was found for levels above 50 m while for 100 m a trend of decrease was observed. Also all along the profile Split-Gargano oxygen saturation at 50 m reached the saturation of the surface while 100 m showed downward trend (Z o r e - A r m a n d a *et al.*, 1987). The downward trend in saturation could be the result of stronger oxygen consumption by bacteria due to higher decomposition of the organic matter as a result of higher phytoplankton productivity of surface layers. But it is also possible that oxygen is not produced any longer at deep levels because recently they have been bellow the euphotic depth limits.

The decrease in euphotic depth in coastal areas could have some consequences for benthic organisms. Sedentary species could be left beyond the reach of necessary amount of light energy and also could be exposed to longer wavelength than before. Regressions of the *Posidonia* beds that have been observed in the Mediterranean could have been besides other environmental factors influenced by changed light conditions. The increase in size as adaptation to reduced light intensities has been also observed for some benthic species in the middle Adriatic (Š p a n and A n t o l i ć , personal communication).

Increased concentrations of both phytoplanktonic and benthic species were found in the surface layers. Sedentary benthic organisms living in the shadow zone probably bear the strongest influence from changed light conditions. In the northern Adriatic the changes in benthic communities were also found which were attributed to the oxygen depletion in the bottom layers (J u s t i ć , 1988), but it is possible that the reason for oxygen depletion may be not only decomposition of organic matter but decreased light intensity played some role.

CONCLUSIONS

Euphotic zone depth has considerably decreased in the middle and southern Adriatic from sixties to eighties in the coastal areas and in the open sea.

The most oligotrophic part of the Adriatic is reduced to a limited area of the south Adriatic while middle Adriatic and coastal areas has become more productive.

It is possible that the observed changes in light conditions in the Adriatic sea could have dramatic consequences for the most sensitive stenophotic species especially the benthic ones.

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PROMJENE SLABLJENJA SVJETLOSTI U SREDNJEM I JUŽNOM DIJELU JADRANSKOG MORA

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KRATKI SADRŽAJ

Vertikalno slabljenje dnevne svjetlosti u moru u razdoblju 1962-1990. upotrijebljeno je za računanje dubine osvijetljene zone i približno odredjivanje optičkih tipova vode. Uočeno je smanjenje dubine osvijetljene zone kao posljedice smanjene prozirnosti. Promijenjeni uvjeti svjetlosti u moru: smanjen intenzitet i promijenjen spektralni sastav mogli bi prouzročiti promjene unutar osvijetljene zone.