Acta Adriat.,32(2):837-868(1991)

ISSN:0001-5113
AADRAY

UDC:504.4:574.4:597(262.3)
Conference paper

ECOLOGICAL AND FISHING FEATURES OF THE ADRIATIC SEA

EKOLOŠKA I RIBARSTVENA OBILJEŽJA JADRANSKOG MORA

G. Bombace

Institute of Marine Fisheries Research, C.N.R., Ancona, Italy

A BRIEF OUTLINE ON THE ORIGIN AND HISTORY OF THE MEDITERRANEAN AND THE ADRIATIC

For most of the tertiary age the Mediterranean was part of the Tethys Sea, that vast primaeval ocean. The current configuration of the Mediterranean was produced by the tectonic events that followed during the upper Miocene, Pliocene and Quartenary periods (R u g g e r i , 1967).

According to the most widely accepted theory, this intermediate ocean was largely open to the Indo-Pacific region and populated by a tropical type fauna (*Paleomediterranean Element*).

After the salinity crisis at the end of Miocene period(during the so-called Messinian period) due mainly to reduced intercommunication with the Atlantic and the closing of intercommunications with the Indo-Pacific (previously via Syria), the Mediterranean consisted of a series of lagoons.

A certain degree of irregular intercommunication was maintained with the Indo-Pacific through the north sea of Paratethys populated by a distinctly Sarmatic fauna, while the paleomediterranean fauna element was disappearing or being transformed as part of the *Endemic Element*, consisting of typical species of the Mediterranean. This geomorphological transformation and this process of speciation were completed during the Pliocene period. In the meantime the Mediterranean was gradually becoming a temperate sea, which still characterizes it today. Its intercommunications with the Indo-Pacific were closed definitely while those with the Atlantic were reopened. In this phase, the *Atlanto-Mediterranean Element* was introduced in the Mediterranean, which is to remain constant and constitutes the main element of the current populations.

During the events of the Quarternary period, with its alternating regressions (cold periods) and transgressions (hot periods), the *Northern Element* alternated with the *Senegalian Element*, which can be considered as a superimpression on the *Endemic* and *Atlanto-Mediterranean Elements* (Pérès et Picard, 1964). After the great post-Würmian deglaciation, the situation has remained fundamentally as it is today. The gradual increase in salinity has led to the extinction of almost all the northern species to reach the following fauna situation: the majority involving Atlantic-Mediterranean species (immigrated during the Pliocene) and endemic species (formed during the Calabrian and Sicilian periods). To these two numerically dominant groups it must be added the survivors of the Senegalian Element (which entered the Mediterranean during the Tyrrhenian period) and a number of survivors of the Northern Element (entered at Würm) (Pérès and Picard, 1964).

It is important to underline that the alternation of warm and cold fauna in the Mediterranean is not due to temperature variations but to the modifications of the flow of the currents in the Strait of Gibraltar and Bosphorus (Mars, 1963), which were in turn related to the climatic fluctuations of the glacial and interglacial periods which were in turn related to the climatic fluctuations of the glacial and interglacial periods which characterized the Quarternary period.

Regarding the Adriatic, several biogeographers and paleontologists retain that the last contact of the Mediterranean with the Indo-Pacific occurred through a corridor which connected Miocene and the Pliocene periods. The Sarmatic Sea collected in a vast basin the Black Sea, the Caspian Sea and the Lake of Aral, which were once also a part of the Tethys Sea.

A BRIEF OUTLINE ON THE BIOGEOGRAPHY OF THE MEDITERRANEAN AND THE ADRIATIC SEA

The current biogeographical situation of the Mediterranean derives from the historical and paleogeographical events occurring during the Miocene and Pliocene, but above all, from the climatic fluctuations which occurred during the Quarternary Period.

As far as the benthos is concerned, the following distinct biogeographical districts can be identified: the Alboran Sea; 2) the Western Mediterranean; 3) the Eastern Mediterranean; 4) the Adriatic; 5) the Black Sea which is a sea in itself. With the exception of the Alboran Sea, these biogeographical areas can be farther subdivided. the Western Mediterranean includes a northern area (the Ligurian Sea, The Lyon Gulf) where in winter the deep Tyrrhenian waters form as a result of surface cooling and cascading, a central area and a southern area tied to the North African coast; the Eastern Mediterranean, which is certainly the richest in endemic elements and which has certain affinities with the Pacific region for historical events, can be subdivided into a northern area which includes the Greek coasts and those of Asia Minor, and a southern area. The latter is also characterized by the so called Lessepsian species, that are the species entering the Mediterranean from the Red Sea, and consequently from Indo-Pacific region, via the Suez canal. Finally, we have the Adriatic which is the most different sea of all which wash the Italian coasts. It can be subdivided into three sub-areas of which the Northern and Central Adriatic have greater bio-ecological and oceanographic affinities than the Southern Adriatic (Fig. 1).

The Northern Adriatic is also very particular in terms of fish fauna where several "sensu strictu" endemic species may be found (T o r t o n e s e , 1983), such as *Acipenser naccarii*, *Syngnathus taenionotus* and several Gobides such as *Knipowitschia panizzae*, *Pomatoschistus canestrini* and others.

In the Northern Adriatic and partially in the Central Adriatic, there are a number of fish species of pontic origin living in the colder areas of the Mediterranean, while the Atlantic species are very northern.

For example *Merlangius merlangus merlangus* (whiting) travels as far as the Norwegian and Icelandic coasts in the Atlantic, while in the Mediterranean it can be found in the Lyon Gulf, in the Northern and Central Adriatic, in the Northern Aegean, in the Sea of Marmara and in the Black sea (*M. merlangus euxinus*). The same applies to the sprat (*Sprattus sprattus*) which in the Northern and Central Adriatic is an important stock, even if it is not adequately exploited. It can be distinguished in an Atlantic form which never travels any further than just under Gibraltar, a Baltic form and a Mediterranean form living above all in the colder areas. Other pontic or ponto-caspian species present in the Northern Adriatic are *Huso huso*, *Syngnathus tenuirostris*, *Knipowitschia caucasica*, *Platyichthys flesus luscus*.

The *Knipowitschia*, which is a ponto-caspian genus, is well represented in the Northern Adriatic since it is typical of lagoon and estuary brackish-water environment. In the case of these pontic-Mediterranean species it is difficult to establish if they are fish species passing through the Bosphorus during the alternating events of the Plio-Quarternary periods or survivors of more ancient periods (Sarmatic Sea), which were trapped in particular Mediterranean biota.

ECOLOGICAL AND FISHING FEATURES OF THE ADRIATIC SEA

Apart the Southern Adriatic, which from a biogeographical, ecological and fishing point of view is very similar to the Northern Ionian Sea (Ionic coasts of Calabria and Sicily), where there is a combination of "western" and "eastern" elements, a number of the ecological parameters and aspects related to fishing should be examined for the

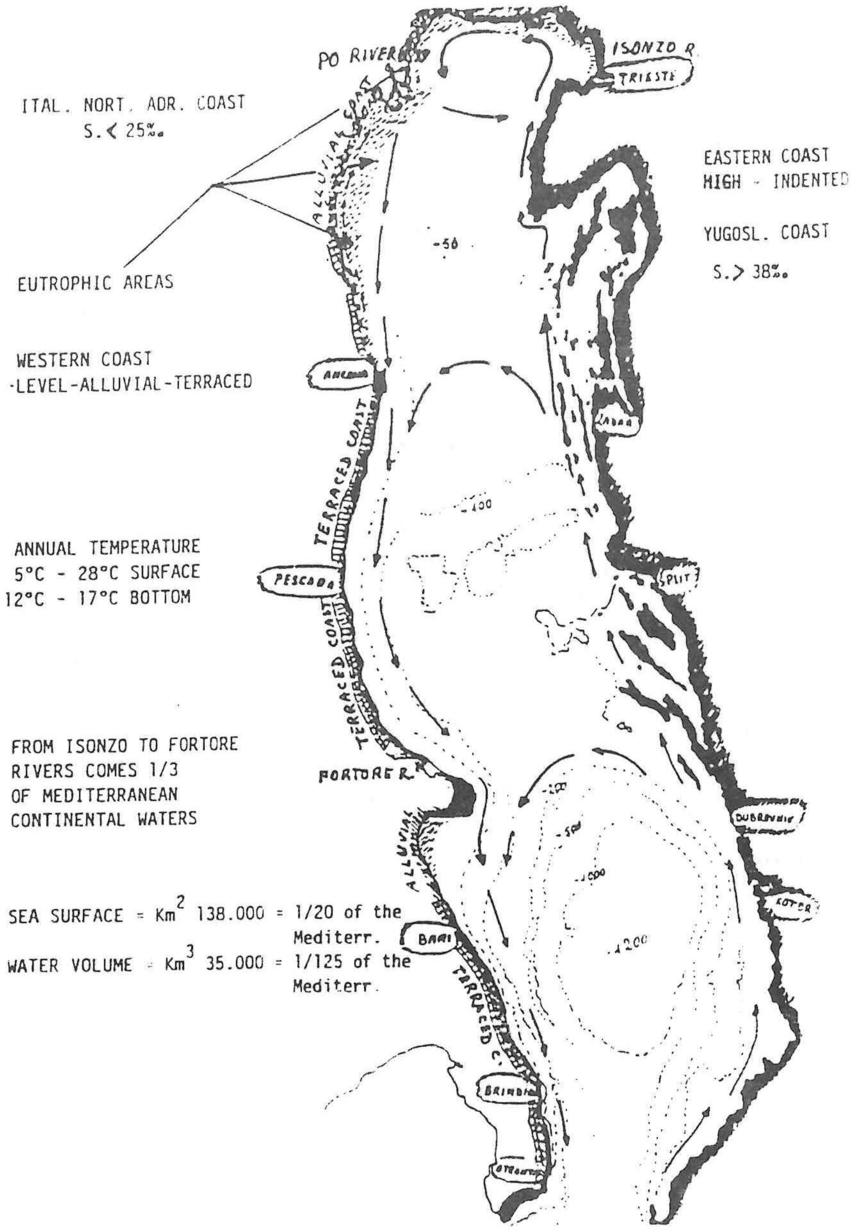


Fig. 1. Adriatic Sea: some ecological characteristics

Mediterranean. Its water volume is 35,000 cu. km equal to 1/125th of the Northern and central Adriatic, which are the two most similar basins.

The coast, the sea bottom and the inflow of fresh water (Fig. 1)

The Adriatic extends in a NW/SE direction for more than 700 km. The width between Pescara and Split is about 200 km. The major fetch is consequently by the South East wind. The Adriatic has a surface area of 138,000 sq. km equal to 1/20th of the entire

Mediterranean. If the fishing resources were distributed uniformly considering the total production in the Mediterranean of 1,000,000 tons per year, the Adriatic should produce 50,000 tons of catch per year. On the contrary it produces 5 times this amount. The coastal morphology differs according to whether it is Slovenian-Croatian-Albanese coast or the Italian coast. The first one is high, rocky, articulated, indented and dotted with small and large islands. There is a low fresh water inflow. The Italian coast is generally flat and alluvial to the North and South of the Po River with lagoon facies in the North and near Gargano too (Lesina, Varano and Manfredonia) or the raised terraces (tableboard of the Puglie region, between Ancona and Pescara, etc.).

About 1/3rd of all the Mediterranean continental water flows into the Northern and Central Adriatic. Considering the number of rivers which flow from Isonzo (Trieste) to Fortore (Gargano), the volume of water per second which flows into the sea can vary from 3,000 cu. m to 10,000 cu.m and over, half of which comes from the Po River. The sea bottoms of the Northern and Central Adriatic consist mainly of recent and ancient sediments (sandy, muddy, silty, etc.) and constitute a large shelf for trawling. This favours access to fishing resources with the use of grazing gears (trawling, mid-water trawling, dredging for bivalve mollusks, beam-trawling for flatfish, etc.), above all in international waters and along the coast on the Italian side. The coastal bottoms of the Slovenian-Croatian side are rather uneven and permit the use of trawling gear only along the channels between the islands.

Thermohaline fronts and fishing resources

The Northern and central Adriatic are subject to very strong annual thermal variations, above all in the superficial layers of water (for examples: 5°C - 28°C at the surface and 12°C - 17°C at the bottom).

During winter, the coastal water (as far as 6-7 miles from the coast) is uniform from the surface to the bottom, with low temperatures of 5° - 6° and a salinity below 37 ppt (Fig. 2a, Fig. 3).

In open sea the temperatures are about 10° - 12° and the salinity is higher than 38 ppt (F r a n c o 1970, 1972, 1983; A r t e g i a n i , 1984, 1987).

A thermohaline density front, which involves the entire water mass vertically, divides the coastal waters horizontally from the open sea waters.

During the autumn and the early winter, because of the more comfortable thermal conditions in the open sea, there is a migration of exploitable demersal species from the coast towards the open sea. Therefore during winter a number of small eurythermic and euryhaline species characterized by an annual biological cycle (some Gobiidae, Atherinidae, etc.) remain inshore, where they constitute the only fishing resources available. For this reason only the Departments of the Northern Adriatic are allowed to trawling within the three miles in the period from October to March, in spite of the national law. This derogation involves the distance from the coast and the mesh size. From the ecological point of view, the vertical thermohaline front, which runs parallel

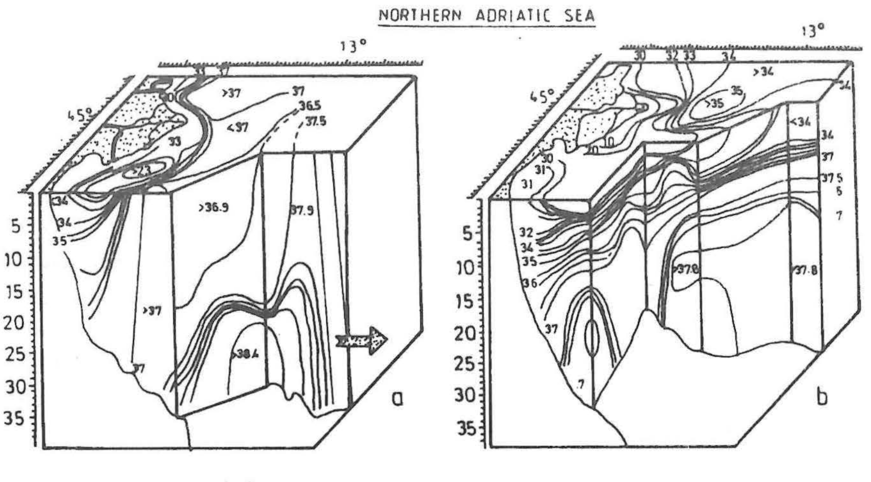


Fig. 2. Tridimensional perspective of salinity distribution in the northern Adriatic Sea (delta Po); a) under autumn winter conditions (modified after F r a n c o, 1983); b) under conditions of summer stratifications (F r a n c o, 1983)

⇒ migration of most demersal species offshore

to the coast, blocks the terrigeneous materials (nutrients and other substances which flow from the rivers and water ways) inside the coastal area, creating in this way the conditions for the spring blooms. In summer (Fig. 2b, Fig. 4), water stratifications may occur which vertically separate (horizontal thermohaline front) the hot superficial waters with lower salinity from the deeper and colder waters with greater salinity. The thermic differences between the two layers is 11° - 13°C. This stratification occurs only if the meteo-marine conditions are suitable (extended period of calm sea, strong insolation, high temperatures, inflow of fresh water). These are the ideal conditions for autumnal algal blooms and extended hypoxia or anoxia. The two phenomena can occur separately, as shown by the events taking place over the last 20 years. Damage to the demersal resources (both during the prerecruitment and the subsequent phases) as well as to the sedentary and benthic ones (e.g. bivalves such as baby clams) may be considerable.

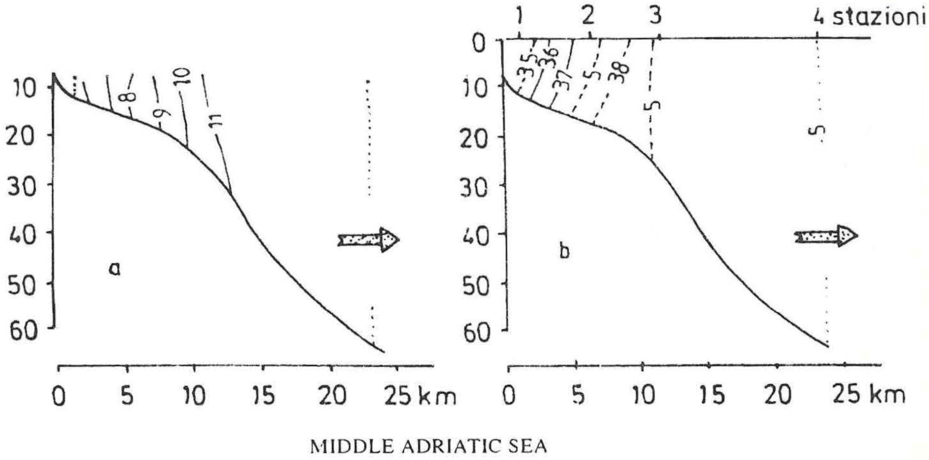


Fig. 3. Temperature (a) and salinity (b) distribution on Portonovo transect under winter conditions (modified after A r t e g i a n i, 1987) ⇒ migration of most demersal species offshore

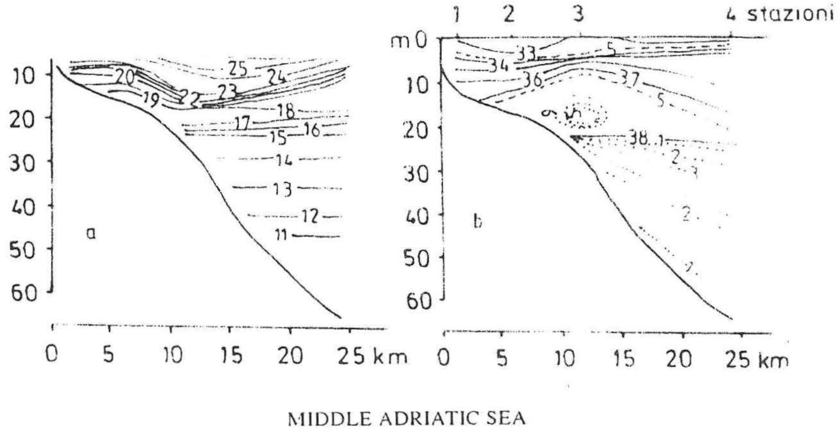


Fig. 4. Temperature (a) and salinity (b) distribution on Portonovo transect under conditions of summer stratification (A r t e g i a n i, 1987)

Sea Depth

The Northern and Central Adriatic basins are not extremely deep. In the Northern Adriatic the maximum depth does not exceed 75 metres, while in the central Adriatic it is about 100 m, with the exception of the Jabuka Pit where the depth is about 300 m.

It is interesting to note how the "low depth" factor plays an ambivalent and ambiguous role, according to the situations and events resulting from the meteo-marine conditions.

Positive role for the Environment:

a - Exchange of the water masses
The low depth and the slight inclination of the bottom reduce the time required for the exchange of the water masses. In the Northern Adriatic, the exchange of the water masses occurs over few months.

b - Recirculation of the sedimented nutrients
Stormy seas, above all, under the force of the North East winds, rehash the sea bottom with low inclination and recirculate the sedimented nutrients. This effect occurs up to 10-15 m of depth, that is 3-4 miles offshore in Northern Adriatic. In deep seas these salts are completely lost

c - Compacting of the food chains (Fig. 5)
The low depth creates bio-ecological mechanisms having high productivity. The benthic and demersal species come in predatory connection with the pelagic species and this reduces the energy losses. For example, in the feeding of the Adriatic hake (F r o g l i a , 1973), Clupeiformes are found to make up about 50% of the full stomachs of specimens above 14 cm and 85% in the case of specimens longer than 16 cm. This is far less probable in the case of hakes living in deep seas.

Adverse impact on the environment:

- Conditions of stagnation and accumulation, stratification and lack of oxygen.

When thermohaline fronts involving the all water column form, during the winter the terrigeneous flows stagnate and accumulate along the coast, while during summer there is no vertical mixing of the waters with consequent lack of oxygen an the sea bottom.

The ideal conditions for a basin with the above ecological factors would be to have periodical turbulence and remixing of the water masses (wind and stormy seas) so as to distribute the terrigeneous flows and to oxygenate the bottom. It is not by chance that some authors have related the frequency of algal blooms as well as stratification and anoxia in the Adriatic with the reduced frequency of North East winds over the last

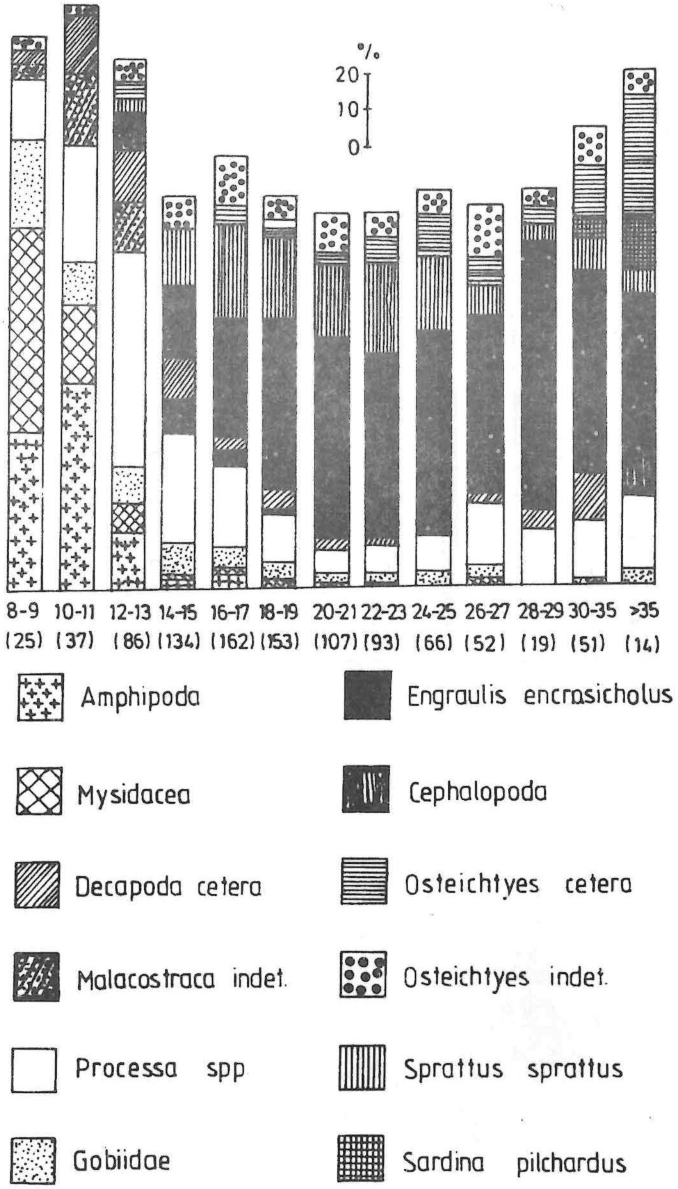


Fig. 5. Feeding of the hake in the middle Adriatic Sea (F r o g l i a, 1973)

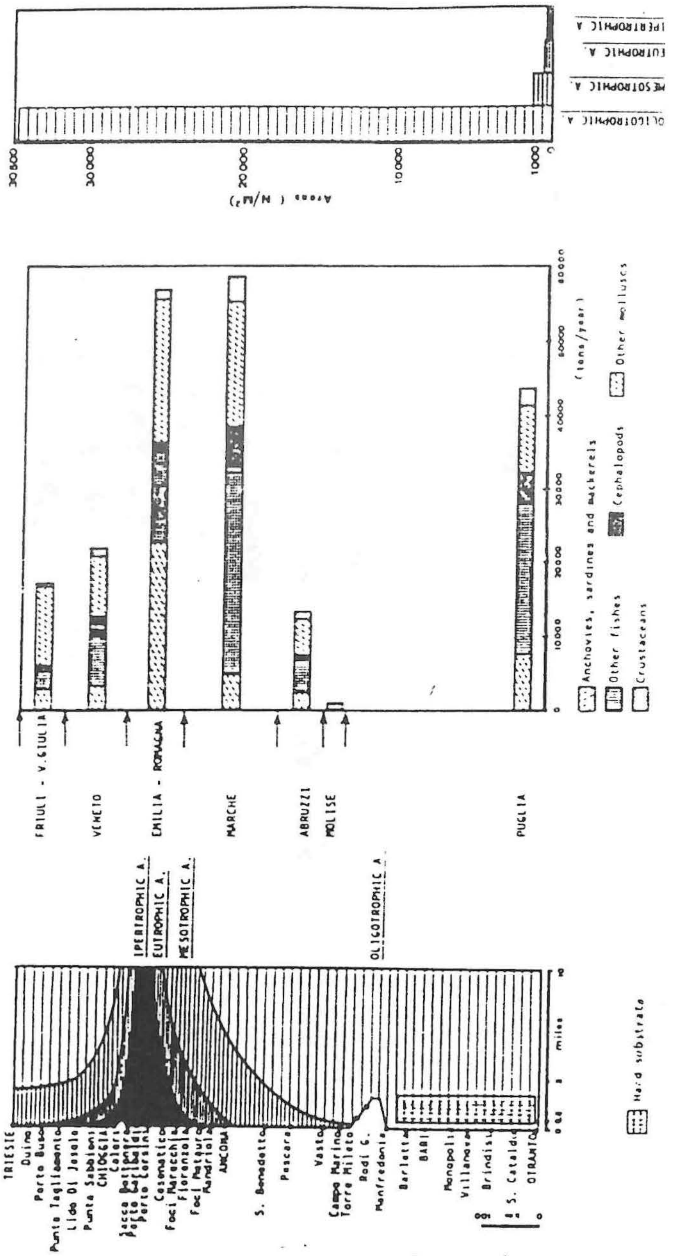


Fig. 6. Synoptic table of the trophic situation in Adriatic coastal waters (by IRSA 1982 modified) and regional fisheries production (by Olivotti, 1989, modified). The large fisheries production for Apulia region is given by extension of hard substrata

twenty years. As it can be seen, a number of parameters and factors play a role which is sometimes negative and sometimes positive for the environment, according to the meteo-marine and hydrodynamic conditions. In this ambivalence, factors and parameters with ambiguous roles can be considered.

Eutrophication and Productivity of the Sea (Fig. 6, Fig. 7)

Since enormous flow of water and the consequent contribution of nutrients, the Adriatic (above all the Northern and Central Adriatic) has a high primary productivity in spring which can vary from several thousand cells/litre to 600,00/700,000 (B o n i, 1985). Obviously in the case of algal blooms millions of cells/litre of the main species can be counted. Together with the high primary productivity in the Adriatic there is a considerable paraprimary productivity which is given by the particles of suspended organic material. This is the main form of food for the enormous mass of sestonophaguous and detritivorous mollusks (razor shells, clams, striped venus, mussels, oysters, etc.) which represent resources of great economic importance in the Adriatic.

The process of eutrophication, which involves above all the coast of the Northern and Central Adriatic, obviously affects all the links of the food chains, and permits high levels of productivity in the fishing sector. There is certainly a very clear relationship

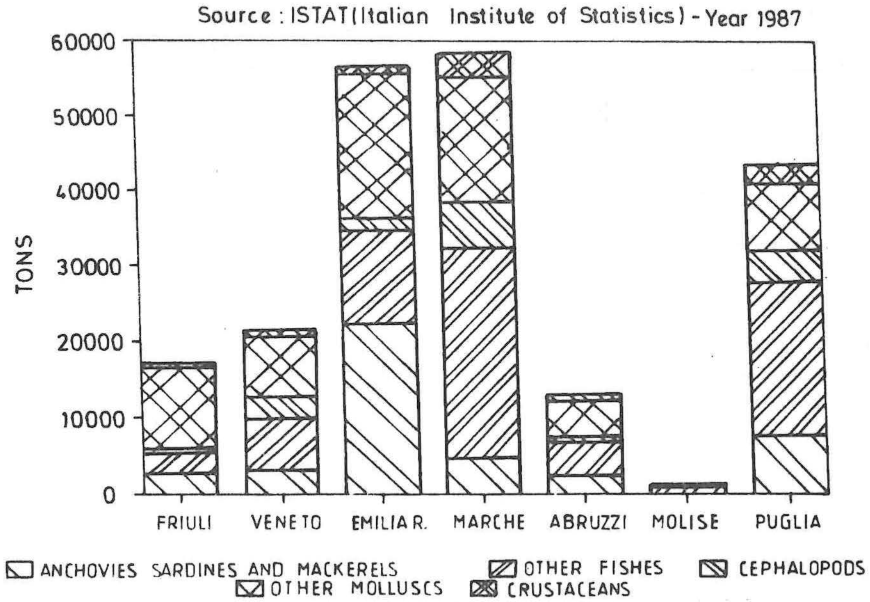


Fig. 7. Total Italian catches in Adriatic Sea per regions

between eutrophication and catches, but also between the type of energetic material available, the nature of bottom and the type of catches. the large extension of soft substrata, the richness of particulate matter, of phyto and zooplankton favour planktonophagous, sestonophagous and detritivorous organisms. the regions of major eutrophication are also those in which the catches are greater (Fig. 6, Fig. 7).

FISHING FEATURES AND STATE OF RESOURCES IN THE ADRIATIC

The 55 % of the total Italian catch comes from the Adriatic. The Northern and Central Adriatic contribute with 48 % (Table 1) to this. The contribution of the Adriatic in terms of "small pelagic" groups and mollusks, above all bivalves, is very important. The fishing features of the Adriatic basin can be obtained from the composition of the catches per groups of species, both within the Adriatic production and in comparison to other Italian seas (Tables 2 and 3). The importance of the "small pelagic" group, and above all of the group "other mollusks", mainly represented by Bivalves, is evident.

Table 1. Per cent contribution of the Adriatic Sea to the global Italian catches (average years 1982 -1987)

RESOURCES	ADRIATIC %	NORTH & CENTRAL ADRIATIC SEA
Small pelagic species	63	57
Demersal species	44	36
Mollusks	60	48
Striped venus	97	96
Crustaceans	30	25
Total Italian catch 100%	**55**	**48**

SOURCE: Ital. Inst. Statist.
Even if the absolute values are not careful, the relative values remain significant

State of Resources

In terms of fishing biology, the Mediterranean in general is characterized as follows:

a - the majority of species have a short average life span, permitting a renewal of resources within a space of a few years;

b - polyspecific stocks living in the same fishing grounds. Since the different species in the pool have different biological parameters (growth, fertility index, mortality,

Table 2. Catch composition in the Adriatic Sea

1982 - 1987 (AVERAGE)	ADRIATIC		CONTRIBUTION OF NORTHERN AND CENTRAL ADRIATIC	
Resources	**Tons**	**%**	**Tons**	**%**
Small pelagic species	63.408	30	57.361	90
Demersal species	80.076	35	65.758	82
Mollusks	41.584	18	33.147	80
Striped venus	30.506	13	30.324	99
Crustaceans	8.506	4	6.697	79
	224.270	**100**	**193.287**	**86**

(ISTAT data underestimate fisheries production; nevertheless the percent relationships remain significant)

selectivity, etc.) various phenomena of compensation and biological alternation occur. This complexity leads to the difficulty of using selective fishing systems;

c - fishing effort generally not balanced to resources. It has grown considerably in the entire Mediterranean in terms of engine power above all, the global catches have increased but the catches per fishing effort unit and the first recruitment sizes have been reduced. Generally, for the demersal resources, it can be said that today fishing involves young age classes (0+, 1), so that the fishing yield now largely depends on the results of recruitment.

d - variety of fishing gears; use of different gears for the same boat in relation to the seasons and opportunities;

e - atomization of the leading places and difficulty for realistic fishery statistics. As far as the Adriatic is concerned, the following observations can be made:

a - All the species

The contribution of the Adriatic to the Italian global production which was 62.5% in 1982, dropped to 52% in 1987, with a decrease of 10% (Fig. 8).

Table 3. Catches percentage composition per groups of species in different italian seas (average years 1985 -86 -87)

RESOURCES	ADRIATIC	IONIAN	SICILIAN	SARDENIAN	TYRRHENIAN	LIGURIAN
Pelagic	27	13	10	6	28	32
Demersal	35	57	62	69	49	48
Cephalopods	8	9	9	10	9	7
O. Mollusks	26	13	6	10	6	9
Crustaceans	4	8	13	5	8	4
	100	100	100	100	100	100

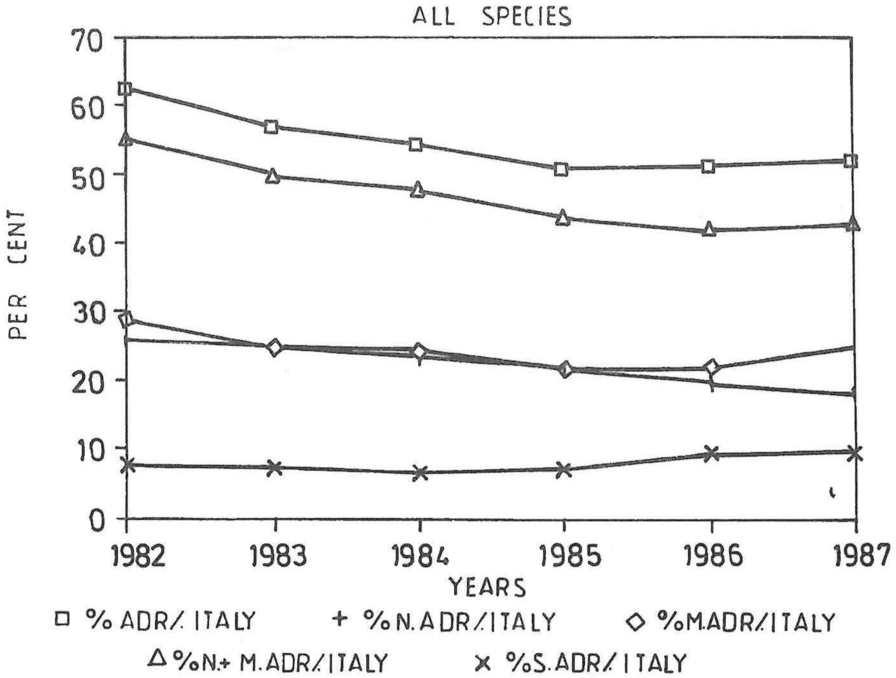


Fig. 8. Catches relationship Adriatic Sea/Italy

This reduction occurred mainly in the Northern Adriatic. The catches per unit fishing effort decreased even further, above all in the Northern Adriatic. While in 1982 a one HP engine used in the Northern Adriatic caught 510 kg of biomass (different species), in 1987 one HP in the same basin produced a biomass of 258 kg. The catch per unit effort has therefore halved (Fig. 9).

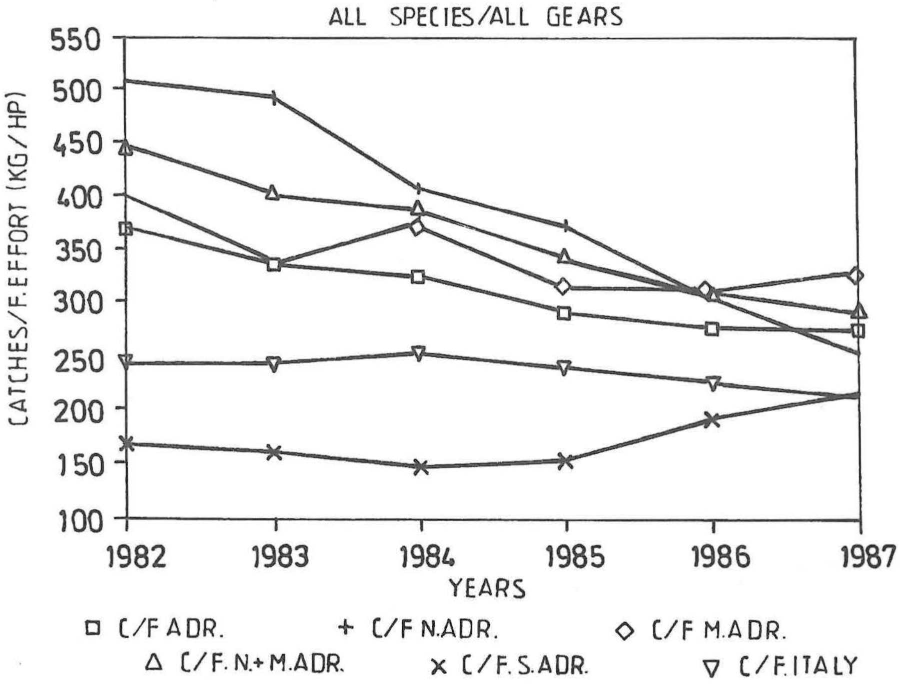


Fig. 9. Catches/f. effort (kg/HP)

b - Prevalently demersal species
Fish

There has ben a heavy drop mainly in the catches of demersal species. The contribution of the Adriatic to the national production dropped from 55% (1982) to 39% (1987) with a decrease of 16% (Fig. 10).

This decrease occurred mainly in the Northern Adriatic: from almost 20% (1982) to about 10% (1987). Since the fishing effort in the Northern Adriatic in this last decade has not increased significantly, but was previously high, the reduction in catch could probably be attributed to a number of factors among which natural mortality plays a particularly important role. One of the causes of mortality affecting the demersal stocks during prerecruitment (eggs and larvae), as well as during their adult life (sedentary or benthic species as for example baby clams) is that caused by anoxia and by the lack of oxygen on the sea bottom, because of the prolonged stratification of the waters with or without algae blooms. The fact that in the last decades there have been intense and vast occurrences of anoxia on the Northern Adriatic bottoms, cannot be overlooked. Obviously the stratification of the water mass, in terms of intensity and duration, are affected by meteo-marine conditions.

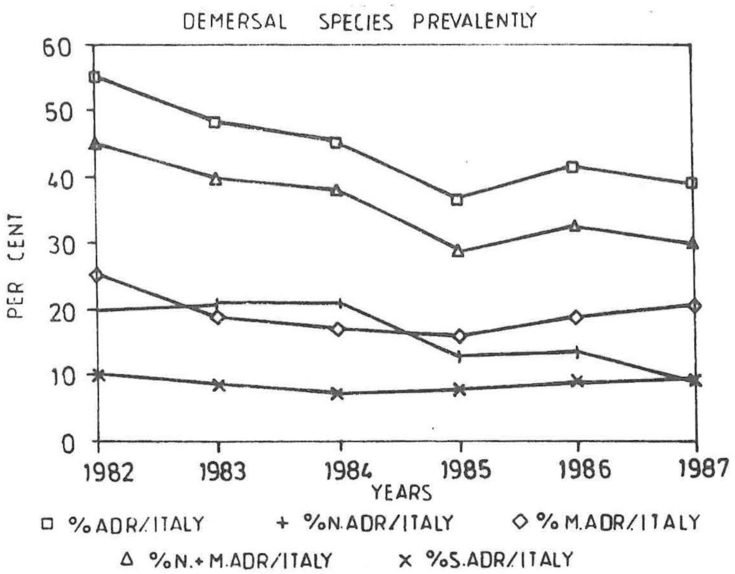


Fig. 10. Catches relationship Adriatic Sea/Italy

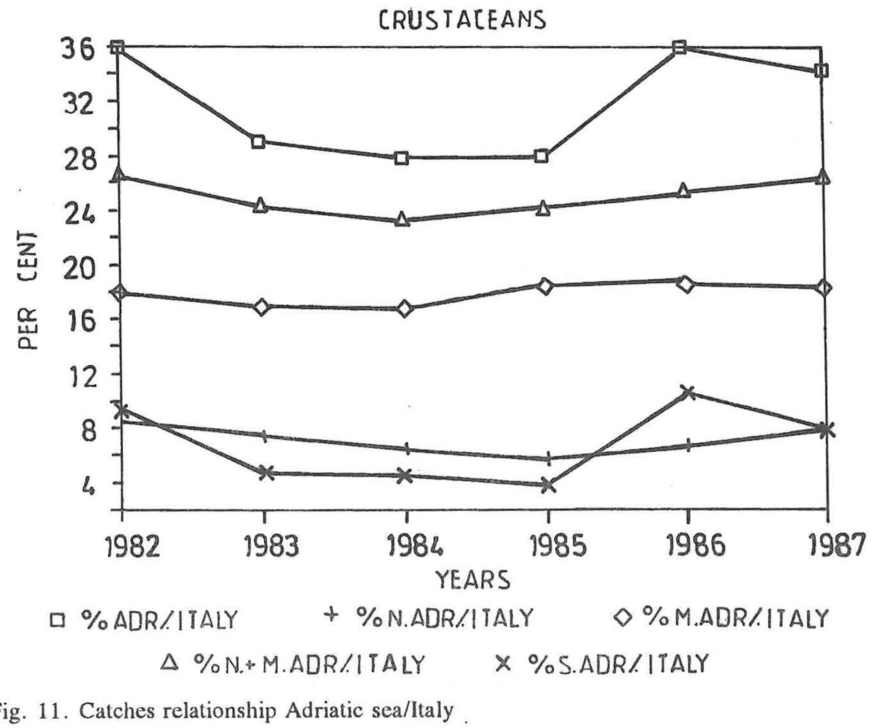


Fig. 11. Catches relationship Adriatic sea/Italy

- Baby clams or Striped venus (*Chamelea gallina* L.) (Fig. 12)

Certainly the environmental stress (anoxia in the coastal band) and the over-fishing have contributed to a general decrease of the "baby clam" stock, which is very important in the Adriatic. This resource shows different states of exploitation in the various Departments of the Adriatic.

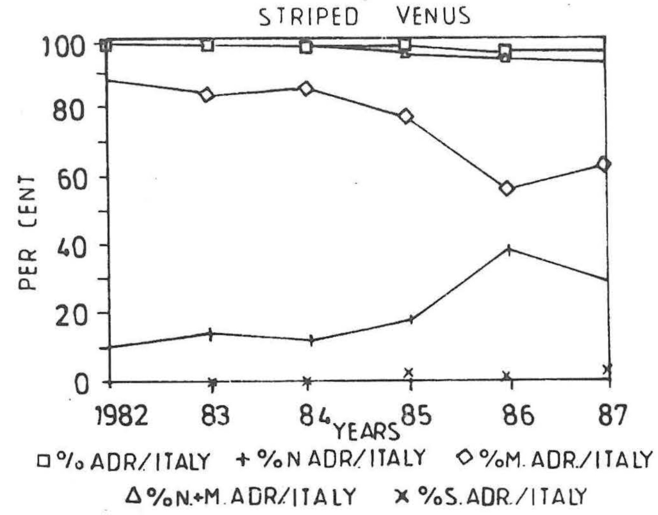


Fig. 12. Catches relationship Adriatic Sea/Italy

In the Northern Adriatic, the contribution to the global catches has passed from 10.57% (1982) to 28.94% (1987) with a peak of 38.45% (1986). The most exploited population is that of 1 year. The minimum size of 2.5 cm (2 years) as provided by law is hardly ever respected. The temporary increase in quantity is therefore due to the recruitment of juveniles and this is very dangerous for a resource whose stock of reproducers can be decimated by extended anoxia.

In the Central Adriatic there has been a decrease in stock (Fig.12) so that the percent contribution to the global production dropped from 88.28% (1982) to 63.45 (1984), with a reduction of about 25%. On the other hand, the fishing effort cannot be blocked and it has almost doubled (from 400 dredge vessels to 760) in this last decade; nor have the different initiatives attempted, such as a gradual reduction in the fishing quotas (25 q.; 12; 6) closing the fishing season for 2 instead of 1 month and reducing the weekly fishing activities, managed to slow down the process of decrease of the resource. In recent years, fishing boats have integrated their catch by fishing Golden carpet shells (*Tapes aureus*) which live in the baby clam boundary area. The preservation industry, which could not compete with the baby clam market prices, started purchasing Golden carpet shell supplies, but even this resource will not be able to sustain the growing fishing effort and the demand from the preservation industries.

- Other mollusks (Fig. 13)

As far as the cephalopods are concerned, the situation is generally constant, while there has been an increase in mussels and oysters as a result of the greater use of breeding systems offshore, as will be explained in due course.

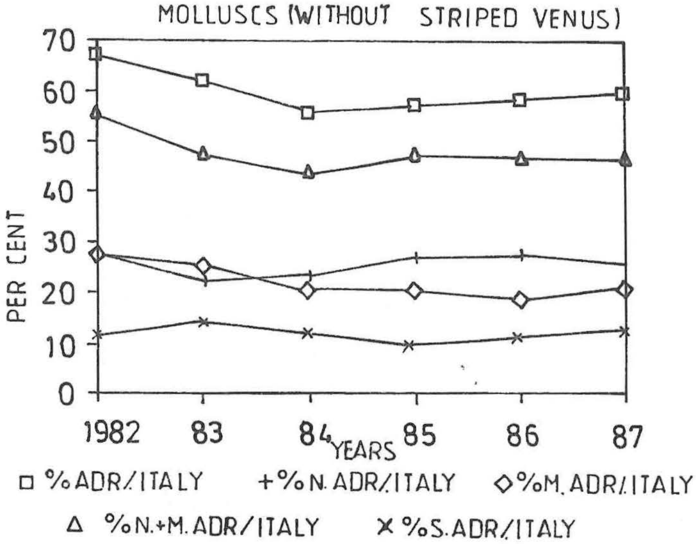


Fig. 13. Catches relationship Adriatic Sea/Italy

- Crustaceans (Fig. 11)

The contribution of the Adriatic to the total production of Crustaceans, after a decrease in 1983, 1984, 1985, has returned to the 1982 values of about 35% (refer to the fig.)

- Small pelagic species (Fig. 14)

Considering the "anchovy, sardine and mackerel" group, the percent contribution of the Adriatic to the global Italian production remains very high, on the average 63%.

Besides the fluctuations which characterize the small pelagic species, something has happened in recent years, after 1986, which has caused a decrease of the pelagic biomass and of the corresponding catch, above all in the Northern Adriatic. The contribution has dropped there from 38.56% (1982) to 30% (1987), while in the Northern and Central Adriatic the percent reduction in 7 years (1982-1987) was 10% of the contribution to the global catch in the same area.

A more precise idea of what has happened in the Adriatic ecosystem in the case of

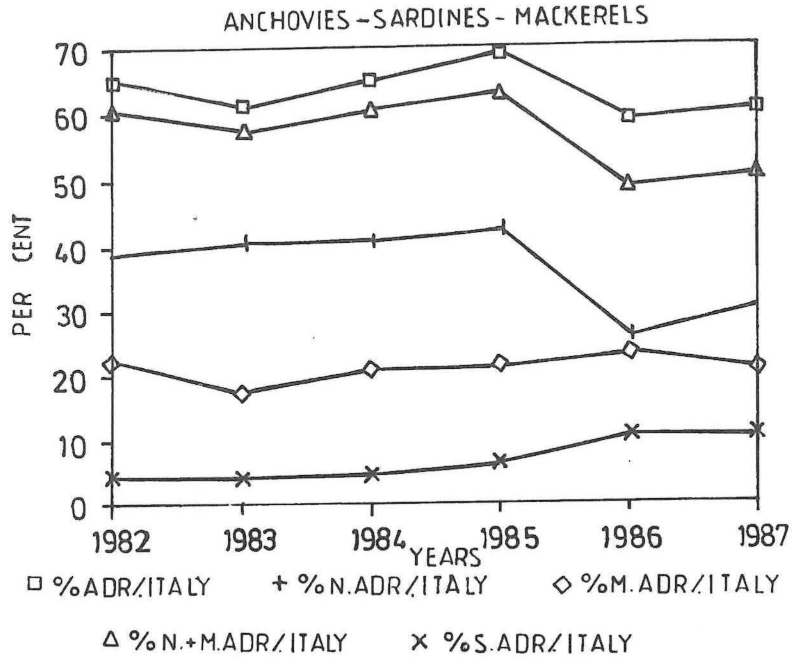


Fig. 14. Catches relationship Adriatic Sea/Italy

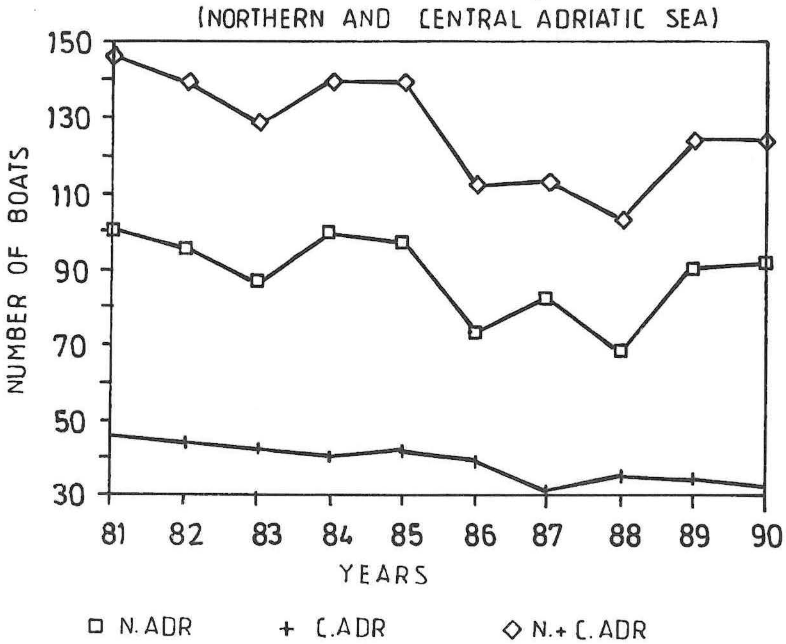


Fig. 15. Fishing effort in number of boats operating on pelagic stocks

the small pelagic species, can be obtained by examining the results of the echosurvey researches carried out by I.R.P.E.M. for the last 13 years.

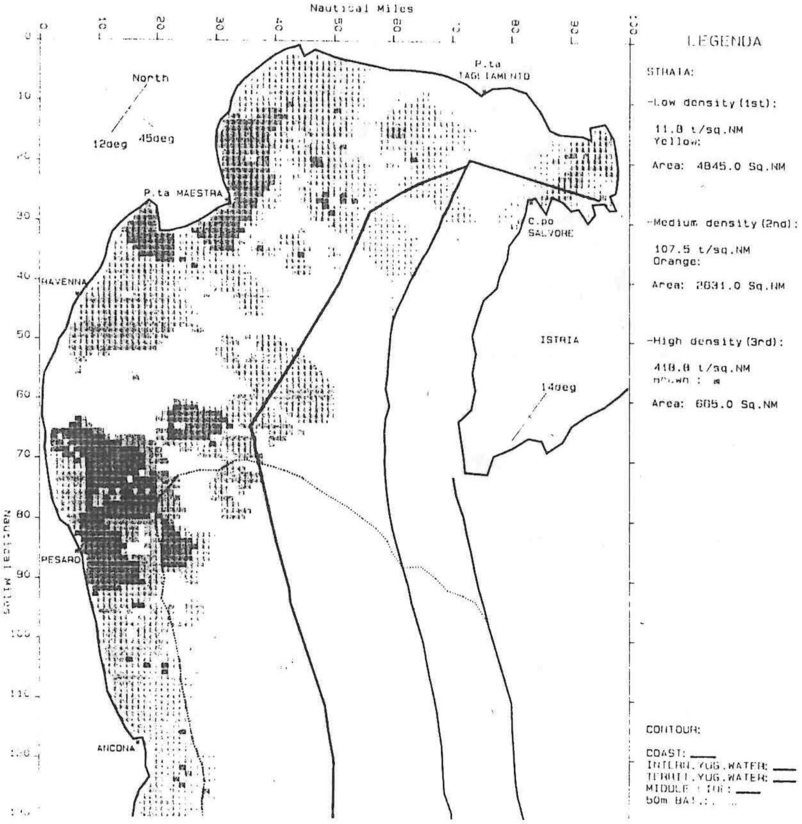


Fig. 16. Pelagic distribution in northern Adriatic Sea
(QD Elaboration-Day&Night) (Azzali, Cosini and Luna, 1989)

It should also be noted that acoustic explorations in order to evaluate pelagic resources have also been carried out in other Italian seas but only in more recent years.

- In the Northern Adriatic, the global pelagic biomass evaluated in 1988 was about 283,000 tons (+/-35%) in an area of about 8,000 square nautical miles. The previous year (1987) a pelagic biomass of more than double had been evaluated.

In terms of geographic distribution (Figs. 16 and 17) the disappearance of the high density concentration from the Gulf of Trieste, a certain concentration in front of the Istrian peninsula, the breaking down of the concentration previously existing toward delta Po and along the coasts between Emilia-Romagna and Marche regions, were observed. This leads to a number of observations and considerations. The trend of the

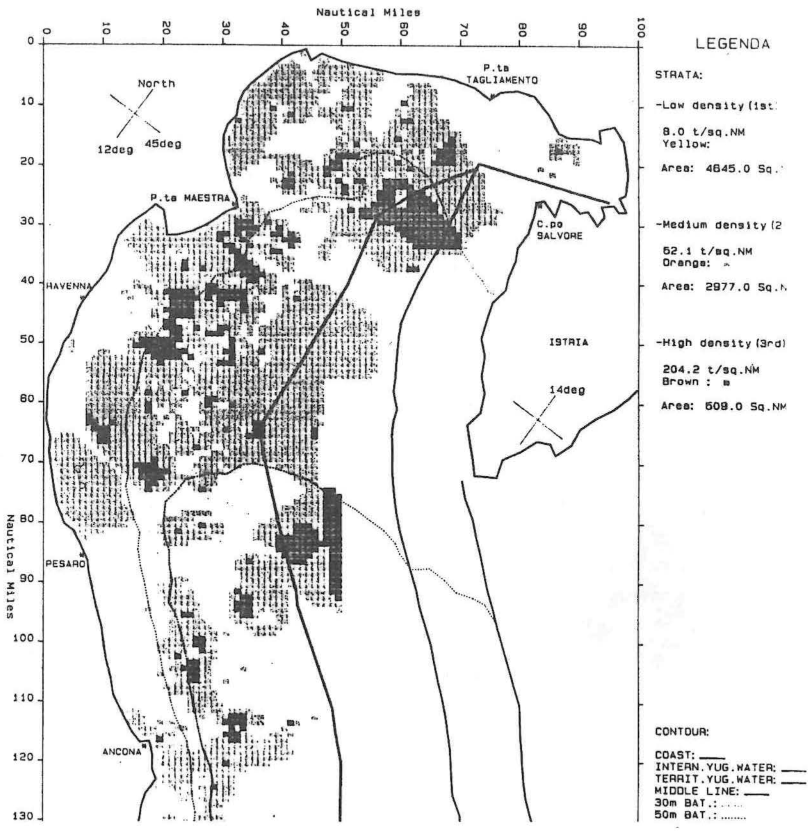


Fig. 17. Pelagic biomass distribution in northern Adriatic Sea
(QD Elaboration-Day&Night) (Azzali, Cosini and Luna, 1989)

total pelagic biomass indicates a decrease in 1988 to almost the same level as 1985 and 1980.

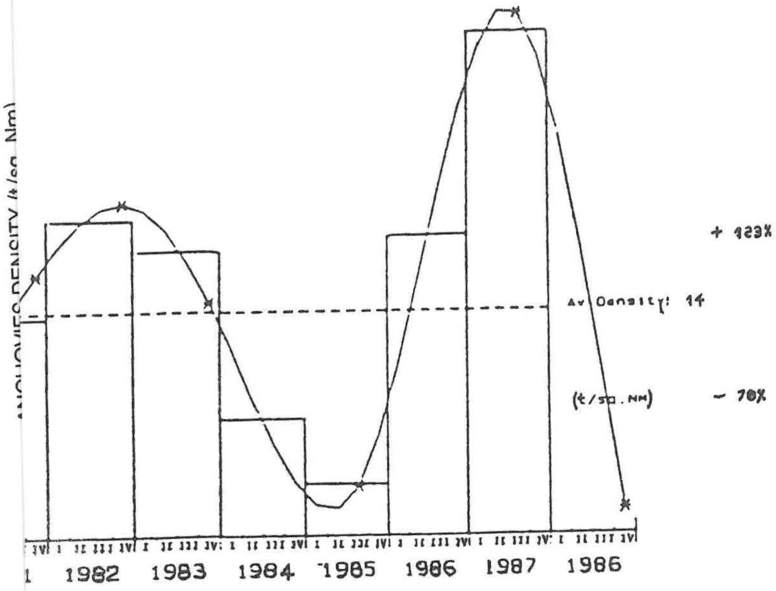
The average density in tons/NM^2 is very high, namely 77 tons/NM^2, but with large oscillations (72%-58%). The average biomass per year is 596,312 tons with a maximum of 1,025.187 tons/year and a minimum of 249,096 tons/year.

Of major interest in the trend of the biomass per single species.

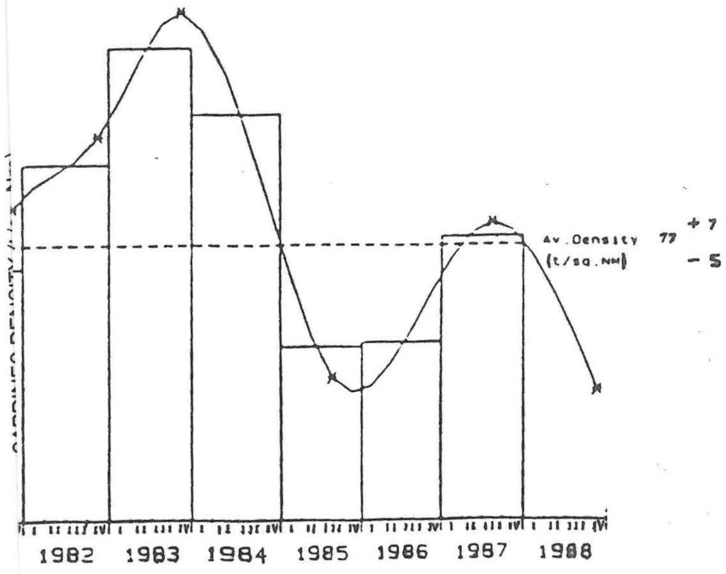
ANCHOVY (Fig. 18)

The stock of anchovy has collapsed in the space of 10 years.

From a maximum biomass of more than 640,000 tons in 1978, it has dropped to a



Luna, 1989)



Cosini, Luna, 1989)

biomass of just a several tons. Many of pair midwater trawlers have had to stop their activities, while prices have increased tenfold. the actual average density is 24 tons per NM^2 (+251% - 94%).

From 1980 to 1985 the stock levelled to an average biomass of about 200,000 tons/year, while there was a total collapse from 1986 onwards.

SARDINE (Fig. 19)

From 1981 to 1984 the increase in the sardine production compensated the decrease in the anchovy production, with a peak in 1983. (Maximum biomass of more than 580,000 tons).

Another increase occurred in 1987, which was once again in opposition to the anchovy trend (partial biological compensation); finally there was a decrease in 1988. The average density still maintains at about 30 tons/NM^{2}.

SPRAT (Fig. 20)

The fluctuations are more regular than in the case of sardine and anchovy. The peak occurred in 1987 with a density of about 32 tons/NM^2, while in 1988 a decrease to just a few tons/NM^2 was reported. Actually the average density is 14 tons/NM2.

OTHER PELAGIC SPECIES (Fig. 21)

Above all, this involves horse mackerels (*Trachurus* spp.). The trend seems to repeat the one of the sardine.

The peak was reported in 1983 with a density of about 28 Ton/NM^2, while the minimum was reported in 1986 with a density of just several tons/NM^2. The actual average density is 8 tons/NM^2. Even in the case of this group, 1988 proved to be a year in which density dropped.

OBSERVATIONS

Anchovy and sardine catches have followed the trend of the biomass fluctuations and prices have in some way compensated the falling catches. In particular the collapse of the anchovy stock has been felt very considerably. Sprats are as yet a largely unexploited resource, while sardines are difficult to sell because of market demand problems and because of the fact that the product preserved in Italy is not competitive. It is important to raise the question of what the causes of the impoverishment of these pelagic resources may be.

The facts of importance from a bio-ecological point of view are as follows:

a - the break up of the large density area which previously existed around the delta Po;

b - the below average biomass trend in the period 1981-1985 and the collapse of the anchovy stock from 1986-1988. In 1989 there were some signs of a very slight recovery;

c - the decrease of the sardine stock in just one year (1989) during which the competitor species (anchovy) is at a minimum. It seems that the mechanism of biological compensation no longer works as it did in the past (1981-1984);

d - the vertical drop of the sprat stock from a maximum to an absolute minimum in just two years (1987-1988), while before the fluctuation occurred more gradually in three years;

e - the fact that the fishing effort, in terms of the number of boats (pair midwater trawlers) has decreased in recent years (Fig. 15), should have allowed the renewal of the pelagic biomass while the opposite has in fact occurred.

What explanation can be given to all this?

Probably all this can be accounted for by antropic, ecological and meteo-climatic causes. Most certainly there has been a considerable destruction of pelagic stocks in the Adriatic during the 70's and 80's both because of the fishing for fish meal and because of the complicating factor of EEC regulations which permitted refunds for unsold product, added to the authorized fishing of juveniles which still occurs today.

But all this destruction would not have led to such radical changes without the contribution of ecological and meteo-climatic factors.

A hypothesis which has still to be backed by data, but which seems to be feasible, is that of a reduced flow of fluvial waters as a result of draught conditions and much higher average temperatures, both on land and at the sea. In fact a reduced amount of water means less nutrients and organic particulate matter and consequently reduced vproduc tivity. For example a reduction o0f 12% in the annual average flow of the Po has been recorded in the last years (G r e g o , 1990, in press) and also a reduction in the organic load (S a n s e b a s t i a n o , 1990, in press). This naturally leads to the break up of the area of pelagic fish concentration around the delta Po. The qualityquantitative composition of the phytoplankton seems to have changed in this last decade (in favour of the microflagellates) and we are not yet certain of how this fact will affect the diet of the plantonophagous organisms.

The higher average temperatures (above all on the sea bottom) drastically excluded, eliminated or reduced the stocks of sprats that live in the colder part of the water mass, namely the layer in direct contact with the sea bottom.

This species is in fact typically northern and lives only in the Northern Adriatic. Research on meteo-marine data is underway to prove the hypothetical explanation or otherwise.

MANAGEMENT AND EXPLOITATION OF THE COASTAL ZONE

The management of the coastal zone from an ecological and biological point of view can resolve a number of fishing problems and can facilitate the renewal of impoverished resources.

Firstly, it is necessary to regulate the fishing effort with respect to resources and, if necessary, stop it very seriously.

Space-time fishing regulations must be respected and all those bio-technological mechanisms which are required to reduce fishing mortality during the prerecruitment phase must be implemented (gear selectivity, protection of the juveniles, etc.). Lastly, it is ecologically and biologically important to use the biochemical energy which accumulates inshore by means of recycling systems. Eutrophication should be channeled towards halieutic production. All this can be achieved by introducing multipurpose artificial reefs and mariculture structures in the open sea as demonstrated by the experiments carried out in this field by the I.R.P.E.M., started in 1974 and which are still underway (F a b i and F i o r e n t i n i , 1990). There are currently a total of 16 experimental artificial reefs in Italy, of which 8 are in the Adriatic, 4 in the Ligurian Sea, 2 in the Tyrrhenian and 2 in Sicily.

Results of some experiments concerning artificial reefs in the Adriatic Sea

These can be divided into results and effects of protection and results of production. As far as the former are concerned the following has been obtained:

a - protection of the bottom in the areas affected by illegal trawling and consequent growth of the juveniles of the original species;

b - protection and refuge for many organisms, such as adults, eggs and juveniles of pelagic, nekto-benthic and benthic fish, crustaceans during the ecdysis and also cephalopods (cuttlefish, octopus, squid);

c - protection of small scale fishing gears from the impact of trawling. It is difficult to quantify the extent of these benefits.

As far as the fishing and bio-ecological results are concerned, the following data are available:

- the total catch data for the various years (Porto Recanati) (B o m b a c e, 1982 and 1986);
- fishing yield data concerning fish, mollusks and crustaceans obtained from standard experimental trammel net for many of the artificial reefs realized (B o m b a c e *et al.*, 1989);
- yield data from fishing with traps in the case of the gastropods *Nassarius mutabilis* and *Hinia reticulata*;
- biomass data for mussels settled on substrata and artificial modules, as well as for the breeding of mussels on suspended structures associated to the reefs (F a b i and F i o r e n t i n i , 1989).

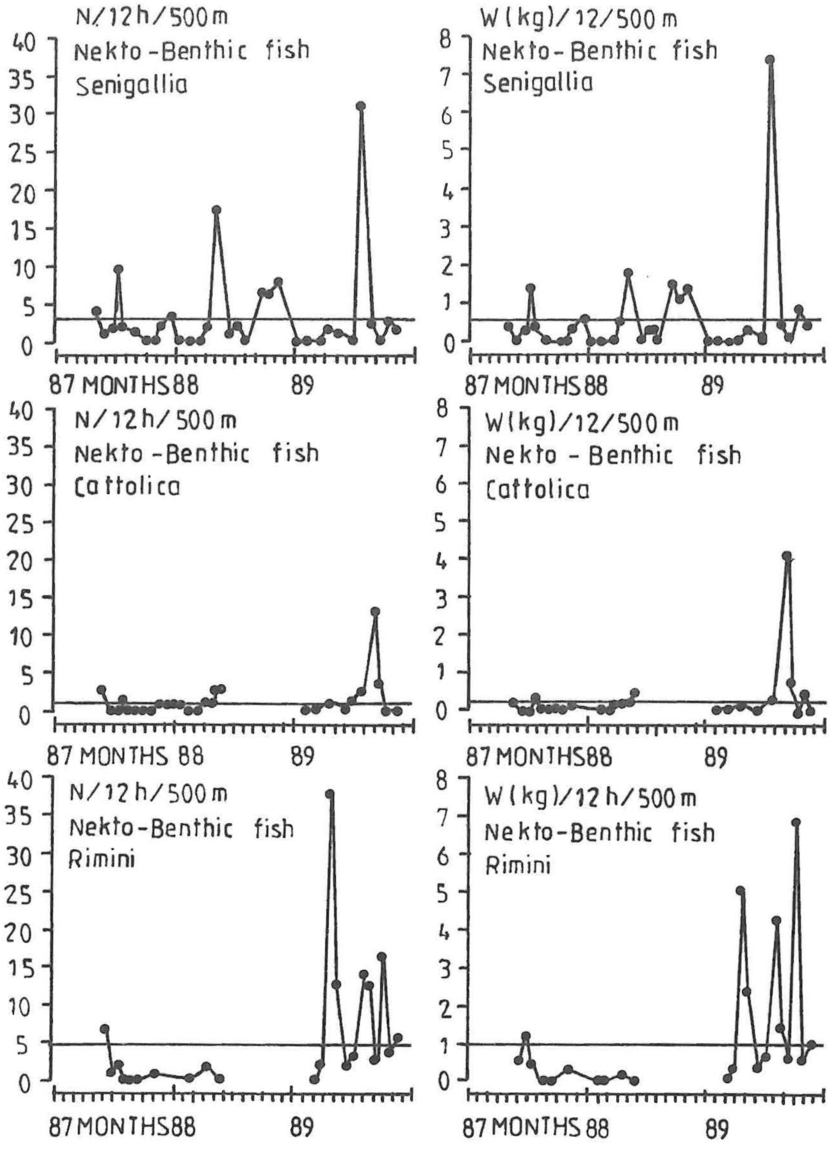


Fig. 22. Number and biomass of nekto-benthic fish in catches before and after reef deployment. The horizontal lines represent the average values estimated for the entire survey period (Bombace, Fabi and Fiorentini, 1989)

Finally, biological data are available on growth, recruitment, mortality of mussels and also partially in the case of oysters as well as biological data for the feeding etology of different fish species which frequent the artificial reefs and biological data for the two species of gastropod mollusks mentioned above. There is also a mass of biological and ecological data and observations regarding sessile settlements, the biological evolution of substrata, interspecific relationships, etc. Finally, environmental and technological data concerning both the substrata and the supports for mariculture, and other on the methods of immersion are available as well as socio-economic data.

An evolution of these catch data and yield indexes has led to the following deductions:

a - the unit fishing yield by standard nets progressively increases as the sampling stations are moved out to the sea towards the heart of a protected area (artificial reefs).

b - the unit fishing yields by standard nets or the capture of organisms are always greater (about 3:1) in a reef area in comparison to the other areas without reefs.

c - the fishing yield in the same area is considerably higher after the construction of artificial reefs, above all in the case of prized species (Sciaenidae, Sparidae, etc.) belonging to the nekto-benthic group species (from 3 to 8 times and much more in the case of the Sciaenidae) (Fig. 22).

d - the capture of gastropods with traps is 2.5 times to 6 times greater after the installation of a reef.

e - the mussel and oyster biomass is a total gain since it never existed (larvae died) without the supports (substrata, ropes, nylon nets, etc.). This is variable in terms of unit biomass per sq.m. according to the various parameters. Today in the reef and mussel-culture installations of the protected marine areas of the Adriatic this involves several hundreds of tons per installation. Mussel and oyster cultures as well as breeding of other bivalves (*Tapes* spp.) can be achieved with suspended and submersed installations in the open sea, associated or not with artificial reefs.

****

In conclusion, the above facts backed by observations and scientific reports, prove that artificial reefs are useful from a bio-ecological and halieutic point of view. From the economic and cost-profit ratio point of view, the data obtained from the experiments carried out in Porto Recanati indicated that from 1977 to 1980 the return in costs triplicated (B o m b a c e , 1982) and that the gross income for a reef fisherman in 1982-1984 doubled (B o m b a c e , 1986).

Finally, if there is to be a recovery of the small-scale fishing industry with fixed equipment (about 7,000 boats in Italy), if the small trawlers are to be reconverted towards the management of reefs and mariculture (about 2,000 boats in Italy), and if there is to be a general policy of protection for the damaged stocks, protection of nurseries, recovery of resources, energy recycling and a correct management and exploitation of the coastal environment, we must aim at integrated initiatives which provide marine areas protected by artificial reefs as the first and most essential point. These must be planned, extended and guarded. The water spaces involved can be allocated or otherwise, according to the type of intervention and extension in question, according to whether one is wanting to work in favour of a Cooperative or an associated group of fishermen or for all concerned.

Ideally, a vast plan for the coastal areas in question should be programmed for which an integrated system (artificial reefs, hatcheries, mariculture, research stations etc.) should be considered.

An International Technique Conference of the FAO was held on this subject in Ancona in 1986 (FAO, 1986). Another international conference was held again in Ancona in November 1989 on the same subject (FAO, 1990) and a work group was formed by the CGPM and by the SIBM. Artificial reefs are in fact an excellent opportunity for interdisciplinary research.

Problems

There are different types and degree of problems today but they can all be solved with the help and effort of all involved (Administration, Research, Operators).

Scientific Aspects

The research on the theoretical bio-ecological and fishing aspects and the trophic relations within the reef and those between the reef and the external area must be continued and extended. Sampling methods must be perfected even with the use of other equipment and integrated with visual methods of evaluation.

Technological aspects

The relationship between forms, architecture and geometry of the habitats, density and distribution of bodies and fishing resources must be examined more thoroughly.

The casting and immersion techniques used for the modules and the structures for reducing production costs must be perfected.

Legal-administrative, financial and institutional aspects

- The procedure for state concessions for the coastal marine waters must be simplified.
- The possibility of an institutional liaison with the coastal regions should be considered.
- In the revision of the Law on fishing (L. 41/82) the problem of "coastal area management and marine culture" should be considered individually.
- At an EEC level, several administrative laws regarding the initiatives financed with community funds should be modified while a new chapter should be opened for programmed general initiatives.

The experiments with artificial reefs, associated or otherwise to marine culture are costly and the small private fishing sector cannot sustain these costs. Substantial public intervention, both by the EEC and by the member State is necessary at least for the first system.

ACKNOWLEDGEMENTS

Special thanks to Fabi G., Fiorentini F., Bolognini S., Cingolani N., Luna M., Angeli Temperoni M.G. and Sala A.

REFERENCES

Arneri, E. and S. Jukić. 1985. Some preliminary observations on the biology and dynamics of *Mullus barbatus* L. in the Adriatic Sea. FAO Fish. Rep., 345: 79-86.

Artegiani, A. 1984. Seasonal flow rates of the Italian rivers having outlets in the Northern and Central Adriatic. FAO Fish. Rep., 290: 81-83.

Artegiani, A. 1987. Parametri ambientali, dinamica delle acque costiere, della produtt. primaria, delle caratt. geomorfol. e fisionomia della fascia costiera marchigiana. Report for the Marche Region.

Artegiani, A., R. Azzolini, M. Marzocchi, M. Morbidoni, A. Solazzi e F. Cavolo. 1985. Prime osservazioni su un bloom fitoplanctonico lungo la costa marchigiana nell'anno 1984. Nova Thalassia, 7, Suppl., 3: 137-142.

Azzali, M. e M. Luna. 1988. Nota preliminare sulle risorse pelagiche nei mari italiani, stimati con tecniche acustiche. Atti. Semin. Un. Operat. Min. Mar. Mercantile C.N.R., 1: 99-174.

Azzali, M., G. Cosimi e M. Luna. 1990. Rapporto sulle risorse pelagiche dei mari italiani stimate con metodi acustici. Ancona, Rapporto per il Min.Mar.Mercantile, 12 pp.

Bombace, G. 1981. Note sur les experiences de création de récifs artificiels en Italie. FAO/CGPM, Etud. Rev., 58: 231-337.

Bombace, G. 1982. Il punto sulle barriere artificiali: problemi e prospettive. Naturalista Sicil., ser 4, 6 (Suppl. 3): 573-591.

Bombace, G. 1985. Eutrofizzazione e produzione di pesca. Nova Thalassia, 7 Suppl. 3: 277-295.

Bombace, G. 1987. Iniziative di protezione e valorizzazione della fascia costiera mediante barriere artificali a fini multipli. Atti LIX riun. SIPS: 201-233.

Bombace, G. et V. Rossi. 1986. Effects socio-économiques consécutifs à la réalisation d'une zone marine protégée par des récifs artificeles dans la zone de Porto Recanati. FAO/CGPM, Rapport sur les pêches, 357: 157-164.

Bombace, G., N. Cingolani, S., R. Coppola and J. Mortera. 1987. Summary report on the quality check sample survey of fisheries catch and effort statistics. Adriatic Area. FAO Fish. Rep., 394: 245-259.

Bombace, G. et N. Cingolani. 1987. Distribution de l'effort de pêche dans les pecheries des mers italiennes. FAO/CGPM, Rapport sur les pêches, 394: 234-244.

Bombace, G., G. Fabi and L. Fiorentini. 1989. Preliminary analysis of catch data from artificial reefs in Central Adriatic. FAO Fish. Rep., 428: 86-98.

Boni, L. and A. Solazzi. 1989. "Alghe" in L'eutrofizzazione nel mare Adriatico. Atti. Conv. Nazion., Ancona 4 Aprile: 44-48.

Fabi, G. and L. Fiorentini. 1989. Shellfish culture associated with artificial reefs. FAO Fish Rep., 428: 99-107.

Franco, P. 1970. Oceanography of Northern Adriatic Sea. Cruises July-August and Oct.-Nov. 1965. Arch. Oceanogr. Limnol., 16, Suppl, 93 pp.

Franco, P. 1972. Oceanography of Northern Adriatic Sea. Cruises Jan.-Febr. and Apr.- May 1966. Arch. Oceanogr. Limnol., 17 Suppl., 97 pp.

Franco, P. 1983. L'Adriatico settentrionale: caratteri oceanografici e problemi. Atti 5° Congresso AIOL, (Stresa), 29 pp.

F r o g l i a , C. 1973. Osservazioni sull'alimentazione del merluzzo (*Merluccius merluccius*) del Medio Adriatico. Atti V Congresso SIBM, Ed. Salent., pp. 327-341.

F r o g l i a , C. 1989. Clam fisheries with hydraulic dredges in the Adriatic Sea. In: Marine Invertebrate Fisheries, Caddy J.F. (Ed.)., J. Wiley, New York, pp. 507-524.

G r e g o , G. 1990. Idrologia del Delta del Po. - Evoluz. nell'ultimo ventennio. Conv. Ecol. Delta Po. Albarella, (in press).

M a r s , P. 1963. Les faunes et la stratigraphie du Quarternaire méditerranéen. Rec. Trav. St. Mar. Endoume, 28, p. 61.

O l i v o t t i , R. 1989. Tutela delle acque costiere. Cosa e cambiato negli ultimi venti anni. Atti Conv. Nazion., Ancona, 4 Aprile, pp. 116-142.

O r e l , G., E. V i o and F. A l e f f i . 1989. Biocenosi bentoniche e loro modificazioni in seguito a stress anossici. Atti Conv. nazion., Ancona, 4 Aprile, pp. 59-63.

P é r è s , J.M. and J. P i c a r d . 1964. Nouveau manuel de bionomie benthique de la mer Méditerranée. Rec. Trav. St. Mar. Endoume, Bull., 31, fasc.47.

P o r , F.D. 1978. Lessepsian migration, Springer Verlag, Heidelberg, 228 pp.

S a n s e b a s t i a n o , G. 1990. Qualita delle acque in rapporto al funzionamento della centrale di Porto Tolle. P. II Aspetti microbiologici. Conv. Ecol. Delta Po. Albarella, (in press).

S a r a , M. 1983. Ecological factors and their biogeographic consequences in the Mediterranean ecosystems. Med. Mar. Ecosyst., NATO Conf. Ser., pp. 1-18.

T o r t o n e s e , E. 1983. Distribution and ecology of endemic elements in the Mediterranean Fauna (Fishes and Echinoderms). Medit. Mar. Ecosyst., NATO Conf. Ser., pp. 57-83.

Accepted: November 9, 1990