12

ADRIAMED - TECHNICAL DOCUMENTS

Review of current knowledge on demersal Shared stocks of the Adriatic Sea

ADRIAMED

SCIENTIFIC COOPERATION TO SUPPORT RESPONSIBLE FISHERIES IN THE ADRIATIC SEA

MiPAF

Food and Agriculture Organization of the United Nations

Italian Ministry of Agriculture and Forestry Policies

AdriaMed

GCP/RER/010/ITA

Review of current knowledge on shared demersal stocks of the Adriatic Sea

by

Vrgoč N., Arneri E., Jukić-Peladić S., Krstulović Šifner S., Mannini P., Marčeta B., Osmani K., Piccinetti C., Ungaro N.

AdriaMed Technical Documents No.12
GCP/RER/010/ITA/TD-12

Termoli (Italy), March 2004

Preface

The Regional Project "Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea" (AdriaMed) is executed by the Food and Agriculture Organization of the United Nations (FAO) and funded by the Italian Ministry of Agriculture and Forestry Policies (MiPAF).

Adriamed was conceived to contribute to the promotion of cooperative fishery management between the participating countries (Republics of Albania, Croatia, Italy and Slovenia), in line with the Code of Conduct for Responsible Fisheries adopted by the UN-FAO.

Particular attention is given to encouraging and sustaining a smooth process of international collaboration between the Adriatic Sea coastal countries in fishery management, planning and implementation. Consideration is also given to strengthening technical coordination between the national fishery research institutes and administrations, the fishery organizations and the other relevant stakeholders of the Adriatic countries.

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Occasionally, relevant documents may be translated into national languages as AdriaMed Translations (GCP/RER/010/ITA/AT-00).

Comments on this document would be welcomed and should be sent to the Project headquarters:

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For bibliographic purposes this document should be cited as follows:

Vrgoč, N., Arneri, E., Jukić-Peladić, S., Krstulović Šifner, S., Mannini, P., Marčeta, B., Osmani, K., Piccinetti, C., and Ungaro, N. 2004. Review of current knowledge on shared demersal stocks of the Adriatic Sea. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-12. *AdriaMed Technical Documents*, 12: 91 pp.

Preparation of this document

In the Mediterranean, the Adriatic Sea is probably the largest and the best defined area of occurrence of shared fishery stocks. The Adriatic countries participating in the AdriaMed Regional Project (*Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea*) deemed if necessary and highly desirable to have a scientific review available encompassing and compiling the large amount of scientific knowledge which has been accrued since the past, through fishery research work, on some of the main shared demersal resources of the Adriatic Sea. The collaboration of several co-authors from four countries has also permitted the retrieval of the scientific works originally issued in the national languages, the content of which has been summarised. Furthermore, attention has been given to the so-called grey literature, often of value and relevance but poorly known.

This work cannot, and does not aim to, be exhaustive either in terms of species coverage or of literature screened. Moreover, recently considerable amount of relevant scientific literature has been published which could not be accounted in this review, the periodically updating of which should be sought in the future.

This review is one of the products outcomes of the AdriaMed Project component “Adriatic Sea Shared Resources” which focuses on the appraisal of shared fishery resources of the Adriatic Sea. It is primarily for Adriatic fishery scientists and managers; it can also be of interest for students and professional of fisheries research in the Mediterranean Sea region. This review is believed to meet, as far as the Adriatic Sea region is concerned, the request of the General Fisheries Commission for the Mediterranean, (Twenty-sixth GFCM Session, 2001) to its Scientific Advisory Committee to produce summaries of available information on the biology, life history and gear selectivity parameters of key fishery species.

It is hoped that this document will contribute to strengthen the cooperation between the fishery research institutes around the Adriatic Sea.

Acknowledgements

The assistance of Nicoletta Milone, Caroline Bennett and Patrizia Putalivo in the preparation of this document is gratefully acknowledged.

Vrgoč, N., Arneri, E., Jukić-Peladić, S., Krstulović Šifner, S., Mannini, P., Marčeta, B., Osmani, K., Piccinetti, C., and Ungaro, N.
Review of current knowledge on shared demersal stocks of the Adriatic Sea.
AdriaMed Technical Documents. No.12. GCP/RER/010/ITA/TD-12, Termoli, 2004: 91 pp.

ABSTRACT

This document reviews and compiles the scientific information on the main commercial species whose stocks are shared by the coastal countries of the Adriatic Sea: European hake (*Merluccius merluccius*), Red mullet (*Mullus barbatus*), breams (*Pagellus* spp.), Whiting

(*Merlangius merlangus*), anglerfish (*Lophius budegassa* and *Lophius piscatorius*), Commons sole (*Solea vulgaris*), Horned octopus (*Eledone cirrhosa*) and Musky octopus (*Eledone moschata*)*,* Common cuttlefish *(Sepia officinalis*), European squid (*Loligo vulgaris*), Norway lobster (*Nephrops norvegicus*) and Deepwater rose shrimp (*Parapenaeus longirostris*). Following an introductory section, giving a geographical and hydrographical description of the area this document reviews, in its first part, the research carried out over the years on demersal fishery resources in the Adriatic Sea. It starts from the first expedition "Challenger" in 1873 and includes the results achieved up to year 2000-01. The second part of the document provides a description of each target species including bio-ecology, life-history parameters, fishery exploitation and fishing gear selectivity information. This work is the result of international scientific cooperation among the fishery research institutions participating in the FAO-AdriaMed Project.

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LIST OF SYMBOLS AND ABBREVIATIONS

a	intercept of ordinary regression
b	slope of ordinary regression
CL	Carapax Length
CPUE	Catch Per Unit of Effort
F	instantaneous rate of fishing mortality ($time^{-1}$)
K	parameter of the VBGF, of dimension $time^{-1}$, expressing the rate at which asymptotic length is approached
L_∞	asymptotic length, a parameter of the VBGF expressing the mean length the fish of a given stock would reach if they were to grow for an infinitely long period
L_m	mean length at maturity
L_{25}	length at which 25% of the fish will be vulnerable to the gear
L_{50}	length at which 50% of the fish will be vulnerable to the gear
L_{75}	length at which 75% of the fish will be vulnerable to the gear
L_c	mean length of fish at first capture; equivalent to L_{50}
M	instantaneous rate of natural mortality ($time^{-1}$)
ML	Mantle Length
MSY	Maximum Sustainable Yield
Φ' (phi prime)	length-based index of growth performance equal to $\log K + 2\log L_\infty$, where K and L_∞ are parameters of the VBGF
R	correlation coefficient
SF	Selection Factor
SR	Selection Range
TL	Total Length
t_o	a parameter of the VBGF expressing the theoretical age the fish of a given stock would have at length zero if they had always grown as predicted by that equation
VBGF	Von Bertalanffy Growth Function, used to describe the growth in length and weight of fish
Z	instantaneous rate of total mortality ($time^{-1}$)
Y/R	Yield per Recruit
W_∞	asymptotic weight, a parameter of the VBGF expressing the mean weight the fish of a given stock would reach if they were to grow for an infinitely long period. Also: the weight corresponding to L_∞

Preface

Although biological research of the Adriatic Sea goes back to the 19th century, the expedition "Hvar" (1948-1949) was the first organised fishery-biological expedition. It was important, not only for the richness of the data collected, but also for the fact that it was conducted in the period when the demersal fish and invertebrate communities were not intensely exploited. Therefore, these data can serve as reference information for the changes that came with time. Most of the studies that were organised after this expedition until the 1980s were limited in terms of space and time.

In the 1980s, seasonal trawl surveys started. They included mainly Italian territorial and international waters (GRUppo Nazionale Demersali, GRUND). In the territorial waters of former Yugoslavia, samples were only taken in five surveys. The MEDiterranean International Trawl Survey (MEDITS) programme that included four European Union countries (France, Greece, Italy, Spain) was established in 1994. Albania, Croatia and Slovenia joined this programme in 1996. It was the first survey of the demersal communities of the entire Adriatic. The programme ended in 2001. On the Italian side, studies continued under the GRUND programme. Parallel studies were carried out in the Albanian, Croatian and Slovenian waters under the FAO AdriaMed project. The same methodology of sampling and data processing was used.

Thanks to these studies a great amount of information on the demersal organisms, primarily those of high commercial value, was collected. Thus, spatial and temporal distribution of most of the demersal species in the Adriatic has been described. Much less is known about the biological and ecological characteristics of the species and their population dynamics. Although, the commercially most important species (as European hake, red mullet, Norway lobster) are relatively well investigated, the situation is much worse with the other species. It is especially bad with those species whose abundance is low (like anglerfish) or species that are hard for the bottom trawl net to reach (e.g. some cephalopod species).

In the Adriatic, the demersal species catch statistics are generally questionable. Although statistical data exist, their reliability is poor. The situation is similar with the fleet statistics, particularly because a consistent number of fishing vessels is registered under "polyvalent" or "multipurpose licence". It should be noted that there was a substantial increase in the fleet along the eastern Adriatic coast. For example, in Croatia there were about 120 trawlers in 1986, whereas there are over 700 licences for trawl fisheries today. Most of these trawlers were bought in Italy, so most of them had already been operating in the Adriatic. Nevertheless, in some cases they were replaced by new vessels on the Italian side.

Because of these difficulties and the fact that demersal fishery in the Adriatic is multispecies and multigear, the demersal stock assessment has mostly been based on direct method, i.e. experimental trawl survey. However, it is questionable how much this method alone is suitable for stock assessment. The key question is whether samples obtained by a trawl survey can be considered representative of the population in terms of the size composition, age, geographic and abundance distribution (Arneri, 1996).

Although many fishery scientists think that most of the commercial demersal resources of the Adriatic Sea are fully or overexploited, this is not easy to prove as no fishery-induced stock collapse has been recorded to date. This is because the catch is composed mostly of relatively short-lived species and of specimens under two years of age; therefore, abundance trends would seem to reflect more the fluctuation of recruitment than the response to fishing mortality. This fluctuation of catch is typical for short-lived species, in this instance cephalopods, with rapid turnover and high production/biomass ratio and therefore particularly resilient to fishery exploitation. Under these circumstances it is believed that management measures such as closed areas and seasons (e.g., as enforced in Italy since 1987), once implemented in nursery or spawning grounds (or seasons) are likely to be more successful than other management measures (mesh size regulations, minimum landing sizes, quotas, limitations to the fishing power of the vessel, etc.) (Caddy, 1993).

1. General features of the Adriatic Sea

1.1 Position and size

The Adriatic Sea is a semiclosed basin in the Mediterranean Sea. It is connected to the rest of the Mediterranean by the Channel of Otranto, which is 40 NM wide and about 741 m deep. The Adriatic Sea covers about 800 Km by latitude and from 100 to 200 Km by longitude (Fonda Umani *et al*, 1990). It has a surface area, islands included, of 138 595 km^2, which is around 4,6% of the total Mediterranean surface (Buljan and Zore-Armanda, 1971).

1.2 Formation

The Mediterranean Sea had its origin in the Tethys Sea, a big Mediterranean geosynclinal that lay between the European and the African continent from the Palaeozoic to the Jurassic periods. It was a tropical sea, extending to the Atlantic and across the Mediterranean and southern Asia to the Pacific. Because of the elevation of great mountain massifs - Alps, Dinarids, Carpathians, Apennines, Atlas, Caucasus and the Himalayas - during the Tertiary period, it was gradually divided into a number of separate basins. With its submersion, the western Tethys expanded to the western Atlantic and today's Mediterranean. The Black Sea and Caspian Sea, together with the Aral Lake, were formed from its eastern part.
The Adriatic Sea is a long depression or a synclinal. Its present shape and form originated at the beginning of the Quaternary period, when it was formed by a transgression. In the late Tertiary period in this area the Earth's crust sagged forming a depression. Later, this was filled with seawater creating the northern Adriatic.

During the Pleistocene period, a part of the sag, the north Italian plain, became dry again. The deeper southern Adriatic was formed when the Earth's crust collapsed in the late Tertiary period. The Gate of Otranto that connects the Adriatic to the Ionian Sea was formed the same way. The coastal line of the Adriatic was unstable during the Tertiary period. The eastern, Dinaric part was flooded in the beginning, later, the water withdrew to the west flooding almost the entire Apennine coast and leaving the eastern coast dry. After that, the western part raised and the eastern part subsided, so water entered among the islands all the way to the present coastal line. The raising of the western and the lowering of the eastern coast probably still goes on (Buljan and Zore-Armanda, 1971; Peres and Gamulin-Brida, 1973).

1.3 Depth

The Adriatic is a shallow sea. Most of the bottom, about 102 415 km^2 or 73 %, is less than 200 m deep. The depth gradually decreases from south to north. The Jabuka/Pomo Pit (273 m) and the south Adriatic Pit (1330 m) are the only areas where the water is over 200 m deep, averaging 231 m. So, most of the bottom is on the continental shelf and a significantly smaller part on the continental slope (sea bottom under 200 m deep) (Buljan and Zore-Armanda, 1971).

1.4 Bottom sediments

The sea bottom of the Adriatic shelf is covered with recent sediments of various structural and mineral-petrographic composition. The muddy and sandy sediments are present at the largest part of the shelf (Figure 1). They cover almost the entire south and central Adriatic Sea bottoms, together with the channel area of the north-eastern Adriatic, the Gulf of Trieste and a narrow belt along the north-eastern side of the Italian coast. Muddy sediments also cover most of the northern Adriatic, smaller part of the central area and some limited areas of the southern Adriatic (Peres and Gamulin-Brida, 1973).

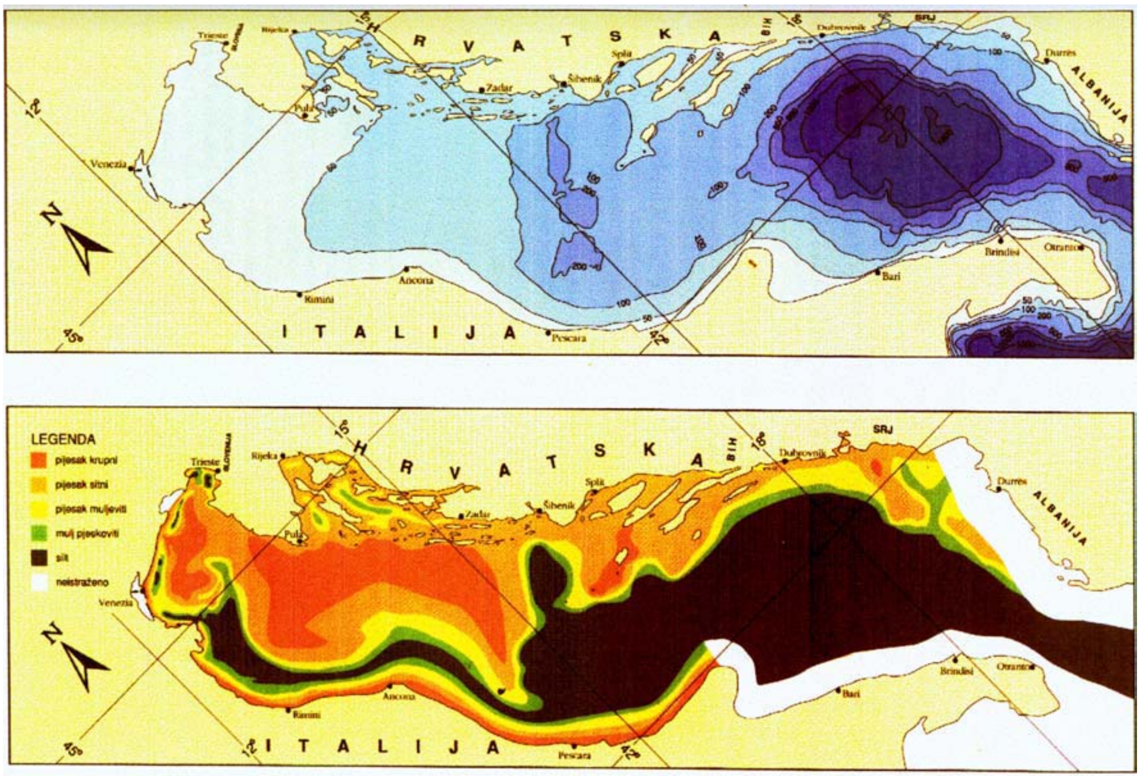


Figure 1. Bathimetric map and map of sediments of the Adriatic Sea. (Hrvatski hidrografski institut, Peljar, 1999)

1.5 Salinity

The salinity of the Adriatic basin is quite high with an average value of about 38,3‰, which is lower than in the eastern Mediterranean (about 39‰), but higher than in the western

Mediterranean (about 37‰). Generally, it could be said that the Adriatic Sea water salinity decreases from south to north and from the open sea to the coast.
Besides the normal annual variation of salinity, there are variations that last several years. It is the result of the exchange of sea water masses between Adriatic and the eastern Mediterranean Sea. That phenomenon probably plays an important role in the appearance of some rare fish in the Adriatic (Buljan and Zore-Armanda, 1971; Peres and Gamulin-Brida, 1973).

1.6 Temperature

The Adriatic is a relatively warm sea. The deepest waters are almost always warmer than 11-12^o C. In summer, the superficial temperature of the open sea water is about 22-25^o C, falling to 11,5^o C near the bottom (the Jabuka Pit) or 12^o C (the South Adriatic Pit). In winter, the difference between the northern and the southern Adriatic is about 8-10^o C. In some parts of the northern and western coastal Adriatic, waters can be colder then 11^o C (Buljan and Zore-Armanda, 1971).

1.7 Movement of the water masses

The Adriatic Sea can be divided into three separate horizontal layers, according to the movement of the water masses: the superficial, the intermediate and the near-bottom layer. Although they influence each other, they each have a more or less independent system of stream. In the northern and southern Adriatic, the superficial layer is about 40 m deep, with seasonal and annual variations; in summer it includes the layer up to the thermocline, and is more shallow in the northern Adriatic and in the coastal region; in winter it is deeper and includes the intermediate layer too. In the southern Adriatic the intermediate layer includes water from about 40 to 400-500 m, and in the central to about 150 m (Buljan and Zore-Armanda, 1971).
Between the intermediate layer and the bottom is the near-bottom layer. In the southern Adriatic it contains the largest part of the basin, while in the central Adriatic it is not significant.
In the superficial layer the stream is circular, flowing in a counter-clockwise direction (Figure 2). The water masses enter from the eastern Mediterranean along the eastern side (the north-western flow) and go out along the western coast (the south-eastern flow). Because of the great seasonal differences in salinity and temperature, i.e. in the density of the seawater, many transversal branches come off that basic north-western entering flow horizontally.
In the intermediate layer the entering flow prevails during the entire year, especially in summer when it comes as a compensation stream of the exit flow (north-eastern) in the superficial layer. The intermediate layer therefore is characterised by eastern Mediterranean water of higher salinity.
The flow in the near-bottom layer is the least known. The exit flow prevails, especially in winter, when it appears as a compensational stream of the entering water in the superficial and intermediate layers (Peres and Gamulin-Brida, 1973).

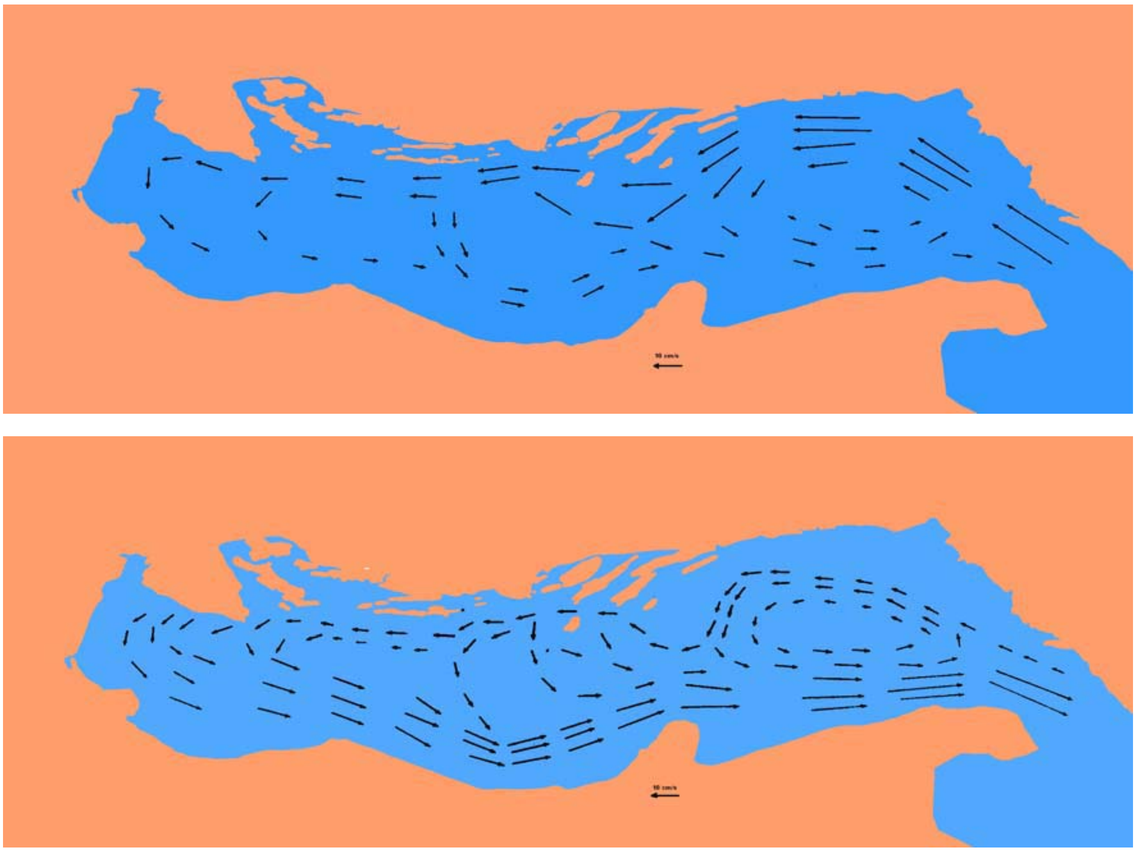


Figure 2. Surface currents in the Adriatic Sea in summer (above) and winter period (below) (Zore-Armanda, 1967).

2. The demersal fishery in the Adriatic Sea

In the Adriatic Sea, the demersal fishery takes place on the entire continental shelf and on a part of the continental slope in the southern Adriatic. Most of the fishing activity is carried out by trawlers of various sizes and engine power. The use of fixed gear is usually limited to the area unsuitable for trawling (Arneri, 1996).

Unlike the pelagic fishery, where mostly one or two species are targeted, in the demersal fishery the situation is more complex. The demersal fishery is a multispecies fishery and the main target species are: European hake (*Merluccius merluccius*), Red mullet (*Mullus barbatus*), breams (*Pagellus* spp.), Whiting (*Merlangius merlangus*), anglerfish (*Lophius* spp.), flatfish (*Solea* spp.), *Eledone* spp., Common cuttlefish *(Sepia officinalis*), squids (*Loligo* and *Illex*), Norway lobster (*Nephrops norvegicus*) and Deepwater rose shrimp (*Parapenaeus longirostris*).

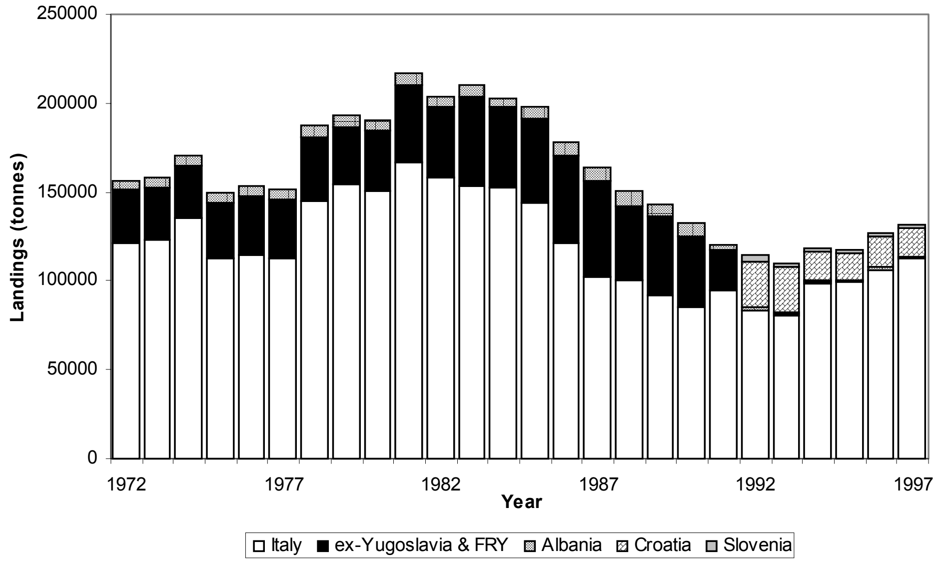


Figure 3. Adriatic Sea capture fishery production (excluding bivalve molluscs, aquaculture and Apulia) (Mannini and Massa, 2000).

By analysing the General Fisheries Commission for the Mediterranean (GFCM) landing statistics the total landing of the commercial capture fisheries in the Adriatic Sea from 1972-1997, (Mannini and Massa, 2000), found it had reached a maximum in 1981 with about 220000 t, and a minimum value of 110000 t in 1993 (Figure 3). The latter was probably caused by the combined effects of the low small pelagic stock level and the social-economic crisis that affected the fishery sector, mainly pelagic, of some coastal countries.

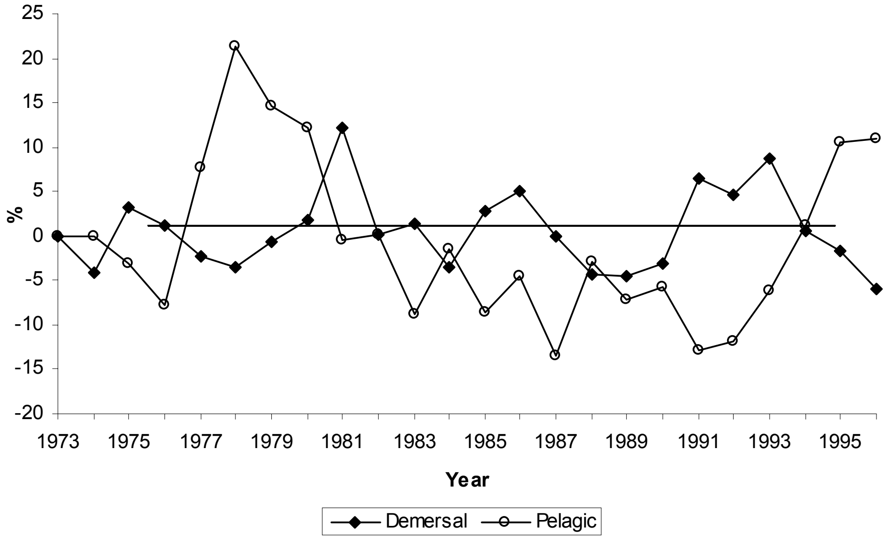


Figure 4. Relative increase rate of landing between pairs of years from all Adriatic countries (Mannini and Massa, 2000).

Unlike the pelagic fishery, the total annual landing of the demersal species and the landing of the most commercially important species remained almost constant throughout the 1972 to 1997 period (Mannini and Massa, 2000) (Figure 4). The reason for this continuity of resources, in spite of the high levels of fishery exploitation that was mainly concentrated on juveniles (Marano *et al*., 1994; Piccinetti and Piccinetti Manfrin, 1994), is still a matter of

research. The demersal catches are composed mainly of individuals of the age classes 0, 1 or 2. Therefore, trends in abundance reflect more a fluctuation in recruitment than a response to the fishing effort (Arneri, 1996). Also, the landing of some species, for example European hake, has been sustained for a relatively long period in spite of heavy apparently unsustainable exploitation. This could be due to the adult occurrence in deeper waters outside the traditional trawl fishing grounds, as Abella and Serena (1998) hypothesised for the Tyrrhenian Sea. Furthermore, the short-lived species, such as the commercially important cephalopods, with a short life span and a high production/biomass ratio are particularly resilient to fishery exploitation compared to the long-lived species. The situation is similar for the burrowing crustaceans, where the fluctuation in catches can be explained by the behaviour of the species in different seasons of the year (Arneri, 1996).
However, in the present conditions, it is very difficult to define the level of exploitation and the current state of the demersal resources in the Adriatic precisely, because there are no reliable commercial catch and effort statistics. This is why the stock assessment for standard population dynamics analysis is based mainly on the direct method, i.e. experimental trawl survey. On the basis of direct methods there is enough evidence indicating that demersal stocks are from fully to overexploited.
According to the GFCM Geographical SubAreas (GSA; GFCM 2001), the Adriatic Sea is divided in two sub-areas: Northern and Central Adriatic (GSA 17) and Southern Adriatic Sea (GSA 18) (Figure 5).

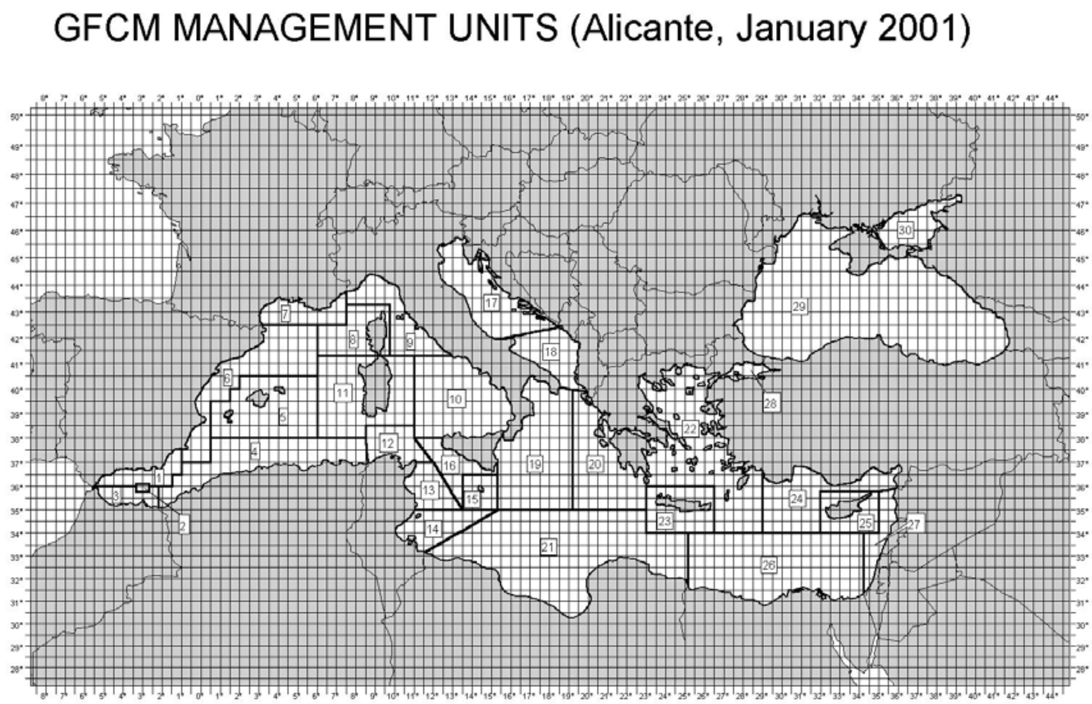


Figure 5. GFCM Geographical Management Units in the Mediterranean and Adriatic Seas (currently named as Geographical Sub-areas; GFCM, 2001).

3. Review of research on demersal resources in the Adriatic Sea

In the year 1873, the expedition "Challenger" embarked on a voyage around the world. It marked the beginning of modern oceanographic research. It also influenced the rise of research work in the Adriatic; from 1874 to 1880 a hydrographic study of the Adriatic by the ships "Nautilus", "Deli" and "Hera" took place and the international expedition "Pola", which was exploring the Mediterranean and the Black Seas, came to the Adriatic in 1894.

The "Society for the Improvement of the Natural Research of the Adriatic" ("Adriaverein") was established in the year 1903. Its mission was to co-ordinate all future research in the Adriatic. Initiated by the Society, the northern Adriatic was researched by the ships "Argo" and "Adria" from 1906 to 1910.

In 1907, 1909 and 1911, German biologists organised very successful research using the ship "Rudolf Wirchof", and in 1908 the Danish expedition "Thor" worked in the Adriatic.

Italy and Austria established "The Permanent Commission for the Research of the Adriatic" in Venice in 1910. It was decided to carry out a systematic biological and hydrographic research. The "Najade" expedition (1913-1914) was organised by Austria and the "Ciclope" (1911-1914) by Italy. They gathered mostly hydrographic data, but included biological data as well. Parallel to those expeditions, Croatian scientists were researching the Kvarner Bay area with the school ship "Vila Velebita" (1913-1914).

During the First World War all the researches in the Adriatic was stopped and between the two World Wars several research projects were organised by the ships "Ustrajni", "Veliki brat" and "Bios I". In the period from 1934 to 1935, Italian scientists in Rovinj organised a cruise in the northern and central Adriatic with the ship "San Marco".

The northern Adriatic channels were researched in 1938 and 1940. The objective was to assess the situation of the demersal fish assemblages (Zei, 1940), and in the period from 1939-1940 the Institute of Oceanography and Fishery (IOF) of Split organised and conducted research of the central Adriatic channels at 20 stations; samples were taken with a bottom trawl net and the duration of a haul was one hour. Qualitative and quantitative composition of the catch was analysed and for the economically most important species length, sex and the maturity of gonads were also analysed. The data gathered were published in the Institute's Year Book (Zei and Sabioncello, 1940) (Figure 6). The original data no longer exist.

After the Second World War the Institute of Oceanography and Fishery Split (IOF) organised a fishery-biological expedition "Hvar" (1948-49). During a thirteen month long cruise, samplings were made on the widest part of the continental shelf of the Adriatic Sea accessible at the time (Figure 7). The purpose of the research was to determine the qualitative and quantitative characteristics of the demersal communities of fish, crustaceans and cephalopods and to assess the possibility of their exploitation.

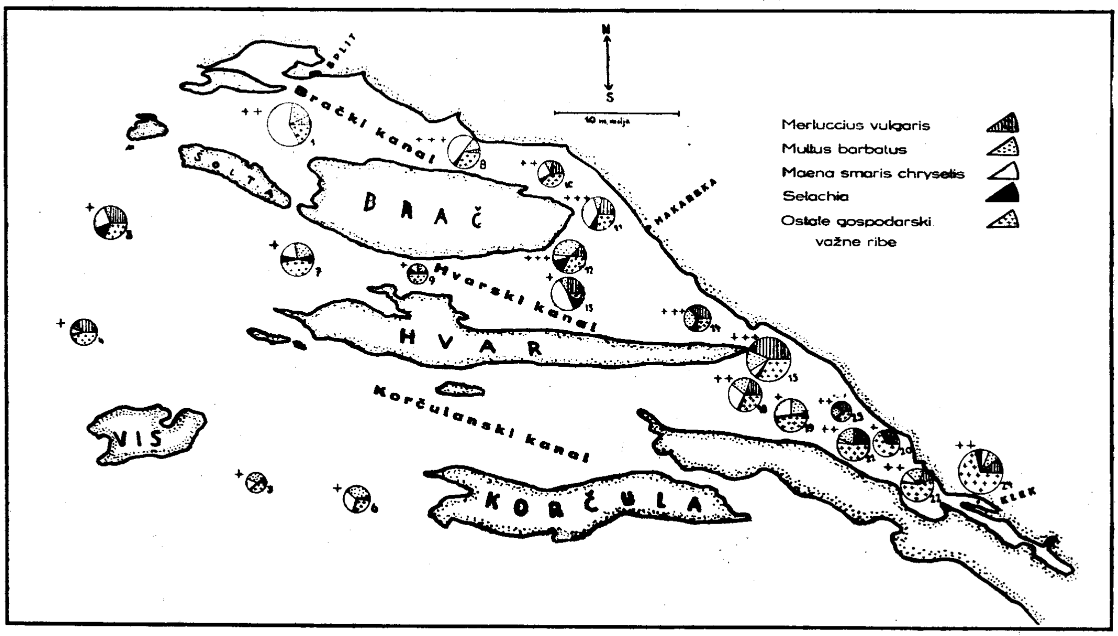


Figure 6. Map of area investigated in central Adriatic from 1939-1940 (Zei and Sabioncello, 1940).

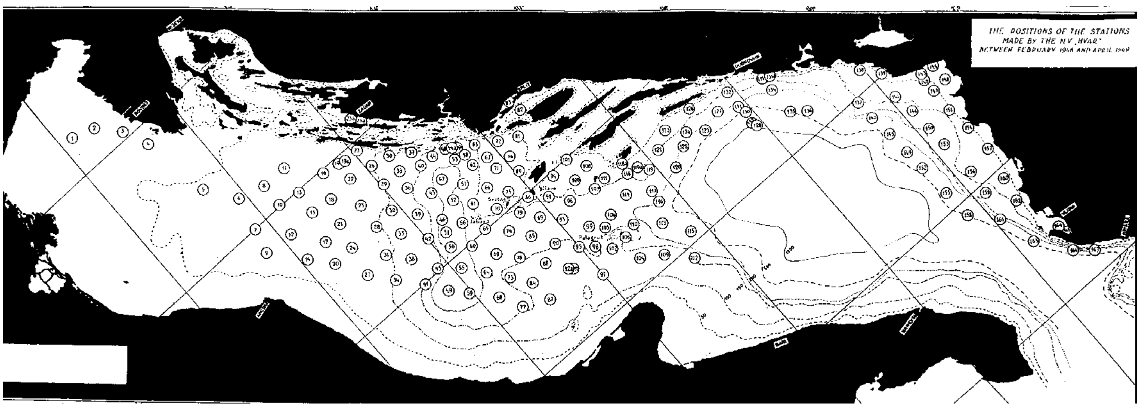


Figure 7. Map of the stations of expedition “Hvar”(Šoljan, 1977).

That study was conducted in the territorial waters of the former Yugoslavia (currently territorial waters of the Republics of Slovenia, Croatia, Bosnia and Hercegovina and Serbia and Montenegro) and Albania and in the international waters to approximately twenty nautical miles off the Italian coast. It was not possible to take samples in the channel regions of the northern Adriatic and a part of the central Adriatic because of the mines that had been left over from World War II. At the same time, in the open southern Adriatic, because of the technical limitations, sampling below 400 m was not conducted.

Samples were taken with a bottom trawl net with the stretched mesh size on the cod-end of 36 mm. Altogether, 167 fixed stations were systematically arranged in the region explored. The trawling was done only by day; duration of a haul was one hour except for the cases when two stations were connected with a two-hour haul. At greater depths in the southern Adriatic, sampling was done with long-lines.

The following parameters were taken during the expedition: depth, temperature, salinity, sediment and plankton composition. The qualitative and quantitative composition of the catch (vertebrates and invertebrates) was also determined, and for the economically most important species, the length, sex, the gonad maturity stages, otoliths or scales and the content of stomach were recorded.

Most of this data was analysed and published in the special publications of the Institute - “Izvješća (Reports) ribarstveno biološke ekspedicije “Hvar” 1948-49”.

Today, the Institute of Oceanography and Fishery has only a part of the original data of the rich biological material collected during the “Hvar” expedition. The Expedition’s log book and the lists of the stations were made later according to the original material with the list of the species that were fished, that is, their mass, number and the length frequencies data.

Some of the data was entered into a computer and that is the qualitative and quantitative structure of the catch per station and the length frequency data for the most economically important species of fish (European hake, red mullet and common pandora).

After the “Hvar” expedition, a number of studies that were mostly limited in terms of time and space were organised in ex-Yugoslavia.

In 1949, research continued at 31 stations of the open central Adriatic (some of the stations of the “Hvar” expedition), and in 1951-52 in the channel regions of the northern-eastern Adriatic (Karlovac, 1953). The purpose was to describe ecological characteristics of the Norway lobster population (Figure 8). The methodology of the work was the same as during the “Hvar” expedition. The data collected were published in the Institute’s journal “Izvješća (Reports) ribarstveno biološke ekspedicije “Hvar” 1948-49” (Karlovac, 1953), and the original data no longer exist.

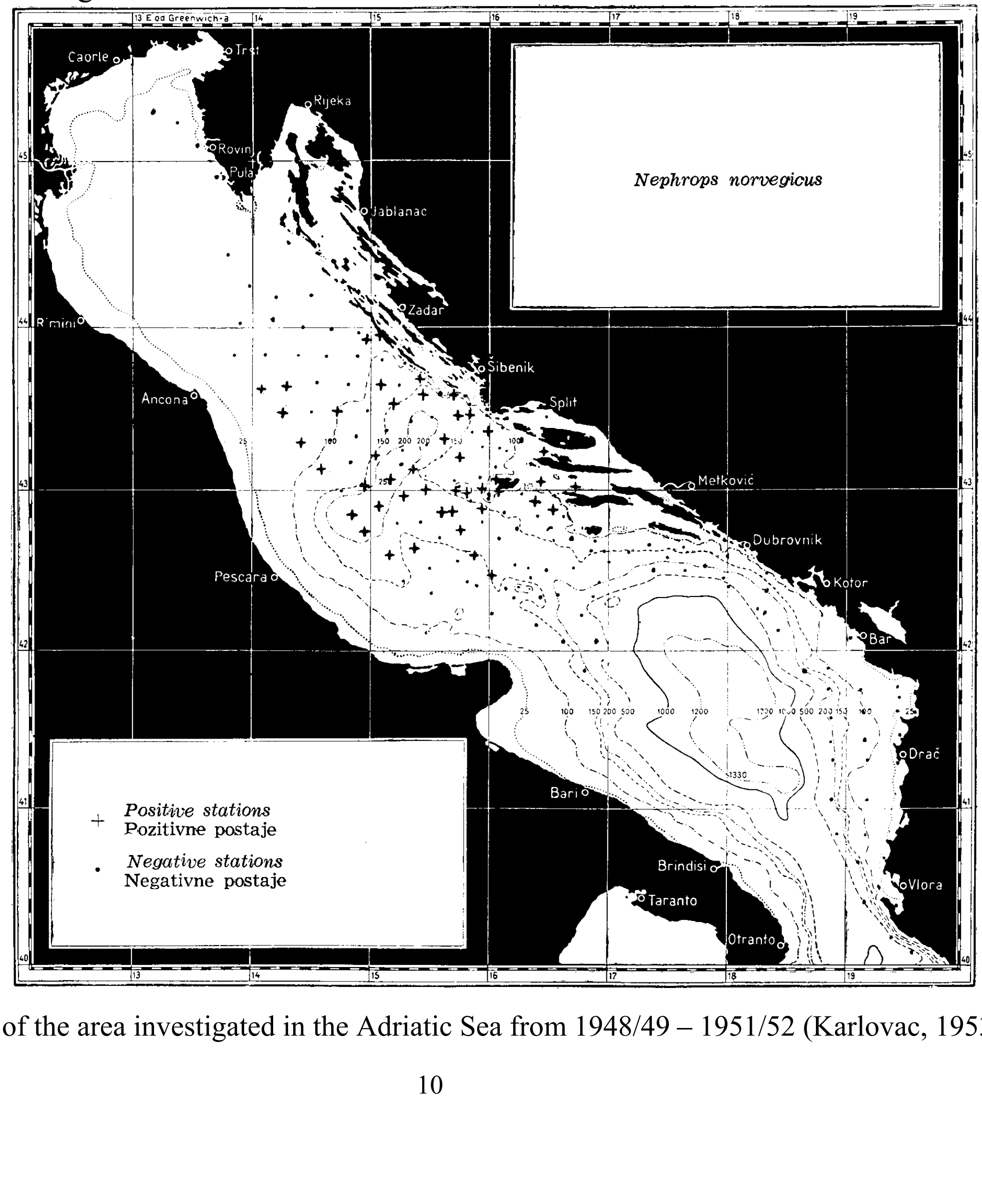


Figure 8. Map of the area investigated in the Adriatic Sea from 1948/49 – 1951/52 (Karlovac, 1953).

The analysis of the demersal assemblages of the northern Adriatic was done with monthly sampling at ten stations in the period from 1956 to 1957; a bottom trawl net was used. The quantitative and qualitative composition of the demersal communities was analysed and, for the most economically important species, length was measured and sex was determined. The data gathered were published (Crnković, 1959, 1970) (Figure 9). The original data no longer exist.

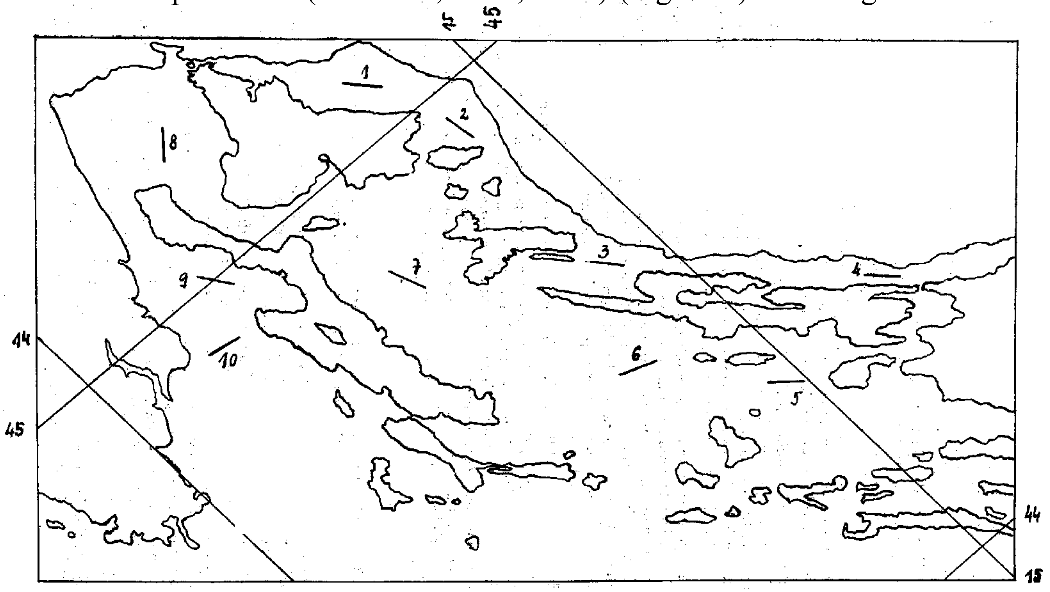


Figure 9. Map of the area investigated in the northern Adriatic Sea during 1956-57 (Crnković, 1959).

In the 1957-58 period, intensive research of the demersal assemblages was conducted by monthly sampling, (Županović, 1961b). The samplings were taken at a part of the stations where the "Hvar" expedition had been conducted using a bottom trawl net. The duration of hauls was one hour (Figure 10).

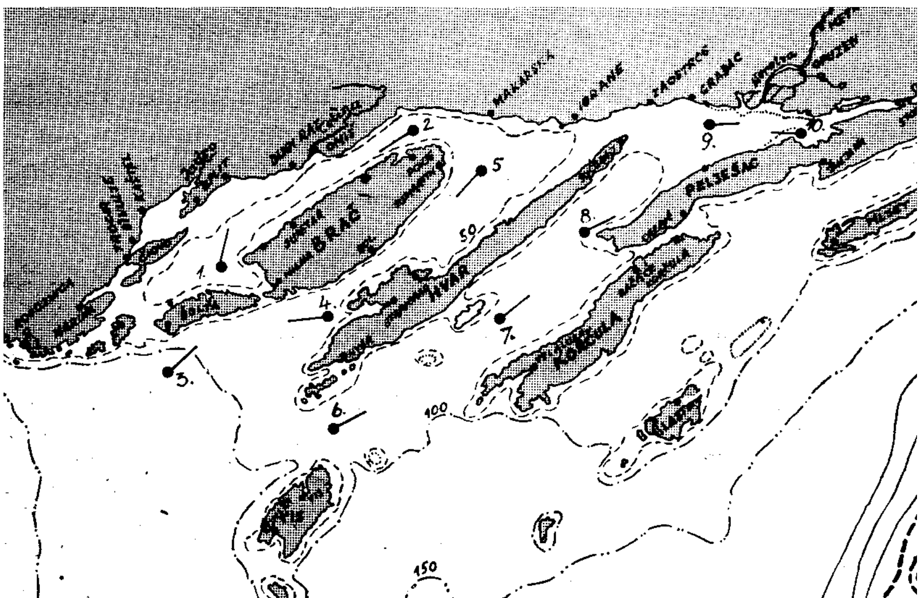


Figure 10. Map of the area investigated in the central Adriatic Sea during 1957-58 (Županović, 1961b).

The following data were gathered for every station: the quantitative and qualitative structure of catches (number and weight) and for economically most important species, length frequency data were collected. The quantitative and qualitative composition of the demersal invertebrates was also determined; sediment samples were taken with the use of the Peterson power shovel, salinity and temperature were also regularly taken at every station. Gathered data were published, (Županović, 1961a), however the original data no longer exist at the Institute.
After these studies, scientists at the IOF Split continued researching demersal species of the Jabuka Pit (Jukić, 1975; Županović and Jardas, 1989). In the period from 1956 to 1971, research was conducted with the ships "Bios" and "Predvodnik" in the wider area of the Pomo/Jabuka Pit, with special attention to the fishing area of Blitvenica (Figure 11).

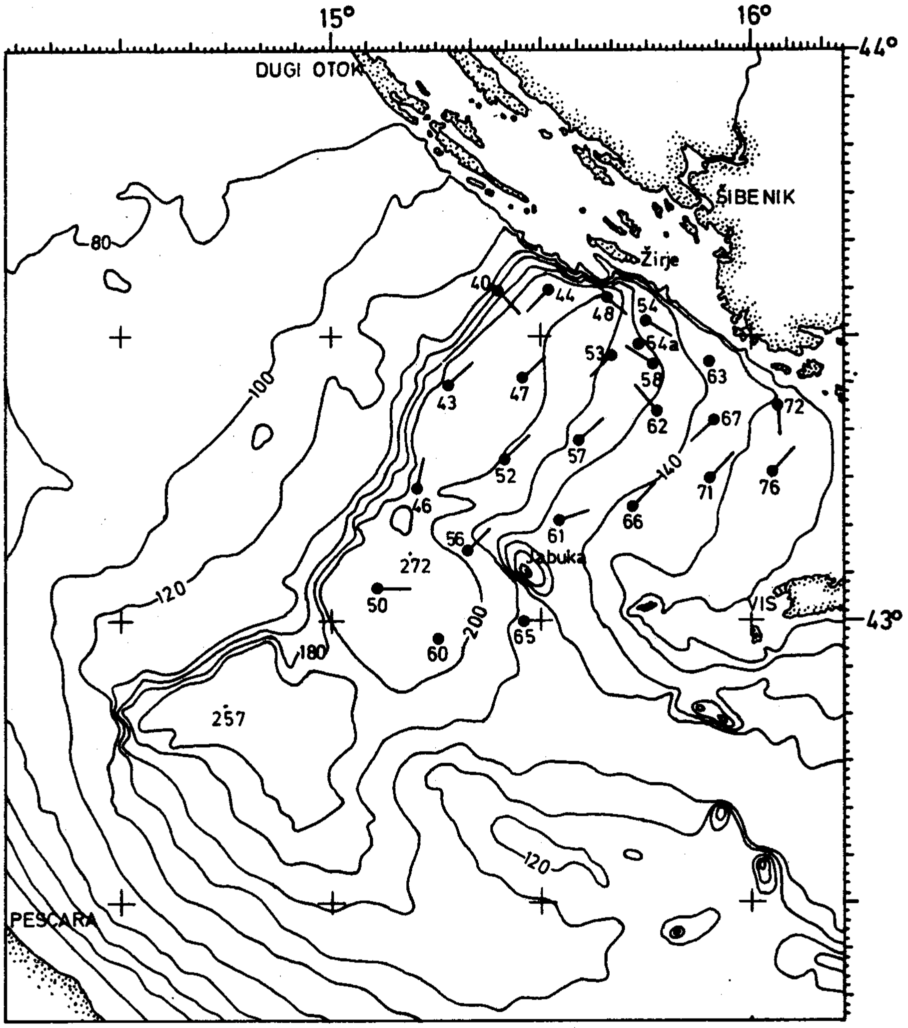


Figure 11. Map of the area investigated in the central Adriatic Sea from 1956 to 1971 (Županović and Jardas, 1989).

A typical bottom trawl net with mesh size on the cod-end of 22 mm side size was used, the duration of a haul was one hour. The qualitative and quantitative composition of the catch was analysed, and for the commercially most important species, the length, sex, the gonad maturity stage and the alimentation data were gathered. Qualitative and quantitative composition of demersal invertebrates caught with bottom trawl net was also analysed.

Composition of the sea bottom was also analysed at each station, using an echo sounder; hydrographic data, salinity and temperature were taken regularly at every station.
Most of the data collected was published, (Jukić, 1975; Županović and Jardas, 1989). A part of the original data still exists in paper form at the IOF Split (in the field workbooks). One part has been stored in computer Excel files (the Norway lobster and European hake length frequency data).

In 1963-64, scientists from Montenegro conducted large-scale research at eight stations in the Boka Kotorska Bay, (Lepetić, 1965). Qualitative and quantitative composition of the catch was analysed. For the most economically important species, the length and weight were measured and the sex of every specimen was determined. Additionally, the following hydrographic data were gathered: temperature, salinity, transparency of the water, sediments. Demersal fauna were analysed as well (Figure 12).

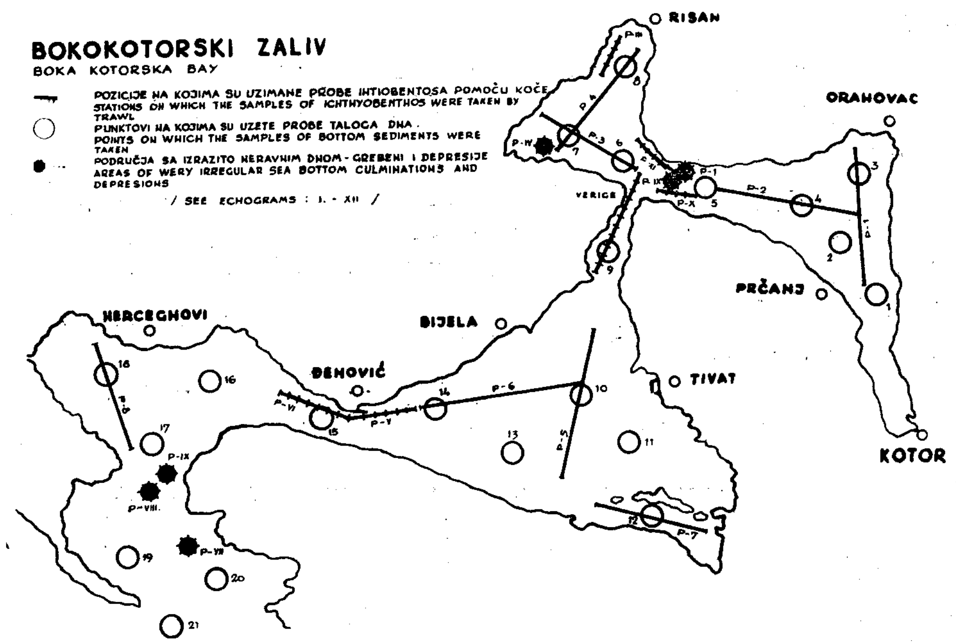


Figure 12. Map of the area investigated in Boka Kotorska Bay (Montenegro) during 1963/64 (Lepetić, 1965).

More extensive research of the southern Adriatic was conducted in the period from 1968 to 1979. The qualitative and quantitative composition of the catch was analysed and for the most economically important species data about length, weight, the gonad maturity stage and the alimentation were gathered. The composition of demersal fish communities was analysed and a map was made of southern Adriatic demersal biocenosis (Figure 13) (Merker and Ninčić, 1973).

Studies of ichthyobenthos in the deep southern Adriatic were organised in 1950-51. Depth ranged from 100 to 1200 m. Sampling stations were located on a transect of 30 NM south of Dubrovnik. Catch in terms of quantity was analysed and samples of sediment taken. The data were analysed and published (Kirinčić and Lepetić, 1955).

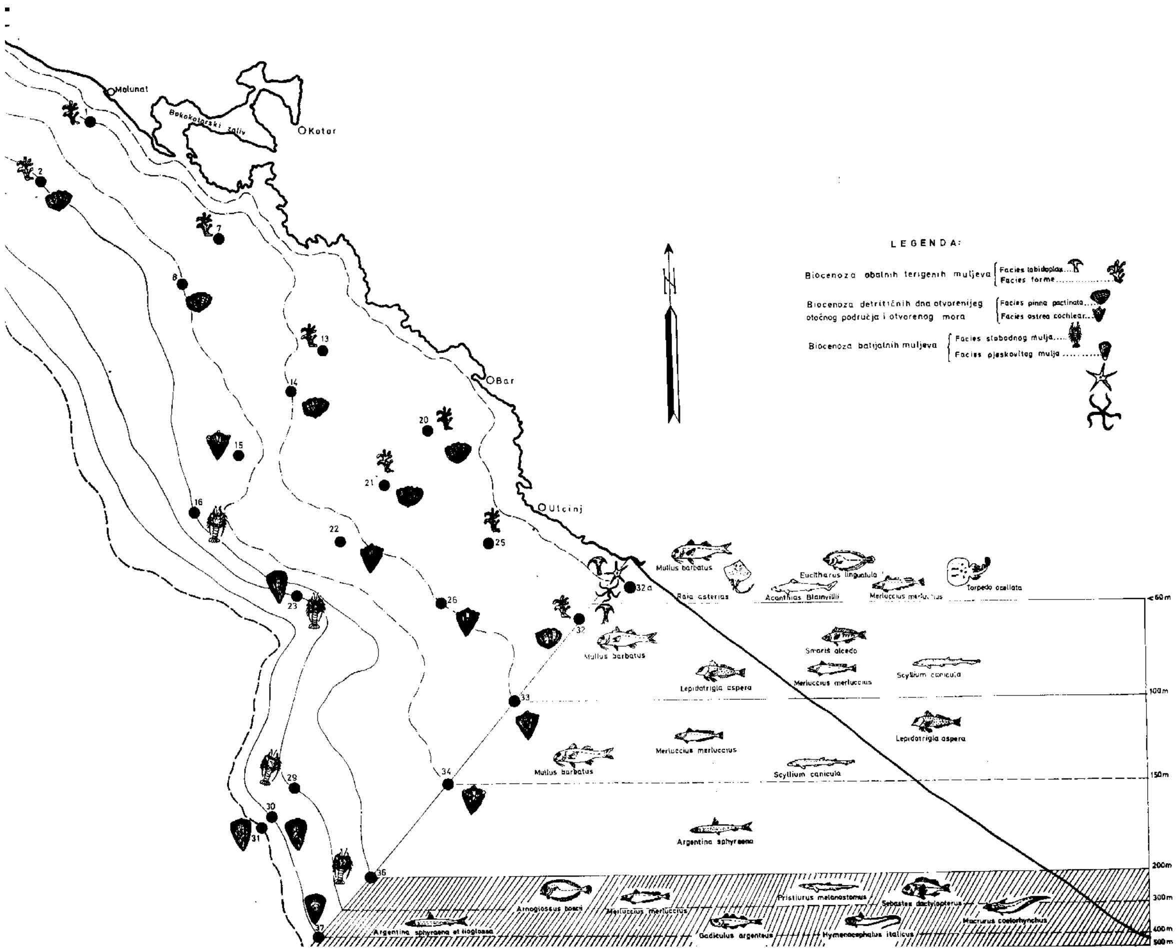


Figure 13. Map of the area investigated in the southern Adriatic Sea from 1968 to 1979 (Merker and Ninčić, 1973).

At present it is uncertain whether the original data from these investigations still exist in Montenegro and if they are available.

Scientists from the Laboratory of Marine Biology and Fisheries (LMBF) of Fano (Italy) and the Institute of Oceanography and Fisheries (IOF) of Split (Croatia) organised joint research in the central Adriatic in 1972; the transect was Fano-Dugi Otok. In 1973 and 1975 it was extended to four profiles in the northern and central Adriatic (Jukić and Piccinetti, 1974, 1979, 1981). The composition of the demersal assemblages was analysed in terms of quantity and quality with the use of a bottom trawl net. For most of the commercially important species, the length, weight, sex and the maturity of gonads were determined (*M. merluccius, M. barbatus, Pagellus erythrinus, Trisopterus minutus capelanus* and *N. norvegicus*). Since different vessels were used (on the Croatian side the "Bios" and on the Italian the "Santi Medici"), the efficiency of gear was also compared.

Data collected were published, (Jukić and Piccinetti, 1974, 1979, 1981). The original data still exist in the LMBF of Fano in paper format (Figure 14).

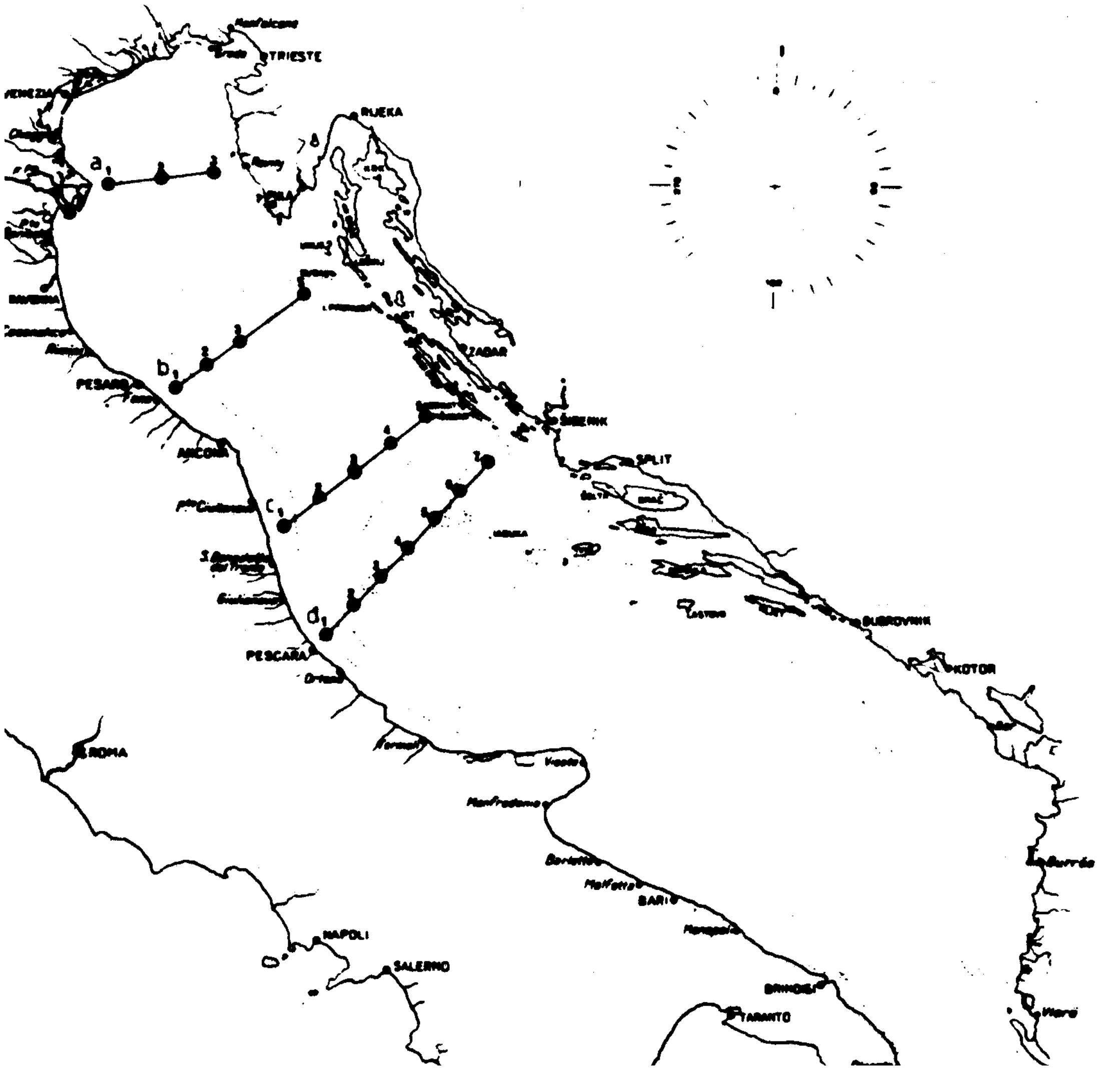


Figure 14. Map of the area investigated in the northern and central Adriatic Sea from 1973 to 1975 (Jukić and Piccinetti 1979).

No extensive research was organised along the eastern coast of the Adriatic after this period until the 1990s when the MEDITS program started. Studies, limited in terms of space and time, were restricted mostly to the channel regions and the open central Adriatic.

Before 1985, there was no research at national level in Italian seas on biological aspects and assessment of demersal resources fished by otter trawl, although this type of fishery is one of the main ones in Italy in terms of boat tonnage, landings and employment, (Relini, 1998). An exception is the expedition "Pipeta" which started in 1982, funded by the European Commission. Nevertheless, some studies, albeit limited in terms of space and time, were conducted.

In 1954 and 1955, Ghirardelli (1959a, b) researched demersal fish communities in the trawling area off Fano. The aim was primarily to study the biological characteristics of European hake and common sole. He described the biometric characteristics of the populations.

From 1969 to 1974, scientists of the Institute of Marine Fishery Research (IRPEM*) of Ancona did selectivity experiments on different kinds of bottom trawl net. The goal was to research their influence on populations of the most economically important species (*M. barbatus, M. merluccius, T. minutus capelanus, M. merlangus, Trachurus trachurus, Solea vulgaris*).
The gears tested were the Italian bottom trawl net, the French trawl net and the "rapido" (a kind of beam trawl used in pleuronectid fishery). The methods mostly used in the experiments were the cover cod-end technique and the method of alternate and parallel hauls. The data gathered were analysed and published (Froglia and Galli, 1970, Levi *et al*., 1971, Ferretti and Froglia, 1975).

Because of its economical value, Norway lobster was the object of much research. In 1970, the IRPEM of Ancona researched its biology in the Pomo/Jabuka Pit. A series of day-night samplings were made; the purpose was to describe the day-night fluctuations of the catch (Froglia, 1972a).

In 1973, the IRPEM conducted research on European hake in the Pomo/Jabuka Pit region and the trawling area off Ancona (Figure 15). The main goal was to study its alimentation (stomach contents). The research was conducted three times during the year at 15 stations. The gathered data were analysed and published (Froglia, 1973).

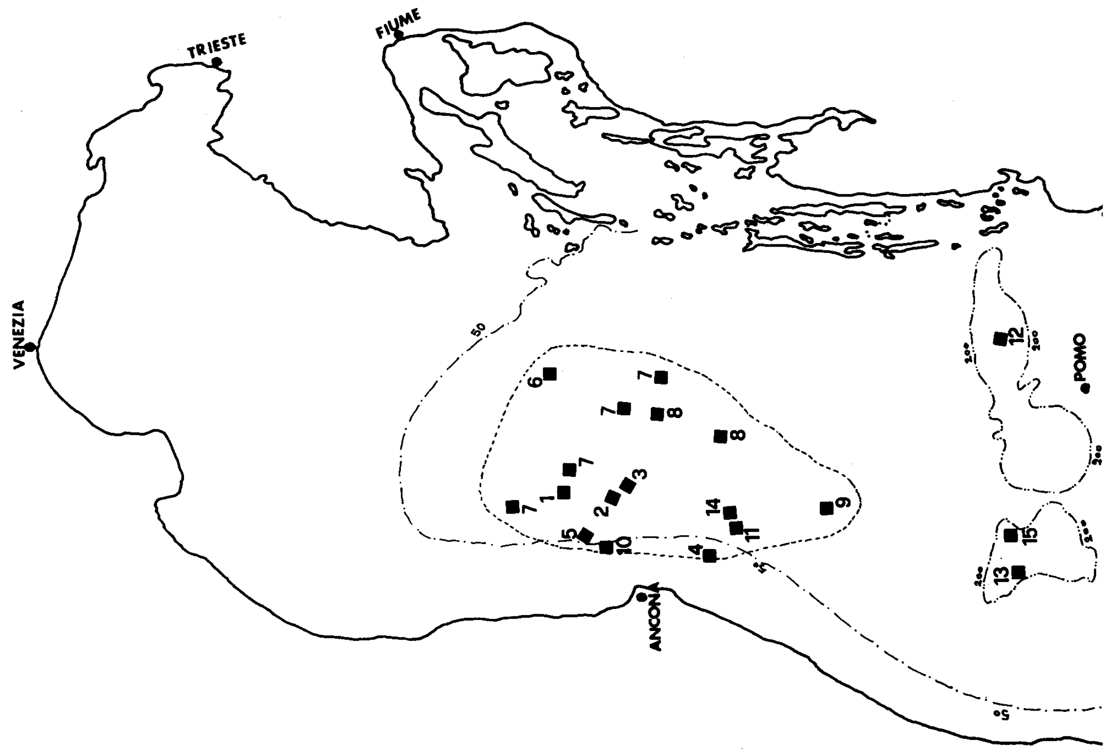


Figure 15. Map of the area investigated in the central Adriatic Sea during 1973 (Froglia, 1973).

* now Marine Sciences Institute - Marine Fisheries Department (ISMAR).

In 1975-1976, scientists from the Laboratory of Marine Biology (LMB) of Bari conducted research in the southern Adriatic off Bari (Figure 16). They studied the structure of catch in terms of quality and quantity. The data collected were analysed and published (Marano *et al.*, 1977).

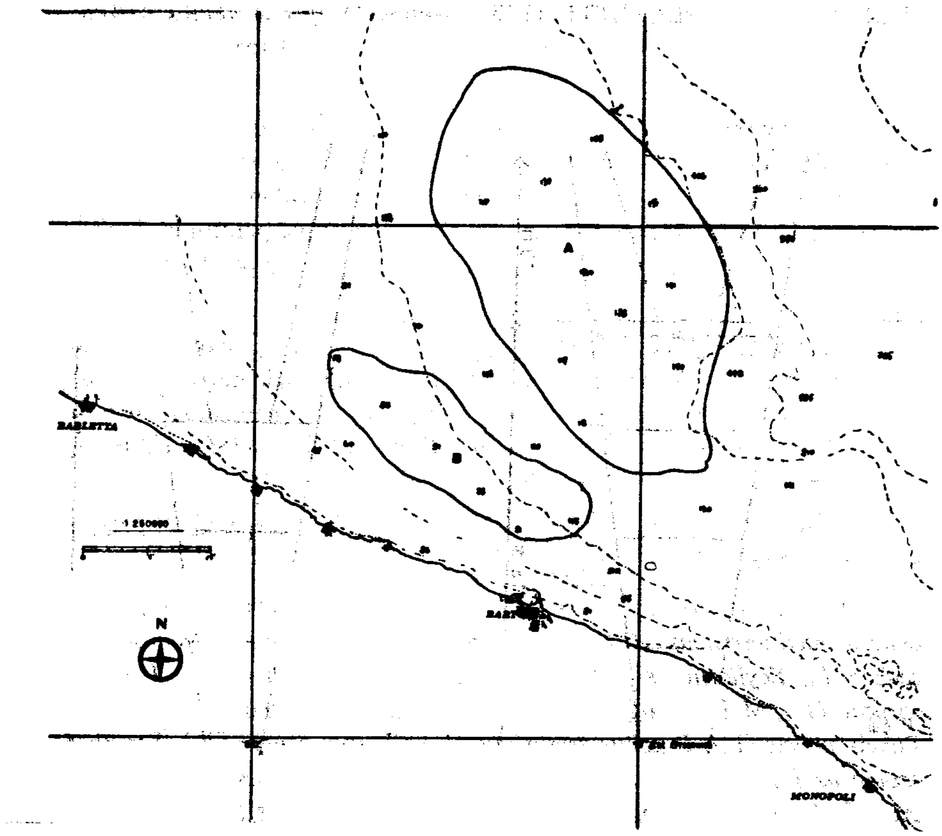


Figure 16. Map of the area investigated in the southern Adriatic Sea during 1975/76 (Marano *et al.*, 1977).

The LMBF of Fano conducted experiments in the northern Adriatic from 1976 to 1977. *S. vulgaris* specimens were tagged for biological characteristics and an attempt was made to assess the species' biomass using this method. The following species were marked: *S. vulgaris, Platichtis flessus, Pegusa impar, Psetta maxima*, (Pagotto *et al.*, 1979; Pagotto and Piccinetti, 1982).

The IRPEM of Ancona continued researching the biology of Norway lobster from 1976 to 1986 with special consideration given to fecundity. Samples were taken with a trawl in the Pomo/Jabuka Pit and north of Ancona. Length, weight, sex, mass and maturity of gonads were determined for every specimen (Figure 17).
Based on these data, the distribution of population, demographic structure, characteristics of growth, mortality and fecundity were determined (Froglia and Gramitto, 1979, 1986; Gramitto and Froglia, 1980).

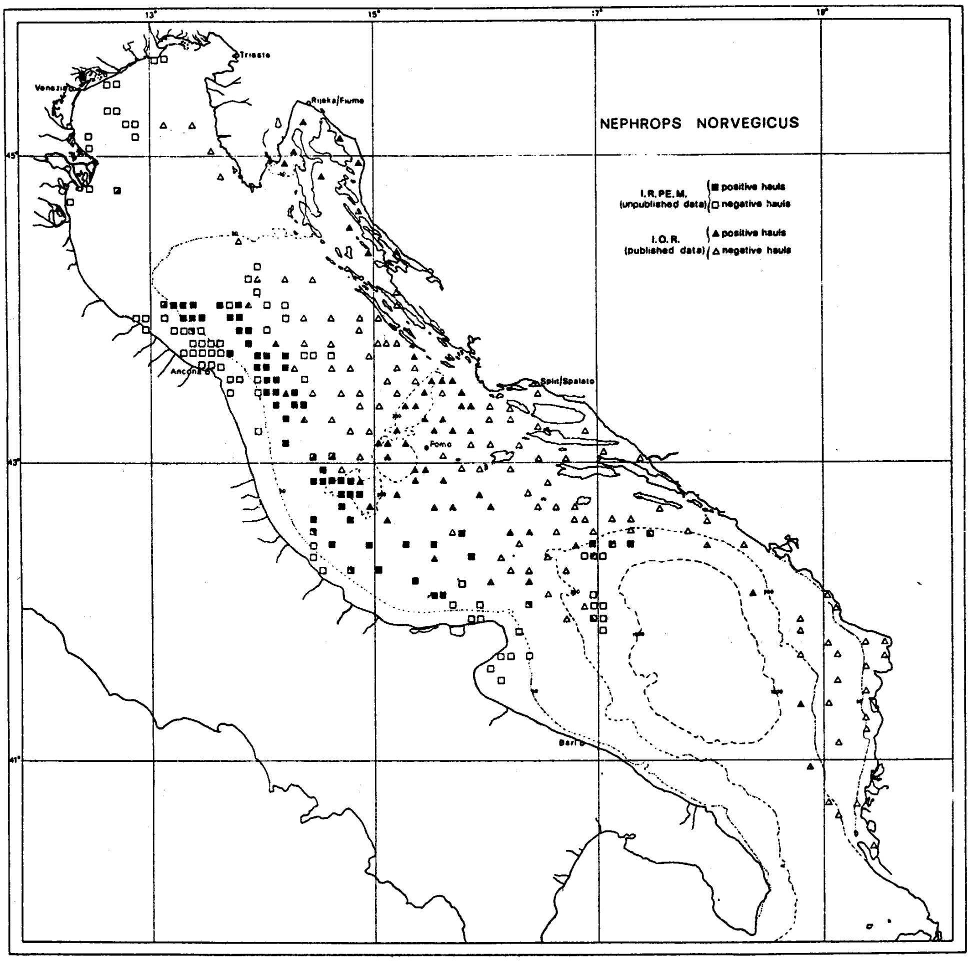


Figure 17. Map of the area investigated in the central Adriatic Sea from 1976 to 1986 (Froglia and Gramitto, 1979).

A research programme called "Feasibility Study of a Sampling System for the Collection of Fishery Statistics in Italy (PESTAT)" was conducted in all Italian seas from 1980 to 1986. This study, financed by the Ministry of the Merchant Navy, was designed and executed by IRPEM with technical assistance provided by the FAO Fishery Department (Figure 18).

The collection of fishing catch and effort data started in September 1981 and finished in September 1983. The purpose was to estimate the status of exploitation of fishing areas in Italian waters and their yield.

The following are some of the salient phases in which the PESTAT research was organised:
- Census of the structural data of the fishing boats contained in the official registers of the port authorities;
- Field activity, with vast coverage of the structural data of the boat and comparison with the official data;
- Catch and effort sample survey on a sample of 65 fishing sites composed of ports and landings places.
- Collection of fishing catch and effort data started in September 1981 and finished in September 1983 (Mortera *et al*., 1984; Bombace and Cingolani, 1986, 1988; Coppola and Cingolani, 1992).

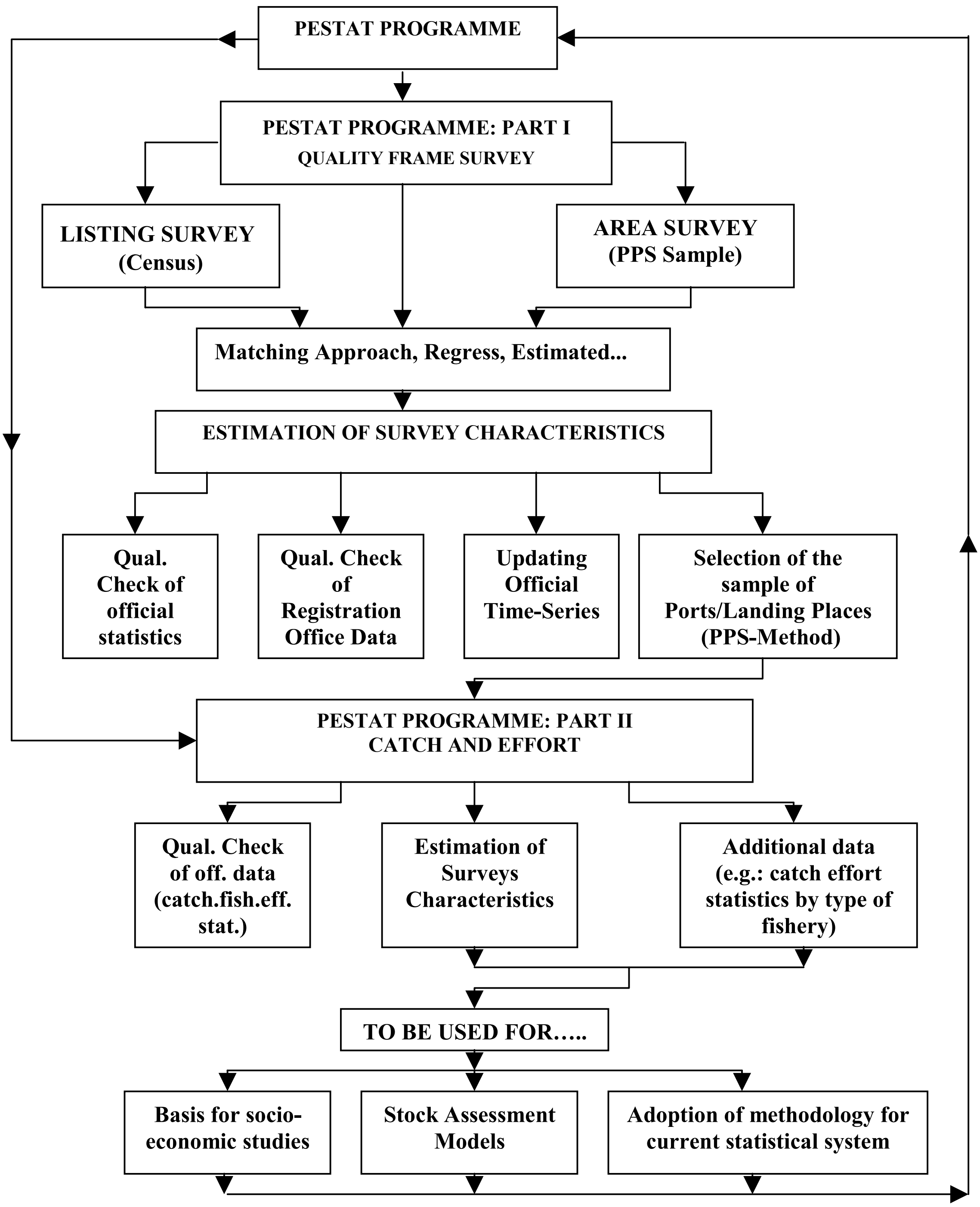


Figure 18. Phases of PESTAT programme (Bombace and Cingolani, 1986).

In 1982, the LMBF of Fano started the most extensive research of the demersal communities in the Adriatic. The research is still going on as a GRUND programme (see GRUND description below).

Together with scientists from LMBF, scientists from the IOF of Split have also been included. Among scientists, this research is known as the expedition “Pipeta”, named after the fishing vessel used until 2000 in surveys (Figure 19).

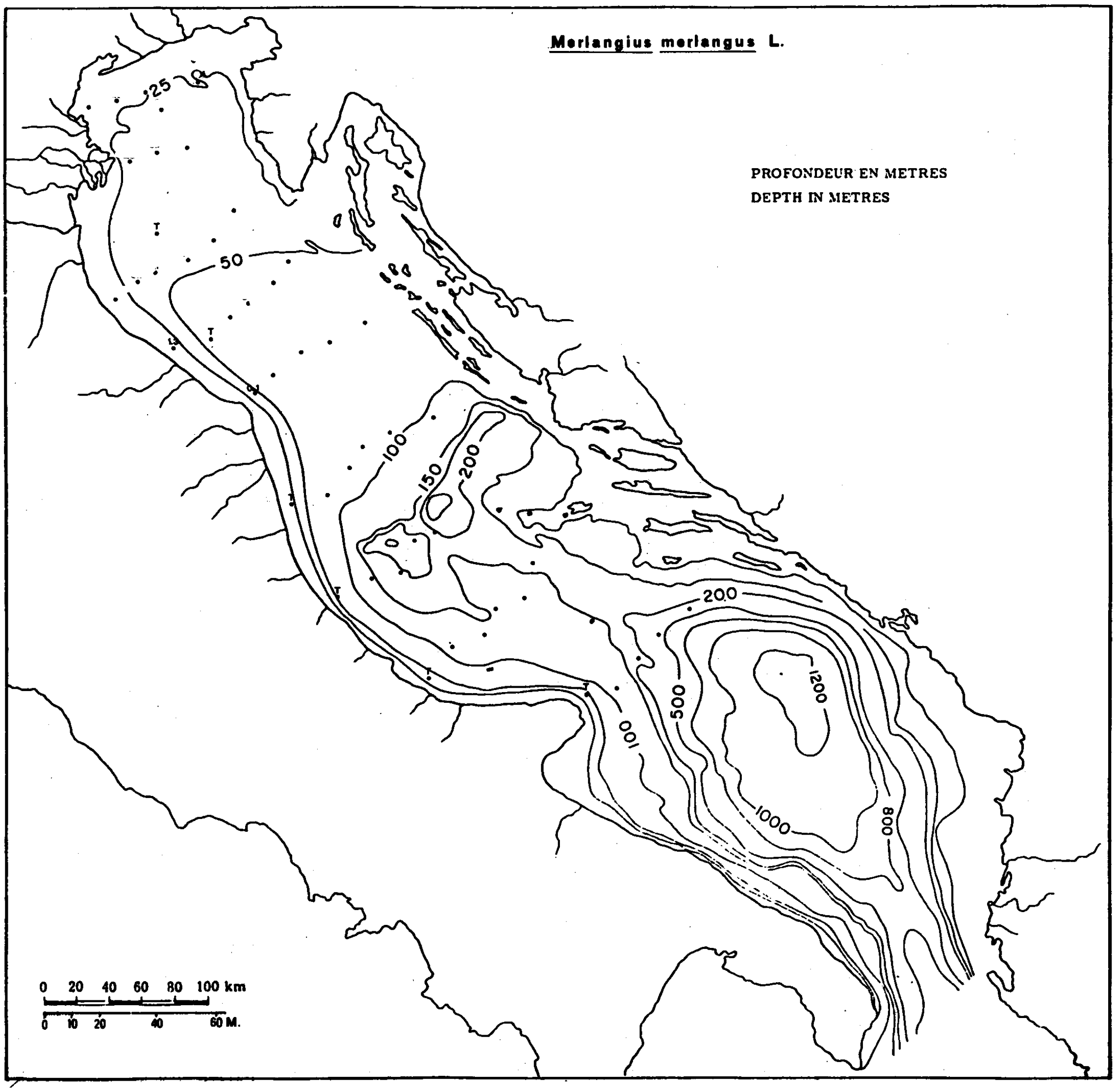


Figure 19. Map of the area investigated during the expedition "Pipeta" (Piccinetti and Jukić, 1984).

The studies are conducted mainly twice a year: in spring and autumn. The entire surface of the central Adriatic, (59 000 km^2) to the Monte Gargano Cape in the south and the Croatian territorial waters in the east, is being surveyed. On occasion, some stations in Croatian territorial waters were included (1983-1984).

The stations were systematically arranged in nine profiles, duration of a haul was mostly one hour. Two hauls in opposite directions were made at each station, chosen with respect to the distribution of biocenosis and the depth of the water. Samples were taken with a typical Italian commercial net: a bottom trawl net with side mesh size on the cod-end of 20 mm. At the beginning, sampling was carried out day and night. The methodology later changed because of the standardisation with other studies in Italy (i.e. GRUND).
From the beginning of the programme, temperature, salinity and oxygen have been measured together with an analysis the composition of the catch in terms of quantity, and quality, taking samples of the most economically important species. Sediment samples were also taken, using the Ven Venn grab, these samples were sieved later to collect organisms that live

in the sediment. Length, sex and maturity stage of gonads of the most commercially important species were determined afterwards in the laboratory. Otoliths and scales were examined and the diet of certain species was also studied.

In 1985, the monitoring of demersal communities was established on the basis of the Italian Law 41/82. A uniform methodology of sampling and data analysis was ordered for the entire research area.

The LMB of Bari began research in the southern Adriatic in 1985. Stations were arranged systematically (in transects) in the research area, from Vieste to Otranto (12000 km^2). In 1985, there were 42 sampling stations, there were no activities in 1986 and 1989 while in other years, 25 stations were studied. The stations were selected in such a way that their number is proportional to the surface of a particular deep stratum (up to 50 m, 50-500, 100-200, 200-400 and over 400 m). Sampling was carried out twice a year (spring and autumn), with one hour hauls mostly. The trawl was a commercial one, with side mesh size on the cod-end of 20 mm (Figure 20). The catch was analysed in terms of quantity and quality while sampling on board. Length, weight maturity stage of gonads and sex of the most economically important species were determined in the laboratory. Otoliths were also extracted.

In 1985 target species were *M. merluccius, M. barbatus* and *Lepidorhombus boscii. S. officinalis, Eledone moschata* and *Eledone cirrhosa* were added in 1987-88, together with *Micromesistius poutassou, Phycis blennoides, T. minutus capelanus, Helicolenus dactylopterus, Octopus vulgaris, Loligo vulgaris, N. norvegicus, P. longirostris, Aristaeomorpha foliacea* and *Squilla mantis* from 1990 to 1993.

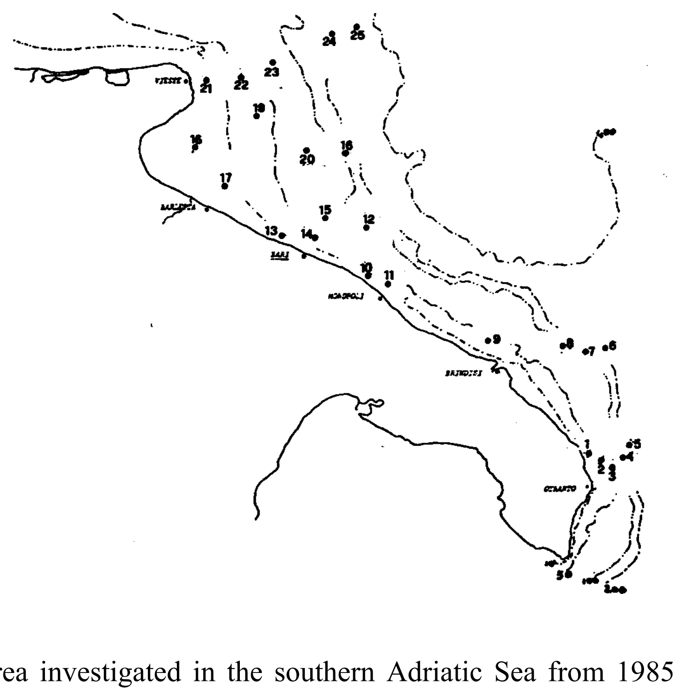


Figure 20. Map of the area investigated in the southern Adriatic Sea from 1985 to 1993 (Marano, 1993).

Since 1994 all the groups conducting research in Italian waters have been united into a common national programme GRUND. The protocol for the method of collecting and analysing data has been uniform.

In this context, there were some changes in the studies mentioned of the Adriatic; the arrangement of stations was altered to random stratified sampling, where the depth of the water is concerned (bottom depth stratified sampling). The target species were also redefined, they are: *M. merluccius, M. barbatus, P. blenoides, M. poutassou, N. norvegicus, A. foliacea, Aristeus antenatus, P. longirostris, O. vulgaris* and *E. cirrhosa*. Since 1996 the list has been extended to include the following species: *Mullus surmuletus, P. erythrinus, H. dactylopterus, L. boscii, S. mantis, E. moschata, L. vulgaris* and *Illex coindetti.*

The EU has funded new surveys in the Adriatic since 1994 in the framework of the MEDITS (MEDiterranean International Trawl Survey) programme (Figure 21). This programme was organised in 1993 and sampling started in 1994. Initially, only EU member countries participated in the programme (France, Greece, Italy and Spain). Albania, Croatia and Slovenia joined the programme in 1996. It was the first time in history that the most of the Adriatic Sea was covered by a bottom trawl survey. The programme ended in 2001.

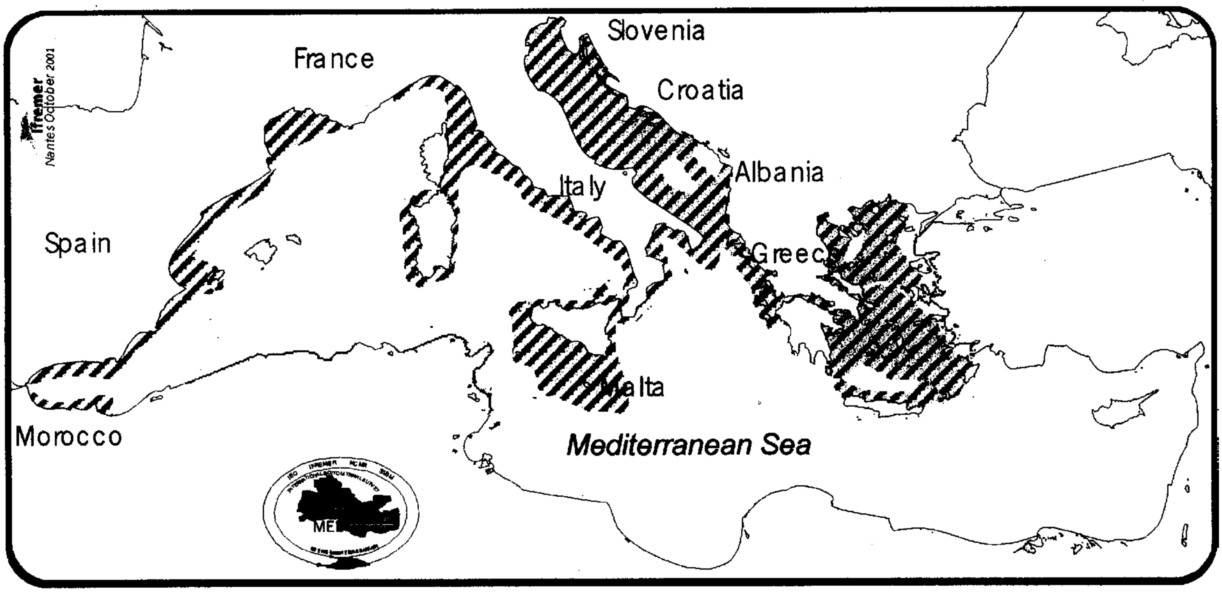


Figure 21. Map of the area investigated during the MEDITS expedition.

About twenty institutes and laboratories from seven countries were involved in the MEDITS programme which was the first to produce such common data on this scale in the Mediterranean. It covered all the trawlable areas on shelves and the slope (at depths from 10 to 800 m) using the same, standardised protocol (Bertrand *et al.*, 1997). Stations were selected on the basis of a stratified scheme with random selection of stations in every stratum (10-50 m; 50- 100 m, 100-200 m, 200- 500 m and over 500 m). The number of stations in each stratum is proportional to the surface of the stratum.

A special, French type of bottom trawl net (GOC 73) was used for sampling; it was constructed by P. Y. Dremiere from IFREMER, Sete. The main characteristics of the net are a smaller mesh size of the net cod-end (10 mm knot to knot), as well as a larger vertical and horizontal opening than the ordinary commercial net used in the trawl fishery of the Adriatic.

Samples were taken only during the daylight hours in the spring period. Towing time was half an hour at the stations located on the shelf and one hour at those on the slope. Qualitative and quantitative structure (number and weight) and species composition of the catch were analysed on board. Subsamples of the target species (36 commercially important species of fish, crustaceans and cephalopods) were taken for the laboratory data analysis. Length, sex and stage of maturity of gonads were determined in laboratory using a unified methodology (Bertrand, 1995).

Since 1996, parallel research activities in Italy have been conducted: the MEDITS in the spring period and the GRUND in autumn. In the GRUND, the arrangement of the stations was adjusted according to MEDITS stratification; the stations are the same every year. Sampling and methodology of data analysis are standardised as well, the only difference is the net used: GOC 73 for the MEDITS and the Italian commercial net for GRUND. Because of that difference, the data of these two expeditions are not completely comparable. That was affirmed by studies in the framework of the ESMED 1995-96 programme (Fiorentini and Dremiere, 1999).

All the data of the above mentioned studies ("Pipeta", GRUND, MEDITS) are in the relevant national institutes and laboratories which participated in these investigations. In Croatia it is the IOF of Split, in Slovenia it is the National Institute of Biology (NIB), in Albania it is the Fisheries Research Institute (FRI) in Dürres. The data for the central and northern Adriatic that were studied by Italian scientists are at the LMBF in Fano and for the southern Adriatic are at the LMB in Bari.

In Fano, the data still exist in the paper form, but the majority are entered in computer files: the "Pipeta" expeditions in the EXTRABASE programme and the MEDITS in the DAME programme. The only original data that exist in Bari are those collected after 1990. Earlier data are reported only in documents prepared for the Italian fisheries administration.

Detailed research of the Slovenian national waters were first conducted in 1987-88. Samples were taken in the Gulf of Trieste with a bottom trawl net; the catch was analysed in terms of quality and quantity. Collected data were published (Štrin and Bolje, 1989; Bolje, 1992). However, the original data no longer exist. Permanent monitoring of demersal communities in the Slovenian waters has been carried out since 1995 by the National Institute of Biology (NIB) of Ljubljana. The monitoring has been conducted with a commercial vessel, with bi-monthly frequency at three fixed stations, the duration of a haul is 40 minutes. Quantitative and qualitative composition of the catch is analysed and length, weight, sex and degree of maturity of gonads for all the species are determined, stomach contents are analysed too. Collected data are entered in a computer files (ACCESS).

The first attempts to evaluate the qualitative and quantitative features of demersal communities in the Albanian waters were done during the “Hvar” expedition (Karlovac, 1953). After this, there was another joint campaign of Russian and Albanian research, carried out in 1958, which concentrated on listing and describing of demersal assemblage composition. During the period 1960-1990, data about the annual fishing yield were recorded. Data from these investigations in Albanian waters no longer exist.

The IRPEM conducted numerous research programmes on Norway lobster in the region of the Pomo/Jabuka Pit and off Ancona in the Nineties. In 1993-1994, parallel studies were conducted in the Clyde (Scotland), the Adriatic and Aegean Seas. Besides the study of Norway lobster population (length, weight, sex, maturity stage of gonads), analyses included investigations of demersal fauna, sediments, temperature, salinity, oxygen and organic carbon. These investigations were conducted with the use of underwater television-UWTV, and the main goal was biomass determination (Froglia *et al*., 1997).

In the period from 1993 to 1995, the programme NEMED (*N. norvegicus*: Comparative Biology and Fishery in the Mediterranean Sea) was conducted in the Mediterranean region. It was financed by EC DG-XIV (MED92/08). In the Adriatic, samples were taken once a month at the trawling areas off Ancona by IRPEM. Length, weight, sex, stage of maturity of gonads, mass of gonads, biometry characteristic and stomach contents were determined for every specimen. Samples were taken for genetic analyses as well. The data collected were published in the special edition of the Journal Scientia Marina 1998 (vol. 62, suppl. 1). In the period from 1996 to 1998 the LMB of Bari organized the project “European hake” (“Biological study on the Mediterranean European hake (*M. merluccius*): spawning stock unavailable to trawl fishery”), funded by the EC. In the scope of the project, bathyal areas of the Southern Adriatic Sea were investigated: samples were taken using bottom long-lines and gill-nets. From 1998 to 2000 the LMB was involved in the project “MEDLAND” (“Mediterranean landings pilot project”), also funded by the EC. The principal aim of this investigation was the monitoring of demersal catch and effort data from local trawlers. All data collected are stored in the LMB of Bari. The IRPEM scientists conducted a pilot study “Improvement of *Nephrops* stock assessment by use of micro-scale mapping of effort and landings” in 1998-1999. The GPS data loggers were installed in two vessels at the end of November 1998, in order to cover a full year, data were recorded until the beginning of December 1999. The GPS data and the logbook data were used to estimate the actual size of the landings and to run a preliminary Length Cohort Analysis (Marrs *et al*., 2000). In the period 1999-2000, IRPEM studied the influence of various gears on the *S. officinalis* population. The research area was in the waters off Ancona (Figure 22). The following gears were studied: fyke nets, pots and trammel nets. The research included the collection of data on *S. officinalis* (dorsal mantle length, weight, sex, maturity stage), environment (bottom depth, water temperature and transparency) and bycatch (Fabi, 2001).

Since 2001, research on the demersal communities along the eastern coast of the Adriatic (Albania, Croatia and Slovenia) has been organised as a part of the FAO regional Project AdriaMed.

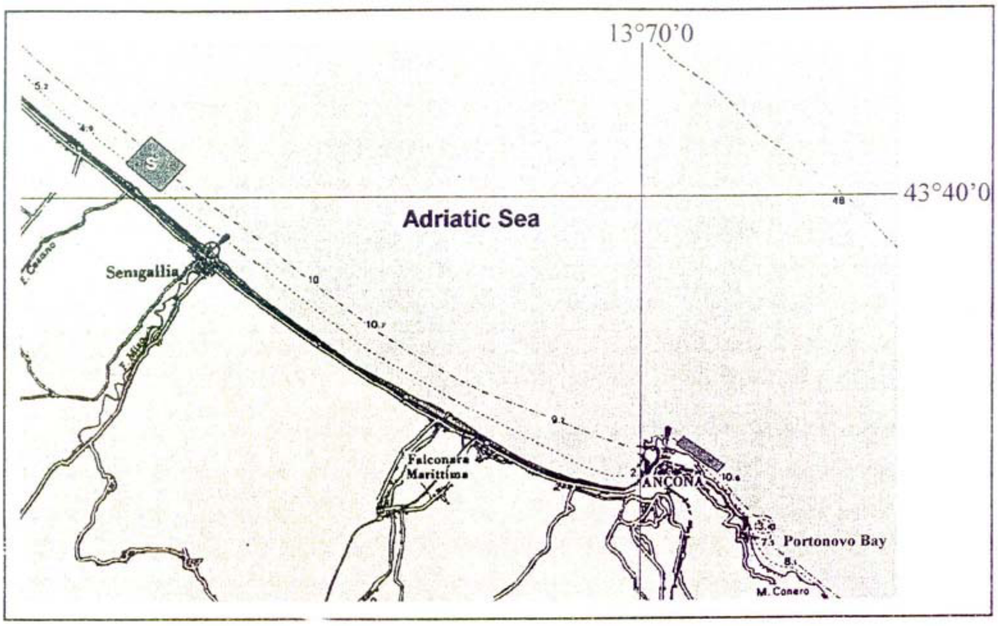


Figure 22. Map of the area investigated around Ancona during 1999-2000 (Fabi, 2001).

The methodology of data gathering and processing is the same as in the GRUND programme. These surveys are being conducted once a year (the autumn-winter period) at 42 stations altogether. The target species are the thirteen most economically important demersal fish, crustaceans and cephalopods whose stocks are regarded as shared in the Adriatic Sea (AdriaMed, 2000): *M. merluccius, M. barbatus, P. erythrinus, M. merlangus, Lophius budegassa, Lophius piscatorius, S. vulgaris, N. norvegicus, P. longirostris, E. moschata, E. cirrhosa, L. vulgaris* and *S. officinalis*. The data collected during this research can be found in relevant national institutes and laboratories.

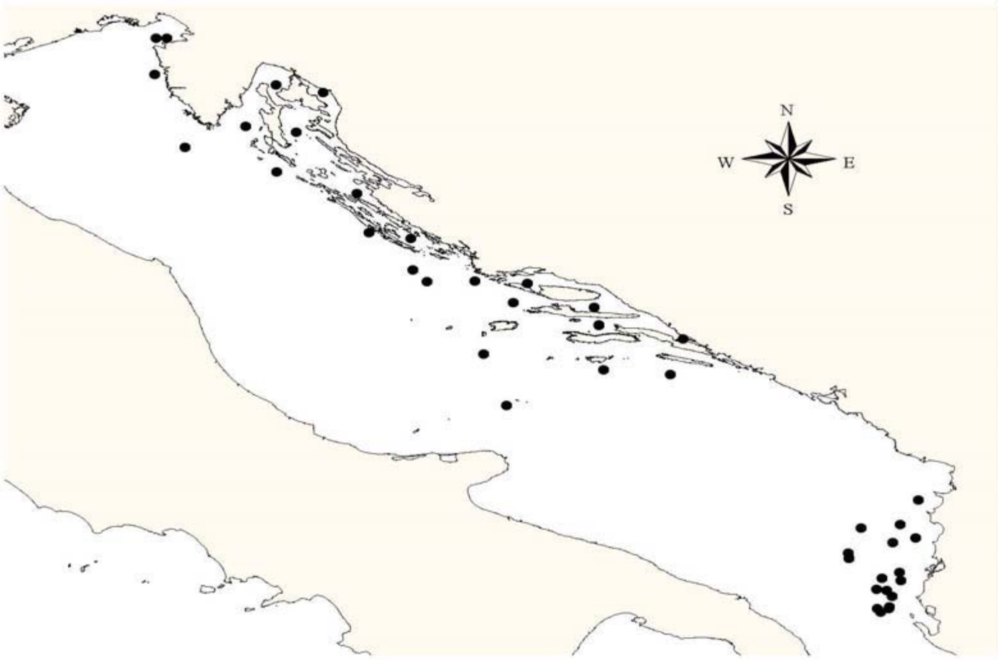


Figure 23. Area investigated during FAO AdriaMed trawl survey 2001-2002.

Table 1. Summarised data about the most important investigations of demersal resources in the Adriatic Sea.

Year	Institute	Area of investigation	No. station	Gear	Note	Author
1938-1940	IOF - Split	Channel region of the Northern Adriatic		trawl	demersal resources	Zei, 1940
1939-1940	IOF - Split	Channel region of the Central Adriatic	20	trawl	demersal resources	Zei and Sabioncello, 1940
1948-1949 Ekspedition "Hvar"	IOF - Split	Whole open Adriatic Sea	167	trawl, long–line	demersal resources	Šoljan, 1977
1949	IOF - Split	Central open Adriatic Sea	31	trawl	Norway lobster	Karlovac, 1953
1950-1951	IOF - Split	Northern Adriatic		long-line	demersal resources	Kirinčić and Lepetić. 1955
1951-1952	IOF - Split	Channel region of the Northern Adriatic	23	trawl	Norway lobster	Karlovac, 1953
1956-1957	IOF - Split	Channel region of the Northern Adriatic	10	trawl	Norway lobster	Crnković, 1959, 1970
1957-1958	IOF - Split	Channel region of the Central Adriatic	10	trawl	demersal resources	Županović, 1961b
1956-1971	IOF - Split	Pomo/Jabuka Pit	24	trawl	demersal resources	Jukić, 1975 Županović and Jardas, 1989
1963-1964	Kotor	Bay of Boka Kotorska (Montenegro)	8	trawl	demersal resources	Lepetić, 1965
1968-1972	Kotor	Southern Adriatic	38	trawl	demersal resources	Merker and Ninčić, 1973
1972, 1974, 1975	IOF - Split LMBF-Fano	Central and open Adriatic	5 + 19	trawl	demersal resources	Jukić and Piccinetti, 1981
1987-1988	NIB- Ljubljana	Slovenian territotial waters	3	trawl	demersal resources	Bolje, 1992
1995 until now	NIB- Ljubljana	Slovenian territotial waters	3	trawl	demersal resources	Marčeta, 1996
1954-1955	LMBF-Fano	Middle Adriatic		trawl	European hake, Common sole	Ghirardelli, 1959a, b
1969-1974	IRPEM-Ancona	Pomo/Jabuka and Middle Adriatic		trawl	selectivity	Ferretti and Froglia, 1975

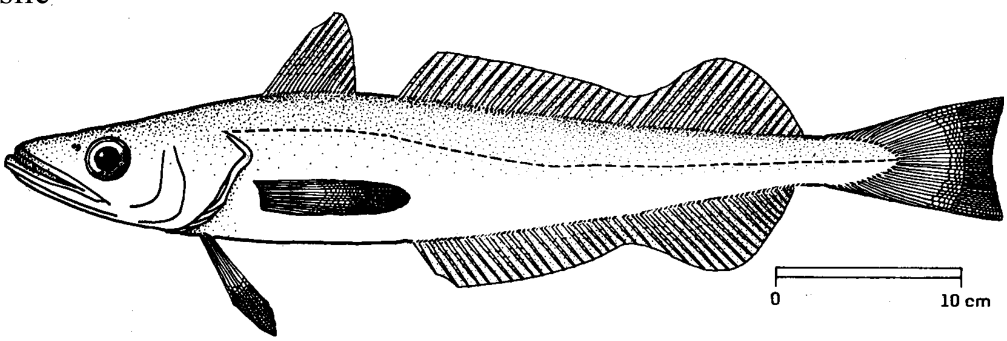
Year	Institute	Area of investigation	No. station	Gear	Note	Author
1970	IRPEM-Ancona	Pomo/Jabuka Pit and northern Adriatic off Ancona		trawl	Norway lobster	Froglia, 1972a
1973	IRPEM-Ancona	Middle Adriatic	15	trawl	European hake	Froglia, 1973
1975 –1976	LMB - Bari	Southern Adriatic		trawl	demersal resources	Marano *et al*. 1977
1976–1977	LMBF-Fano	Northern Adriatic		rapido	Common sole, tagging	Pagotto *et al*. 1979
1976–1986	IRPEM-Ancona	Pomo/Jabuka Pit and north of Ancona		trawl	Norway lobster	Froglia and Gramitto, 1979, 1988; Gramitto and Froglia, 1980
1980-1986	IRPEM-Ancona	PESTAT			landings	Coppola and Cingolani, 1992
1982-1984 Pipeta	LMBF-Fano	Northern and Middle Adriatic	9 profiles	trawl	demersal resources	Piccinetti and Jukić, 1984
1984– until now	LMBF-Fano	Northern and Middle Adriatic	9 profiles	trawl	demersal resources Pipeta, GRUND	Piccinetti and Piccinetti Manfrin, 1994
1984- until now	LMB-Bari	Southern Adriatic	42 (1985) 25	trawl	demersal resources GRUND	Marano, 1985, 1987, 1993, 1996
1993–1994	IRPEM-Ancona	Pomo/Jabuka Pit and off Ancona		trawl	Norway lobster	IMBC, UMBSM, IRPEM, 1994, Froglia *et al*., 1997
1993-1995	IRPEM-Ancona	Trawling areas off Ancona		trawl UWTV	Norway lobster NEMED	Scientia Marina 1998 (vol.61, suppl 1)
1994–2001 MEDITS	LMBF-Fano IOF-Split LMB-Bari FRI-Dürres NIB-Ljubljana	1994 – 1996. Italian teritorial waters and international waters 1996 – 2001. Whole Adriatic Sea		trawl	demersal resources MEDITS	Bertrand *et al*., 1997

Year	Institute	Area of investigation	No. station	Gear	Note	Author
1996-1998	LMB-Bari	Southern Adriatic Sea		long-line, gill-nets	Project «HAKE»	
1998-1999	IRPEM-Ancona	Trawling areas off Ancona		trawl	Norway lobster-GPS	Marrs *et al*., 2000
1998-2000	LMB-Bari	Southern Adriatic Sea		landings	Project «MEDLAND»	
1999-2000	IRPEM-Ancona	Trawling areas off Ancona		fyke n. pots trammel	Common cuttlefish	Fabi, 2001
2001 until now AdriaMed	NIB-Ljubljana IOF-Split FRI-Dürres	Eastern Adriatic coast	42	trawl	demersal resources AdriaMed	

Merluccius merluccius (Linnaeus, 1758)

(Sin. *Merluccius vulgaris* Fleming, 1818)
Family: Merlucciidae

EN: European hake
SQ: Merluci
HR: Oslić, mol
IT: Nasello, merluzzo
SL: Oslić



Species description

The body of European hake is long and cylindrical. The widest part is behind the head. The mouth is large. There are two dorsal fins. The first one is short and triangular and the second one is long. The anal fin is similar in shape and size to the second dorsal fin. The ventral fins are placed before the pectoral ones. The caudal fin is cut in a straight line.
The number of rays in particular fins is as follows: D1: 8-10, D2: 35-40, A: 36-40, P: 12-14, V: 7 (Fisher *et al.*, 1987; Jardas, 1996). The colour is slate grey above and lighter on sides, the belly is whitish (Relini *et al.*, 1999).

Distribution

European hake inhabit the north-eastern Atlantic from Norway to Mauritania and the entire Mediterranean; in the Black Sea the species lives only along the southern coasts (Jardas, 1996, Relini *et al.*, 1999). According to available data, European hakes are distributed throughout the Adriatic. It is a distinctively euritopic species. Bathymetric distribution of the species in the Adriatic is from only several meters in the coastal area to 800 m in the South Adriatic Pit (Kirinčić and Lepetić, 1955; Županović and Jardas, 1986; Ungaro *et al.*, 1993; Jukić *et al.*, 1999). There are only limited areas to the north of the Po delta in which it is not caught (Jukić and Arneri, 1984; Frattini and Paolini, 1995; Frattini and Casali, 1998). This nectobenthonic species is most abundant at depths between 100 and 200 m, where the catches are mainly composed of juveniles (Ghirardelli, 1959b; Županović, 1968; Jukić and Arneri, 1984; Flamigni, 1983; Giovanardi and Rizzoli, 1984; Bello *et al.*, 1986; Županović and Jardas, 1989; Ungaro *et al.*, 1993; Vrgoč, 2000).
In daylight, the European hake stay on the bottom and move vertically to higher strata at night (Jardas, 1996). In addition to circadian migrations, there are also horizontal migrations as a consequence of searching for food. In the spring months, there are local movements of sexually immature adolescent hakes into the more shallow channel waters of the central

Adriatic between Croatian islands. Adult European hake are mainly caught at depths of 100 to 150 m. In the spring, adult hakes migrate to more shallow coastal waters for spawning. The juveniles display migration patterns in search of food. In the winter period, after spawning, adult fish migrate towards the deeper water, wintering with the juveniles (Županović and Jardas, 1989). In the southern Adriatic the largest individuals are caught in waters deeper than 200 m, whereas medium-sized fish appear in the stratum not deeper than 100 m (Ungaro *et al.*, 1993). European hake prefer muddy bottoms, but are well distributed on other types of bottom as well (muddy-sandy and sandy bottoms). It is most abundant in the open central Adriatic (the Pomo/Jabuka Pit) and further southwards (Županović, 1961a, Županović and Jardas, 1986).

Biological data

According to Jardas (1996), European hake can grow to 130 cm of total length. However, its usual length in trawl catches is from 10 to 60 cm. This is a long-lived species, it can live more than 20 years. In the Adriatic, however, the exploited stock is mainly composed in number of 0+, 1+ and 2+ year-old individuals. On the basis of the vertebral counts of European hake from the northern and central Adriatic, Piccinetti and Piccinetti Manfrin (1971b) found that all specimens analysed belonged to the same population. Similarly, the Adriatic population has the same number of vertebrae as the European hake from the rest of the Mediterranean (Maurin, 1965).
The data about the length-weight relationship are summarised in Table 2. Jardas (1976) found out that the length-weight relationship could be divided into three phases according to the coefficient *b*: juvenile, adolescent and adult.

Table 2. Total Length (TL, cm) – weight (g) relationship.

Author	Sex	*a*	*b*
Matta, 1954	M	-	2.80
	F	-	3.01
Jardas, 1976	M (juven.-adult.)	-	2.625-3.235
	F (juven.-adult.)	-	3.033-2.862
Flamigni, 1983	M (May)	0.0043	3.16
	F (May)	0.0035	3.26
	M+F (May)	0.0032	3.27
	M (November)	0.0025	3.35
	F (November)	0.0029	3.32
	M+F (November)	0.0035	3.25
Marano, 1993	M+F	0.00257	3.29
Ungaro *et al.*, 1993	M	0.00217	3.35
	F	0.00328	3.22
	M+F	0.00257	3.29
Marano, 1996	M+F	0.0055	3.07

In the Adriatic, European hake spawn throughout the year, but with different intensities. The spawning peaks are in the summer and winter periods (Karlovac, 1965; Županović, 1968; Županović and Jardas 1986, 1989; Jukić and Piccinetti, 1981; Ungaro *et al.*, 1993). Hake are partial spawners. Females spawn usually four or five times without ovarian rests. In females in the pre-spawning stage, fish 70 cm long can contain more than 400 000 oocytes (Sarano, 1986). The earliest spawning in the Pomo/Jabuka Pit occurs in winter in deeper water, (up to 200 m). As the season progresses into the spring-summer period, spawning occurs in more shallow water. The recruitment of young individuals into the breeding stock has two different maxima. The first one is in the spring and the second one in the autumn. In the Pomo/Jabuka Pit, both of these maxima can be linked to hake's more intense summer and winter spawning period in the central Adriatic (Županović and Jardas, 1989). The recruitment peaks are in the spring and autumn (Karlovac, 1965). Recruitment does not seem to be related to the parental stock size (Alegria Hernandez and Jukić, 1992). Nursery areas are located close to the Pomo/Jabuka Pit, between 150 and 200 m, on the upper part of the slope, and off the Gargano Cape (Županović, 1968; Jukić and Arneri, 1984; Županović and Jardas 1986, 1989; Frattini and Paolini, 1995; Frattini and Casali, 1998). Karlovac (1965) recorded young hake larvae from October to June, the highest numbers were recorded in January and February. Larvae and postlarvae were mainly distributed between 40 and 200 m; the highest number of individuals was caught mainly between 50 and 100 m. Different data about the size at first sexual maturity of European hake in the Adriatic Sea, given by different authors, are shown in Table 3.

Table 3. Total Length (L_m, cm) at the first sexual maturity.

Author	**Sex**	**L_m (cm)**
Zei, 1949	M	22-30
Županović, 1968;	M	20-28
	F	26-33
Županović and Jardas, 1986	M	20-28
	F	23-33
Ungaro *et al*., 1993	M+F	25-30
Cetinić *et al*., 1999	M+F (Velebit Channel)	24

Differences in the growth dynamics between males and females can be seen in the Tables 3, 4 and 5. Females attain larger size than males, who grow more slowly after maturation at the age of three or four years. Consequently, the proportion of males in the population is higher in lower length classes and proportion of females is higher at greater lengths. In the central and northern Adriatic, females already start dominating the population at lengths of about 30 to 33 cm. In trawl catches over 38 to 40 cm, almost all the specimens are females (Vrgoč, 2000).

Table 4. Total Length (TL, cm) and age (year) data.

Author	**Sex**	**Age (yr)**							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Ghirardelli, 1959b	M+F	18.8	23.0	28.8	38.0				
Županović, 1968	M+F	9	19	28	35	40	44	49	57
Flamigni, 1983	M+F(May)	14.3	21.3	29.0	35.0				
	M+F(Nov.)	19.0	26.2	33.3	39.0				

Table 5. Parameters of the Von Bertalanffy Growth Function (VBGF).

Author	Sex	L_∞ (cm)	K (yr^{-1})	t_0 (yr)	Φ'
Flamigni, 1983	M+F	85	0.12		6.77
Alegria Hernandez and Jukić, 1990	M+F	92.83	0.097	-0.629	6.73
Bolje, 1992	M+F	75	0.12		6.52
Vrgoč, 1995 ("Hvar")	M+F	83.27	0.125	-0.73	6.76
Ungaro *et al*., 1993	M+F	75.68	0.153	0.14	6.78
	F	82.63	0.126	-0.312	6.76
Marano, 1996	M	57	0.17	-0.83	6.31
	F	67.5	0.159	-0.436	6.59
	M+F	67.5	0.144	-0.807	6.49
	M+F(Bhat)	81	0.25	-	7.40
Marano *et al*., 1998b, c	M	72	0.15	-0.005	6.66
	F	84	0.13	0.102	6.82
	M+F	84	0.12	-0.14	6.74
	M+F(Bhat.)	62.2	0.23	-	6.79
	M+F(Surf.)	68	0.25	-	7.05
Vrgoč, 2000	M+F	77.95	0.130	-	6.67
EC XIV/298/96-EN, Ionian and Southern Adriatic	M+F	68.19	0.157	-	6.59
EC XIV/298/96-EN, Adriatic Sea	M+F	85	0.12	-	6.77

Until they are about 16 cm long (first year of life), European hake feed mostly on crustaceans (Euphasiacea, Mysidacea and Amphipoda). During that period, they live predominantly in the Pomo/Jabuka Pit and in the southern Adriatic pit region.
Their migration to the channel regions of the eastern Adriatic coast is linked to the changes of feeding patterns as they start feeding on fish, primarily *Sardina pilchardus, Sprattus sprattus* and *Engraulis encrasicolus*. Other fish prey of European hake are *Scomber scomber, Trachurus* spp. and *Merluccius merluccius*. Cephalopods were also found in hake stomachs (Kirinčić and Lepetić, 1955, Karlovac, 1959; Županović, 1968; Piccinetti and Piccinetti Manfrin, 1971a; Jukić, 1972; Froglia 1973; Jardas, 1976; Ungaro *et al*., 1993).

Evaluation and exploitation

By comparing the catch of European hake during the expeditions "Hvar" and "Pipeta" (1982), in the northern and central Adriatic, Jukić and Arneri (1984) found that the highest catches were during the "Hvar" expedition in depths over 200 m (6.05 kg/hr).

During the "Pipeta" expedition, the highest catches were in the 50 to 100 m stratum (2.96 kg/hr). Jukić and Piccinetti (1981) found that, in the 1970s, catches were about 6 kg/hr. In the southern Adriatic, the CPUE varied from 1985 to 1997 in the range of 1.4 to 9.9 kg/hr (Marano *et al*., 1998b, c).
During the MEDITS expedition (1996-98), in the central and northern Adriatic, the European hake's biomass index was 47.45 kg/km^2 (the average value for the entire region). The highest catches were in the 100 to 200 m stratum (71.80 kg/km^2) and the smallest in the 50 m stratum (14.65 kg/km^2). The proportion of hake in the total demersal fish catch was 16.41% (Vrgoč, 2000).

In the Adriatic, small specimens dominate the catches. Most specimens are under 20 cm TL (Županović, 1968; Jukić and Piccinetti, 1981; Flamigni and Giovanardi 1984; Jukić and Arneri, 1984; Bello *et al*., 1986; Giovanardi *et al*., 1986; Županović and Jardas 1986, 1989; Alegria Hernandez and Jukić, 1992; Ungaro *et al*., 1993; Marano *et al*., 1998b, c; Ungaro *et al*., 1998, Vrgoč, 2000). The proportion of juveniles in the catch of European hake in the Adriatic during the expedition "Hvar" was 72.3% and during the MEDITS expedition, 81.52% (Vrgoč, 2000). In 1972-73, a maximum production (MSY) of 3000-4000 tonnes/year was estimated for the Adriatic Sea (Jukić and Piccinetti, 1981). From the management point of view, an increase of the mesh size at first capture will increase the hake yield (Giovanardi *et al*., 1986; Jukić and Piccinetti, 1987). Kirinčić and Lepetić (1955) and De Zio *et al*. (1998) investigated the catch size structure from the bottom long-line fishery in the Southern Adriatic. The average total length of the European hake was 58.6 cm (Kirinčić and Lepetić, 1955), while De Zio *et al*. (1998) found a median total length of 70 cm. The average catch was 5.6 specimens per 100 hooks.
In the Adriatic, the species is mainly fished with bottom trawl nets, but long-lines and trammel-net are also used. According to the FAO statistics, in the 1980s and 1990s the annual European hake landings in the Adriatic were estimated at 2000 – 4000 tonnes, and this species was the most abundant within the demersal fish group.
Results from global models underlined the overexploitation of the European hake stock since the 1960s (Levi and Giannetti, 1972, Alegria Hernandez *et al*., 1982).
The mortality parameters of the European hake population in the Adriatic are shown in Table 6 and the selectivity of trawl net towards hake in Table 7.

Table 6. Mortality rate coefficients for European hake in the Adriatic.

Author	**M (yr^{-1})**	**F (yr^{-1})**	**Z (yr^{-1})**
Županović, 1967			0.90
Granić and Jukić, 1982			0.77
Alegria Hernandez *et al*., 1982	0.408	0.382	0.790
Flamigni and Giovanardi, 1984	0.25	0.75	0.92 – 1.05
Giovanardi *et al*., 1986			0.88-1.37
Jukić and Piccinetti, 1988			1.12
Marano,1993a; Ungaro *et al*., 1993	0.29	0.81-1.40	1.11-1.69
Marano, 1996	0.38	1.14 F_{max} = 0.23-0.27	1.52(1.22-1.82)
GMS-GRUND, 1998			1.23
Marano *et al*., 1998b, c	0.31	0.92 F_{max} = 0.23	1.23(1.02-1.43)
Vrgoč, 2000	0.25	0.80	1.05
EC XIV/298/96-EN (Ionian Sea and Southern Adriatic Sea)		0.46 – 0.68	
	0.32 (Pauly)	$F_{0.1}$ = 0.18	
	0. 25 (Djabali)	$F_{0.1}$ = 0.14-0.15	
EC XIV/298/96-EN (Adriatic Sea)		0.78-1.08	
	0.25 (Pauly)	$F_{0.1}$ = 0.14-0.17	
	0.21 (Djabali)	$F_{0.1}$ = 0.11-0.14	

Recent time-series studies carried out in the southern and central Adriatic showed an apparent increasing trend of the survey catch rates from 1985 to 1995 and a decreasing trend during the second half of the 1990s (Piccinetti and Piccinetti Manfrin, 1994, Manfrin *et al*., 1998). In the southern Adriatic, recent time-series showed an apparent increasing trend from 1985 to 1993, and a decreasing trend from 1994 to 1997. Italian landings reached the maximum in the first half of the 1990s. In the eastern Adriatic, where the demersal fishery appeared to have developed quickly during the 1990s, a positive yield trend could be observed starting from the 1980s. However, in general a marked decrease could be observed after the relatively high landing of 1993 (Mannini and Massa, 2000).

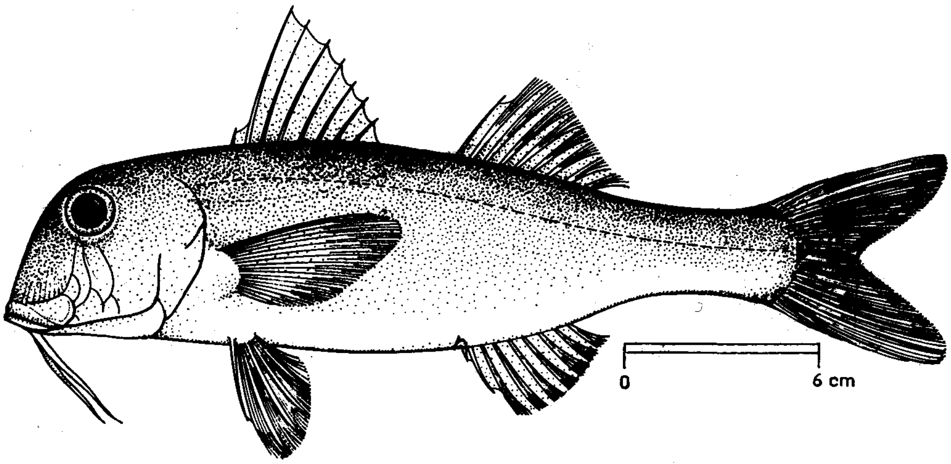
Table 7. Selectivity of trawl towards European hake.

Author	**Mesh size stretched (mm)**	**$L_{50\%}$ (cm)**	**SF**	**SR $L_{25\%}$-$L_{75\%}$**
Levi *et al*., 1971	35.5	9.5	2.67	7.7 – 11.1
Ferretti and Froglia, 1975	35.5	9.0	2.8	7.7 – 11.1
	42.0	11	2.6	9.5 – 12.5
Jukić, 1975	40	10.5	2.6	-
	41.4	13.2	3.2	-
	55.2	19.3	3.5	-
	60	21.4	3.6	-
	64.6	30.2	4.7	-
Jukić and Piccinetti, 1987	41	13.9	3.4	-
	55	19.7	3.6	-
	65	26.8	4.1	-
	40	12.4	3,1	-
	40	12.0	3.0	-
Marano *et al*., 1998b, c	36	8.4	2.09	-

Mullus barbatus (Linnaeus, 1758)

Family: Mullidae

EN: Red mullet
SQ: Barbuni
HR: Trlja od blata
IT: Triglia di fango
SL: Bradač



Species description

The body of Red mullet is long strong, and laterally slightly flat. The head is relatively short; the snout is short as well, with a steep anterior profile. The eyes are positioned near the top of the head. The mouth is small, positioned low on the head. There are two barbels under the mouth aperture. They have a sensory function and are used in searching for prey. The number of rays in the fins is the following: D1:VII-VIII, D2: I+7-8, A: II+6-7, P: 15-17, V: I+5 (Jardas, 1996).
The colour is uniformly pink, the back is darker and the belly is white. The fins are without any well-defined coloration (Tortonese, 1975; Fisher *et al.*, 1987; Jardas, 1996, Relini *et al.*, 1999).

Distribution

The red mullet is distributed in the eastern Atlantic - from the North Sea and England to Senegal and in the Mediterranean. It is uniformly distributed in all parts of the Adriatic (Jardas, 1996). This is a benthic species, found mostly on muddy bottoms in depth range of 5 to 250 m (Relini *et al.*, 1999). It prefers the more shallow waters of the northern and central Adriatic, i.e. depths above 100 m, while only few specimens may be caught in deeper waters (Jukić and Piccinetti, 1981). Although the species is widely distributed, the relative index of the population abundance decreases with depth (Haidar, 1970; Jukić, 1972; Jukić and Arneri, 1984; Županović and Jardas, 1989; Jukić *et al.*, 1999, Vrgoč, 2000). During the spring, red mullet is found mostly along the eastern coast, on sandy bottoms, and in the autumn on the entire Adriatic Sea shelf (Arneri and Jukić, 1986). Haidar (1970) showed that in the central and northern Adriatic, there are two migration types in this species: the migration of the young fish from the coast towards the open sea and the spring migration of adult spawning fish towards channels region along the Croatian coast at depths between 50 and 85 meters. Other authors found similar inshore-offshore behaviour (Scaccini, 1947a; Županović, 1963; Jardas, 1996). Jukić and Piccinetti (1981) found that adult specimens did not migrate significantly during the year and migrations were limited to 100 m isobath. Županović and Jardas (1989), however, did not notice significant migrations in the Pomo/Jabuka Pit region. So, it seems that the area is primarily inhabited by adult specimens in the second year of their life (Županović, 1963). Generally, the population abundance decreases with depth (Haidar, 1970; Jukić, 1972; Merker and Ninčić, 1973; Jukić, 1975; Županović and Jardas, 1989; Vrgoč, 2000). Regarding the type of sediment, Županović and Jardas (1989) found in the Pomo/Jabuka Pit region that the abundance of this species was higher at stations with a rugged type of sediment, which, at the same time, correlates with the shallower areas. Jukić and Piccinetti (1981) pointed out that red mullet prefer muddy and sandy bottoms, e.g. the regions with the highest availability of its food.

Biological data

According to Jardas (1996), red mullet grow up to about 30 cm (about 0,5 kg). The usual total length in catches is 10 to 20 cm. On average, females have greater body length than males (Jardas, 1996). They also grow faster, which can be already noticed in the first year of their life (Haidar, 1970). Therefore, almost all the bigger specimens are females (28 to 29 cm). Males do not grow more than about 20 cm (Relini *et al*., 1999).
The length-weight relationship shows that the growth of this species is isometric (Table 8) There are two different inflexion points in the length-weight relationship of females, one at 12-13 cm (corresponding to the first sexual maturity) and the other one between 16 and 17 cm. There is only one male inflexion point, between 11,5 and 12 cm and it corresponds to the length at first sexual maturity (Županović and Jardas, 1989).

Table 8. Total Length (TL, cm) – weight (g) relationship.

Author	Sex	*a*	*b*
Županović, 1963	M	0.00655	3.179
	F	0.00847	3.082
Haidar, 1970	M+F (small)	0.0088	3.052
	M+F (large)	0.0051	3.262
Froglia and Magistrelli, 1981 (in Županović and Jardas 1989)	M+F (juveniles)	0.00665	3.223
Jukić and Piccinetti, 1981	M	0.00508	3.2624
	F	0.0088	3.0523
Marano, 1994; Ungaro *et al*., 1994	M+F	0.008	3.09
Marano,1996	M+F	0.0125	2.970
GMS-GRUND, 1998	M+F	0.000012	3.015

According to all the authors, Red mullet spawns in the Adriatic Sea in late spring and summer (May, June, July). According to Haidar (1970), males have two types of sexual cycle: specimens smaller than 14 cm (three years according to this author) have annual sexual cycles, with the spawning phase from May to July, whereas bigger specimens have biennial sex cycle with the reproductive phase from May to December. Females always have an annual reproduction cycle and they spawn from April to May. Red mullet reach sexual maturity in the first year of life at lengths between 10 and 14 cm (Table 9). The most intensive spawning occurs at depths of 60 to 70 m. After the spawning, post larvae move towards shallower water (30-40 m) and coast (Županović and Jardas, 1989). Larvae, post larvae and juveniles up to 4-5 cm of total length are pelagic. Afterwards, individuals move towards sandy coastal areas and become demersal. They concentrate particularly near river mouths and sometimes enter rivers for several hundreds of meters (Scaccini, 1947a). Later, they start their dispersion towards sandy, muddy and gravel grounds at depths between 10 and 250 m (Relini *et al*., 1999). A high density of larvae was found in the Central Adriatic at 50 to 100 m depth (Guescini *et al.*, 1983). The sex ratio is extremely variable, depending on the different zones studied. Županović (1963) demonstrated, through analysis of the literature, that in the eastern Mediterranean, including the Adriatic Sea, females predominate while an inverse situation is observed in the Western Mediterranean.

In the Pomo/Jabuka Pit region, males are dominant at lengths up to 17 cm, while females dominate at greater lengths, most probably because of different growth rates of males and females (Županović and Jardas, 1989). This was confirmed by Vrgoč (2000) in the central and northern Adriatic, during the MEDITS expedition it was found that males were dominant in the population up to 14 to 15 cm; above 15 cm, females were dominant.

Table 9. Total Length (L_m, cm) at the first sexual maturity.

Author	Sex	L_m (cm)	Age (yr)
Zei and Sabioncello, 1940	M+F	11-14	1
Scaccini, 1947a	M+F		2
Županović, 1963	M	11-12	
	F	12-13	
Haidar, 1970	M	10.5	1
	F	12	1
Jukić and Piccinetti, 1981	M	10,5	1
Marano *et al.*, 1998b, c	M+F	11-14	
Relini *et al.*, 1999	M	11-13	1
	F	12-14	1
Vrgoč, 2000	M	10.5-11.5	
	F	10 – 11	

Table 10. Total Length (TL, cm) and age (year) data.

Author	Sex	Age (yr)							
		1	2	3	4	5	6	7	8
Scaccini, 1947b	M	12.63	17.47	20.42	23.31	23.32	24.19	24.88	25.50
	F	12.71	20.26	23.94	25.93	27.04	27.93	28.66	29.34
Bougis and Mužinić, 1958	M	10-11	14.0	15.6	16.6	17.7			
	F	12-14	18.0	18.9	20.4	21.8			
Haidar, 1970	M	10.1	12.9	14.2	15.1	15.7			
	F	12.2	15.2	16.5	17.5	18.3			
Jukić and Piccinetti, 1981	M	10.0	12.5	14.0	15.0	15.4			
	F	12.3	15.1	16.3	17.4	18.0			

There are some distinct differences in the growth dynamics between males and females as can be seen in Tables 9, 10 and 11. Females are 1 to 2 centimetres longer than males of the same age (Županović and Jardas, 1989). The growth dynamics change also through the year; Scaccini (1947b) and Haidar (1970) found that there is almost no growth during the winter months. However, the methodology used to determine the age could have significantly influenced the results (Relini *et al*., 1999).

Table 11. Parameters of the Von Bertalanffy Growth Function (VBGF).

Author	**Sex**	**L_∞ (cm)**	**K (yr^{-1})**	**t_0 (yr)**	**Φ'**
Scaccini (in Levi *et al*., 1994)	M+F	27.49	0.5	-0.25	5.93
Jukić and Piccinetti, 1988	M+F	27.0	1.8		7.18
Marano, 1994; Ungaro *et al*., 1994	M+F	19.70	0.360	-1.18	4.94
Vrgoč, 1995 ("Hvar")	M+F	27.75	0.274	-0.616	5.35
Marano, 1996; Marano *et al*., 1998b, c	M	27	0.184	-1.92	4.90
	F	34.5	0.156	-1.53	5.22
	M+F	31.5	0.182	-1.45	5.19
	M+F (Bhatt)	26.3	0.45		5.74
Ardizzone, 1998	M+F	27.50	0.50		5.93
Marano, 1998b, c	M	22.5	0.24	-1.29	4.80
	F	26.2	0.23	-1.41	5.06
	M+F	22.5	0.38	-0.63	5.26
	M+F (Bhatt)	25.4	0.25		5.08
	M+F (Surf.)	23	0.52		5.62
Vrgoč, 2000	M+F	26.86	0.295		5.36
EC XIV/298/96-EN, Ionian and Southern Adriatic	M+F	21.72	0.31		4.99
EC XIV/298/96-EN, Adriatic Sea	M+F	27.5	0.50		5.94

The red mullet is a carnivorous species. The bulk of its food is made of endo-, meso- and epi-biontic sea organisms. Jukić (1972, 1975) found that, in the central Adriatic channels, the Red mullet's food consists of Polychaeta, Lamellibranchiata and Crustacea. The same prey was described as the dominant food of this species by Haidar (1970) and Froglia (1988). It is also observed that the larger specimens eat bigger prey (Froglia, 1988). Jukić and Županović (1965) showed that, in the eastern Adriatic, the red mullet eat continuously throughout the year but more so during summer and autumn, which is probably in relation to the water temperature.

In the Adriatic, the main fish predators of juvenile and adult red mullet are *Lophius piscatorius, Raja clavata, Trygon pastinaca, Galeus canis, Zeus faber* and *Merluccius merluccius* (Haidar, 1970).

Evaluation and exploitation

Although the red mullet is distributed in the entire Adriatic, the density of the population is not the same in terms of space as well as time. For example, Arneri and Jukić (1986) found that the biomass index between Italian and Croatian waters is about 1:4. It was also observed that the population abundance decreased with depth (Županović and Jardas, 1989).

In the period from 1989 to 1994, the CPUE was from 0,33 to 2,45 kg/h in the southern Adriatic and from 0,96 to 1,43 kg/h in the central and eastern Adriatic (EC XIV/298/96-EN, 1996).

During the MEDITS expedition (1996-1998), the average biomass index for red mullet in the central and northern Adriatic was 16,36 kg/km^2. The highest population density was found in the 50 to 100 m stratum (28,81 kg/km^2). The proportion of this species in the total catch of the demersal fish was 5,66% (Vrgoč, 2000). The average length value was 14,43 cm and it increased with depth.
By comparing red mullet catch during the expeditions "Hvar" and "Pipeta", Jukić and Arneri (1984) found a significant decrease of the catch per unit effort in the open central Adriatic region, primarily in depths under 50 m. However, these data are not completely compatible because of certain differences in the sampling methodology.

Vrgoč (2000) did not find significant changes in the proportion of red mullet in the total catch of demersal fish species when comparing the data collected during the expeditions "Hvar" and "MEDITS". During the "Hvar" expedition, Red mullet made about 6,27% of the catch and was the fifth species according to the proportion of catch. This proportion was 6,79% during the MEDITS expedition (ranking as fourth species in the catch). Differences in medium body lengths of specimens caught were also low ("Hvar" 14,14 cm, MEDITS 14,40 cm). The problem here, as in the previous comparison, is the incompatibility of data because of the existing differences in technical characteristics of the sampling tools.

In the summer and autumn periods, young specimens are dominant in the population. In some coastal areas of the Western Adriatic Sea, this fraction is 60-90%, with catch rates up to 100 kg/h (Froglia, 1988). The length frequency data analysis showed a massive presence of newcomers during the autumn surveys and, during the spring surveys, a modest number of individuals of age close to one year (Piccinetti and Piccinetti Manfrin, 1994; Ungaro *et al*, 1996). Individuals older than one year were always a minor part of the catch (near 5% in autumn and 20% in spring) in the surveys performed in these seasons (Relini *et al*., 1999).

The red mullet mortality rates in the Adriatic are summarized in Table 12. They show a high exploitation level of the species. Nevertheless, Piccinetti and Piccinetti Manfrin (1994) and Marano *et al*., (1998c) did not find a clear trend in changes of the CPUE in the Adriatic. Using the Beverton and Holt model (Y/R), Ungaro *et al*., (1994) found an optimum exploitation during 1991-1992.

Mannini and Massa (2000) analysed trends of the Red mullet landings in the Adriatic from 1972 to 1997. The landing of red mullet, although subject to fluctuations, showed an overall increase. This positive trend seems to be continuing in the western Adriatic, whereas the eastern Adriatic fishery landings decreased during the second half of the 1990s.

Table 12. Mortality rate coefficients for red mullet in the Adriatic.

Author	M (yr^{-1})	F(yr^{-1})	Z (yr^{-1})
Arneri and Jukić, 1986			2.47 –4.37 (age 0 – 1)
			1.64
Haidar, 1970	-	-	0.64
Jukić and Piccinetti, 1988			1.64
Piccinetti and Jukic, 1988			1.45-1.63
Marano *et al*., 1994	0.43	0.10 – 0.64	0.53-1.07
Ungaro *et al.,* 1994	0.43		1.13 – 1.28
Marano, 1996	0.77	1.11 F_{max}=0.6-0.85	1.88(1.61-2.15)
Ardizzone, 1998	0.91 (Pauly) 0.51 (Djabali)	$F_{(obs)}$=2.60 $F_{(0,1)}$=1.00	
GMS-GRUND, 1998			2.99
Marano *et al*., 1998b	0.31	0.92	1.23(1.02-1.43)
Marano *et al*., 1998c	0.43-0.77		1.2-1.9
Vrgoč, 2000	0.58	0.90	0.61
EC XIV/298/96-EN (Ionian Sea and Southern Adriatic Sea)		$F_{(obs)}$=0.65-1.28	
	0.69 (Pauly)	$F_{(0,1)}$=0.6-1.63	
	0.41 (Djabali)	$F_{(0,1)}$=0.36-0.65	
EC XIV/298/96-EN (Adriatic Sea)		$F_{(obs)}$=0.91-4.09 (obs)	
	0.91 (Pauly)	$F_{(0,1)}$= 0.95-1.85	
	0.51 (Djabali)	$F_{(0,1)}$=0.52-0.79	

In the Adriatic, red mullet is almost exclusively fished with bottom trawl nets. Smaller quantities are fished with trammel-nets as well. The total annual catch is about 2000 tonnes. The data about the selectivity of trawl to the red mullet population are shown in Table 13. Jukić and Piccinetti (1987) indicate that, in the long-term, the enlargement of the mesh size on the cod-end would have positive consequences on catches of this species in the Adriatic.

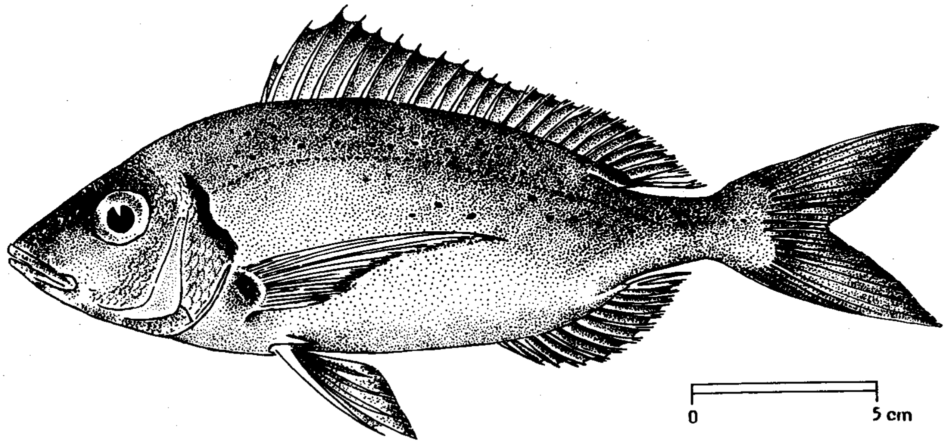
Table 13. Selectivity of trawl towards red mullet.

Author	Mesh size stretched (mm)	$L_{50\%}$ (cm)	SF	SR $L_{25\%}$-$L_{75\%}$
Froglia and Galli, 1970	22	7.5	2	6.8 – 8.2
Levi *et al*., 1971	35.5	8.3	2.33	7.4 – 9.0
Jukić and Piccinetti, 1987	41	12.0	2.9	
	55	18.0	3.3	
	65	19.4	3.0	
	40	11.4	2.8	
	40	11.6	2.9	
	51	12.9	2.5	
Vrgoč, 1995 (Hvar)	40	12.11		11.13 – 13.02
Marano *et al.,* 1998c	36	8.37	2.09	

Pagellus erythrinus (Linnaeus, 1758)

Family: Sparidae

EN: Common pandora
SQ: Spalca e kuqe
HR: Arbun, rumenac
IT: Pagello
SL: Ribon



Species description

The body of the Common pandora is long, oval and laterally flat. The diameter of the eye is much shorter than the length of the snout; the pectoral fins are pointed, of the same length as head. The caudal fin is big and forked. The number of fin rays is the following: D: XII+9-11, A: III+8-9, P: 15, V: I+5.

The colour is pink-red with a silvery glint. The sides are paler and the belly is whitish. There are several small bluish spots on the back and sides of the grown specimens. The inside of the mouth is whitish or greyish. Sometimes a dark red mark is present at the base of the last dorsal rays (Tortonese, 1975; Fisher *et al*., 1987; Jardas, 1996; Relini *et al*., 1999).

Distribution

The common pandora is distributed in the eastern Atlantic - from Scandinavia to Senegal, and in the entire Mediterranean. It is rare in the Black Sea (Fisher *et al*., 1987; Jardas, 1996; Relini *et al*., 1999). It is spread throughout the Adriatic, but more so in channels than in open sea (Jardas, 1996). According to the data from the "Pipeta" expedition, this species inhabits depths up to 150 meters, mostly among sandy coastal sediments (Jukić and Arneri, 1984). However, Rijavec and Županović (1965) and Županović and Rijavec (1980) show that the distribution of the species in the central Adriatic is strictly limited by the 100 meters isobath. According to these data, the common pandora seems to be a typical species of the circalittoral zone. The edaphic factors do not seem to play a decisive role in the distribution of this species; primarily, the kind and amount of accessible food and hydrography seem to be decisive (Rijavec, 1975; Županović and Rijavec, 1980). The seasonal migration of common pandora in shallow waters was observed in the insular zone of the central Adriatic (Županović and Rijavec, 1980). A similar phenomenon was observed by Rijavec (1975) in the Boka Kotorska Bay.

Biological data

The common pandora can grow up to 60 cm (3 kg), but its usual length in catches is 10 to 30 cm. The length range of common pandora caught during the "Hvar" expedition was from 4 to 26 cm (average value 15,58 cm). During the MEDITS expedition, the range was from 4 to 27 cm (average value 14,72 cm) (Vrgoč, 2000), in the same area. Generally, in deeper water, longer fish were caught.

Common pandora is a protogynous hermaphroditic species. In the beginning all individuals are females and then they become males. Because of this, the proportion of females among smaller specimens is 100% (up to 13 cm), and it decreases with the increase of length. Males over 16 cm are dominant, and when over 23 cm their proportion is 100% (Rijavec and Županović, 1965). The average difference in body length between two sexes is about 2,8 cm. Because of protogonic hermaphroditism, females are always dominant in the population. So, during the expedition MEDITS, the sex ratio was 83% females and 17% males. It was observed that some specimens were males from the start, whereas a number of females do not ever change their sex, i.e., they remain females even at their greatest body lengths (Vrgoč, 2000). Data from different authors on the body length at which change of sex occurs are presented in Table 14.

Table 14. Total Length (L_m, cm) at first sexual maturity and sex inversion.

Author	**Area**	**L_m (cm)**	**Sex inversion**	
			TL (cm)	**Age (yr)**
D'Ancona, 1949	Northern Adriatic		17-17.5	3
Zei and Županović, 1961	Cental Adriatic		17.0	3-4
Rijavec and Županović, 1965	Central Adriatic	11-12	16-17	
Županović and Rijavec, 1980	Central Adriatic	11-12	16-17	2-3
Relini *et al*., 1999	-	-	17-18	3
Vrgoč, 2000	Northern and Central Adriatic	12.5	16	-

Two inflexion points can be observed in the length - weight relation. The first one, between 11 and 12 cm, corresponds to the first stage of female sexual maturity. The second point is situated between 16 and 17 cm, and is linked to the sex inversion (Županović and Rijavec, 1980). Rijavec (1975) also found two points of inflexion (12,5-13,5 cm and 18,5-19,5 cm) in the Boka Kotorska Bay.

Table 15. The Total Length (TL, cm) – weight (g) relationship.

Author	**Area**	***a***	***b***
Rijavec and Županović, 1965	Middle Adriatic	0.134	2.981
Bolje 1992	Gulf of Trieste	0.011	3.08

The length and age data of specimens (determined by scales) are shown in Table 16 and the growth curve parameters in Table 17. From these data, it is obvious that females grow faster than males.

Table 16. Total Length (TL, cm) and age (year) data.

Author	Sex	Age (yr)					
		1	2	3	4	5	6
Rijavec and Županović, 1965	M	13.20	15.15	17.86	21.02	24.42	26.70
	F	13.40	15.36	17.18	21.15	24.10	-
	M+F	13.30	15.20	17.49	21.20	24.21	26.70

Table 17. Parameters of the Von Bertalanffy Growth Function (VBGF).

Author	Sex	L_∞ (cm)	K (yr^{-1})	t_o (yr)	Φ'
Rijavec and Županović, 1965	M+F	37.88	0.20	-	5.66
Rijavec, 1975	M+F	30.91	0.239	-	5.43
	M+F	30.0	0.245	-	5.40
Županović and Rijavec, 1980	M+F	37.88	0.20	-0.093	5.66
	M+F	37.7	0.201	-	5.65
	M	-	0.165	-	
	F	-	0.30	-	
Jukić and Piccinetti, 1988	M+F	60.0	0.20	-	5.68
Bolje, 1992	M+F	33.0	0.29	-0.33	5.76
Vrgoč, 1995	M+F	29.32	0.229	-1.004	5.28
Vrgoč, 2000	M+F	31.05	0.205	-	5.29

In the Adriatic, *Pagellus erythrinus* spawn once a year: in the spring and the beginning of summer (Županović, 1961b; Grubišić, 1980; Bolje, 1992; Jardas, 1996). The data about the length at the first sexual maturity are shown in Table 14.

In analyses of hydrographic changes and common pandora population abundance, regular movements from shallow coastal water towards deep sea (but all within the 100 m isobath) were noted in the period from October to April and in the opposite direction from May to October. These migrations were more or less distinct in some years. The movement towards deeper sea in the winter-spring period is for reproductive reasons, and the opposite movement in the summer-autumn period, is for trophic (alimentary) reasons (Županović and Jardas, 1989).

The species is essentially carnivorous and feeds on crustaceans, worms and other marine invertebrates (Relini *et al.*, 1999). By analysing common pandora's alimentation in the Kaštela Bay, Jukić (1972) found that the bulk of the food was made up of invertebrates from epi and endo fauna: Polychaeta, Crustacea Decapoda and Lamellibranchiata, whereas other groups of organisms such as, for example, Isopoda, Ophiuroida, Pisces and Cephalopoda can rarely be found in stomachs. Rijavec and Županović (1965) came to similar conclusions in the channels area of the eastern central Adriatic.

The intensity of the alimentation is not the same throughout the year. It declines in the winter period and in May and June, which is related to spawning. In July, after spawning, the food quantity in stomachs shows maximal values. A strong correlation between the alimentation intensity and the sea temperature was also established (Jukić and Županović, 1965; Jukić, 1972).

Evaluation and exploitation

By comparing the common pandora catches during the expedition "Hvar" to those during the expedition "Pipeta" in the same area, Jukić and Arneri (1984) found that the CPUE had been considerably smaller during the expedition "Pipeta". Because of the efficiency of the Pipeta trawl, it is believed that the observed decrease in catch rate is largely an underestimate of the true one. During the expedition MEDITS in the north and central Adriatic, common pandora was most abundant in the 50 to 100 m stratum (10,46 kg/km^2) and in stratum to 50 m (5,68 kg/km^2). It was rarely found in strata below 100 m (only 1% of fished specimens) (Vrgoč, 2000).

Using the swept area method, Bolje (1992) estimated *P. erythrinus*'s biomass in the Gulf of Trieste at 15 tonnes and the MSY at 2,6 tonnes (the Gulland method, 1968) or 4,3 tonnes (the Pauly method, 1984).

Mortality coefficients of the common pandora population in the Adriatic, estimated by different authors, are summarised in Table 18.

Table 18. Mortality rate coefficients for common pandora in the Adriatic.

Author	**Area**	**M (yr^{-1})**	**F(yr^{-1})**	**Z(yr^{-1})**
Rijavec and Županović, 1965	Central Adriatic	-	-	1.50
Rijavec, 1975	-	-	-	0.63
Županović and Rijavec, 1980	Central Adriatic	-	-	1.50-1.57
Jukić and Piccinetti, 1988	-	-	-	1.10
Bolje, 1992	Gulf of Trieste	0.58	0.06	0.64
Vrgoč, 2000	Northern and Central Adriatic	0.44	0.38	0.83

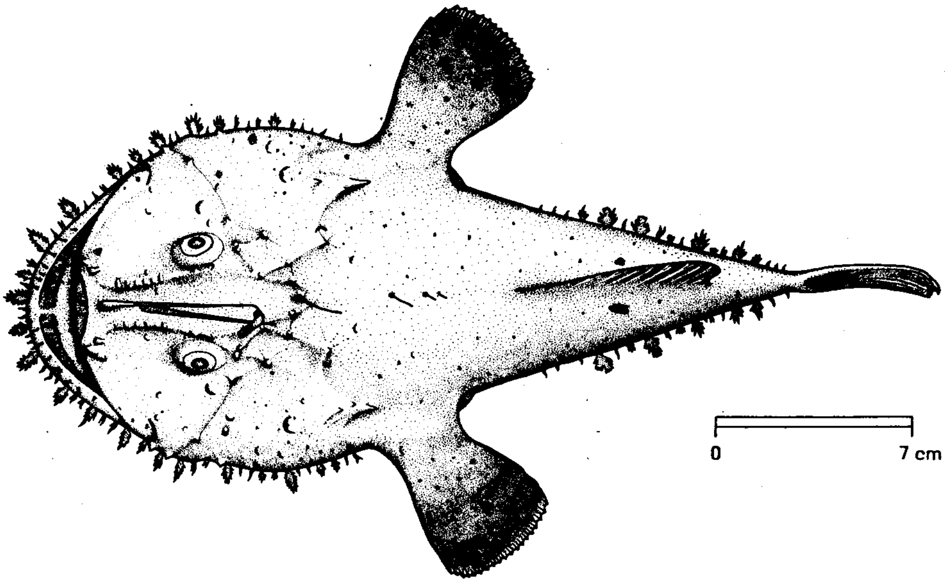
In the Adriatic, common pandora is fished mostly with a bottom trawl net. Long-line and other hook tools are used as well. The selectivity coefficients of trawls with different mesh sizes on the cod-end are shown in Table 19. It is apparent that the L50% of the usual trawl nets in the Adriatic (about 40 mm) is very low (under 12 cm) and that the change of length at first capture should be one of the measures of protection of the species (Jukić and Piccinetti, 1987).

Table 19. Selectivity of trawl towards *P. erythrinus*.

Author	**Mesh size stretched (mm)**	**$L_{50\%}$ (cm)**	**SF**	**SR $L_{25\%}$-$L_{75\%}$**
Jukić and Piccinetti, 1987	41	11.8	0.89	-
	55	16.4	0.90	-
	65	20.5	0.91	-
	51	12.2	0.95	-
Jukić and Piccinetti, 1988	40	11.8	0.89	-
Vrgoč, 1995	40 (Hvar)	11.30	-	10.70-12.32

Lophius budegassa (Spinola, 1807)
Family: Lophiidae

EN: Black-bellied angler
SQ: Zhabe deti
HR: Grdobina žutka
IT: Budego
SL: Mala morska spaka



Species description

The form of *Lophius budegassa* is very similar to *Lophius piscatorius*, its head is proportionally less wide, the skin endings on the body's brim are less developed, the caudal shaft is longer and thinner, and the peritoneum is black. At the end of the first dorsal spine, there is a fleshy appendage which is a simple pennant-like flap. The number of rays, in particular fins, is the following: D1: VI, D2: 8-10, A: 8-9, P: 20-24, V: 6.
The colour is yellowish-brown to pink-grey. Sometimes it has dark stains or white spots (Fisher *et al*., 1987; Jardas, 1996; Relini *et al*., 1999).

Distribution

This species is distributed in the eastern Atlantic (from England and the North Sea to Senegal) and in the entire Mediterranean. This is a demersal fish. It lives on soft bottoms, but does not prefer any specific type of sediment (Tortonese, 1975, Jardas, 1996, Fisher *et al*., 1987).
The Black-bellied angler is widespread in the Adriatic Sea, in the Croatian channel regions, and in the open sea. It is more abundant than *L. piscatorius*. Their ratio is 1:5,7 in favour of *L. budegassa* according to the data of the "Hvar" expedition, and 1:1,74 according to data from the middle Adriatic for the 1956-1967 period (Jardas, 1987).
According to the Jardas (1987), the depth range of *L. budegassa* is between 13 and 404 m. Most individuals, however, were fished between 90 and 170 m. Therefore, it is quite likely that this species prefers depths between 90 and 170 m (Jardas, 1987). In the southern

Adriatic, Merker and Ninčić (1973) recorded *L. budegassa* at depth between 20 and 500 m. In the central Adriatic, *L. budegassa* was fished more intensively in the north-eastern edge of the Pomo/Jabuka Pit and in the transitive areas towards the channels, whereas in the deepest central areas it was either not fished or only few specimens were noted (Jukić, 1975; Županović and Jardas, 1989)

Although some authors find that the catches are larger on muddy bottoms (Jukić and Crnković, 1974; Grubišić, 1982), what seems to be decisive for the distribution of the species is not the type of sediment, but the depth (Jardas, 1987, Županović and Jardas, 1989).

Biological data

The biological and ecological characteristics of this species like those of *L. piscatorius,* have in general been poorly studied in the Adriatic. Šoljan (1948) showed that the maximum length of *L. budegassa* did not exceed 80 cm. Similar data were reported by Grubišić (1982), Bini (1968-70), Tortonese (1975) and Jardas (1996). In the study of Jardas (1987), the length of specimens in the sampled population was from 4 to 74 cm, and juveniles were predominant. Specimens with lengths corresponding to those in the early stages of the benthic way of life were found in channels as well as in the open sea (Table 20). This shows that the species reproduces in both regions (Jardas, 1987). The percentage of adults was higher in the channel regions than in the open sea (Županović and Jardas, 1989).

Table 20. The Total Length (TL, cm) – weight (g) relationship.

Author	Sex	*a*	*b*
Jardas, 1987	M+F (juveniles)	0.0190	2.089
	M+F (adults)	0.0123	3.024

Jardas (1987) analysed the length-weight relationship of the black-bellied angler in the Adriatic. He found the inflexion point at lengths of 33 and 34 cm, which can be correlated to the length at the first sexual maturity (weight 480-570 g) (Table 21).

This species spawns at the end of spring and in the beginning of summer. Specimens are pelagic until several centimetres long (Jardas, 1996).

Table 21. Probable Total Length (L_m, cm) at the first sexual maturity.

Author	Sex	L_m (cm)
Jardas, 1987	M+F	33-34

By analysing the stomach content of the species, Jardas (1987) found that the bulk of the food was made up of fish (*Trisopterus minutus capelanus, Argentina sphyraena* and *M. merluccius* the most), then cephalopods and occasionally crustaceans.

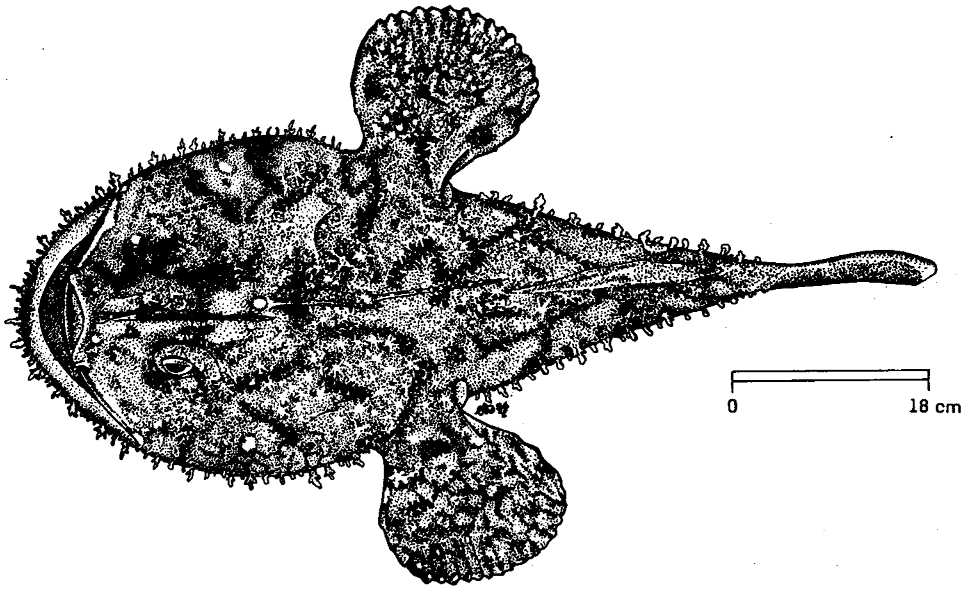
Evaluation and exploitation

This species is, in general, not abundant in the Adriatic; with only few specimens occurring in a haul (Jukić, 1975; Jardas, 1987). During the expedition MEDITS 1996-1998 in the central and northern Adriatic, the average catch was 5,68 kg/km^2, thus the proportion of the

species in the total demersal fish catch was about 2%. It was lowest in the surface to 50 m stratum (1,73kg/km^2), and highest from 100 to 200 m (8,36 kg/km^2) (Vrgoč, 2000).
By comparing the catch of this species during the "Hvar" and MEDITS expeditions in the same area of the open central and northern Adriatic, the same author found that the catch had been 8,55 kg/km^2 during the expedition "Hvar" and 6,67 kg/km^2 during the expedition MEDITS. In the Adriatic, the black-bellied angler is fished primarily with bottom trawl nets. However other tools are also used as well (trammel-nets, for example).

Lophius piscatorius (Linnaeus, 1758)
Family: Lophiidae

EN: Angler
SQ: Henez deti
HR: Grdobina
IT: Rana pescatrice
SL: Morska spaka



Species description

The Angler has a very big, flat head. Its mouth is wide and round; the lower jaw (mandibula) is projected. Its body, bare and slimy, is significantly narrower than the head and slightly flat. On the brim of the body, (the edge between belly and sides), there is a large number of fringed skin endings. The first dorsal fin is composed of six separated rays. The front one is the longest and ends with a small forked flag. The number of rays in particular fins is the following: D1: VI, D2: 11-12; A: 9-11, P: 23-28, V: 6.
The colour is olive-brown, usually with black stains. Peritoneum is pale. (Fisher *et al*., 1987; Jardas, 1996; Relini *et al*., 1999).

Distribution

L. piscatorius lives throughout the Mediterranean basin and in the eastern Atlantic from Norway to Senegal (Tortonese, 1975, Jardas, 1996). It is a demersal sedentary species. It resides mainly on soft bottoms, but does not prefer any specific sediment. The angler is distributed throughout the Adriatic Sea, in the channel regions, and in the open sea, but is rare (Jukić, 1975; Jukić and Piccinetti, 1981; Grubišić, 1982, Jardas, 1987). During the expedition MEDITS 1995 it was not fished in the northern Adriatic (Relini *et al*., 1999). In the Adriatic Sea, the angler is, in general, distributed on the continental shelf at depths from 20 to 200 m. It prefers depths from 100 to 200 m (Županović and Jardas, 1989). In the open central and northern Adriatic, it is distributed from 70 to 140 m (Jardas, 1987) and in the southern

Adriatic from 20 to 400 m (Merker and Ninčić, 1973). Karlovac and Karlovac (1968) showed that the juvenile specimens were fished more on soft bottoms while adults were found on the various types of sea bottoms. The type of bottom does not seem to be important for the distribution of the species. What seems to be an important ecological factor for the distribution and abundance is depth (Jardas, 1987).

Biological data

The biological and ecological characteristics of the angler are, in general, poorly investigated in the Adriatic. Its maximal length is 2 m (40 kg), but is usually 20 to 100 cm long (Bini, 1968; Tortonese, 1975; Jardas, 1996).

This species spawns from February until July. Specimens shorter than 7 cm are planktonic. Only later do they transfer to the benthic way of life (Bini, 1968; Jardas, 1996). Nevertheless, Karlovac and Karlovac (1968) found 4 cm long specimens who had the typical benthic form and specimens over 7 cm that were still in plankton. The dominance of juvenile specimens and those who have just transferred to the benthic lifestyle in the Pomo/Jabuka Pit region, shows that the central Adriatic is a region of intense reproduction of the species although its planktonic stages have not be found there (Karlovac and Karlovac, 1968; Jardas, 1987; Županović and Jardas, 1989).

The angler feeds mostly on fish, less on crustaceans, cephalopods have only a small role in its alimentation. The main fish preys are *T. minutus capelanus* and *Argentina sphyraena. N. norvegicus* was also found in stomachs (Jardas, 1987).

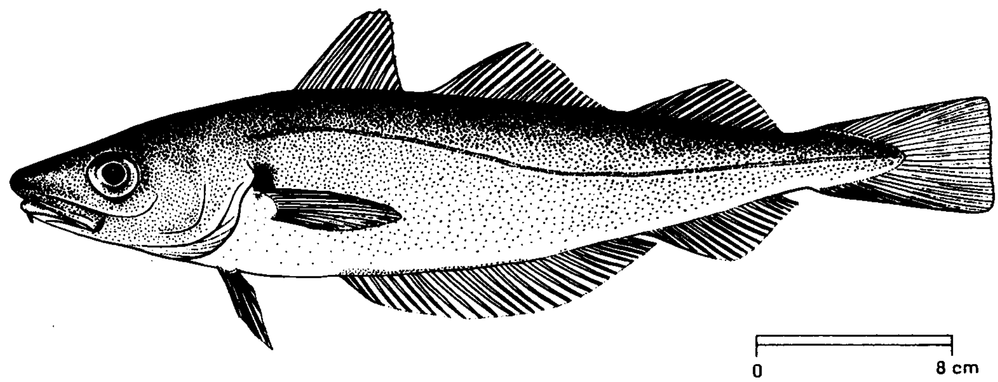
Evaluation and exploitation

In the southern Adriatic, during the expedition MEDITS 1995, the relative abundance of this species ranged from 3 to 18 kg/km^2 (Relini *et al.*, 1999). During the expedition MEDITS 1996-1998 in the central and northern Adriatic, the catch was small (0,80 kg/km^2), although it was fished in all the depth strata (Vrgoč, 2000). By comparing the catches during the expeditions "Hvar" and MEDITS in the open central and northern Adriatic, the same author found that the average values were 4,20 kg/km^2 and 1,01 kg/km^2. However, because of certain differences in the sampling methodology, these data are not completely comparable (see previous description of expeditions "Hvar" and MEDITS).

In the Adriatic, the angler is fished mainly with bottom trawl nets and less with other fishing gears (for example trammel-nets).

***Merlangius merlangus* (Linnaeus, 1758)**
(Sin. *Gadus merlangus* Linnaeus, 1758;
Odontogadus merlangus euxinus Svetovidov, 1935)
Family: Gadidae

EN: Whiting
SQ: Merluci tripendesh
HR: Pišmolj, molet
IT: Merlano
SL: Mol



Species description

The body of the Whiting is long and laterally slightly flat. The upper jaw is visibly projected. Under the tip of the chin, there is a small worm-like barbel. There are three dorsal and two anal fins. The first anal fin is significantly longer than the other one; it begins under the first dorsal fin's base. The ventral fins are anterior to the pectoral ones and are under the operculum. The caudal fin is cut in a straight line. The scales are tiny. The fin formula is the following: D1: 14-17, D2: 16-19, D3: 18-22, A1: 28-32, A2: 19-22, P: 19-20, V: 6 (Fisher *et al.*, 1987; Jardas, 1996).
The back is greyish-green to grey-yellowish or olive-brown. The sides are yellowish and the belly white. There is a dark spot on the base of the pectoral fins (Jardas, 1996).

Distribution

The whiting is distributed from Norway and Iceland to the Mediterranean and into the Adriatic, the Aegean, the Azov and the Black Seas. Whiting is a bathi-pelagic species, living in shallow water up to 200 m, but mostly from 30 to 100 m (Fisher *et al.*, 1987; Jardas 1996). In the Adriatic Sea it is distributed primarily in the northern part, mostly to the depths of 50 m, but it can be found in depths of about 100 m in the northern Adriatic channel waters of Croatia (Frattini and Casali, 1998). Some specimens have been fished along the Italian coast by the Gargano promontory because of coastal currents that carry eggs and larvae (Giovanardi and Rizzoli, 1984). In general, whiting mostly inhabit those regions of the Adriatic where European hake is less abundant.

Biological data

The distribution of whiting in the Mediterranean basin often gives rise to the debate about the possible distinction of the subspecies: *M. merlangus merlangus* (L) and *M. merlangus euxinus* (Nordman). Bini (1968-70) distinguished *M. merlangus merlangus* of the Adriatic Sea from *M. merlangus euxinus* of the Black Sea by the absence or presence of a barbell and by some measurable and meristic features (number of fin rays). Tortonese (1970), using the same data, assigned both populations to the subspecies *M. merlangus euxinus*. Ungaro *et al.* (1995 a) found existence of a certain differentiation, at least at morphological level, between the two populations by analysing some meristic and metric characteristics of whiting samples collected in the Adriatic and Black Sea.
Whiting can grow up to 70 cm, but its usual length in catches is from 30 to 40 cm. Females are usually bigger than males of the same age. This species lives approximately 10 years (Jardas, 1996).
The whiting spawns in the winter period (Bolje, 1992), that is, from winter until spring (Giovanardi and Rizzoli, 1984; Jardas, 1996) at depths between 20 and 80 m, the larvae are pelagic. Sexual maturity occurs when the fish attain a length of 20 cm; Jardas (1996) showed that sexual maturity is reached after two years. In winter, females are dominant in the population, with M/F ratio 0,85 (Giovanardi and Rizzoli, 1984). The length-weight relationship and the length-age key are presented in Tables 22 and 23.

Table 22. The Total Length (TL, cm) – weight (g) relationship.

Author	**Area**	***a***	***b***
Giovanardi and Rizzoli, 1984	Northern Adriatic	0.00607	3.109
Bolje, 1992	Gulf of Trieste	0.0011	2.94

Table 23. Total Length (TL, cm) and age (year) data.

Author	**Sex**		**Age (yr)**		
			0	**1**	**2**
Giovanardi and Rizzoli, 1984	M	May	11.2	22.5	25.2
		Nov.	19.4	23.1	-
	F	May	11.2	25.5	28.3
		Nov.	21.5	26.9	30.5

Evaluation and exploitation

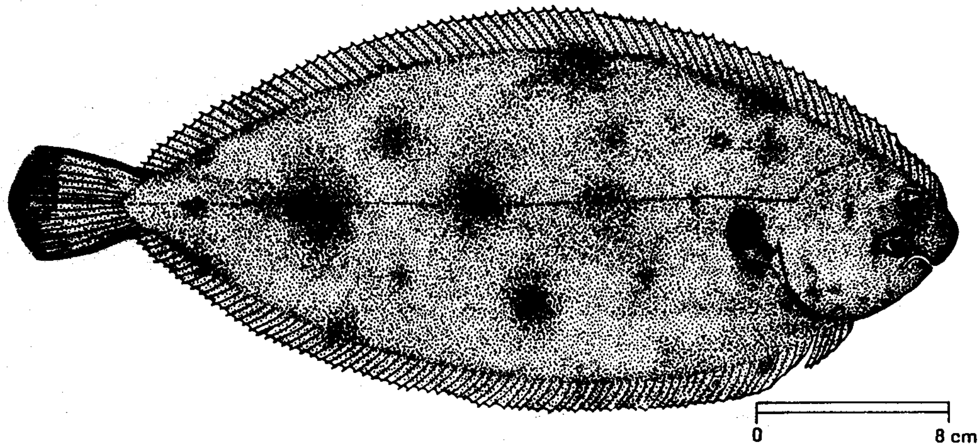
The average catch of whiting in the northern Adriatic is from 1 to 2,5 kg/h. The highest catch is in the mouth of the Po River, primarily in winter months because of the presence of the newly recruited fish in the catch (Frattini and Casali, 1998). In Trieste Bay, the average catch is about 1,2 kg/h (Bolje, 1992). During the expedition MEDITS (1996-98), the average value of the catch in the central and northern Adriatic was 27,9 kg/km^2, in the 50 m stratum (Vrgoč, 2000). The whiting was rarely fished in deeper strata. It is fished almost entirely with trawls and, to a much lesser extent, with long-lines and small hook tools (Jardas, 1996). Selectivity of trawl to the species, according to the cover cod-end method, is shown in Table 24.

Table 24. Selectivity of trawl towards whiting.

Author	Mesh size stretched (mm)	$L_{50\%}$ (cm)	SF	SR
Ferretti and Froglia, 1975	34	8.7	2.6	7.0-10.4
	33.7	10.6	3.1	7.2-14.0

Solea vulgaris (Quensel, 1806)
(Sin. *Solea solea* Jordan & Gross, 1889)
Family: Soleidae

EN: Common sole
SQ: Gjuze kanali
HR: List, šfoja
IT: Sogliola
SL: Morski list



Species description

The body of the Common sole is egg-shaped and flat. The maximum body height is equal to 1/3 of the total length. The eyes are on the right side, the upper one slightly anterior to the lower. Both pectoral fins are well developed, the left one being somewhat smaller than the right one. The dorsal fin begins anterior to the eyes, by the mouth. The last rods of the dorsal and the anal fins are connected to the caudal fin, which is round. The number of rods in particular fins is as follows: D: 69-97, A: 53- 79, P: 9-10, V: 5-6 (Tortonese, 1975, Fisher *et al.*, 1987, Jardas, 1996).
The colour on the eyed side of the body is greyish-brown to reddish-brown, with large and diffused dark spots. The pectoral fin has a blackfish spot at its distal half. The posterior margin of the caudal fin is generally dark (Relini *et al.*, 1999).

Distribution

This common sole species lives in the eastern Atlantic, from Scandinavia to Senegal and in the entire Mediterranean. It is rare in the Black Sea but widespread in the Adriatic Sea, especially in the northern part. It is a demersal and sedentary species, living on sandy and muddy bottoms, mostly in rivers and near the river mouths and also digging into sea bottoms (Tortonese, 1975, Fisher *et al.*, 1987, Jardas, 1996). Although Jardas (1996) stated that the species is distributed from coastal waters toa depth of 250 m, it was only caught during the expedition MEDITS (1996-1998) in depth strata up to 100 m (Vrgoč, 2000).
In the northern and central Adriatic, the distribution of this species depends on age: mature fish occur on the outer side of the Istrian coast, and younger fish (12-15 cm) are found in the

Italian coastal waters, primarily at the mouth of the Po River (Giovanardi *et al.*, 1984, Piccinetti and Giovanardi, 1984). Data from tagging experiments (Pagotto *et al.*, 1979, Pagotto and Piccinetti, 1982) showed that the majority of the Adriatic population was moving from north to south along the Italian coast and, probably, from south to north along the eastern Adriatic coast.

Biological data

The maximum length of this species in the Adriatic is 30 cm (Bini, 1968; Tortonese, 1975). Jardas (1996) reported a maximum length of 47 cm, measured on a specimen found at the Pula fish market in 1957. According to Tortonese (1975), the maximum age is about 20 years, while Fisher *et al.*, (1987) and Jardas (1996) reported longevity up to 24 years in females and 27 years in males.

Table 25. Total Length (TL, cm) – weight (g) relationship.

Author	Sex	*a*	*b*
Piccinetti and Giovanardi, 1984	M	0.00864	3.013
	F	0.00571	3.143
	M+F	0.00693	3.084
Froglia and Giannetti, 1985	M+F	0.004353	3.236
Vallisneri *et al.*, 2000	F	$W = 6.21 * 10^{(5.14e-2TL)}$ R=0.951	
	M	$W = 5.55 * 10^{(5.48e-2TL)}$ R=0.883	

In the Adriatic, growth analyses on this species have been made, using otoliths, scales and tagging experiments. A great variability in the growth rate was noted: some specimens had grown 2 cm in one month, while the others, of the same age group, needed a whole year (Piccinetti and Giovanardi, 1984). These differences in the growth dynamics are shown in Table 26.

Table 26. Total Length (TL, cm) and age (year) data.

Author	Sex	Age (yr)					
		1	2	3	4	5	6
Ghirardelli, 1959a	M+F	16.8	21.4	23.9	25.6	33.1	
Piccinetti and Giovanardi, 1984	M+F	18- 20	21– 30				
Vallisneri *et al.*, 2000	F	20	25	29	32	34	37

Froglia and Gianetti (1985) found the linear relation between the otolith length (OL) and total length (TL) of fish:

OL (mm)=0,4667+0,1287 TL (cm); R=0,96

Von Bertalanffy growth equation parameters, calculated using various methods are summarised in Table 27.

Table 27. Parameters of the Von Bertalanffy Growth Function (VBGF).

Author	Sex	W_∞ (g)	L_∞ (cm)	K ($month^{-1}$)	t_o ($month^{-1}$)	Φ'
Piccinetti and Giovanardi, 1984	M+F	-	40.10	0.679*	-	7.00
Froglia and Giannetti, 1985	M+F	-	38.25	0.041	-3.57	6.58
Froglia and Giannetti, 1986	M	323	23.20	0.069	-1.66	6.10
	F	562	37.87	0.042	-5.36	6.58
	M+F	576	38.25	0.041	-3.57	6.58

* k (yr^{-1})

In the Mediterranean Sea, the reproduction of common sole occurs from December to May (Bini, 1968, Tortonese, 1975, Fisher *et al.,* 1987), and in the Adriatic from November to March (Piccinetti and Giovanardi, 1984) or from autumn to early winter (Jardas, 1996).
Although it occurs in the entire area of this species distribution, there are some regions with a higher concentration of reproducers, like the western coast of Istria (Piccinetti and Giovanardi, 1984).

Length at maturity is 25 cm (Fisher *et al*., 1987; Jardas, 1996; Vallisneri *et al*., 2000). The age of the first maturity is 2 years (Jardas, 1996) and 3 to 5 years (Fisher *et al*., 1987). Females having a weight of 300 g have about 150000 eggs, while those weighting 400 g have about 250000 eggs (Piccinetti and Giovanardi, 1984); eggs are pelagic. The male-female ratio is approximately 1:1 (Piccinetti and Giovanardi, 1984).

Hatching occurs after eight days and larva measures 3 to 4 mm (Tortonese, 1975). Eye migration starts at 7 mm length and ends at 10-11 mm length. Benthic life begins after seven or eight weeks (15 mm) near coastal and brackish waters (Bini, 1968).
The fish feed night and day on remains buried in the substrate. Food includes mostly invertebrates and small fish (Tortonese, 1975); polichaetes worms, molluscs, small crustaceans (Fisher *et al*., 1987; Jardas, 1996) and small echinoderms (Bini, 1968).

Evaluation and exploitation

Using a tagging method Pagotto and Piccinetti (1982) estimated the total biomass of *Solea vulgaris*, in the entire Adriatic, to be 19000 tonnes. On the basis of the expedition MEDITS (1996-1998), Vrgoč (2000) stated that, in the central and northern Adriatic, the biomass index of this species amounted to 0,43 kg/km^2 (0,80 kg/km^2 in stratum 0-50 m, and 0,51 kg/km^2 in stratum 50-100 m). He also found that the proportion of common sole in the total survey catch of all the demersal fish was 0,15%.
The common sole is an economically important species in the Adriatic, especially in its northern part (Ghirardelli, 1959a; Piccinetti, 1967; Jardas, 1996; Vallisneri *et al.,* 2000). It is caught with various bottom trawl gears, such as beam trawl ("rapido"), "tartana" (the Italian commercial trawl net), "sfogliara", and secondarily by trammel net and trident which is also used along the Croatian coast.

Selectivity of the fishery gear for this species was studied for "rapido". The data are listed in Table 28.

Table 28. Selectivity of "rapido" towards common sole.

Author	Mesh size (mm)	$L_{50\%}$ (cm)	SF	SR $L_{25\%}$-$L_{75\%}$
Ferretti and Froglia, 1975	43	17.2	4.0	14.4 – 19.1
	42.5	14.6	3.4	13.7 – 15.5
	41.6	16.2	3.9	14.9 – 17.6
	41.5	15.5	3.7	12.9 – 18.1
Piccinetti and Giovanardi, 1984		15	3.4 – 4.0	

The species is very vulnerable to exploitation because of its way of life (by night more exposed to fishing because of its burrowing behaviour during the day) and because it is a species that reaches sexual maturity relatively slowly (Relini *et al*., 1999). After the introduction of "rapido", which is much more efficient than a common trawl, symptoms of overfishing of this species in the Adriatic were noted as early as 1962 or 1963 (Scaccini and Furlani, 1965; Piccinetti 1967).

Piccinetti and Giovanardi (1984) give mortality coefficient values for the species in the Adriatic (Table 29).

Table 29. The mortality rate coefficients for common sole in the Adriatic. (Piccinetti and Giovanardi, 1984).

Method	Natural mortality ($M\ yr^{-1}$)
Pauly (1984)	0.9
Tanaka (1960)	0.6

Method	Total mortality ($Z\ yr^{-1}$)
Beverton & Holt, (1956)	2.0
Catch curve (without 0 class)	1.4

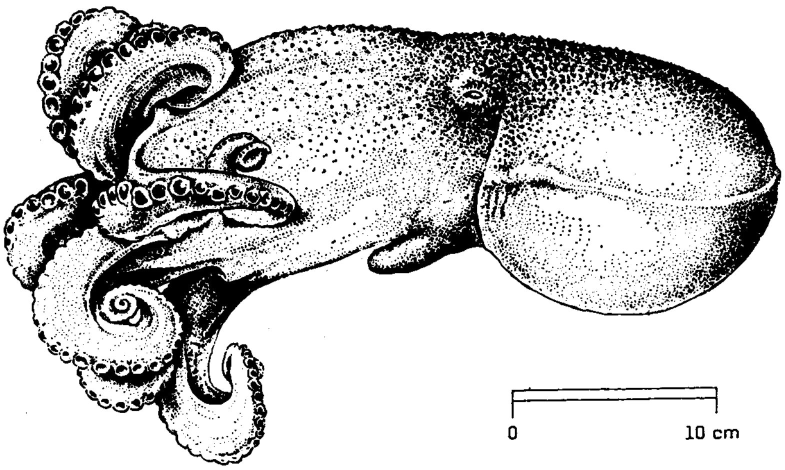
The annual catch of this species in the Adriatic varies from 1.300 to 3.000 tonnes. The highest catches are in autumn period (October-November) when a new year-class enters the catches. Considerable fluctuations in the annual catch are most probably the result of different recruitment magnitude.

Despite its great economical importance, this species has been relatively poorly researched in the Adriatic. The situation is somewhat better for the western coast, while there have not been any studies of this species along the eastern Adriatic coast.

Eledone cirrhosa (Lamarck, 1798)

Family: Octopodidae

EN: Horned octopus
SQ: Kallamar i eger
HR: Muzgavac bijeli (divlji)
IT: Moscardino bianco
SL: Kodrasta hobotnica



Species description

The mantle of the Horned octopus is covered with numerous small warts. The head is narrower than the mantle. There is one barb on each eye. Generally, the arms are shorter than those in *Eledone moschata.* There is only one row of suckers on each arm. The third right arm in males is much shorter and its tip is transformed into a hectocotylus. The horned octopus has 11 external gills.
The colour of the body is yellowish, reddish-orange or brownish-red with rust-coloured spots (Fisher *et al*., 1987; Relini *et al*., 1999)

Distribution

Eledone cirrhosa can be found throughout the Mediterranean Sea and in the north-eastern Atlantic. The northern limit of distribution is about 66-67^{o} N, while the southern limit is in the latitudes of the Moroccan coast. The horned octopus is a typical soft-bottom species. It is present in a wide bathymetric range, generally up to 700 m (Relini *et al*., 1999).
In the central and northern Adriatic it is less abundant than *E. moschata*, while in the southern Adriatic the situation is the opposite. The distribution area of these two species partly overlaps. The horned octopus lives in depths from 25 to 400 m, but it is most abundant over 75 m (Casali *et al*., 1998). It was found in all the stations surveyed in the Pomo/Jabuka Pit where it does not show any preference towards a particular depth or sediment type (Jukić, 1975; Županović and Jardas, 1989). In the southern Adriatic, along the Montenegrin coast, it lives in the depth range from 40 to 200 m, on muddy sediments (Mandić, 1984). Pastorelli *et al*., (1998) found a similar range along the Italian coast of the southern Adriatic.

Biological data

Very little is known about the biology and ecology of *E. cirrhosa* in the Adriatic Sea. It reproduces from March to August; the abundance of the species decreases distinctly in autumn, probably as the result of after-spawning death (Casali *et al*., 1998). In the Adriatic, the proportion of young specimens (under 6 cm of mantle length, ML) is highest in the autumn period (Pastorelli *et al*., 1998) (Tables 30 and 31).

Table 30. Mantle length (ML, cm) – weight (g) relationship.

Author	Sex	*a*	*b*
Marano, 1993	M+F	0.394	2.713
Marano, 1996	M+F	0.336	2.281

Table 31. Mantle length (ML, cm) at the first sexual maturity.

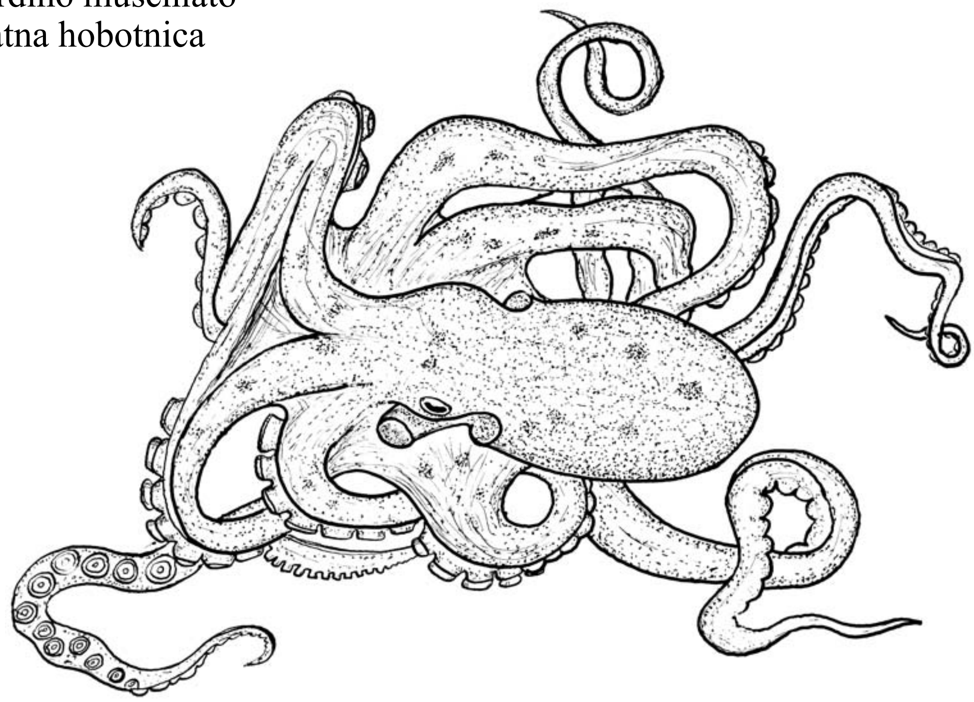
Author	Sex	ML (cm)
Soro and Piccinetti Manfrin, 1989	M	9
	F	11

Evaluation and exploitation

In the central Adriatic Sea, *E. cirrhosa* is less abundant than *E. moschata*. Only several specimens per haul are usually found, except in the deeper waters (Jukić, 1975, Županović and Jardas, 1989). It is most abundant in the southern Adriatic. The CPUE shows a distinct seasonality. The biggest catches, over 2 kg/h, occur in spring months (Pastorelli *et al*., 1995).
In the southern Adriatic the CPUE trend analysis shows distinct fluctuations of 4,5 kg/km2 (1986) to 65,1 kg/km2 (1993) from 1985 to 1995 (Marano *et al*., 1998b, c).
Eledone cirrhosa is a commercially important species, primarily in the central and southern Adriatic. It is fished mainly with bottom trawl nets, but also with artisanal gear. On the market, horned octopus often appears mixed with *E. moschata*.

Eledone moschata (Lamarck, 1798)
Family: Octopodidae

EN: Musky octopus
SQ: Oktapod i eger
HR: Muzgavac crni
IT: Moscardino muschiato
SL: Moškatna hobotnica



Species description

The mantle of the Musky octopus is smooth or thinly granulose. The head is wider than the mantle. The arms are much longer than in *E. cirrhosa*. The third right arm of males functions as a hectocotylus; it is shorter than the other arms and has a small ligula. There is one row of suckers on each arm. It has 11 to 12 external gills.
The colour is brownish-grey with large black spots (Fisher *et al*., 1987; Relini *et al.,* 1999).

Distribution

Eledone moschata is a typical Mediterranean species. Its distribution in the Atlantic is limited to the southern coasts of Portugal, the west coast of Gibraltar and the Gulf of Cadiz. It is present along all the Mediterranean coasts at depths between 15 and 200 m, and has a maximum abundance up to 100 m (Relini *et al*., 1999).
Gamulin-Brida and Ilijanić (1972) and Grubišić (1982) show it is distributed throughout the Adriatic up to 200 m deep, but the most populated settlements are 50 m deep on sandy and muddy bottoms. In the central and northern Adriatic it is distributed on rugged terrains at depths of 20 to 200 m. The concentration is highest in the north-eastern part (Manfrin Piccinetti and Rizzoli, 1984; Casali *et al*., 1998). In the Pomo/Jabuka Pit region, it inhabits mostly shallower and rugged bottoms and the transitional areas (Županović and Jardas, 1989). In the southern Adriatic, (Mandić and Stjepčević, 1981; Mandić 1984, Pastorelli *et al*.,

1998) it can be found in the more shallow littoral region, mostly up to 80 m deep, while very rarely and in small number in up to 100 m deep. The species is most abundant at a depth of 40 m in the summer period.

Biological data

Although this is a commercially very important species, very little is known about its biology in the Adriatic (Tables 32 and 33).

Table 32. The Mantle Length (ML, cm) – weight (g) relationship.

Author	Sex	*a*	*b*
Marano, 1993	M+F	0.858	2.389

Table 33. Mantle length (ML, cm) at the first sexual maturity.

Author	Sex	ML (cm)
Soro and Piccinetti Manfrin, 1989	F	9

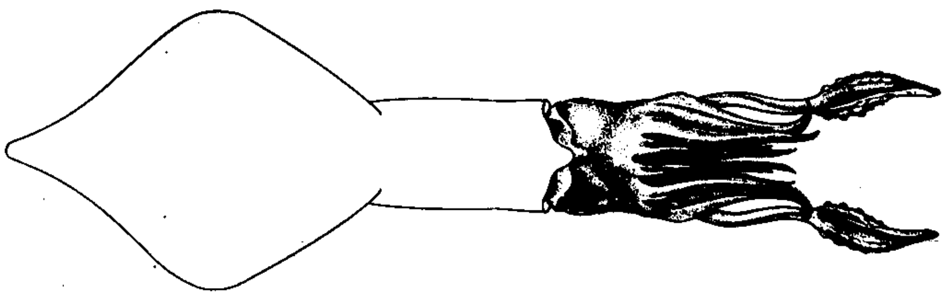
Musky octopus reproduces from winter until spring in the central and northern Adriatic. The highest abundance of the sexually mature specimens is in January and February (Manfrin Piccinetti and Rizzoli, 1984; Casali *et al*., 1998). In the southern Adriatic, mature males can be found throughout the year, mostly from October to May, whereas mature females can be found in spring. The species lays eggs on solid base (*Pinna* shells and stones). They measure 5x15 mm (Mandić, 1984). Females reach sexual maturity when their mantle is 9 cm and the oocytes 15 mm long (Soro and Piccinetti Manfrin, 1989).
Manfrin Piccinetti and Rizzoli (1984) found two age classes in May; juveniles (weight about 50 g – age about five months) and adults (weight about 500 g – age about one year). In November the sex ratio is close to 1 (M/F=0,97).

Evaluation end exploitation

E. moschata is especially abundant in the Northern Adriatic, where in the early winter, bottom trawl yields of up to 53 kg/h were recorded (Manfrin Piccinetti and Rizzoli, 1984). In the Trieste Bay the catches are from 5,6 to 11,9 kg/haul (Bolje, 1992) and the proportion of the species can be even 55%. In the southern Adriatic (along the Montenegrin coast) musky octopus makes up 36% of the cephalopod biomass (Mandić, 1984). Pastorelli *et al*. (1995 and 1998) showed that the species made up about 50 % of the entire cephalopod catch in the Italian part of the southern Adriatic. In the period from 1972 to 1997, the annual catch showed marked fluctuations without any clear trend in the northern and central Adriatic (Mannini and Massa, 2000), as did the CPUE values from 1982 to 1991 (Piccinetti and Piccinetti Manfrin, 1994).
The musky octopus is a commercial species fished throughout the Mediterranean, mainly with bottom trawl nets. Catches made with other gear, such as traps and setnet, are of lesser importance (Relini *et al*., 1999).

Loligo vulgaris (Lamarck, 1798)
Family: Loliginidae

EN: European squid
SQ: Kallamare
HR: Obična lignja
IT: Calamaro comune
SL: Ligenj



Species description

The body of the European squid is long, moderately slender and cylindrical. The fins are rhomboid and their length is two thirds of the mantle length. The posterior border is slightly concave. The head is relatively small with big eyes that are covered with a transparent membrane. There are ten arms around the mouth. Eight of them are relatively short, and two are long (tentacles) and are used to catch prey. The fourth left arm of males is a hectocotylus.
The colour of *Loligo vulgaris* is greyish-transparent or reddish, depending on expansion of the pigmented cells in the skin. On the mantle of the adult males there are small chromatophores. In the internal dorsal side of the mantle there is a supporting structure that is called gladius (Fisher *et al*., 1987; Jardas, 1996; Relini *et al*., 1999).

Distribution

Loligo vulgaris can be found throughout the Mediterranean Sea and in the eastern Atlantic Ocean from the North Sea to the Gulf of Guinea (Fisher *et al*., 1987; Relini *et al*., 1999). It is a neritic, semi-demersal species, known for distinct horizontal and vertical migrations, depending on the environment.
Grubišić (1982) showed that this species is distributed throughout the Adriatic Sea up to depths of 400 m. It inhabits all strata, but, during the spawning period, it migrates into shallower regions. Generally, European squid are most frequent at depths between 40 and 150 m. Gamulin-Brida and Ilijanić (1972) reported that this species lives in coastal regions, most often between 50 and 100 m deep. Based on research in the south Adriatic, Mandić (1984) found that European squid resided in the coastal region up to a depth of 100 m. Nevertheless, it can be found up to 150 m, but rarely and in small quantities. In the Pomo/Jabuka Pit it was fished at all stations (Županović and Jardas, 1989). The species is present in the entire Adriatic. It is most frequent up to depths of 100 m (Mandić and Stjepčević, 1981; Flamigni and Giovanardi, 1984; Soro and Piccinetti Manfrin 1989;

Županović and Jardas, 1989;Pastorelli *et al*., 1995; Casali *et al*., 1998; Krstulović Šifner, 2000). In the Adriatic, *L. vulgaris* occurs above different types of sea sediments; from sandy through sandy-muddy, to the muddy bottoms Gamulin-Brida and Ilijanić, 1972; Casali *et al*., 1998).

Biological data

European squid can grow up to 30 to 40 cm of the mantle length, but their usual size is 15 to 25 cm. The males are generally bigger than the females and they grow faster (Relini *et al*., 1999). The growth shows negative allometry, as can be seen from the length-weight relation data obtained by different authors (Table 34).

Table 34. The Mantle Length (ML, cm) – weight (g) relationship.

Author	Sex	*a*	*b*
Flamigni and Giovanardi, 1984	M+F	0,4703	2.788
Marano, 1993	M+F	0,113	2.511
Krstulović Šifner, 2000	M	0,008	2.3501
	F	0,005	2.4524
	M+F	0,05	2.4181

Flamigni and Giovanardi (1984) and Krstulović Šifner (2000) found that males dominate in the population during springtime. This can be a consequence of the female after-spawning mass mortality. However, the sampling methods used and different behaviour patterns of males and females can also influence sex ratio in the samples (Krstulović Šifner, 2000).
Although, *L. vulgaris* reproduce all year long in the Adriatic, it is most intensive in the winter-spring period (Flamigni and Giovanardi, 1984; Soro and Piccinetti Manfrin, 1989; Krstulović-Šifner, 2000). Mantle length at the first sexual maturity is shown in Table 35. After spawning most individuals die, thus, typical European squid live for only one year and do not regenerate gonads and reproduce again (Table 36).
The average number of oocytes in females is about 6000. They are each about 1,6 mm long. A weak positive correlation between mantle length and number of eggs is found. The number of spermatophores in males is from 15 to 310 and their length from 7,5 to 14 mm (Krstulović Šifner, 2000).

Table 35. Mantle Length (ML, cm) at first sexual maturity.

Author	Sex	ML (cm)
Flamigni and Giovanardi, 1984	M	11.8
	F	15.8
Mandić, 1984	M	11.0-12.0
	F	12.0-13.0
Soro and Piccinetti Manfrin, 1989	M	14.0-15.0
	F	15.0-16.0
Krstulović Šifner, 2000	M	12.0
	F	15.0-16.0

Table 36. The parameters of VBGF (from length frequency analysis).

Author	Sex	L∞ (mm)	K (yr^{-1})	t_o (yr)
Krstulović Šifner, 2000	M+F	238,02	1.74	0.06

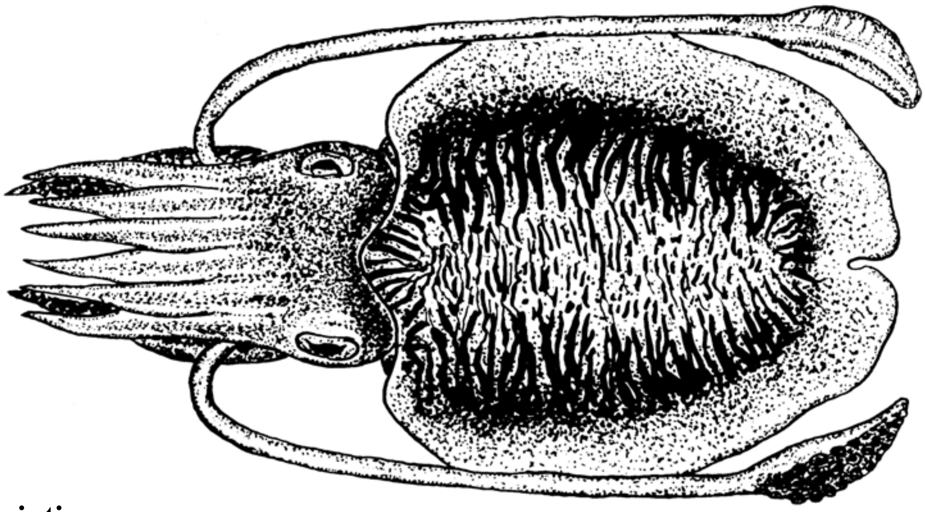
The European squid feeds on fish, crustaceans and cephalopods, but fish is the major, sometimes the only, component. In some areas, polychaetes and chaetognaths are prey as well. Cannibalism was also observed (Relini *et al*., 1999).

Evaluation and exploitation

During the expedition MEDITS (996-1998) in the central and northern Adriatic, the average value of the catch for the entire area studied, was from 0,50 to 0,81 kg/km^2. The highest catch was recorded in the 50 m stratum (Krstulović Šifner, 2000).
An analysis of the commercial landings at the Split fish market from 1995-1999 showed marked seasonality of the catch, with peaks in the winter months (Krstulović Šifner, 2000). In the period from 1982 to 1991, the CPUE from the "Pipeta" expedition values in the central and northern Adriatic, showed marked fluctuations without a clear trend (Piccinetti and Piccinetti Manfrin, 1994).
The total annual catch of the species in the Adriatic Sea (GFCM) is about 1.000 to 1.500 tonnes. It shows wide variations and this is probably linked to the production cycle that is typical for many cephalopods (Mannini and Massa, 2000).
Loligo vulgaris has a considerable commercial value. The species is caught in multispecies trawl fishing throughout the year and, seasonally, in small scale and recreational fishing with a variety of gear (Relini *et al*., 1999).

Sepia officinalis (Linnaeus, 1758)
Family: Sepiidae

EN: Common cuttlefish
SQ: Sepia
HR: Sipa
IT: Seppia comune
SL: Sipa



Species description

The body of the Common cuttlefish is oval, rounded posteriorly, bordered throughout its length by a narrow fin. The mouth is surrounded by eight non-retractile arms and two long, retractile, tentacles that are inserted laterally. The fourth left arm in males is the hectocotylus. The cuttlebone, anteriorly and posteriorly, is rounded, with a weak spine visible in juveniles, but embedded in chitin in adults.
Being a mimetic species, the common cuttlefish has a very variable body colour; i.e., specimens show different colour patterns, depending on substrate. Specimens are generally yellowish or marked with blotches or long vinelike bands, depending on the state of expansion of the chromatophores (Fabi, 2001).

Distribution

Sepia officinalis is found throughout the Mediterranean basin and the eastern Atlantic Ocean, from the Baltic Sea to about 17^{o} N. It is a demersal species, more abundant in coastal waters on muddy and sandy bottoms covered with seaweed and phanerogams, but its distribution can be extended to a depth of about 200 m (Relini *et al*., 1999).
This species inhabits the entire coastal part of the Adriatic Sea (Gamulin Brida and Ilijanić, 1972). It migrates seasonally; in winter it resides mostly in circalitoral zone where it matures sexually, in spring, it migrates to the shallower infralitoral region to spawn (Mandić, 1984). In the central and northern Adriatic it occurs predominantly on sandy and muddy bottoms up to 100-150 m deep (Manfrin Piccinetti and Giovanardi, 1984; Soro and Piccinetti Manfrin, 1989; Županović and Jardas, 1989; Casali *et al*., 1998). In the southern Adriatic, in the colder part of the year, the Common cuttlefish is most dense at depths from 50 to 60 m. During the warmer part of the year it migrates closer to the coast for spawning and forms dense

settlements at 10 to 30 m depth. In autumn it withdraws into deeper waters and, in this part of the year, is most abundant at depths between 40 and 50 m. In spring, the population density is uniform up to 60 m, but it can be also found, in small quantities, up to 110 m (Mandić and Stjepčević, 1981; Mandić, 1984).

Biological data

As with most cephalopod species, the biological and ecological characteristics of common cuttlefish, and also the stock assessment, have been insufficiently investigated in the Adriatic Sea. This species can grow to a maximum of 35 cm (mantle length), but the usual length ranges between 15 to 20 cm. Longevity is 18 to 30 months (Fisher *et al*., 1987). This is a demersal, neritic species that inhabits muddy and sandy sediments. It is particularly active during the night. In the daytime it adopts a sedentary lifestyle, often burrowing into the sand. The length-weight relationship shows negative allometry (Table 37).

Table 37. The Mantle Length (ML, cm) – weight (g) relationship.

Author	Sex	*a*	*b*
Manfrin Piccinetti and Giovanardi, 1984	M+F	0.22041	2.773

The spawning period of this species extends throughout the year, with peaks in spring and summer. In the northern and central Adriatic it reproduces in April and May, but females with mature eggs can be found even in June and July (Manfrin Piccinetti and Giovanardi, 1984). In the southern Adriatic, it spawns from February to September, but with a peak from April to June. The diameter of the eggs is from 6 to 8 mm (Mandić, 1984). The length of the mantle is about 10 cm at first sexual maturity (Table 38).

Table 38. Mantel Length (ML, cm) at the first sexual maturity.

Author	Sex	ML (cm)	Age (yr)
Manfrin Piccinetti and Giovanardi, 1984	M+F	10	1

The common cuttlefish is an active predator. It feeds mostly on crustaceans, especially decapods, and fish. In the absence of this food, it can become cannibalistic (Fabi, 2001).

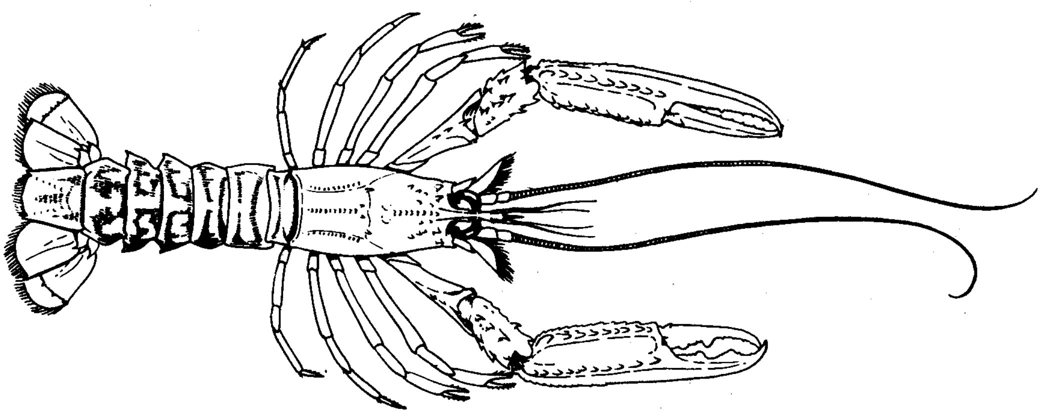
Evaluation and exploitation

In 1982, the highest population density in the central and northern Adriatic was noted along the Italian coast in the biocenosis of *Turritella communis* (Casali *et al*., 1998). The proportion of this species in the total cephalopod biomass in the central Adriatic is about 36% (Mandić, 1984). In the period from 1982 to 1991, in the central and northern Adriatic, the CPUE values from the "Pipeta" expedition showed distinct fluctuations without a clear trend (Piccinetti and Piccinetti Manfrin, 1994).

By analysing the total annual landings of this species in the Adriatic in the period from 1972 to 1997, Mannini and Massa (2000) observed distinct fluctuations in the catch. Nevertheless, a negative trend of the catches was found both in the northern and central Adriatic.
The common cuttlefish is an important commercial resource and one of the most appreciated cephalopod species. It is caught mainly with bottom and beam (“rapido”) trawl nets, but trammel nets, fyke nets and specific pots are used as well. In the Adriatic Sea, the common cuttlefish is also, together with European squid, an important target of small-scale artisanal and recreational fishing activities. The trammel net proved to be the most efficient gear for fishing *S. officinalis* on the sandy-rock seabed. The yield of the fyke nets and pots does not change much when the gear is kept in sea for 24 or 48 h. It was proved that leaving these traps in the sea longer does not increase their efficiency (Fabi, 2001).

Nephrops norvegicus (Linnaeus, 1758)
Family: Homaridae

EN: Norway lobster
SQ: Nefrops
HR: Škamp
IT: Scampo
SL: Škamp



Species description

Norway lobster is a medium to large sized crustacean decapod with well-calcified teguments, very pronounced rostrum, carapace and chelae, reduced pedunculated eyes and non-imbricated abdominal pleurae (Relini *et al.*, 1999).
The body is long and more or less flat laterally. There are three to four bones on the dorsal side and one to two on the ventral side of cephalothorax. The abdomen is long and ends with a fan-shaped telson that enables the lobster to swim. However, when moving, *Nephrops norvegicus* walks more than it swims (Fisher *et al.*, 1987; Relini *et al.*, 1998).
The first pair of cephalic appendices has composite eyes, each with a mobile peduncule. The first pair of antennae is short and forked. Each of the second pair is long and simple. The telson is long, with two pronounced bones at its apex. The first pair of legs is well developed with strong chelae. The second and third are thinner and have chelae as well (Relini *et al.*, 1999).
Norway lobster is orange coloured, with orange-red bands on chelae and on the anterior part of the cephalothorax.

Distribution

The species is distributed in the eastern Atlantic, from Morocco to Norway and Iceland, and in the Mediterranean (Fisher *et al.*, 1987 and Relini *et al.*, 1999).
The species was recorded at depths from about 30 meters in the northern Adriatic Sea to 400 meters in the southern part of the Sea (Karlovac, 1953; Froglia and Gramitto, 1988; Vrgoč, 1995; Marano *et al.*, 1998a). In the northern part of the open Adriatic it can be found off

Ancona. The most dense population is in the Pomo/Jabuka Pit region. There are rich fishing grounds in the Velebit Channel, Kvarner and Kvarnerić region along the Croatian coast (Karlovac, 1953; Crnković, 1964, 1965). In the southern Adriatic, along the western (Italian) and eastern (Albanian) coasts, the settlements are not so dense (Karlovac, 1953; Marano *et al*., 1998a).
Because the range of this species in the Adriatic is a continuous one, particular Norway lobster settlements cannot be regarded as isolated (Karlovac, 1953). Nevertheless, some differences do exist, primarily in length frequencies among the settlements around Ancona and the Pomo/Jabuka Pit (Froglia and Gramitto, 1981, 1988, IMBC *et al*., 1994), as well as among the settlements in the northern Adriatic channels and the Pomo/Jabuka Pit (Karlovac, 1953; Crnković, 1964, 1965, 1970; Jukić, 1974; Županović and Jardas, 1989). Froglia and Gramitto (1981) discussed these differences as the consequence of the difference in ecological factors that dramatically depress growth of *N. norvegicus* and other benthic decapods in the Pomo/Jabuka Pit. Similarly, Mantovani and Scali (1992), using genetic analysis, found that differences between Norway lobster off Ancona and the Pomo/Jabuka Pit did not surpass those at the population level. The differences were only a consequence of different environments.
Previously, Norway lobster was seen as a boreal relic from the ice age (Lorenz's hypothesis). This hypothesis was later refuted (Karlovac, 1953). It was realised that the decisive factor for the diffusion of the species in the Adriatic was the type of sea sediment, not the temperature (Alfirevic *at al*. 1969; Artegiani *et al*., 1979; Froglia and Gramitto (1981); Županović and Jardas, 1989). *N. norvegicus* can be considered a "mud-loving" species, not restricted to a particular biocenosis or to a biocenotical zone (Froglia and Gramitto, 1981). This is certainly related to its habit of digging burrows for shelter (Crnković, 1965; Froglia, 1972; IMBC *et al*., 1994).

Biological data

Nephrops norvegicus is a species with separate sexes. Males are, on an average, larger than females. Although Fisher *et al*. (1987) stated that its maximal total length is 24 cm, larger specimens have been caught, primarily in the northern Adriatic. Crnković (1965), for example, found specimens up to 26,5 cm TL in northern Adriatic channels.
Because two different measures are used in fishery and biological research, total body length (TL) and carapace length (CL), the relationship between them is presented in Table 39, and the carapace length-weight relationship is given in Table 40.

Table 39. Total Length (TL, mm)-Carapace Length (CL, mm) relationship.

Author	Area	Sex	*a*	*b*
Froglia and Gramitto, 1981	Pomo/Jabuka Pit	M	-1.420	3.337
		F	-2.058	3.397
	off Ancona	M	3.549	3.159
		F	2.019	2.254
Froglia and Gramitto, 1988	Pomo/Jabuka Pit	M	-1.880	3.355
		F	-2.541	3.419
	off Ancona	M	2.729	3.179
		F	1.229	3.273
Cetinić *et al*., 1999	Velebit Channel	M+F	-1.0035	3.5507

Table 40. Carapace Length (CL, mm) - weight (g) relationship.

Author	**Area**		**Sex**	***a***	***b***
Froglia and Gramitto, 1981	Pomo/Jabuka Pit		M	0.000246	3.28
			F	0.000489	3.07
	off Ancona		M	0.000263	3.27
			F	0.00490	3.09
Šarčević, 1992 (TL)	Pomo/Jabuka Pit		M+F	0.0098	3.217
Marano, 1993	SW Adriatic		M+F	0.0004	3.164
Marano, 1996	SW Adriatic		M+F	0.0005	3.091
GMS-GRUND, 1998			M+F	0.00103	2.805
Marano *et al*., 1998a	SW Adriatic		M+F	0.00064	3.036
Marano *et al*., 1998a	SW Adriatic	Spring	M	0.0006	3.059
			F	0.0004	3.169
		Autumn	M	0.0005	3.079
			F	0.0005	3.089
Sarda *et al*., 1998	off Ancona		F	0.00043 0.00056	3.12 3.11
			M	0.00028 0.00036	3.26 3.19

The growth of Norway lobster, as in other crustaceans, is a discontinuous process with a succession of molts separated by the intermolt periods. During each molt, the old exoskeleton is shed and the animal grows very quickly before the new exoskeleton hardens. A well-defined molting periodicity was not found among juveniles, they seem to molt all year round. There is a molt synchronism in the adult population, it could be generally said that, in the Mediterranean, the females have one molting period a year (December-March), right after hatching the eggs (Gramitto, 1998).

The molting period of grown males is in late summer and autumn (August-October) (Gramitto, 1998). In the Adriatic, adult males have a molt peak between June and September. The frequency of gastroliths is always very low in adult females, little is known about their molt cycle, except that adult females do not molt between August and January, when they carry eggs externally (Gramitto, 1998).

In the Adriatic, *N. norvegicus* spawns once a year (Froglia and Gramitto, 1981). The proportion of females with mature ovaries peaks in spring or at the beginning of summer (Froglia and Gramitto, 1981; Orsi Relini *et al*., 1998). Berried females were found in October and November (Orsi Relini *et al*., 1998), but some specimens can be present up to late spring (Froglia and Gramitto, 1981). According to Karlovac (1953), Norway lobster larvae are present in the Adriatic plankton in late winter, from January to April (Relini *et al*., 1999).

The sex ratio changes through the year. The proportion of females in the catch is lower when they carry external eggs because they are less active and more often hide in burrows. On the other hand, this proportion increases and is higher in the mating period (Crnković, 1965, Jukić, 1971; Froglia and Gamitto, 1981; Ungaro *et al*., 1999).

Data about the length at first sexual maturity at different localities are shown in Table 41. At the first maturity, the individuals are two (Froglia and Gramitto, 1981) or three years old (Orsi Relini *et al*., 1998).

Table 41. Carapace Length (CL, mm) at the first sexual maturity.

Author	**Area**	**CL (mm)**	**CL (mm) smallest ovigereous**
Karlovac, 1953	Northern Adriatic	95-100 (TL)	
Froglia and Gramitto, 1979	off Ancona	32.5	29.4
	Pomo/Jabuka Pit	25.9	23.9
Gramitto and Froglia, 1980	off Ancona	32	29
	Pomo/Jabuka Pit	26	21
Froglia and Gramitto, 1981	off Ancona	105 (TL)	-
	Pomo/Jabuka Pit	85 (TL)	-
IMBC *et al*., 1994	off Ancona	30	27
	Pomo/Jabuka Pit	26	23
	NW Ancona	31.5	28
Marano *et al*., 1998a	SW Adriatic	25	-
Orsi Relini *et al*., 1998	off Ancona	30	24
Cetinić *et al*., 1999	Velebit Channel	35	
Ungaro *et al*., 1999	SW Adriatic	27.5	-

The relation between length of carapace and number of eggs in females in the Adriatic Sea, as found by different authors, is presented in Table 42. It can be seen that the number of eggs is correlated with the length (CL): i.e. bigger animals lay proportionally more eggs (Froglia and Gramitto, 1979). The relationship between the length of carapace and number of eggs is almost the same in different parts of the Adriatic (Pomo/Jabuka Pit and off Ancona), even though the size of mature females is quite different (Froglia and Gramitto, 1979). Ungaro *et al*. (1999) found smaller values in the southern Adriatic.

The number of eggs hatched is about one third of the numbers of oocytes (Froglia and Gramitto, 1981). Orsi Relini *et al*. (1998) found that, in the Adriatic, fecundity was about double that for embryos close to hatching, therefore meaning that the loss of embryos is about 50%.

Table 42. Ratio between Carapace Length (CL, mm) and number of eggs.

Author	**Area**	**Ratio**
Froglia and Gramitto, 1979, 1981	NW Adriatic	$N=0.0575*CL^{2.942}$
Šarčević, 1992	Pomo/Jabuka Pit	$N=-6980.6+448.96*CL$
Orsi Relini *et al*., 1998	NW Adriatic	$N=-2862.5+120.8*CL$

There are some differences in growth parameters between males and females, as is apparent in Table 43. Males grow larger than females. Differences in growth dynamics among settlements in different parts of the Adriatic can also be observed. They are, as previously mentioned, the result of differences in ecological conditions. However, the methods used in calculating the parameters might influence on the growth parameter estimates.

Table 43. Parameters of the Von Bertalanffy Growth Function (VBGF).

Author	Area	Method	Sex	L_∞ (mm)	K (yr^{-1})	t_o (yr)	Φ'
Froglia and Gramitto, 1988	off Ancona	NORMSEP	M	226*	0.036**	1.70**	10.00
			F	230*	0.044**	1.48**	10.24
	Pomo/Jabuka Pit		M	200*	0.027**	-1.91**	9.47
			F	140*	0.044**	-0.27**	9.25
Šarčević, 1992	Pomo/Jabuka Pit	BHATTACH	M+F	215*	0.215	-0.23	9.20
IMBC *et al*., 1994	Ancona	MULTIFAN	M	56.6	0.426	-	7.22
			F	-	-	-	
		MIX	M	63.5	0.327	-0.13	7.18
			F	55.4	0.361	-0.18	7.01
	NW Ancona	MIX	M	82.5	0.325	0.28	7.70
			F	59.5	0.450	0.06	7.37
	Pomo/Jabuka Pit	MULTIFAN	M	43.4	0.382	-	6.58
			F	43.2	0.437	-	6.70
		MIX	M	55.9	0.229	-0.56	6.57
			F	36.0	0.498	-0.27	6.47
Vrgoč, 1995	Open Adriatic Sea	BHATTACH	M	227*	0.324	-0.29	9.72
			F	179*	0.397	-0.03	9.45
Marano *et al*., 1998a,	SW Adriatic	BHATTACH	M+F	65.0	0.14	-	6.38
			M	67.3	0.14	-	6.45
		Surf. and Sheper	M+F	79.6	0.21	-	7.19
			M	77.6	0.17	-	6.93
Mytilineou *et al*., 1998a	off Ancona	Gauss – Newton	M	71.4	0.11	-1.18	6.33
			F	68.0	0.14	-0.21	6.47
		FISHPARM	M	83.3	0.11	-1.24	6.64
			F	68.5	0.14	-1.02	6.49
Sarda *et al*., 1998	off Ancona		M	81.5	0.11	-0.95	6.59
			F	67.0	0.14	-0.88	6.44

* L_∞ of total length

** K/month, t_o/month

Norway lobster feed mainly on other decapod crustaceans and, to a lesser extent, on different crustaceans (euphausids and peracarids) and fish. Parts of carapace, shells and gastropoda scales, vertebra and fish otoliths and similar fragments were found in *N. norvegicus* stomachs (Cristo and Cartes, 1998). These surveys confirmed that the dominant prey-species in the alimentation were those usually found in demersal communities where Norway lobster lives. It was also determined that stomach was least full in summer, that is, in the period when gonads grow most intensively and occupy a great volume of the body cavity (Cristo and Cartes, 1998).

Evaluation and exploitation

In the Adriatic the catch of Norway lobster fluctuates significantly in different times of day and night (circadian fluctuation), and during the year (seasonal fluctuation) (Crnković, 1970; Jukić, 1971, Froglia, 1972; Froglia and Gramitto, 1981; Marano *et al*., 1998a; Županović and Jardas, 1989, Relini *et al*., 1999). Generally, the catch is highest at sunrise and sunset. This

most probably due to the behaviour of this species; it spends most of its life buried in burrows in the sea sediment and goes out only in search for food before dawn and at dusk (Froglia, 1972; Froglia and Gramitto, 1981). This kind of behaviour is more obvious in younger specimens and ovigerous females. As a result, different parts of the population are accessible to fishing gear at different times of day. Seasonal fluctuations exist for the same reason; the catch is biggest in spring, when the sex ratio is in favour of females (Froglia, 1972; IMBC *et al*., 1994), in winter the catch is at a minimum. (IMBC *et al*., 1994; Marrs *et al*., 2000).
Adriatic Sea landing of Norway lobster increased from the 1980s until the first half of the 1990s when a marked negative trend was established (Mannini and Massa, 2000).
In the Adriatic Sea, the *N. norvegicus* is caught primarily with two types of gear: the majority of the catch is by bottom trawl nets and the rest with traps (mainly in channel areas of the northern Adriatic). Data on bottom trawl selectivity for Norway lobster in the Adriatic are shown in Table 44. Jukić and Picinetti (1987) found, with selectivity experiments using trawls of different mesh size on the cod-end, that in order to preserve the Norway lobster stock, nets of 55 or even 65 mm mesh size on the cod-end should be used. This would result in a 15 % to 48 % loss of the *N. norvegicus* catch in the short-run, but would have positive results in the long-run.

Table 44. Selectivity of trawl towards Norway lobster.

Author	Mesh size stretched (mm)	$L_{50\%}$ (cm)	SF	SR $L_{25\%}$-$L_{75\%}$
Jukić, 1974	41.56	9.2	1.5	5.6 –12.8
	52.83	4.3	0.9	1.2 – 7.2
	62.60	5.2	0.9	3.2 – 7.2
Jukić and Piccinetti, 1987	41	5.7	1.2	
	55	6.5	1.2	
	65	10.3	1.2	
Jukić and Piccinetti, 1988	40	5.7 TL	1.2	
Froglia and Gramitto, 1988	40 (offAncona)	10 TL	-	-
	40 (Pomo/Jabuka Pit)	6 TL	-	-
Vrgoč, 1995	40 (Hvar)	8.2 TL		7.1 – 9.2
Mytilineou *et al*., 1998b Mesh size "knot to knot"	16	fully unselective		
	20	17.83	0.44	15.32 – 20.34
	24	20.06	0.43	16.77 – 23.35
	32	20.53	0.40	16.71 – 24.35
GMS-GRUND, 1998	40	11.1 (TL)	0.3	-
	66	24.4 (TL)	0.4	-
Marano *et al*., 1998a	36	15	0.38	

Šarčević (1992) estimated the *N. norvegicus* standing stock size in the Pomo/Jabuka Pit at 11810 tonnes. He also calculated MSY in the fishing area of Blitvenica (the eastern part of the Jabuka Pit) to be 41 tonnes annually with f_{opt} = 800 fishing days.
In researching the Norway lobster population density with underwater television (UWTV), IMBC *et al*., (1994) and Froglia *et al*., (1997) found that the burrow density in the Pomo/Jabuka Pit was 0,6566 - 0,7185 m^{-2}, and 0,1067 - 0,6255 m^{-2} off Ancona. The frequency of occupancy of the burrow is not known, but it is considered to be high, because

burrow openings collapse quickly if they are not continuously repaired. The following biomass (tonnes) of *N. norvegicus* at various burrows occupancy levels were calculated:

Occupancy	Ancona inshore	Ancona offshore	Pomo/Jabuka Pit
100%	16.60309	6.15520	7.53324
90%	14.94278	5.52818	6.79473
75%	12.45231	4.61640	5.662.27

The mortality rate estimates of the *N. norvegicus* population in the Adriatic are shown in Table 45. It can be seen that females are exposed to higher mortality than males. Froglia and Gramitto (1988) explained this with the fishing which is most intensive in late spring and summer, the mating period, when females are dominant in the population.
Although analyses of the stomach contents of demersal bony and cartiligineous fish did not reveal *N. norvegicus* preys in any significant quantity, it seems that fishing mortality is the main component of overall mortality after recruitment to the seabed when the species assumes benthic life (Froglia and Gramitto, 1988).

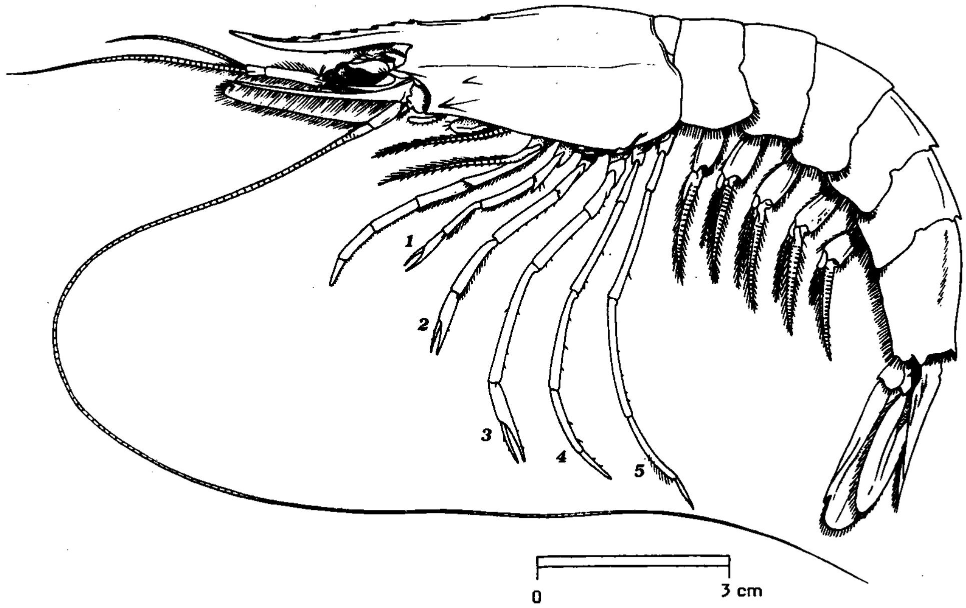
Table 45. Mortality rate coefficients for Norway lobster in the Adriatic.

Author	Area	M (yr^{-1})	F (yr^{-1})	Z (yr^{-1})
Froglia and Gramitto, 1988	off Ancona			males 0.9 – 1.6 females 0.9 – 2.5
	Pomo/Jabuka Pit			males 1.0 – 1.1 females 1.1 – 1.4
Marano *et al.*, 1998a	Southern Adriatic	0.25	0,39 F_{max}=0.22 $F_{0.1}$=0.14	0.64 (0.57-0.72)
Marrs *et al.*, 2000	off Ancona	0.2	males 0.37 – 0.52 females 0.57 – 0.81	males 0.67 – 0.82 females 0.84 – 1.07
		0.4	males 0.22 – 0.34 females 0.38 – 0.54	males 0.72 – 0.84 females 0.84 – 0.99

Norway lobster ranks first by value and second by weight among the crustacean resources exploited in the Adriatic Sea. For the Adriatic (Italy and Croatia), total landings are approximately 2000 tonnes per year (Marrs *et al.*, 2000). Adriatic trawling grounds are considered to be fully exploited or even overexploited (Froglia and Gramitto, 1982; IMBC *et al.*, 1994; Sarda, 1998a, b).
If the mesh size on the cod-end is increased from 40 to 66 mm, the Norway lobster catch would momentarily fall by 23%. In the long run (based on the Thompson and Bell model), this would cause a 47,8% Yield per Recruit (Y/R) increase (GMS-GRUND, 1998).
A 20% reduction of the fishing effort would increase Y/R 10% to 15%, and stock would reach an optimum state of exploitation about six years after implementation of the effort reduction measures. Conversely, an increase in fishing effort would result in heavier exploitation, with overexploitation and consequent Y/R decrease (Sarda, 1998a, b).

Parapenaeus longirostris (Lucas, 1847)
Family: Penaeidae

EN: Deep-water rose shrimp
SQ: Karkaleci i thellesise
HR: Kozica
IT: Gambero rosa
SL: Dolgoostna rdeca kozica



Species description

The deep-water rose shrimp is a large decapod crustacean. It has a pink-orange carapace with a reddish rostrum. On the carapace, there is a long furrow beginning near the eyes and present on the entire length of the carapace. The telson ends with three sharp, hard little teeth. The female gonads vary in colour, from white to dark green, depending on the stage of maturity (Fisher *et al.*, 1987; Relini *et al.*, 1999).

Distribution

This species is distributed in the eastern Atlantic from Angola to Portugal and in the West Atlantic from Guyana to Massachusetts. It inhabits the entire Mediterranean (Fisher *et al.*, 1987). *Parapaeneus longirostris* can be found at depths between 20 and 700 m, but it is common and abundant on sandy-muddy bottoms between 100 and 400 m (Bombace, 1972).
During the expedition "Hvar" this decapod crustacean was not recorded in the northern Adriatic. It occurs in the deeper central Adriatic, in the Pomo/Jabuka Pit and in the southern Adriatic. It inhabits only muddy sediments, at depths over 130 m (Karlovac, 1949). In the Pomo/Jabuka Pit region, this species lives on sea bottoms from 150 to 190 m (Jukić, 1975; Županović and Jardas, 1989). In the southern Adriatic (along the Italian coast) the population is the most dense at depths from 200 to 400 m (Pastorelli *et al.*, 1996). More recently, it was discovered that this species was abundant along the Albanian coast (Pastorelli *et al.*, 1996).

Biological data

Parapenaeus longirostris can grow up to 16 cm (males) and 19 cm (females) in total length. However, males are usually 8 to 14 cm long and females from 12 to 16 cm long (Table 46). Larger specimens are caught mainly in deeper waters. During the expedition "Hvar", the largest specimen caught was a 17 cm long female (Karlovac, 1949). In 1995, during the MEDITS expedition, the carapace length of specimens caught in the central Adriatic ranged from 16 to 42 mm (Relini *et al*., 1999)
Very little is known about the biological and ecological characteristics of this species in the Adriatic.

In the Mediterranean Sea, both sexes of *P. longirostris* reach maturity in the first year of life (Froglia, 1982). After being spawned, the planktonic larval phases (nauplius, zoea and mysis) develop; the postlarva, similar to adults, reaches the sandy-muddy bottoms on the continental shelf and begins the bentho-pelagic cycle (Heldt, 1938).
The adult specimens feed on small fish, cephalopods and crustaceans. They also look for food in the sediment, such as polichets, bivalves, echinoderms and mostly foraminifers.
The growth rate differs between the sexes. Size distribution and growth parameters indicate a life cycle of 3-4 years (Froglia, 1982).

Table 46. The Carapace Length (CL, mm) - weight (g) relationship.

Author	Sex	*a*	*b*
Marano, 1993	M+F	0.00172	2.644
Marano, 1996	M+F	0.0046	2.351
Marano, 1998b, c	M+F	0.0034	2.4364

Evaluation and exploitation

In the northern and central Adriatic, the abundance of *P. longirostris* is very low, except for the Pomo/Jabuka Pit region. In the northern and central Adriatic channel region it is fished only rarely and in small quantities (Karlovac, 1949; Jukić, 1975; Županović and Jardas, 1989). During the expedition MEDITS 1995 in the central and northern Adriatic, the medium biomass index was 0,28 kg/km^2, and in the southern Adriatic (along with one part of the Ionian Sea) it was 3,72 kg/km^2 (Relini *et al*., 1999). In some stations of the southern Adriatic, Pastorelli *et al*., (1996) found biomass indices as high as 3,64 kg/h.
In the Adriatic Sea, *P. longirostris* is fished only with bottom trawl nets. Although the biggest specimens have greater commercial value, the entire catch of *P. longirostris* is marketable.

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