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Fishery and Aquaculture Relationship in the Mediterranean: Present and Future

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Abstract

Although the Mediterranean represents only 0.8% of the world seas, it is the site of a very long-established fishing activity, characterized mainly by multispecific catch and by artisanal or coastal activity, resulting from a mosaic of very diversified structures and gears, along more than 45,000 km of coastline. Two main biological features of this sea are the occurrence of a large richness of species (it represents 5.5% - 7% of world marine fauna and 16.6% of macrophyta), which stands in contrast with its 'trophic poverty' and the absence of large monospecific fishery, except for some small and large pelagic fish. Another biological characteristic of Mare Nostrum is the high invasion of exotic species, some exploited by fishery and aquaculture, some others quite dangerous. For the entire Mediterranean and Black Sea, the production (catch + aquaculture) had been steadily increasing over the period 1972-1988 from 1,140,000 t to 2,080,000 t . The period 1988-1991 has shown a drastic drop in catches (in 1991: 1,400,000 t). From 1990 to 1995 the total catch increased to 1,701,379 t then decreased and in 2000 reached 1,485,046 t . In 2000 Turkey had the first place with 496,174 t, 26.9% of the total value (1,846,026 t, including fishing and aquaculture), followed by Italy with 25%, Greece 9%, Spain 7.6% and Algeria 5.4%. As in many parts of the world, aquaculture production in the Mediterranean is rapidly expanding. In 1970 the total aquaculture production was about 18,297 t of which 74.3% produced in Italy. In 2000 a value of 358,614 t was reached, about 1/4 of the total fishery catch, while the world aquaculture production corresponds to half of the world total catch. Italy is still the main producer with 46.7% , followed by Greece with 21.5%, Turkey 9.9% and France 6.7%. A sharp drop in the production of the European eel (Anguilla anguilla) and of the European flat oyster (Ostrea edulis) is recorded. Positive and negative interactions between fishery and aquaculture are described for environment, food, juveniles, breeders, discards and market. Special attention is devoted to tuna farming, artificial reef and vallicultura. The response of governments and decision makers to the results and suggestions from marine scientists, proposals for urgent action in order to succeed sustainability and priority marine research areas are briefly described. Some urgent needs are outlined.

Keywords: Fishery, Mariculture, Biological Resources, Artificial Reef, Vallicoltura, Tuna Caging, Mediterranean.

Introduction

Fishing and mariculture have a long tradition in the Mediterranean countries, and many methods of fish and shellfish exploitation and cultivation have been developed there from ancient times. The historical, cultural background and peculiar environments are the main reason for the high diversity of gears and methods in use, and the significance of so many small-scale fisheries that are found all around the Mediterranean coast.

In order to understand better the relationship between fishery/aquaculture and environment in the Mediterranean it is essential to remember the characteristics of this semi-enclosed sea on which evaporation or concentration basin extends approximately from 5°W to 36°E and between 30° and 46° N. It covers a surface of 2.5 million km^2 (Black Sea excluded), about the 2.6% of the Atlantic Ocean. The main general characteristics of the Mediterranean sea are described in AUBERT (1994) and MARGALEF (1985).

It has relatively warm deep waters (around 13°C) and evaporation exceeds the contribution made by rains and rivers, so that water is drawn from the Atlantic, the Black Sea and the Suez Canal. Following SVERDRUP *et al.* (1942) the input in the Mediterranean from rivers is 45,000 m^3/s while losses from evaporation are 115,000 m^3/s; exchanges across the Straits of Gibraltar (14 km width and 290 m maximum depth) are evaluated about 168,000 m^3/s of deep water coming out and 175,000 m^3/s of surface waters entering from the Atlantic and flowing eastwards with a salinity gradient up to 39‰ (in front of Lebanon). The general circulation pattern of the superficial water masses, is cyclonic along coastal areas, with some anticyclonic gyres on the Alboran sea, Gulf of Gabès and Lybian zone; the turnover of the Atlantic waters in the Mediterranean Sea is about 80 years (ASTRALDI & GASPARINI, 1992; LE VOURCH *et al*, 1992; MALANOTTE-RIZZOLI & HECHT, 1988; MILLOT, 1987; NIELSEN, 1912).

The Mediterranean Sea is characterized by a marked seasonality of the surface temperatures (ANONIMOUS, 1997; GUIBOUT, 1987; LE VOURCH *et al.*, 1992):

- in summer, warm waters (more than 20°C) at the surface and important stratification of the waters. The absolute maximum is in the eastern part of the basin (28°C, August mean).
- in winter, cold waters (12 to 15°C), which are homogeneous between the surface and the depths, with important vertical convections (upwelling), recycling the nutrients abundant in the depths (these convections are induced in particular by the wind and thus largely depend on the wind speed). In February there are 3 minimum values, with the absolute minimum being in the upper Adriatic (7°C), followed by the Gulf of Lions (11.5°C) and the Aegean Sea (12°C).

This marked seasonality of the Mediterranean environment has very important biological effects on fishery and aquaculture; in particular on the biology of many commercially important species like all the tuna species, because it is conditioning spawning, migrations, growth, etc.

Productivity

It is classically considered that the Mediterranean Sea has a low productivity, its nutrients coming mainly from two sources: the superficial waters from the Atlantic (not very rich), and the river supplies (bringing certain nutrients). The fraction of the nutrients that comes from the deep layers is recycled in winter and in springtime.

Because of the poverty of nutrients, the Mediterranean remains an 'oligotrophic' sea which, on an average, shows relatively poor phytoplankton and zooplankton biomasses compared to those of the classical productive systems such as the upwellings of the eastern Atlantic facade (BETHOUX & COPIN-MONTEGUT, 1988; JACQUES, 1990). These low primary (phytoplankton) and secondary (zooplankton) productivities thus imply that the fishery potentials and top predators must logically also be poor. There are some exceptions as in the Ligurian offshore waters where the high concentration of Cetaceans and other large pelagic animals (such as tuna and swordfish) is in relation to upwellings of deep water (ORSI RELINI *et al.* 1992) mainly due to the mistral wind.

Ecology

A major biological characteristic of the Mediterranean is its large species diversity (large number of species present, 5.5 – 7% of world marine fauna and 16.6% of marine macrophyta) and the high rate of endemism observed in this sea, particularly for the benthic fauna. Another ecological particularity of the Mediterranean Sea is the heterogeneity of its two large eastern and western basins which are separated by the Straits of Sicily (Fig.1). Each of these two basins is further divided into ecologically and oceanographically heterogeneous units, with a gradient of specific diversity decreasing from the west to the east:

1) western basin: the Alboran Sea, the Algero – Provencal basin, the Tyrrhenian Sea, the Ligurian Sea.
2) eastern basin: the Adriatic Sea, the Ionian Sea, the Aegean Sea, the Levant Sea.

The Mediterranean is also characterized by a high invasion of species coming through the Suez Canal and the Straits of Gibraltar, naturally or by anthropic means. Only for fish, 90 species representing 56 families out of a total of 650 fish species recorded in the Mediterranean Sea, are recent arrivals originating from distant seas (GOLANI *et al.* 2002). These are high numbers indeed, given the narrow time frame considered (since 1960 for Atlantic origin and 1869, the opening of Suez Canal for Indopacific species). Some species are exploited by fishery and/or aquaculture, some others like green alga (*Caulerpa taxifolia*) are interfering with fishing activity (RELINI *et al.* 1998, 2000).

Geology

The Mediterranean Sea has had a complex geological past; it remained an isolated basin during the Miocene and was thus unfit for the survival of many species (DI GERONIMO, 1990; TAVIANI, 2002), for example of tunas and associated species (FONTENEAU, 1996). At the beginning of the Pliocene, one can notice a colonization of the Mediterranean by a tropical Atlantic fauna, numerous species of which can still be found in the Mediterranean. It should also be kept in mind that during the quaternary, the Mediterranean sea has had alternances of cold phases (icy periods unfavorable to the presence of species with tropical affinities) and warm phases, comparable to the one observed at the present time (PAILLARD, 1998). These geological fluctuations of the environment, implying several degrees of temperature decreases, modification of the salinity, and of the currents in the Gibraltar Straits, have probably caused important ‘natural’ fluctuations of many species like the tuna resources spawning and living in the Mediterranean.

Topography: shelves and slopes

The Mediterranean Sea generally has narrow continental shelves. Only the Adriatic and the Gulf of Gabès have extensive continental shelves. Other areas with significant shelves, although narrower, are the Gulf of Lions, the south of Sicily and the Gulf of Valencia.

The demersal and small pelagic fisheries occur mainly on the continental shelves, from the coast to 200 or 300 meters in depth. There are also some deeper fisheries on the continental slope, but these are not as extensive as those on the continental shelf. As its topography implies, the Mediterranean does not present extensive and homogeneous fishing banks, as in other zones.

Fisheries

A simple definition of the fishery or fishing activity is ‘the harvesting of any aquatic organism using all kind of devices’.The world total catch per year surpasses a 100 million tons but most of the stocks are overexploited, some fisheries have collapsed and living resources have been depleted (JACKSON *et al.* 2001, MYERS & WORM 2003, WATSON & PAULY 2001). Data from FAO, collated on a global scale, suggest that 47% of fish stocks are already exploited to their maximum sustainable limits, while 18% over-exploited and 10% are depleted (FAO, 2002). According to the FAO the total marine catch reported in the Mediterranean and Black seas in 2000 (Table 1) reached almost 1.5 million tonnes. This figure represents about 1.8% of the world catch even though the surface of the Mediterranean Sea only represents 0.8% of the world marine surface. However, because of the quality of the product, fish prices are five to ten times higher than in most of other parts of the world.

For the entire Mediterranean and Black Sea, the production of all diadromous and marine fish, crustaceans and molluscs in statistical divisions of GFCM-FAO (Fig.1), had steadily increased over the period 1972-1988 from 1,140,000 t to 2,080,000 t (STAMATOUPOULOS, 1995). The period 1988-1991 has shown a drastic drop in catches which were 1,400,000 t in 1991, equivalent to a 30% decrease with respect to the 1988 level. From 1990 to 1995 the total catch increased to 1,701,379 t then decreased reaching 1,485,046 t in 2000 (Fig.2). The increase of catches in the period 1990-95 seems to be partly due to some corrections in catch statistics; it could also be due to a movement away from the original oligotrophic condition of the Mediterranean to a more mesotrophic productive condition, in particular in the coastal zone (FIORENTINI *et al.* 1997). Nevertheless, it is difficult to distinguish the contribution of each factor.

Another estimation of FAO from 1950 to 2000 is referred to in table 2 with data per country of total production (aquaculture included). In 2000 Turkey held the first place with 496,174 t, 26.9% of the total value (1,846,026) followed by Italy with 25%, Greece 9%, Spain 7.6% and Algeria 5.4%.

Mediterranean resources

Two biological features of fishing resources in this sea are: 1) the occurrence of a large richness of species, as above mentioned, which stands in contrast with its 'trophic poverty' and 2) the absence of large monospecific fishery, though some monospecific catches do occasionally occur with small and large pelagic fish. In the two volumes of FAO (FISCHER *et al.* 1987 a,b) devoted to living exploitable resources in the Mediterranean and Black Sea, 896 species (Table 3) are listed and described but those really important for fishery are some hundreds. The fishery resources can be grouped into five main categories: 1) small pelagics, 2) large pelagics, 3) demersals, 4) bivals (mussels, oysters, clams), 5) others (sponges, coral, algae etc.).

Table 1
World capture production (metric tons) with data of the 57 main fishing countries and of the Mediterranean and the Black Sea (FAO - data)

	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
57 countries	79,150,912	80,881,229	82,252,004	87,308,832	87,241,952	88,919,958	89,375,852	82,661,240	88,594,410	90,125,502
Other countries	5,386,075	4,598,643	4,409,229	4,399,667	4,767,554	4,563,362	4,533,780	4,621,759	4,610,524	4,723,172
World total	84,536,978	85,479,872	86,661,233	91,708,499	92,009,506	93,483,320	93,909,632	87,282,999	93,204,934	94,848,674
Mediterranean and Black Sea	1,318,653	1,454,108	1,538,787	1,665,350	1,701,379	1,529,261	1,439,414	1,405,852	1,536,359	1,485,046

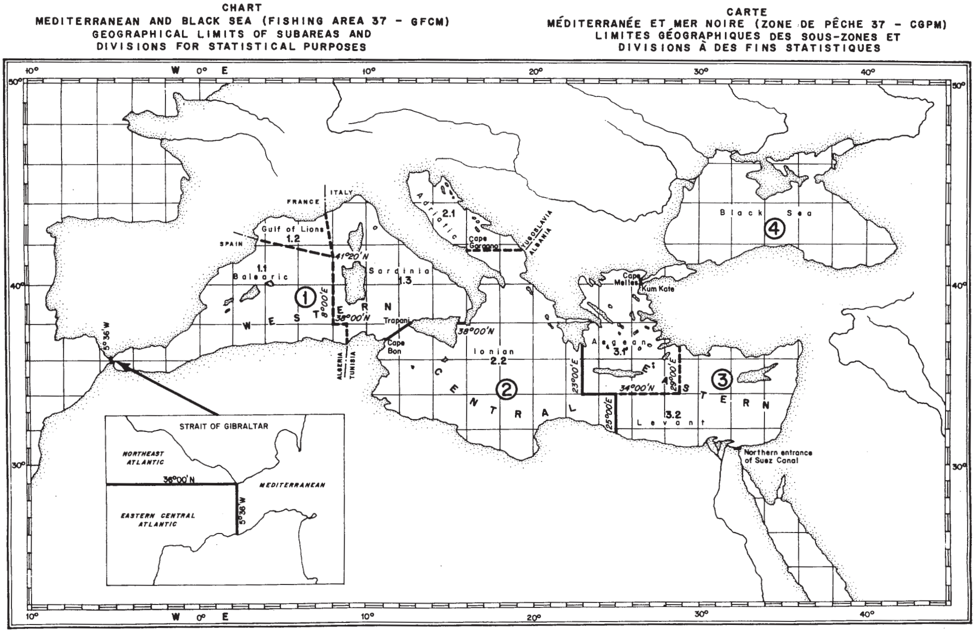

Fig. 1: Fishing area 37 – GFCM. Geographical limits of subareas and divisions for statistical purposes.

Small pelagic stocks

Most of the small pelagic species are in general distributed close to the coast, over the continental platform. The majority of these species undertake rather well- defined seasonal migrations. Sardine, anchovy, mackerel and horse mackerel move close to the coast during summer; during winter, they move away and shift to deeper waters.

Summer is the main fishing period. Large-scale fluctuations in stock size occur which are not yet perfectly explained by science. An important set of data since 1975 on predicted biomass and actual catch of sardine and anchovy is available in the Adriatic Sea (CINGOLANI *et al.* 1998), where there is an alternanation in the peaks of two species biomass (Fig. 3 and 4).

Sardine, *Sardina pilchardus* (Walbaum, 1792) is one of the most important commercial species of the northern and central Adriatic Sea. The annual catch of sardine for these areas, in the time interval 1975-2001, was estimated by CINGOLANI *et al.* (2002) together with mid-year biomass at sea. Values

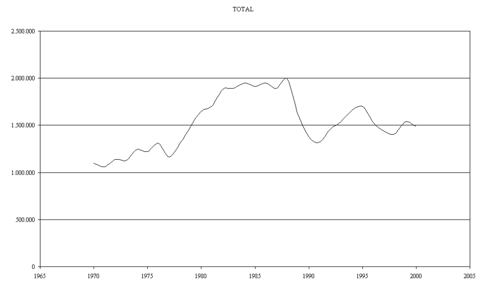

Fig. 2: Mediterranean and Black Sea total capture production in metric tons from 1970 to 2000.

of fishing mortality rates at age, spawning biomass and ratios between catch and spawning biomass were also obtained. The assessment was based on Virtual Population Analysis (VPA). The biomass has declined since the second half of the 1980s. In addition, catches have been quite near to spawning biomass in recent years. Figure 3 shows the results obtained from VPA. The natural mortality rate M was assumed equal to 0.5. The average values of catches, mid-year biomass, and mid-year spawning biomass in the years 1999-2001 are equal to 18,800, 102,960 and 35,420 tonnes respectively.

Table 2
Total production (Catch + Aquaculture) in the Mediterranean and the Black Sea in tons (FAO - data).

Country	1950	1954	1958	1962	1966	1970	1974	1978	1982	1986	1990	1994	1998	2000
Albania	1,000	1,600	1,700	1,800	2,600	5,300	5,500	6,000	6,134	8,725.20	12,801.60	1,693.80	1,968.50	2,568
Algeria	27,200	20,962	18,578	21,500	20,350	24,234	35,708	34,143	64,500	65,277.80	90,671.20	135,442.90	92,377	100,038,90
Bosnia and Herzegovina	-	-	-	-	-	-	-	-	-		-	<0.5	<0.5	<0.5
Bulgaria	3,500	7,900	5,300	8,400	8,100	3,813	7,475	12,017	17,309	12,998	2,899	5,340	8,513	6,147
China	-	-	-	-	-	-	-	-	-	-	-	97	-	-
Croatia	-	-	-	-	-	-	-	-	-	-	-	17,976.50	25,038	24,355
Cyprus	500	500	600	600	1,000	1,363	1,180	1,245	1,545	2,542.40	2,636	2,972	3,486	4,017
Egypt	15,700	16,600	22,200	36,600	15,000	7,858	8,384	12,270	11,239.60	19,342	35,443	45,001.60	77,536	97,031
France	10,907	8,598	17,694	27,114	35,600	46,672	46,041	40,279.30	57,803.60	55,889.60	67,803.80	73,013.60	61,564.50	63,531.60
Gaza Strip (Palestine)	-	-	-	-	-	-	-	-	-	-	-	-	3,625	3.600
Georgia	-	-	-	-	-	-	-	-	-	-	12,748	1,397	2,997	2,260
Gibraltar	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Greece	47,000	48,300	64,900	60,000	52,900	45,572	56,990	73,142	85,990.80	103,286	118,449	198,663.90	156,684.40	167,741.70
Israel	1,800	2,500	3,900	6,000	4,400	6,801	6,891	8,200	5,251	4,143	4,025	2,873	5,901	6,880
Italy	171,600	198,400	181,900	195,400	287,000	335,220	393,176	385,662.40	461,014.70	478,860.40	416,583,10	453,751.80	459,269.70	460,985.90
Japan	-	-	-	-	600	-	2,192	63	965	352	205	530	398	894
Korea, Republic of	.	.	-	-	-	-	-	-	-	-	-	-	-	-
Lebanon	1,600	1,400	1,800	2,000	2,500	2,300	3,100	1,700	1,400	1,500	1,430	2,217	3,500	3,646
Libyan Arab Jamahiriya	2,300	2,300	2,400	1,500	3,300	5,500	4,769	4,355	7,425	16,010	24,020	33,013	32,010	32,510
Malta	1,000	800	1,100	1,300	1,300	1,212	1,546	1,079	1,216	1,121	762	1,790	2,930	2.785
Monaco	-	-	-	-	-	<0.5	1	1	2	2	2	3	3	3
Morocco	5,300	8,700	6,300	8,100	9,779	10,869	20,655	32,154.10	33,207	37,682	35,885.20	36,241.30	29,409.50	39,328.20
Other nei	-	-	-	-	-	-	-	-	994	1,494	2,231	1,537	835	-
Panama	-	-	-	-	-	-	-	-	-	-	74	1-499	-	-
Portugal	-	-	-	-	-	-	-	-	-	-	-	428	54	96

Romania	5,000	5,000	8,000	7,300	3,900	9,309	5,570	7,114	10,374	15,834	6,326	3,060	4,431	2.476
Russian Federation	-	-	-	-	-	-	-	-	-	-	18,848	14,224	9,946	22,685
Slovenia	-	-	-	-	-	-	-	-	-	-	-	2,110	2,113	1.747
Spain	97,050	117,261	148,440	103,778	107,469.80	99,163	121,116	149,978.40	163,022	143,493.60	143,087.20	148,095.30	123,394.30	140,334
Syrian Arab Republic	500	800	900	1,000	1,000	1,000	800	1,477	1,123	923.9	1,591	1,950	2,750	2.581
Taiwan Province of China1	-	-	-	-	-	-	-	-	-	-	-	713	-	3
Tunisia	11,800	11,100	15,400	20,700	25,900	22,560	42,197	56,234.80	65,014	92,947	88,928,50	86,058.80	88,145.60	95,454.80
Turkey	77,100	100,300	79,500	51,500	107,900	160,571	114,812	222,325	469,850	539,610.90	343,323.10	553,471	456,111	496,174
Ukraine	-	-	-	-	-	-	-	-	-	-	71,569	40,121	43,308	65,692
Un. Sov. Soc. Rep.	233,020	221,528	207,534	259,636	338,015	344,851	441,240	364,063	522,124	486,577	-	-	-	-
Yugoslavia SFR	20,400	14,900	20,600	18,400	27,350	26,798	30,220	37,465	40,402	51,523	41,389.90	-	-	-
Yugoslavia, Fed. Rep. of	-	-	-	-	-	-	-	-	-	-	-	266,6	420,9	433
TOTAL	**734,277**	**789,449**	**808,746**	**832,628**	**1,055,963.80**	**1,160,966**	**1,349,563**	**1,450,968**	**2,027,905.70**	**2,140,134.80**	**1,543,731.70**	**1,865,551.10**	**1,698,719.40**	**1,846.026.10**

The estimated stock biomass of Adriatic anchovy, *Engraulis encrasicolus* (Linnaeus, 1758), shows strong fluctuations during the observed period (1976-2001; using split-year starting year is 1976). A collapse occurred in the 1980s and the recovery of the stock biomass shows a constant positive trend except in 1997 and 1998 (Fig. 4). Nevertheless, it should be noted that the increase in 2001 could be overestimated. It is interesting to outline that the peaks of biomass of the two species are separated.

For most of the small pelagic species, including sardine and with the probable exception of anchovy, the existing assessments indicate that they do not seem to be fully exploited everywhere (this situation is likely to be related to difficulties in achieving effective utilisation and marketing). In recent years small pelagic species have also been used as food in mariculture plants, in particular for bluefin tuna fattening, with increasing concern for the stocks.

Large pelagic stocks

They are represented by large fish that live near the surface and are migratory; most of them are gregarious. To this category belong swordfish (*Xiphias gladius*), bluefin tuna (*Thunnus thynnus*), albacore (*Thunnus albacore*), small tunas (*Auxis, Euthynnus, Katsuwonus, Sarda*). Two other species, *Seriola dumerili* and *Coryphaena hippurus*, have been artificially reproduced or small individuals caught for caging.

The Mediterranean provided on an average, 65,000 t of tuna and

Table 3
Number of species per taxon described in the volumes «Fiches FAO d'idéntification des espèces pour les besoins de la pêche, Méditerranée et Mer Noire».

Agnatha	3
Chondrichthyes	80
Osteichthyes	389
Ascidiacea	5
Echinodermata	6
Cephalopoda	53
Gasteropoda	94
Bivalvia	105
Crustacea Decapoda	65
Stomatopoda	2
Cirripedia	2
Cnidaria	7
Porifera	7
Algae	76
Phanerogamae	2
Total	***896***

billfish from 1983 to 1992, i.e. 8% of the overall Mediterranean yearly catch (FONTENEAU, 1996). Among these stocks, bluefin tuna is considered as fully exploited and juveniles of this species are submitted to heavy fishing pressure, increasing in recent years in relation to caging, also of juveniles.

The Mediterranean is an important spawning area for several tuna species, and bluefin tuna in particular. It seems that Mediterranean swordfish and albacore constitute two stocks which are relatively isolated from the northern Atlantic ones (FONTENEAU, 1996).

Concerning the bluefin tuna, the increasing trend of catches, observed during the last thirty years is mainly the result of a constantly growing fishing effort. In the Mediterranean Sea, bluefin tuna is caught mainly by purse seiner and longliner fleets; catches by tuna traps (Tonnara) are still decreasing. Purse seining is a rather recent catch method. It

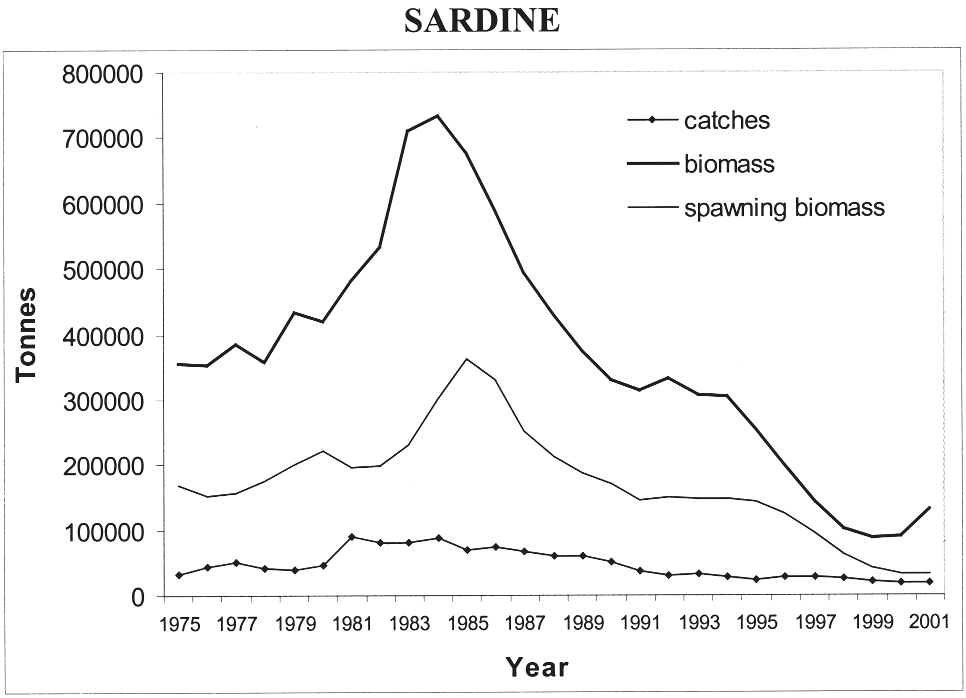

Fig. 3: Annual catches, mid-year total biomass and mid-year spawning biomass at sea estimated by VPA (Cingolani *et al.* 2002).

developed in the 1960's and the purse seiner fleet now accounts for 60 to 80 per cent of the total catch. It relies on high-tech equipment and is very species-selective as well as efficient; also, contrary to what happens in other regions of the world, purse seine fishing in the Mediterranean does not entail high by-catches of cetaceans. The efficiency of purse seining has led ICCAT (International Commission for Conservation of Atlantic Tunas) to establish technical limitations in order to restrict fishing capacity, such as the decision in 2001 to ban the use of spotter helicopters or planes during the month of June.

ICCAT indicated a strong decline in the spawning stock biomass since 1993, as well as an increase in fishing mortality rates. The analysis also indicated that future catch levels in excess of 33,000 tonnes would not be sustainable and only catches of 25,000 tonnes or less would halt the decline in biomass. Nevertheless allowable catch (TAC) for the east Atlantic stock for 2001 was set at 29,500 tonnes (FAO, 2001, appendix D). The bluefin tuna and the swordfish have in common some exploitation particularities (FONTENEAU, 1996), which are essential to keep in mind for stock assessment and management:

1) important 'instantaneous' biomass (numerous age classes can be exploited, while the biological productivity of these species is very low).
2) danger of a fishery disequilibrium and of long response delay of the stock to any management measure.
3) in the most favourable case the reduction of fishing effort would have positive effects only after ten years or more.

Demersal resources

Demersal resources represent about 55% of the Mediterranean catch and consist of those

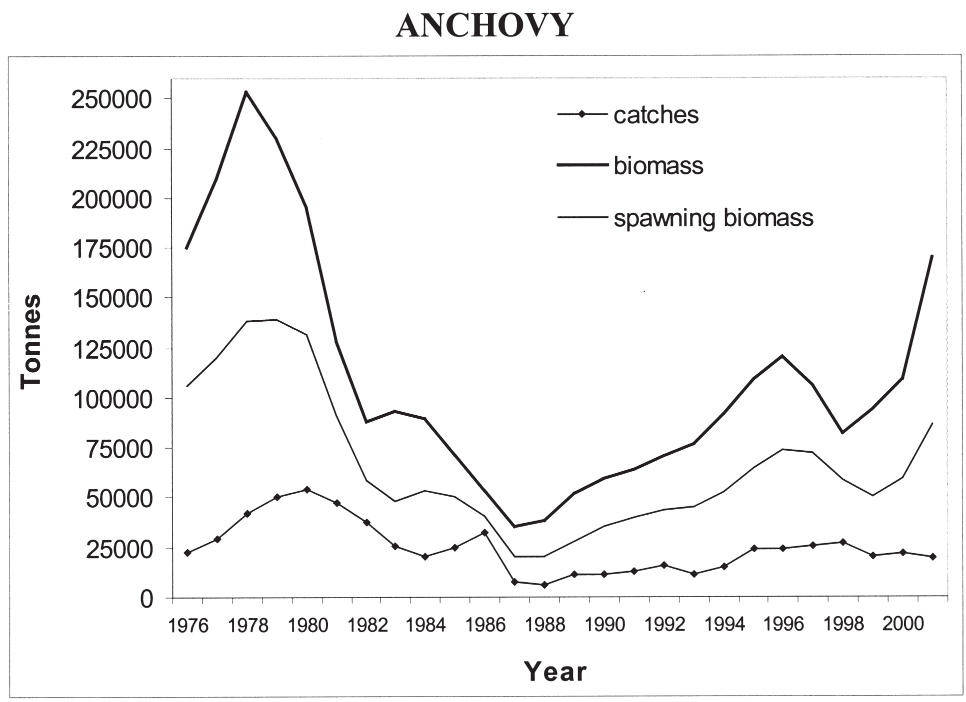

Fig. 4: Annual catches, mid-year total biomass and mid-year spawning biomass at sea estimated by VPA (Cingolani *et al.* 1998 and personal communication).

organisms which live and feed close to the seabed; hundreds of species are exploited: the most important are hake (*Merluccius merluccius*) and gadiforms (*Phycis, Micromesistius*), red mullets (*Mullus surmuletus* and *M. barbatus*), red shrimps (*Aristeus* and *Aristaeomorpha*), Norway lobster (*Nephrops norvegicus*), and some cephalopods (*Octopus, Sepia, Eledone* etc.)

The exploited depth range is usually from 10 to 800 m, but mainly up to 400 m. The key gradient, along which seasonal or life history migrations are likely to occur, is not across an extensive shelf (as in the North Sea), but from a shallow littoral to the deep water of the shelf edge and slope, where spawning refuges for an important component of the adult stock may occur.

Many different gears are used to exploit these species, including bottom trawls, gill-nets, traps, bottom longlines and a variety of dredges. On the basis of the available data, most of the main demersal stocks are either fully exploited, or overexploited (GFCM, 2001).

It is difficult to explain how an inshore fishery with a high level of fishing intensity and juvenile mortality has managed to remain productive. In most of the cases, a decreasing trend in individual length of the fish caught and in the catches per unit of effort of the trawlers can be observed. In general, the juveniles are exposed to the most important fishing pressure by otter trawlers and their sizes at first catch are very often similar to those at which fish appear in the fishery ground (recruitment), even though this is forbidden.

The artisanal fleets, composed of small or medium size boats using fixed nets, pots, longlines, affect the adult population more, even though there is some degree of overlap with trawl fishing. Among demersals there are important species used in aquaculture such as sea breams, sea bars, Sparids, grey mullets, prawns: *Penaeus (Melicertus) kerathurus, Penaeus (Marsupenaeus) japonicus.*

Bivalvs

Bivalv molluscs (mussels, oysters, cockles, scallops, clams in particular *Chamelea* and *Ruditapes*) are very important Mediterranean resources, though it is not easy to separate aquaculture production from that coming from harvest in natural beds in the statistics. Many species are also collected by hand as food, and not documented in the statistics.

The Mediterranean blue mussel (*Mytilus galloprovincialis*) gave a total production of 177,598 tons in 1999 of which 121,779 came from aquaculture. The production of the European flat oyster (*Ostrea edulis*) decreased dramatically. Exotic species like *Crassostrea gigas* (Thimberg, 1793) and *Ruditapes philippinarum* (Adams and Reeve, 1850) were introduced.

Others

In this group are listed different resources like algae, red coral, echinoderms, sponges etc.

Among the 76 Algae described in FISCHER *et al.* (1987a), at least 30 are potentially considered for human consumption, such as *Spirulina* (Cyanobacteriales), *Porphira, Undaria, Laminaria, Ulva* etc. (DELEPINE *et al.*, 1987). Algae are used mainly to produce agar. The warty gracilaria (*Gracillaria verrucosa*) was found in some north Adriatic lagoons (Italy) with a biomass of 2 – 4 kg/m^2 and an estimated production of 1000 t/year. Seven species of Sponges are exploited in the Mediterranean, which at present is the main region (in particular the eastern basin) in the world for the production of natural Sponges (VACELET, 1987 in FISCHER *et al.* 1987a). Some areas are overexploited and because of the high price there is an increasing interest in artificial culture. Also interesting are the tests in progress on the role of Sponges associated with fish farming in cleaning the waters. Among the celenterate, Jellyfish are fished for the Japanese market, anemones (in particular *Anemonis sulcata*) are eaten in different countries around the Mediterranean, red coral (*Corallium rubrum*) is intensively exploited and a production of 60 t/year is estimated for the Mediterranean (CARPINE 1987 in FISCHER *et al.*, 1987a).

Among the Cirripeds only the stalk-barnacle *Mitella pollicipes* is collected and eaten, mainly in Spain (RELINI 1987 in FISCHER *et al.*, 1987a). Among the Echinoderms only four sea urchins are eaten, in particular the gonads of *Paracentrotus lividus* of which 50-100 t were collected during 1985 along the Mediterranean coast of France (TORTONESE & VADON in FISCHER *et al.*, 1987a). Also two sea-cucumber (*Holoturia tubulosa* and *Stichopus regalis*) are eaten in some places, but are mainly used as bait. Among the Ascidians only three species of Piuridae are commonly eaten fresh: *Microcosmus polymorphus, Microcosmus sabatieri, Microcosmus vulgaris*. Some other sea-squirts are used as bait (MONNIOT C. & F. 1987, in FISCHER *et al.*, 1987a).

The fleet

The Mediterranean Sea has not been the theatre of the development of a true industrial fishing, which implies important investments made by companies or financial groups, though some long distance fleets coming outside the basin (from Japan and other eastern countries) are present, in particular for tuna fishing. However, most of the trawlers (bottom and pelagic) and purse-seiners (operating during the night or the day) could be considered semi-industrial or industrial vessels. According to European Union sources, the vessels for industrial fishing (mostly trawlers and seiners) operating from Union ports are 4,300 units, of which some 45%, 32%, 17% and 6% are located in Italy, Spain, Greece and France respectively (FARRUGIO 1996).

Artisanal fishing, which applies to any small-capital exploitation, most often the fishermen's property, is often coastal and thus located on the continental shelf or very close to it, and exploits areas which can be reached in few hours from the ports or beaches where the fishermen are based. Consequently, this type of activity does not imply long periods at sea. Another characteristic of artisanal fishing is that it generally employs a great number of workers, at sea and ashore as well. The kinds of fishing gear are highly diversified and the fleets are generally composed of large numbers of boats, mostly of low tonnage, based in a multitude of ports and havens.

Fishing activities exhibit great variations from one area to another, from the point of view of production methods as well as the adaptation of human communities to the physical and biological environmental conditions.

The complexity of describing and quantifying the small-scale fisheries is not to be underestimated. For the small scale sector, official statistics of 1989-90 state that in EU countries, artisanal fleets made up of 41,930 units were actively operating, of which some 46%, 39%, 8%, 7% were registered for Greece, Italy, Spain and France respectively (FARRUGIO 1996) and use some 45 different gear types; with at least 150 target species, with a wide range of sizes.

Some more recent (1998) EU (European Communities, 2001) data show that in Italy there are 16,325 vessels with an engine power of 1,513,677 kW and a tonnage of 260,603, while in Greece the number of boats is 20,243 with 654,199 kW and total tonnage of 111,933.

To gain a rough idea of the likely importance of landings from this small-scale sector, we could assume an indicative value of 100 fishing days per year, with mean catches of some 30 kg/day. These guesses, if accepted, suggest total landings of the order of 300,000 tons per year, mostly of high value product. (CADDY & OLIVER, 1966).

Although more than 150 species occur regularly in the catch, a significant proportion of catches, at least in the northern and western Mediterranean, are made up of sardine, anchovy, hake, red mullets, blue whiting, sole, anglerfish, sea breams, octopus, squid, cuttlefish, red shrimp and Norway lobster: these make up 68%, 65%, 43% and 40% of the registered landings in Spain, France, Italy and Greece respectively. Fleet and catches in different GFCM divisions are described by CADDY and OLIVER (1966) and by PAPACONSTANTINOU and FARRUGIO (2000).

Types of fishing gears and their effects on the environment

Although the Mediterranean represents only 0.8% of the world seas, it is the site of a very long-established fishing activity, characterised mainly by multispecific catch and by artisanal or coastal activity, resulting from a mosaic of very diversified structures and gears, along more than 45,000 km of coastline. The differences of fishing activities are due not only to ecological and geographical factors influencing ecosystems and exploited biological resources, but also the social, economic and historical context of the countries involved.

A great number of fishing gears and methods are currently used in the Mediterranean; some of them are in strong competition to catch the same resource, and sometimes they have negative effects on the environment.

It is quite impossible to record all gears, in particular small ones that are utilized on local base, following ancient traditions. The main groups as recorded in LLEONART & RECASENS (1996) are the following:

1) Hand lines, pole lines, troll lines

There is a large variety with one or several hooks, natural or artificial bait. They are used mainly by sport fishermen.

2) Longlines

There are two main types of longline that are traditionally utilized in particular by small-scale fishery:

a) Surface longlines, to catch large pelagic species also far from the coast and on a large scale; they may have a heavy impact on many non-commercial and protected species, turtles and sharks being the most affected. Some foreign fleets fish in the Mediterranean international waters, using surface longlines which are extremely long (around 100 km) (GUAL, 1994).

b) Demersal longlines. They are put near the bottom, sometimes at depth of more than 1000 m. It does not seem that demersal longlines damage biotic or abiotic environments in addition to those effects due to removal of individuals of a target species (maybe problems with deep white corals).

3) Nets

- Gillnets. A gillnet is a panel of monofilament plastic net, suspended vertically in the water, by floats attached to the top and weights attached to the bottom of the net. It is usually comprised of a short panel of several strips, laid near the water surface, if targeting pelagic resources, or near the bottom if targeting demersal species. It is a passive fishing device which is acoustically and visually invisible to most marine animals, however it does not seem especially dangerous if correctly used, with an apparently light induced mortality of marine mammals and turtles (LLEONART & RECASENS, 1996). Lost nets however can cause damage to resources and the environment through ghost net fishing, though the problem has not been quantified so far in the Mediterranean.
- Trammel nets are similar and they are used in the same way as small-scale gillnets, but they are made up of three nets: two exterior ones with a wide mesh size and an inside net between them, with a smaller mesh size, which catches fish by entanglement. The problems are the same as those of gillnets.
- Driftnets are surface gillnets, not fixed but drifting in the open ocean. They are of different length and mesh size. Also the largest ones, targeted at swordfish, can catch virtually all living organisms that swim into them independently of size, including the target species as well as non-target species (some tuna, shark etc.) and non-commercial species (including some

elasmobranchs, turtles, mammals, etc.). Discards can reach 80% of the total catch (GUTIERREZ, 1994, quoted by LLEONART & RECASENS 1996). Since 1992 EU regulations have prohibited vessels keeping on board or using for fishing, one or more driftnets whose individual or total length exceeds 2.5 km (and driftnets longer than 1 km must remain attached to the vessel). At present, this gear is totally forbidden in EU countries. However, it seems that most of these nets were sold to other countries or were substituted with other types of net (mainly other names such as *tonaille, ferretara*). So the use of large driftnets fishing bluefin tuna, albacore and/or swordfish still constitutes a major unsolved problem in the Mediterranean fisheries and represent a serious concern, not only for protected species but for large pelagic fish stocks.

4) Traps (Tonnara, fish pots, fish basket)

Many gears are used as traps. The large ones are coastal fixed traps for tuna (tonnare or tonnarelle), or other pelagic fish (*Seriola, Sarda, Auxis*). In the Mediterranean the coastal traps for tuna were very important in the past, in particular from the 12th to the 20th century in relation to salting and then oiling of the bluefin tunas (DOUMENGE, 1999). The number of 'tonnare' in recent decades has diminished due to changes in the behavior of tuna, now swimming further off the coast, and due to the presence of purse-seiners that catch fish in the open sea. Other traps include fish pots or fish baskets made with different materials, in some places vegetal material is still used. The common spiny lobster or common octopus, cuttle fish and many fish are the target catch. These small gears do not cause any damage, the only negative effect may be ghost fishing, but this is generally reduced with time.

5) Dredges, hydraulic dredges

Dredges are gears in the form of an oblong rigid frame in the mouth with an attached bag net of different materials, used mainly by the small-scale fishery, targeted in particular to flatfish and shellfish. These gears are used on sandy and muddy areas up to a depth of less than 50 m. The damage caused to the environment is related mainly to their use close to seagrass beds. Also, disturbances to the structure of sandy bottom communities by a scratching effect are caused.

Hydraulic dredges are powerful gears used mainly in the Adriatic Sea, to collect clams (Vongole) with strong impact on the bottom communities.

6) Seines

There are many types of seines depending on the target species and locality. Two main types are:

- Small purse seines, extensively used in the Mediterranean to catch small pelagics (anchovy, sardine), sometimes in competition with pelagic trawlers. They have no major effects on the ecosystem, unless the lead lines are towed on the seabed.
- Large purse seines. They are targeted mainly at tuna. Their impact on the ecosystem through the accidental catching of dolphins has not been quantified yet and in the Mediterranean seems to be very rare. A few studies have been done on that question, mainly in EU projects (see HAAN *et al.* 1997, 1998).

7) Trawls

Trawls are towed nets consisting of a cone-shaped body closed by a bag or cod end and extended at the opening by wings. They can be towed by one or two boats. When one boat is used the horizontal opening of the net is maintained by an otter board. Fish are caught by filtration through the moving gear. The negative impacts on communities captured by trawls are related to their lack of selectivity: this allows a high yield for trawling, but in the long term it can collapse stocks. There are two main different types of trawl:

- The bottom trawl: is the main demersal gear in terms of number of vessels, fishing effort and catch obtained in the Mediterranean Sea. The gear is very efficient but affects the seabed along which it is towed, and has a bad selectivity pattern. It catches many different species with a wide range of lengths. Particularly dangerous are the otter boards that plough the bottom and destroy living communities, in particular sea grasses.

  The pelagic trawl: this trawl, usually much larger than the bottom trawl, is designed and rigged to work in midwater, including surface water. The front net sections are very often made with very large meshes or ropes, which herd the fish schools towards the net aft sections. It is used to catch small pelagics (anchovy, sardine, mackerel, etc.). Problems with this gear are related to its large dimensions which allows a large catch of small fish of the target species, and causes a significant increase in the mortality of these species.

To give an idea of the differences in fleet and resources in the different parts of the Mediterranean, two summary tables are shown (Table 4, 5). They are made up mainly of data from CADDY & OLIVER (1996).

Mediterranean sub-areas and management units

The whole Mediterranean and Black Sea FAO statistical fishing area 37 was divided into the sub-areas and divisions as shown in Fig.1. The General Fisheries Council for the Mediterranean (GFCM-FAO), an intergovernmental organisation, managed fishery in area 37 since the 1950's and some years later, aquaculture problems too.

This organisation was transformed (some years ago but not all countries have ratified the decision yet) into the General Fisheries Commission for the Mediterranean with a Scientific Advisory Committee (SAC) divided into subcommittees for stock assessment, environment, statistics, etc. The above-mentioned statistical subdivisions of area 37 were changed into 30 management units (Fig.5) (ANONIMOUS 2001) then called geographical sub-areas (FAO, 2001).

Research and management recommendations for the GFCM area

Mediterranean resources have a long history of biological investigation (FARRUGIO *et al.* 1993), but for many countries it is only relatively recently that research has been carried out specifically in support of the management of the fish population, and the level of application of research recommendation in the management of marine fishery is still generally low, in spite of the effort of the European Commission (DG Fishery).

One example will suffice to illustrate the situation: the second meeting of the General Fisheries Council for the Mediterranean (GFCM, 1954), included the following among its first recommendation on Production: *'That, in view of the narrowness of the continental shelf:*

a) ships with a wide range of action be used to avoid continual dragging of the same (i.e. inshore) fishing grounds;

b) the zone from 200 m to 600 m be explored for new working zones;

c) the continental shelf be given a rest by prohibiting trawling during the growing months of the fingerlings.'

Some 37 years later, although recommendations a) and b) have long been accomplished for most of the northern Mediterranean shelf, a reduction in overall fishing efforts, particularly for inshore trawling, still remains the main priority for management actions, but little progress has yet been made in its implementation (CADDY 1993), notwithstanding the fishing effort limitations required by the EU, too.

A lot of research in the Mediterranean was supported by the EU (DG Fishery). The main project was Medits (Mediterranean international trawl survey), a yearly survey for demersal resources in the seas of the four E.C. Mediterranean countries since 1994. Some

Table 4
Main fishery-gear, environment characteristics, biological resources in different zones of the Mediterranean (Fig.1).

Zone	Gear-Fishery	Environment	Resources
1.1	Purse-seiners	Atlantic inflow upwells	Small pelagic
BAL	Trawlers	Local upwelling	Lobster
	Small-scale inshore fishery		Red coral
1.2			
LION	Trawlers (high opening trawls)	Large continental shelf	Small pelagic (anchovy)
	Longliners gillnetters	(high productivity)	Demersals
	Purseiners	Permanent front or divergence	Shellfish
	Tangling and trammel nets	Liguria ⇒ Catalonia	
	Traps dredges	River Rhone	
		Coastal lagoon	
1.3	Trawlers	Low productivity	Demersals
SAR	Small-scale fishery	(except western Liguria)	Sping lobster
		Narrow shelves	Red coral
		Irregular sea beds	
		Steeps slopes	Small pelagic
			Large pelagic
2.1	Trawls (multi-gears)	High productivity	Demersals
ADR	Pelagic pair trawlers	Rivers and antropogenic inflows	Small pelagic
	Gillnets, seiners, purse seiners	Deep water from Medit.	Vongole and other clams
	Hydraulic dredges	Float bottom, gentle slopes,	
	Dredges traps	anoxic die-offs	
		Mucillagin	
2.2	Trawlers	Low-moderate productivity	Small pelagic
ION	Multipurpose vessel	Rocky and sand bottom	Demersals
	Purseiners		Lobster (*Penaeus kerathurus*)
	Long liners		Clams (*Tapes decussatus*)
	Driftnets		Sponges
	Small scale		Large pelagic
3.1	Small boats	Low productivity	Small pelagic
AEG	Gillnets, trammel nets	Complex bottoms,	Demersal
	Bottom longlines	narrow shelves	
	Traps, small towed gears	Many small islands	
	Beach seiners	Nutrient inflows form Black Sea	
	Trawlers and purse-seiners		
	(also lamparas)		
3.2	Small-scale vessels	Low productivity	Small pelagic
LEV	Trawlers	Narrow shelf	Demersals
	Purse-seiners	Reduced seasonal inflows of	Sponges
		nutrients from River Nile	
		coastal lagoons	
		Lessepsian species	

years after Albania, Croatia, Malta, Morocco and Slovenia joined the project, which was carried out with a common standard protocol, international coordination and common elaboration of data (BERTRAND *et al* 2000, BERTRAND and RELINI 2000). The main results are given in ABELLO *et al.*, 2002 and in RELINI *et al.*,1999. Unfortunately from 2002, the EU decided that each member state must manage the collection of fishery data in the frame of 1543/2000 and 1639/2001 regulations, and now the participation of non EU countries in a common survey is more difficult to manage. It is a pity because we have lost a very

Table 5
Key-species in different subareas (from Caddy and Oliver, 1996), 1991 Landings (t.).

	1.1 Balearic	1.2 G. Lion	1.3 Sardinia	2.1 Adriatic	2.2 Ionian	3.1 Aegean	3.2 Levant
Anchovy	20,912		2,619	13,076		17,422	
Sardine	109,250	15,203	4,520	44,512	19,854	25,635	4,747
Sardinellas					15,364		9,701
Silversides							5,272
Trachurus spp,					6,116		
Chub mackerels						8,059	
Picarels						9,708	
Bogue						10,896	
Hake	4,509	3,896	2,690	4,105		4,045	
Grey mullet		2,201		3,802		2,844	
Eel		1,201					
Blue whiting							2,222
Dentex			1,069				
Red mullet	3,548				6,209	2,703	
Angler	1,228						
Lizard fish							1,487
Sole		442	1,030		4,232		
Gilthead seabream							1,432
Mantis shrimp			728	2,877			
Shrimps (prawns)	1,905				18,084		4,507
Norway lobster				2,024		1,257	
Cuttle fish	1,211				8,671		765
Octopus	5,679		2,390		8,671		
Carpet shell nei				16,000			
Stripped venus				25,419			
Mussels		16,148	15,928	52,559	32,069		
European oyster		(10,014)				2,190	

good opportunity to work together and to exchange experience and information, which is the best way to contribute to cooperation between nations and to peace in the Mediterranean.

In Italy thanks to law 41/82, since 1984-85 fishery and aquaculture research has been financed by the Ministry in charge of fisheries. The results were discussed during a meeting in December 1998 and published in four volumes (Biologia Marina Mediterranea, journal of Italian Society for Marine Biology 1998 vol. 5 fasc. 3 part. 1, 2, 3, 2500 pp.; 2000 vol. 7 fasc. 4, 230 pp). Since 1985 trawl surveys are carried out in all the Italian seas (RELINI, 2000 a;b) every year.

At present there are coordinated groups working in all the Italian seas on small pelagics, large pelagics, demersals, bivalves. It would be very useful if this kind of research were extended to the whole Mediterranean which must be considered a unique large marine ecosystem. For a review of fishery research before 1992, see FARRUGIO *et al.*, 1993 and J. LLEONART 1993. A great deal of research has been done, among others that funded by the EU, but it is scattered in different journals without an up-to-date review.

Aquaculture

Aquaculture is defined here according to the definition currently used by FAO for statistical purposes, i.e.:-'Aquaculture is the

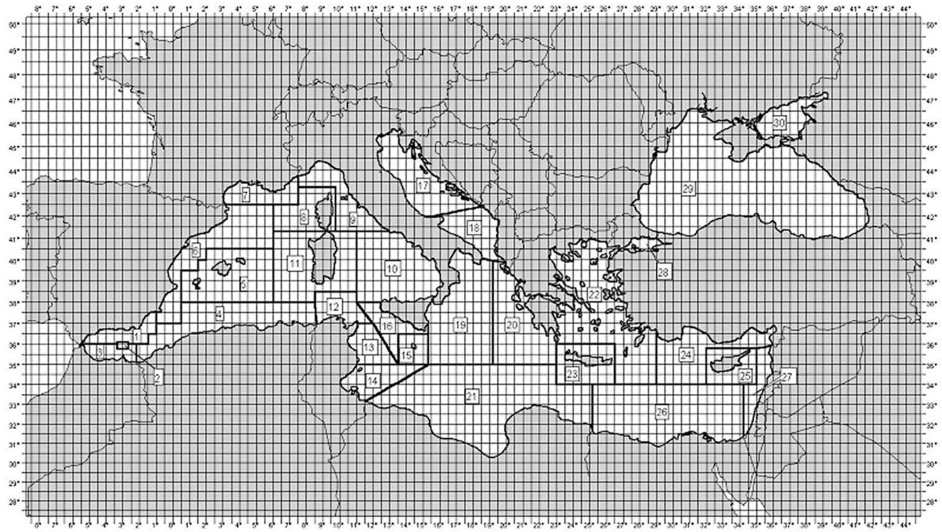

Fig. 5: Limits of the 30 GFCM management units established in Alicante, January 2001 (Anon., 2001): 1 = Northern Alboran Sea, 2 = Alboran, 3 = Southern Alboran Sea, 4 = Algerie, 5 = Northern Spain, 6 = Balearic Islands, 7 = Gulf of Lions Island, 8 = Corsica, 9 = Ligurian and North Tyrrhenian Sea, 10 = South and Central Tyrrhenian Sea, 11 = Sardinia, 12 = Northern Tunisia, 13 = Gulf of Hammamet, 14 = Gulf of Gabes, 15 = Malta, 16 = South of Sicily, 17 = Northern Adriatic Sea, 18 = Southern Adriatic Sea, 19 = Western Ionian Sea, 20 = Eastern Ionian Sea, 21 = Gulf of Sirt – Gabel Akhdar, 22 = Aegean Sea, 23 = Crete, 24 = South of Turkey, 25 = Cyprus, 26 = Egypt, 27 = Levant, 28 = Marmara Sea, 29 = Black Sea, 30 = Azov Sea.

farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sorts of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators etc. Farming also implies individual or corporate ownership of the stock being cultivated. For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to aquaculture while aquatic organisms which are exploitable by the public as a common property resource, with or without appropriate licences, are the harvest of fisheries' (FAO, 1997).

Aquaculture in the world and in the Mediterranean

As in many parts of the world, aquaculture production in the Mediterranean is rapidly expanding. In 1970 the total aquaculture production (Table 6) in the Mediterranean and Black Sea was about 18,297 t of which 74.3% was produced by Italy. In 2000 a value of 358,614 t was reached, Italy is still the main producer with 46.7%, followed by Greece 21.5%, Turkey 9.9%, and France 6.7%.

The world aquaculture production in 2000 (Table 7) reached 45.7 million tons, about half of the world total catch; from 1991 to 2000 the production increased 2.5 times, 77.8% are animals, 22.2% plants. Freshwater production is still high, about 45% of the total; 50.3% is produced in marine waters, and 4.6% from brackish organisms (FAO, 2003). In the Mediterranean the total aquaculture production is about 1/4 of the total fishery catch while at the world level aquaculture (plants included) corresponds to half of the world catch. In the Mediterranean although mollusc and shellfish production still dominate in

Table 6
Aquaculture Production (Metric tons) in the Mediterranean and Black Sea Countries (FAO data).

Country	1970	1972	1974	1976	1978	1980	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
Albania	-	-	-	2	10	100	414	906	1,752	3,107	4,443	281	293	250	108	202
Algeria	-	-	-	-	-	-	-	12	16	13	27	23	33	35	30	36
Bulgaria	-	-	-	-	-	-	11	37	57	100	-	-	-	42	92	10
Croatia	-	-	-	-	-	-	-	-	-	-	-	664	528	510	2,753	3.283
Cyprus	-	-	-	-	-	-	-	1	1	5	52	61	210	682	1,078	1,800
Egypt	-	-	-	-	-	-	-	-	-	-	-	2,400	3,600	7,634	15,494	42,158
France	4,004	13,000	11,992	12,119	8,500	8,520	7,000	7,694	11,062	9,399	26,112	25,559	33,291	28,503	28,335	24,233
Greece	-	-	-	2	6	23	60	242	350	1,430	7,236	17,560	30,307	36,616	56,828	77,033
Israel	-	-	-	-	-	-	-	12	30	60	84	54	400	699	1,902	2,914
Italy	13,603	13,890	22,440	36,846	43,498	50,640	62,547	69,600	77,030	95,699	112,444	123,427	123,546	136,373	156,025	167,775
Malta	-	-	-	-	-	-	-	-	-	-	3	500	904	1,552	1,950	1,746
Morocco	-	-	-	-	-	-	-	-	-	-	224	431	1,242	1,094	751	675
Russian Federation	-	-	-	-	-	-	-	-	-	29	24	26	334	620	140	209
Slovenia	-	-	-	-	-	-	-	-	-	-	-	156	103	125	154	117
Spain	-	-	-	-	-	-	-	-	37	76	79	80	90	114	66	41
Tunisia	-	-	-	9	28	56	117	116	182	951	874	569	657	649	944	719
Turkey	-	-	-	-	-	-	-	-	35	135	1,434	2,525	8,733	15,241	23,410	35,646
Ukraine	-	-	-	-	-	-	-	-	-	5	-	237	670	400	-	10
Un. Sov. Soc. Rep.	300	300	200	6,254	87	20	18	457	306	-	-	-	-	-	-	-
Yugoslavia SFR	390	504	458	402	409	369	425	1,517	1,397	1,567	947	-	-	-	-	-
Yugoslavia, Fed. Rep. of	-	-	-	-	-	-	-	-	-	-	-	2	3	6	8	7

quantity (approx. 60%), marine finfish production (now approx. 39%) is increasing at a higher rate (approx. 25% per year for the period 1994-98) and in 1998, it reached 143,851 tonnes. In 2000 (table 8), 50% of the Mediterranean production was made up of bivalves, the Mediterranean mussel alone was 32.3%. Sea bass production reached 19% of total production, while gilthead seabream reached 77,020 t., about 21.5% of total aquaculture production.

It is interesting to outline the sharp drop in the production of the European eel (A*nguilla anguilla*) and of the European flat oyster (*Ostrea edulis*) as was seen from the catch or harvest of these two species that are in serious danger because of change of environment, overfishing (for the eel), and competition with non-indigenous species (for the oyster). The indigenous species *Ostrea edulis* is being substituted by the introduced species *Crassostrea gigas*. In most of the shallow zone of the middle and north Adriatic Sea *Ostrea edulis* has disappeared, at present only *Crassostrea gigas* occurs.

The Mediterranean coast, which is about 45,000 km long and is highly

Table 7
World aquaculture production by culture environment (FAO data)

		1991	1993	1995	1998	2000
All aquatic	Q	18,275,681	24,466,443	31,195,038	39,062,244	45,715,559
organisms	V	29,449,168	35,801,015	44,542,920	50,424,650	56,466,982
Fish, crustaceans,	Q	13,724,214	17,815,644	24,402,467	30,507,199	35,585,111
molluscs, etc.	V	25,611,354	30,905,553	39,590,661	45,033,492	50,859,147
Aquatic plants	Q	4,551,467	6,650,799	6,792,571	8,555,045	10,130,448
	V	3,837,814	4,895,462	4,952,259	5,391,158	5,607,835
Freshwater	Q	7,863,664	10,065,997	13,526,048	17,906,717	20,631,858
	V	11,649,606	13,913,324	17,927,530	22,358,218	24,604,443
Brackishwater	Q	1,464,442	1,403,180	1,594,177	1,785,343	2,106,281
	V	6,337,254	6,485,216	7,747,198	7,648,249	8,850,709
Marine	Q	8,947,575	12,997,286	16,074,813	19,370,184	22,977,420
	V	11,462,308	15,402,475	18,868,192	20,418,183	23,011,830

Q = quantity in t
V = value in US $ x 1000

populated, displays a wide range of geographical characteristics and supports many functions, such as tourism, industry, navigation, military, residential development, and conservation, which may compete with aquaculture for resources. Many coastal areas are also physically exposed and therefore unsuitable for traditional inshore-based farming.

Offshore farming is seen as a means to overcome such difficulties, and as a way to increase production in areas where it would otherwise not be possible. Indeed, a number of offshore farms have already been established and have operated with varying degrees of success for a number of years. However, the offshore environment continues to present many challenges, not only to system design and installation, but also to stock management.

Types of mariculture and fishery relationships

In a true aquaculture practice, also artificial reproduction (breeding) of organisms is made. In many cases (mussel, oyster, eel, tuna etc.) juveniles are collected in the sea and then reared in an artificial environment. Though classification and subdivision are difficult, three main types of plants may be considered:

1) Intensive plants (tanks, cages, ponds etc.) where a large quantity of animals are fed and water quality must be controlled. Juveniles come from the sea or from artificial hatcheries;
2) Extensive plants where the regimes of water and movement of animals are managed. No food is added, sometimes juveniles are artificially added. A special case is vallicoltura;
3) Fixed plants in the sea like those for mussel cultivation or artificial habitats.

The main relationship between fishery and aquaculture is summarized in Figure 6. Most of the food used in mariculture derives from the sea. The artificial food supplied is mainly composed of fishmeal. Although it is used for its high quality protein content, it has several disadvantages, including high cost and instability of supply. Wild fish catches are on the decline and there are increasing environmental concerns (eutrophication, pollution associated with excess nutrient waste), ethical concerns over feeding fish to non piscivorous fish, and social concerns over using aquatic protein to feed fish that could be used for human nutrition (especially in nutritionally-deficient areas of the world) (NAYLOR *et al.* 2000, SUBASINGHE *et al.* 2003).

Table 8
Aquaculture production (in tonnes) per species in the Mediterranean (FAO data)

Species	1970	1980	1985	1990	1995	1998	2000
Atlantic salmon	-	-	-	300	654	40	-
Caramote prawn	-	-	1	<0.5	<0.5	<0.5	<0.5
Clams, etc. nei	-	-	-	7	11	<0.5	-
Common carp	300	20	227	-	-	-	-
Common cuttlefish	-	-	-	17	<0.5	-	-
Common dentex	-	-	-	-	<0.5	-	-
Common pandora	-	-	-	-	-	-	2
Common sole	-	-	7	9	25	12	13
Common two-banded seabream	-	-	-	1	-	-	-
European eel	413	907	852	1,668	829	411	298
European flat oyster	100	53	5,078	79	64	65	60
European seabass	-	125	510	3,786	18,748	33,666	50,300
Flatfishes nei	-	-	-	20	50	20	3
Flathead grey mullet	1,270	2,500	3,200	3,004	7,246	11,653	26,768
Giant tiger prawn	-	-	-	2	<0.5	-	-
Gilthead seabream	10	250	392	3,900	21,343	48,223	77,020
Gobies nei	-	-	-	-	-	-	2
Gracilaria seaweeds	-	-	-	5,000	5,000	3,000	3,000
Greater amberjack	-	-	13	21	1	<0.5	-
Grooved carpet shell	-	-	-	4	17	22	6
Groupers nei	-	-	-	-	<0.5	-	-
Indian white prawn	-	-	-	-	6	25	65
Japanese carpet shell	-	-	1	16,710	60,000	48,000	53,000
Kuruma prawn	-	-	16	73	83	58	27
Marine crustaceans nei	-	-	-	3	<0.5	-	-
Marine fishes nei	-	-	-	197	90	1,355	1,557
Marine molluscs nei	-	-	-	-	-	-	11
Meagre	-	-	-	-	-	30	33
Mediterranean mussel	15,954	52,833	72,852	108,276	111,775	118,601	115,771
Mullets nei	-	-	100	4	250	-	-
Natantian decapods nei	-	-	-	-	40	270	27
Nile tilapia	-	-	-	2	<0.5	-	-
Octopuses nei	-	-	-	10	<0.5	32	28
Oreochromis spilurus	-	-	-	1	<0.5	-	-
Pacific cupped oyster	250	3,040	4,676	10,675	14,000	13,003	10,000
Penaeus shrimps nei	-	-	-	-	1	-	-
Red drum	-	-	-	-	-	128	197
Red porgy	-	-	-	-	11	<0.5	-
Sargo breams nei	-	-	-	90	-	-	-
Seabasses nei	-	-	-	102	2,773	8,660	17,877
Sharpsnout seabream	-	-	-	-	15	321	452
Silversides(=Sand smelts) nei	-	-	-	-	-	-	4
Striped bass, hybrid	-	-	-	-	-	80	40
Thinlip grey mullet	-	-	5	2	-	-	-
Trouts nei	-	-	-	-	-	2,290	1,961
Turbot	-	-	-	-	1	-	-
Venus clams nei	-	-	-	-	13	55	8
Warty venus	-	-	6	10	5	<0.5	-
White seabream	-	-	-	-	1	43	84
TOTAL	**18,297**	**59,728**	**87,936**	**153,983**	**243,052**	**290,068**	**358,614**

For the time being, the number of juveniles and breeders coming from the sea and utilized in aquaculture is higher than the ones produced by aquaculture and released in the sea. In the future the proportion will probably change, though there are strong genetic concerns. Surplus of fishery catch and discards could be used as food for animals cultivated, although some health problem could arise (parasite, contamination, disease). The environment can be changed negatively and affect fishery also. Sometimes the change is positive as in the case of cages or other fixed plants that attract and concentrate the fish around the plants, and so fishermen can easily catch them by nets or hooks. These could be an added income for fish farmers also through the development of sport fishing by line and hook. Aquaculture and fishery may compete for market and sometimes the prices of cultivated fish are very low and the quality is poor. The catching in the natural environment of fish, mainly sea-bass and sea-bream escaped from aquaculture cages, is an increasing problem also for the prices in the fish market.

Tuna farming in the Mediterranean

Tuna farming is a new, rapidly developing practice in the Mediterranean region and it is completely reshaping the bluefin tuna fishery. Most of the purse seine catches in the region are now transferred to cages for fattening rather than sold directly. Tuna farming has potentially positive effects on the commercial aspect of the fishery, since it creates mechanisms for regulating market supply; but it also creates a number of serious problems that must be addressed without delay, such as undersized tunas and fishing pressure on small pelagics.

Tuna farming cannot be considered true aquaculture since the fish are not bred and reared in captivity. Instead, the rapidly growing industry is based on wild tuna caught alive from already declining stocks (FONTENEAU, 1996; FAO, 2001). Purse seines are the only mobile gear able to capture tuna alive; a feature that makes the purse seine fleets a necessary element of the tuna farming industry.

With the new practice the reliability of catch statistics has further deteriorated – an already serious problem hampering efforts to properly manage the eastern Atlantic bluefin tuna population. A significant component of the tuna captured and transferred to cages is undersized or just within the legal minimum landing weight set by ICCAT to 6.4 kg.

In addition, demand for the tuna farming industry has created increasing fishing pressure on small pelagic fish stocks. Some of these fisheries are poorly regulated and affect stocks already in decline in some areas, such as the anchovy. The low conversion factor from feed to tuna meat also makes tuna farming a wasteful practice (TUDELA 2002).

Indeed, MIYAKE (2001) states that ‘the worst problem’ with tuna farming is that this practice has further confused catch statistics because of transhipments at sea and the lack of data on fish weight at capture. It is worth mentioning here that tuna is assumed to increase their weight by 25% at the end of the farming period.

The wild fish are put in cages and fattened for a relatively short time to improve the oil content of the flesh in order to meet the Japanese market standards. According to some information this focus on meat quality entails very low food conversion efficiency. In Murcia, Spain, the conversion is on average 4.26 % - a factor less than 20:1 (Cunningham & BEJARANO, 2002, in TUDELA, 2002). So, the large amounts of fish fed to the caged tuna (mainly small and medium pelagics, such as anchovy or round sardinella) only result in a relatively modest increase in tuna biomass.

Based on current practices and information, tuna farming in the Mediterranean cannot be considered a viable sustainable option.

A ‘true’ tuna aquaculture independent of capture fisheries on wild tuna – controlling all the stages of the life cycle – with cages placed in off-shores locations would greatly improve the current situation. But concerns regarding fishing pressure on small pelagics to feed the farmed tuna would remain.

Vallicultura

Vallicultura is one of the most ancient forms of aquaculture: its origins date back to the first rudimental fish ponding and fattening systems used along the Adriatic and Tyrrhenian coasts. This technique was developed by the upper Adriatic populations to exploit the seasonal migrations of some fish species from the sea into the lagoon and delta areas, which are more suitable for their growth. The fish returns to the sea when temperature decreases and/or for reproduction. To exploit these periodic movements, large brackish areas were enclosed to prevent the fish descent toward the sea and complex permanent capture systems, lavorieri (fish barriers), were developed, consisting of barriers in the channels communicating with the sea to catch the adults. Later, from the simple ponding of fry freely immigrated into the lagoon, came a man-made seeding of fry fished elsewhere and introduced into the basins to be reared for a few years.

At present, the term 'fishing valle' means a lagoon water surface of extremely variable dimensions, surrounded by embankments made from earth or other inert material communicating directly or indirectly with the sea, and in some cases, with fresh waters.

The Italian experience (ARDIZZONE *et al.*, 1988) in the management of coastal lagoons for fisheries and aquaculture is an interesting reference model, probably the most diversified in the Mediterranean region, and it is also an important means of protection/conservation of the environment Thus, it may be useful to draw examples at a technical and administrative level, above all in those developing countries, particularly in the Mediterranean area, which request interventions to fill the growing need for fish products. The productive activities in Italian lagoons, and above all in the valli, may indicate management strategies that can provide yields of qualitative and quantitative importance, without necessarily requiring large investments for units of surface managed.

Even from the pre-Roman age, the concept of hydraulic control has been associated with that of lagoon fishing management, and to this purpose it is enough to recall the hydraulic works in the Latium coastal lakes or on the Orbetello lagoon.

The possibility of catching juveniles of the economically most valuable species near the outlets and the shorelines has made it possible to satisfy the demand for fry of the valli, which have oriented themselves towards the more interesting species which are best fitted to the environmental conditions.

The uncontrolled development of human settlements and industrial activities near the lagoon areas and the related pouring of polluted waters into the lagoons have created wide phenomena of eutrophication, which in turn have caused seasonal dystrophies, and in any case modifications of environmental qualities whose effects on the biotic community have been immediate. The present policy of environmental conservation requires expensive interventions to reduce those negatives impacts (ARDIZZONE *et al.*, 1988).

Artificial reef

A promising development in mariculture and fishery, and more widely in the integrated management of the coastal water are the artificial reefs or artificial habitats for protection and restocking of biological resources in neritic environments. One of the main goals in artificial reef (AR) construction programmes is the enhancement of biomass and thus the production of harvestable resources, in particular fish.

A general assumption of artificial reef research is that when reefs are placed on soft, sedimentary seabed, the new available hard substrata tends to attract fish from the neighbouring areas and/or to increase the area colonized by epifaunal species. There are several mechanisms which may increase the total biomass production in Ars (RELINI & RELINI 1997):

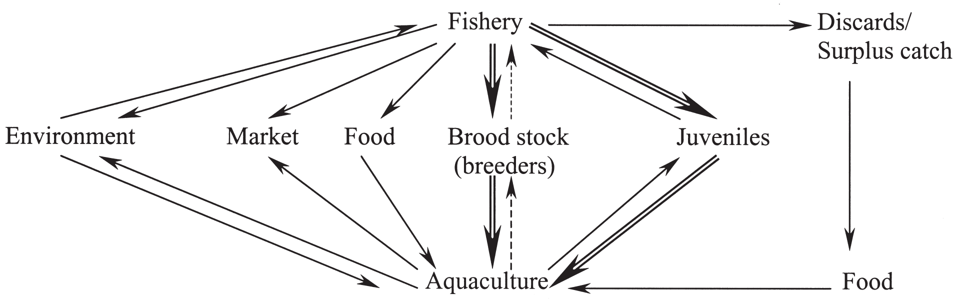

Fig. 6: Relationship between fishery and aquaculture. The larger arrows show the prevailing direction of the process.

1) ARs provide shelter from predation and from some illegal fishing, so reducing mortality rates.
2) ARs provide additional food and new food webs.
3) ARs increase feeding efficiency which probably produces faster growth rates (in particular for fish) on ARs than in natural environment.
4) ARs provide habitats for settling individuals (eggs, larvae, juveniles) favouring recruitment.
5) ARs increase the production of natural reef environment creating new space.
6) ARs protects the surrounding natural habitats (in particular *Posidonia* beds).

Around the Italian coast, reefs have been deployed in a variety of situations providing a gradient from oligotrophic waters in the southern Tyrrhenian Sea to the eutrophic conditions of the central Adriatic Sea.

In the oligotrophic condition the aims of reef deployment were to physically protect the sensitive *Posidonia* (seagrass) biotope from illegal trawling and increase habitat complexity with a hypothesized improvement in biomass and biodiversity. ARs in eutrophic waters were developed to utilize the excess nutrients in the water column to increase fishery yield.

One of the best known and studied ARs is that of Loano (RELINI 2000 c), immerged in 1986, covering an area of about 350 ha in water depths ranging from 5 m to 45 m. The AR is composed of two parts: a central main group of 30 pyramids (5 cubic blocks of 2 m side) 25 m apart, positioned along a 100 x 200 m rectangle. The second part is composed of a grid of 200 single blocks (cubic blocks of 1.2 m side)distributed in rectangle of about 3 x 1.5 km in such a way as to prevent any passage wider than 250 x 50 m. The aim was to prevent trawling in the area while allowing the use of artisanal gear. In 1989, 150 8 m^3 blocks were placed in such a way as to reinforce the protection of the central restocking zone and the most external part of the area. So far 76 species of algae and 120 of animals (invertebrates of which 58 belong to the Bryozoans) have been identified on panels and more on blocks. Settlement and development of sessile benthos was described (RELINI *et al.* 1994).

Fish, cephalopods and crustaceans have been surveyed using fishing gears and direct underwater observations and seasonal variations have been described (RELINI M. *et al.* 1994). The list comprises 76 species, including 67 species of fish (45 found during visual census), 4 crustaceans and 5 cephalopods. There are some species of a certain commercial interest, such as the sea-breams *Pagellus acarne* and *Pagellus erythrinus*, the gilthead *Sparus aurata*, the white bream *Diplodus sargus*, the common dentex *Dentex dentex*, the mullets *Mullus barbatus* and *M. surmuletus*, the sea bass *Dicentrarchus labrax* and the lobster *Palinurus elephas*. Other species present on the reef, such as the shi drum *Umbrina cirrosa*, the black brown meagre *Sciaena umbra*, the European lobster *Homarus gammarus* and the groupers

Mycteroperca rubra and *Epinephelus marginatus*, are not only of a certain economic interest but are particularly important because they have become rare along the Ligurian coast. The qualitative and quantitative composition of the fish population is the same as can be found in protected rocky areas, such as the marine park at Port Cros (France). The most highly represented families are Sparids, Labrids and Serranids, as is characteristic of the rocky areas of the North West Mediterranean (RELINI *et al.* 2002).

The yield of net fishing (average 2.32kg/100m) is higher than the ones obtained in ecologically similar areas in the Tyrrhenian Sea, and it is comparable to the ones obtained on artificial reefs after a year of installation in highly productive environments such as the Adriatic (1.71 – 2.8 kg/100m) (RELINI M. *et al.* 1995a).

Spatial distribution of the fish (RELINI M. and TORCHIA G. 1993), fish recruitment (RELINI *et al.*, 1997), the role of FAD (fishing attracting device) (RELINI M. *et al.*, 1995b) have been also described in the Loano AR.

The results obtained in Italy show that ARs made from concrete blocks act in the same way as a natural rocky bottom and increase bottom species diversity and fish biomass. It seem likely, therefore, that ARs could be used as successful tool in the management of coastal waters providing areas of feed, shelter and also nurseries for many species (RELINI M. *et al.*, 1995a). Furthermore, the protected areas inside the AR are suitable sites for mariculture of fish in cages, molluscs, crustaceans, sponges, algae etc.. However, their potential negative impact must be considered.

Many applications for the use of artificial structures for molluscan aquaculture exist in the world, but only in a few cases have artificial reefs deployed on the bottom been specially planned for this purpose. The only European model based on the Japanese concept is the 'intensive multi-purpose artificial reef' deployed in Italy (Adriatic Sea)(BOMBACE *et al.* 2000). This model combines seabed artificial reefs with shellfish culture equipment. The aim is to increase the settling opportunities of drifting bivalve larvae and juveniles whose distribution can extend over a very wide area. Along the Adriatic coast, the deployment of large-scale, commercial, multi-purpose artificial reefs has allowed the development of a new exploitable population of mussels (*Mytilus galloprovincialis*) and oysters (*Ostrea edulis* and *Crassostrea gigas*) in sandy bottom areas far from natural rocky habitats. Artificial reef research in Italy is continuing in order to develop new structures suitable for the settlement and on-growing of other edible bivalves (i.e. *Pholas dactylus*). The aim is to improve and diversify existing mussel monocultures (BOMBACE *et al.*, 2000).

Commercially fished crustacea, in particular clawed lobsters and spiny lobsters, are generally dependent on hard substratum in which to live. This makes crustaceans an obvious target group when considering the possible fisheries benefits of artificial reef deployment.

Prospects concerning the development of aquaculture

The second session of the GFCM Committee on Aquaculture, held in Rome in June 2000, reviewed the status of aquaculture in the region and the activities of the four networks linked to the Committee. However, the main focus of attention centered on the results of the Consultation on the Application of Article 9 of the FAO CCRF (Code of Conduct for Responsible Fisheries, FAO, 1995) in the Mediterranean Region, and on its Action Plan, which was endorsed by the Committee.

It was pointed out that the fast growth of the sector in the region was still dominated by production from France, Italy and Spain, but with faster growth rates in countries like Egypt, Greece and Turkey. The total value of aquaculture production also increased considerably, reaching US$ 2,430 millions in 1998, which is US$ 702 million over the 1994 values. In terms of economic contribution, marine finfish became the most important group, with US$ 837 millions, while in 1994 it was only the third, with US$ 336 millions.

It was highlighted that while some countries have experienced a negative growth, in particular countries with economies in transition, which were in serious difficulties as to re-launching the sector, some others, such as Cyprus, Lebanon, Malta and Syria had shown rapid development in the four years under examination. In terms of species contribution, marine and brackish water species molluscs seemed to have experienced a good recovery in these four years. Efforts to diversify finfish production had not yet given the expected results, and the contribution of the new candidate species for aquaculture remained marginal.

The Committee's conclusion emphasized the need for a clear analysis of the interaction between capture fisheries and aquaculture. It was also indicated that problems emerged in terms of impacts on different subjects like genetic contamination on stocks, market and price structure and that a systems analysis to study the relationship between sectors under local conditions was required. The discussion focused also on the need for diversification of production, which was interpreted not only as species diversification but also as diversification of product processing and technologies of production, which could address different local requirements.

Management of the biological resources in the Mediterranean

As mentioned above, GFCM-FAO is the international body charged with management of living marine resources in the Mediterranean. Some years ago the fishery scientist of Fishery Resources and Environment Division (FAO), T.F. CADDY (1996) had suggested the following three main categories of tactical measures for fisheries management in the Mediterranean:

1) <u>Measures that aim to conserve the resource and its critical environment</u>

As for north Atlantic fisheries, those measures have been specially concerned with ensuring that an adequate resource base is maintained. Among these can be listed the following:

- Maximizing landings from the fishery
- Maintaining an adequate spawning biomass or escapement
- Protecting young fish from overexploitation
- Protecting critical habitats from degradation and habitat enhancement
- Maintaining ecosystems at an acceptable level of diversity

2) <u>Socio-economic measures</u>

In situations where the fishery is recognized as a distinct sector of the national economy, with its own social and economical characteristics, some relevant measures may be the following:

- Maximizing earnings from the fishery
- Maximizing employment in the fishery sector
- Fleet replacement policy and reducing fleet size
- Maintaining equity of current participants in the fishery
- Reducing imports or promoting import substitution
- Providing a product for consumers at a reasonable price
- Maintaining stability in coastal communities

3) <u>Measures related to the title of Integrated Coastal Zone Management</u>

Here the mutual impacts of fishing and other human activities in the coastal zone are taken into account:

- Integration and integrated planning of fisheries all coastal zone activities (e.g. agriculture, aquaculture, shipping, tourism)
- Zonation for alternate uses of coastal waters
- Pollution abatement measures

In addition, the reference points and precautionary principle are two new approaches to fisheries assessment and management. The urgency of a better understanding of the relationship between environment (biotic and abiotic) and fishery is also reciprocally highlighted: fishery on the environment and the environment on fishery.

Conclusions

The exploitation of living marine resources in the Mediterranean is a complex system with a lot of interactions. This system needs a better management and cooperation among the countries because many species and ecosystems are overexploited and the environment is changing not only in relation to the climate. Mariculture strongly depends on fishery, and its contribution to restocking natural resources or to decreasing the fishing effort is still poor.

At present worries are arising from the release into the natural environment of artificially reproduced animals, mainly because of genetic modifications.

In short, the Mediterranean fishery is characterized by:

- multispecific catch
- high richness of species (biodiversity is increasing, due to immigrants, mainly lessepsians);
- disappearance of species, in particular elasmobranchs in some sites or extreme reduction of the number of individuals.
- low productivity that seems to increase in relation to a higher arrival of nutrients;
- wide spectrum of fishing activity, large variety of gears and methods, due to technological and geographical factors and also to economic, social and historical context;
- absence of good statistics on catches in the whole basin;
- lack of coordinated activity on stock assessment (with the exception of tuna and swordfish by ICCAT).

Mediterranean aquaculture is characterized by:

- importance of molluscs and in particular of mussels
- importance of extensive farms like lagoons and 'valli'
- limited numbers of species reared
- too strong a dependence by fisheries in particular on finfish, juveniles and breeders
- scarce utilization of offshore plants

Urgent needs:

- coordinated research, evaluation of stocks and management of fisheries
- protection and conservation not only of biological resources, but also of traditional local fisheries in the frame of the precautional approach
- relevant importance of small, local and traditional fisheries must be recognised by European Union fishery policy
- reduction of the catches of non target species and protected species
- ecosystem approach to fishery and aquaculture and development of 'artificial reefs' approach
- sustainable development of aquaculture following article 9 of the Code of Conduct for Responsible Fisheries.
- diversification of finfish farming and development of offshore aquaculture.

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