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FISH STOCK ASSESSMENTS AND PREDICTIONS: INTEGRATING RELEVANT KNOWLEDGE.
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Fish stock assessments in the Mediterranean: state of the art*

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SUMMARY: The Mediterranean fisheries are characterised by fragmented fleets, usually composed by relatively small vessels, use of a large number of landing sites, multi-species catches and low CPUEs. Fish are commercialised mainly fresh and the prices are relatively high. These factors make it difficult and expensive to get extensive and reliable data time series and to get biological samples. Most of the fish caught in the Mediterranean are the recruits (0-1 year old) of the main target species. Since the recruitment is much more uncertain than the abundance of the adult stages, the assessments are also more uncertain. Furthermore, no TAC or adaptive management is in place, so the administrations do not require monitoring in order to manage the fisheries. The continental shelf is narrow (with some exceptions) and there are few stocks shared between two or more countries. Consequently, the international management structures have not been sufficiently enforced, and until recently no regular assessments were made by international working groups. These characteristics have led to a situation in which most of the assessments have been done in the framework of scientific projects, and therefore do not have continuity in time. The results of these assessments have rarely been incorporated in management.

Key words: Mediterranean fisheries, stock assessment.

INTRODUCTION

The assessment of Mediterranean fisheries faces some significant challenges arising from both the physical constraints of the Mediterranean Sea and the socio-economic and historic characteristics of the fishing activities. In general, the lack of connection between assessment and management is the main problem for Mediterranean fisheries. Large pelagics, small pelagics and demersals constitute three very different groups of resources involving very different problems and issues. Small pelagics provide the larger catches, based mainly on two species: sardine and anchovy. The demersal group constitutes a complex fishery; it is composed of a great number of species (over 100) of fish, crustaceans and molluscs that usually fetch a high price. The large pelagics, mainly bluefin tuna and swordfish, are caught by the only industrial fleet working in the Mediterranean; the fleets fishing on the small pelagics and demersals are semi-industrial or artisanal.

In the Mediterranean there are fairly reliable historical data series of landings, but data on effort are almost absent. However, given the complexity and diversity of Mediterranean fisheries the available data are probably not sufficient for regular and trustworthy assessments for most species. The very structure of Mediterranean fisheries (atomised fleets, a huge number of landing points, multi-species catches and the lack of an industry as it

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exists in other seas) make it difficult and expensive to obtain data. Additionally, for social and political reasons there was no interest in the past on behalf of the administrations to obtain and divulge these data. Even nowadays it is very difficult to obtain official fleet censuses.

The biological parameters of the main target species (hake, anchovy, sardine, some expensive crustaceans) are quite well known. However most of this knowledge is obtained by on-going scientific projects, without continuity in time. It is difficult to maintain and update series of biological data, size frequency distributions, etc. without monitoring long-term projects.

Assessments suffer from the same shortcomings. Since no adaptive management is implemented in the Mediterranean, there is no pressure on the scientists to assess the resources.

OVERVIEW OF THE MEDITERRANEAN

The Mediterranean (Fig. 1) is a semi-enclosed sea with a surface of about 3 million Km^2 (including the Black Sea), contributing 0.8 % to the total world marine surface. Due to its geographical position, being placed at a relatively narrow range of latitudes (from 30ºN to 46ºN) in the temperate zone of the Northern Hemisphere, the Mediterranean Sea shows a marked seasonal cycle. Water masses are stratified in summer, but the deep-water (below 400 m) temperature is 13±0.3ºC throughout the year. The absence of precipitation in the summer period is the main characteristic of the Mediterranean climate. The Mediterranean has a negative water budget: the loss of water through evaporation is greater than the inputs due to rain and river runoff, but the contribution of Atlantic water through the Strait of Gibraltar balances these losses.

The continental shelf is mostly a narrow coastal fringe with the exceptions of the Adriatic Sea, the Gulf of Gabès and the northern Black Sea (see Fig. 1).

The Mediterranean has been generally considered as an oligotrophic sea (Margalef, 1985; Estrada, 1996; Stergiou *et al.*, 1997b). From the fisheries biology point of view, two of its fundamental features are the presence of a large variety of species, which represent 5.5% of the world marine fauna (Farrugio *et al.*, 1993), and the absence of large single-species stocks comparable to those inhabiting wide areas of the open oceans.

The Mediterranean counts 21 border countries, or 26 if one takes into account the Black Sea basin. Among these countries, the four EU members (Spain, France, Italy and Greece) occupy a third of the Mediterranean coastline (Farrugio, 1996). No EEZ has been implemented in the Mediterranean, almost all countries have territorial waters within 12 nautical miles (Ronzitti, 1999), and due to the narrowness of the shelf there are few areas sharing demersal or small pelagic stocks (Caddy, 1998). Consequently, the international management structures have not been enforced sufficiently and no regular assessments have been made by international working groups.

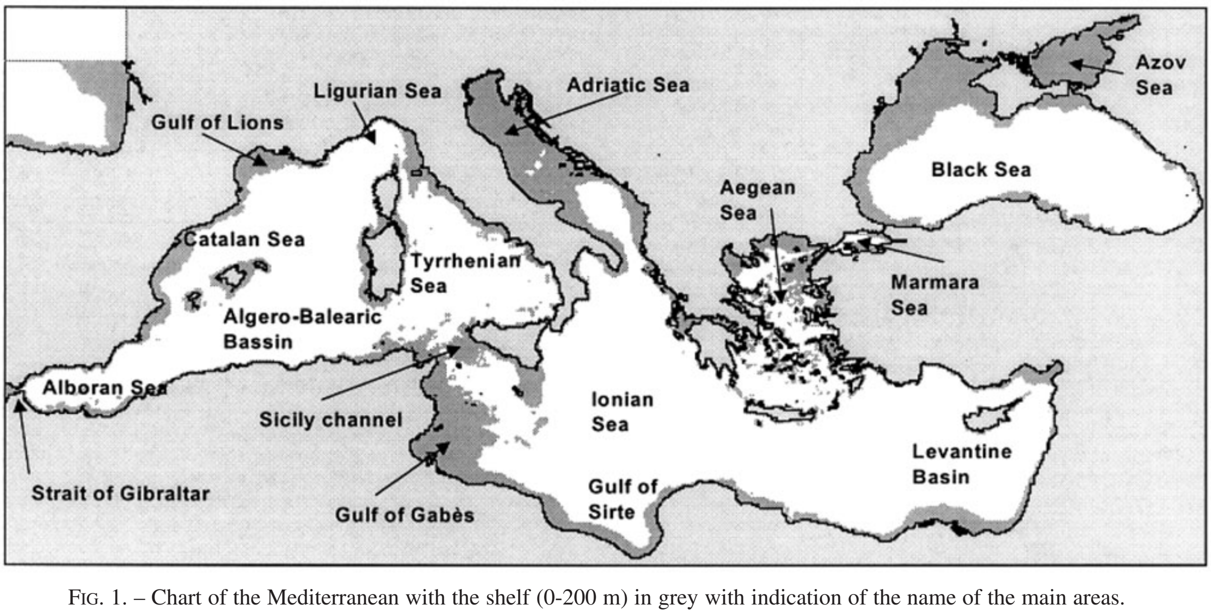

FIG. 1. – Chart of the Mediterranean with the shelf (0-200 m) in grey with indication of the name of the main areas.

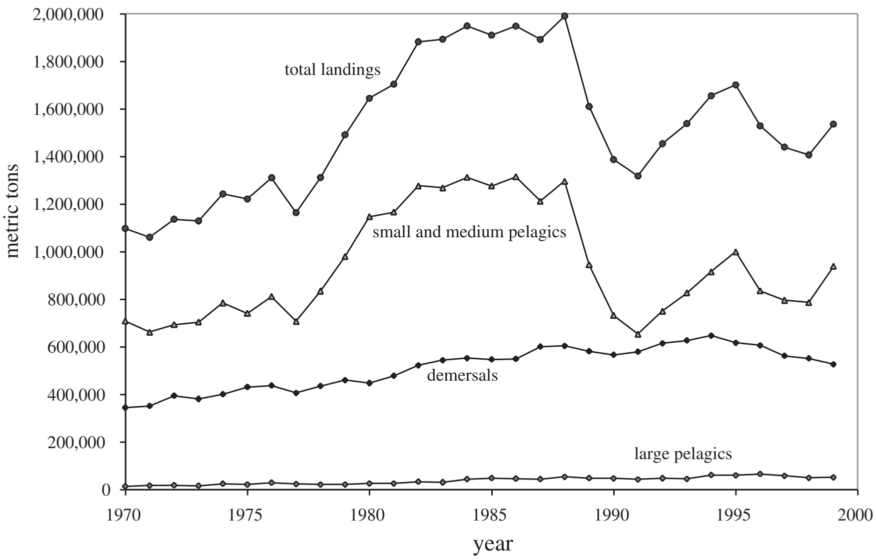

FIG. 2. – Series of landings in the Mediterranean and Black Sea (FAO, 2000a)

MEDITERRANEAN FISHERIES

Mediterranean fisheries have existed since ancient times, so the current fisheries pattern is the result of this long history, rather than the outcome of a specific management policy. For most commercial species, a significant feature is that juvenile fish support most of the fishery.

The mean annual landings have been around 1.5 million tons (1.54 in 1999 according to the FAO, 2000a) in the last decade (Fig. 2). The Mediterranean fisheries only represent a small proportion of the world production, which amounts to *ca.* 100 million tons. However, the mean prices of landings (which are mainly sold fresh) are well above the average prices of world markets. In the European Union, Mediterranean fisheries represent about 20% of the total catch but 35% of the total value of landings. From a socio-economic point of view, fishing activities in the Mediterranean employ several hundreds of thousands of persons. Mediterranean fisheries are highly diverse and vary geographically, not only because of the existence of different marine environments, but also because of different socio-economic situations.

Large pelagics

Bluefin tuna and swordfish are the most important large pelagic species in the Mediterranean. They represent around 4% of the total reported landings (Fig. 2), but their economic importance is far greater. ICCAT (International Commission for the Conservation of Atlantic Tunas) considers a single stock of bluefin tuna for the Eastern Atlantic and the Mediterranean, and the Mediterranean holds the main spawning area. The prices of the Japanese market of bluefin tuna generate a huge effort on this species. Driftnets, longlines and seines exploit the buefin tuna often under convenience flags. They represent the only real industrial fleet in the Mediterranean. Recently there has been a huge development of coastal cages to fatten the bluefin tuna in order to increase quality and to make the market independent of the catch season.

Swordfish is the second large pelagic species in importance. ICCAT considers the existence of a single Mediterranean stock. Swordfish is fished with longlines and driftnets. Albacore is the third species.

Small pelagics

Small pelagics are the main contributors to total landings in the Mediterranean (with the exception of the period 1989-1992 due to the Black Sea collapse) (Fig. 2; Table 1). Anchovy, sardine, sardinella and sprat represent almost 50% annually of the total landings in the Mediterranean. Adding medium-size pelagics (mackerels, bogue, bonite) this figure reached 53% in 1999. Sardine and anchovy are the main species in the Western Mediterranenan, sprat and anchovy are important in the Eastern Mediterranean and sardinella is important in the Southern Mediterranean. The collapse and recovery of small pelagic catches in the Black Sea dominates the landings trend in recent years.

TABLE 1. – Principal species and groups of species in the 1999 Mediterranean production sorted according to abundance. Only the first 21 species with more than 1% of the total catch are presented. Anchovy takes the 1st place due mainly to the Turkish catches in the Black Sea. Sardine is more evenly distributed although the principal catches are recorded in the northwestern Mediterranean. Italy is the first contributor to the Mediterranean mussel catches. Note the 4th group corresponds to a mixture of species. Source FAO-GFCM Data Base 2000. (FAO, 2000a)

rank	species	tons	%	Cummulative %
1	Anchovy	447,622	29.10	29.10
2	Sardine	212,058	13.78	42.88
3	Sardinella	77,020	5.01	47.89
4	Mixed fishes	61,613	4.01	51.89
5	Mussel	55,819	3.63	55.52
6	Striped venus	40,421	2.63	58.15
7	Sprat	39,371	2.56	60.71
8	Mullets	37,523	2.44	63.15
9	Jack and horse mackerels	27,262	1.77	64.92
10	Bonite	25,001	1.63	66.54
11	Bogue	24,392	1.59	68.13
12	Hake	23,947	1.56	69.69
13	Bluefin tuna	23,752	1.54	71.23
14	Blue whiting	23,529	1.53	72.76
15	Red mullets	18,960	1.23	73.99
16	Chub mackerel	17,610	1.14	75.14
17	Whiting	14,650	0.95	76.09
18	Mixed molluscs	13,740	0.89	76.98
19	Swordfish	13,728	0.89	77.87
20	Common octopus	13,296	0.86	78.74
21	Horse mackerel	12,898	0.84	79.58

The gears used in the catch of small pelagics are purse seine (with or without light) and pelagic trawl. The traditional pelagic gillnets have almost disappeared for catching small pelagics (but not for large pelagics). The EU allows the use of pelagic trawls with a mesh size of 20 mm, but in some countries (Spain) it is forbidden.

Demersals

There are many target demersal species in the Mediterranean. More than 100 species have commercial value and are abundant, although according to the FAO statistics none of them counts more than 3% of total catch. The main species in landings are shown in Table 1.

Many different fishing gears exploit the demersal community. Trawl is the main gear in terms of catch and fleet power, but artisanal gears are also important: trammel nets, gillnet, bottom longlines, and a number of different traps and drags. In almost all cases the exploitation results in multispecies catches.

The evaluations of demersal resources have been based mainly on the swept area method, production models (almost abandoned nowadays), and analytic (mostly length-based) methods.

Since 1994, annual trawl surveys have been carried out by the four European Union countries at the end of spring within the MEDITS project (Bertrand *et al.*, 1998; Abelló *et al.*, 2002).

Stocks

Definition of unit stocks has been largely absent and is in some cases problematic (Caddy, 1993). The Scientific Advisory Committee of the GFCM (General Fisheries Commission for the Mediterranean) has established management areas based on political and statistical considerations rather than biological or economic ones (FAO, 1999).

Considering small pelagics and demersals, shared stocks are rare in the Mediterranean (Caddy, 1998). Only in part of the Gulf of Lions, Gulf of Gabès, Sicily channel, Adriatic Sea, Ionian and Aegean Sea and Alboran Sea are some small pelagic or demersal stocks shared by two countries.

Morphometric and genetic techniques have been applied to the problem of stock definition and identification of anchovy (Bembo *et al.*, 1995; Bembo *et al.*, 1996a, 1996b; Pla *et al.*, 1996; Tudela, 1999; Tudela *et al.*, 1999), hake (Roldán *et al.*, 1998), Norway lobster (Castro *et al.*, 1998; Maltagliati *et al.*, 1998) and red shrimp (Sardà *et al.*, 1998), but the impact of these studies have been weak because they were not conclusive.

Data on catches and landings

Since 1970 FAO has provided regularly updated official bulletins and on-line data bases for production statistics by year, area, subarea and species (FAO, 2000a). These data are usually under-estimates of real catches because under-reporting is widespread. Even if there is an auction at the port base of a given ship, fish can be sold at any market. Thus, official statistics for commercial catches should be taken with care. They are useful for indicating relative, rather than absolute, trends.

Discards are also important, particularly for species of lower commercial value. They are difficult to quantify and have only been estimated during occasional research projects. They present a high variability according to the country, area, gear, season and fishing ground. In the northwestern Mediterranean, discards of the trawl fleet are *ca.* 20% of the total catch at depths greater that 350 m, but they reach up to 40% at depths shallower than 150 m (Carbonell, 1997; Carbonell *et al.*, 1998). The reasons for discarding are diverse: illegal sizes, non-commercial species or sizes, or market reasons.

Fleets

The fleet censuses, when available, are generally quite inexact. Sometimes not all boats are accounted for. The figures for HP are in many instances unrealistic and heavily underestimated. The difficulty of effort computation is compounded by the multi-species character of most Mediterranean fisheries.

Three different types of fleets can be considered: artisanal, industrial and semi-industrial, (Farrugio, 1996; Farrugio and Papaconstantinou, 1998).

An artisanal fleet is a small-capital business, usually the fishermen's property. Artisanal fishing is often associated with the notion of "coastal fishing", i.e. fisheries located essentially on the continental shelf or very close to it, and exploiting areas that can be reached within a few hours from the ports or beaches where the fishermen are based. Consequently this type of activity does not involve a large number of hours at sea. Another characteristic of this type of fishing is that it employs a large workforce at sea as well as ashore. The fishing gears are extremely diversified and the fleets are generally composed of a large number of boats, mostly of low tonnage, based in a multitude of ports and shelters.

Official statistics over the period 1989-90 suggest that in the EU Mediterranean countries, artisanal fleets are constituted of 41,930 units, of which 46, 39, 8 and 7% are registered in Greece, Italy, Spain and France respectively (Farrugio, 1996). They use 45 different gear types and target at least 100 species. Considering the whole Mediterranean, estimates give around 100,000 small-scale units, while this number seems to increase because of the development of the fishing activity in the southern Mediterranean countries.

Industrial fleets involve major investments by companies or financial groups. In the Mediterranean, they are mainly represented by the tuna fishery and use large seiners. This is the only fishery involving not only fleets of the Mediterranean border countries, but also fleets from non-Mediterranean countries (mainly Japan and Korea) fishing in international waters, and vessels with convenience flags.

The semi-industrial fleet is an intermediate group between the artisanal and the industrial fleet, but more closer to an artisanal scheme. It is mainly composed of trawlers, purse seiners and some longliners. Catches are usually landed on a daily or bi-daily basis, so catches are made near the coast, on the shelf or on the upper slope. The trawl catches comprise mainly juveniles of many different species. Target species are more than 20, e.g. red mullet, anchovy, blue whiting, hake, Norway lobster and red shrimp. There is great seasonality in catches, due in some cases to the biology of the species (seasonal availability), in other cases to meteorological conditions, and in yet others to the possibility of reaching deeper fishing grounds. 4,300 fishing vessels of this type operate from European Union ports, of which some 45, 32, 17 and 6% are located in Italy, Spain, Greece and France respectively.

The available data show that the semi-industrial fleet size rose regularly in most areas of the Mediterranean during the 1970s and 1980s. The tendency of this kind of vessels is to increase the power and improve the technological equipment.

Current management

The management of the Mediterranean fisheries is based on effort control. No TACs are implemented (except for bluefin tuna), nor are other types of adaptive management. Other technical measures, such as minimum landing sizes and minimum mesh sizes, are also implemented but not always enforced, and in all cases they are lower than in the Atlantic.

Most of the rules concerning the management of demersal fisheries have been developed for trawling, not only because it is the main gear contributing to demersal catches, but also because it presents a bad selectivity in comparison with the most important artisanal gears (nets and lines). However relatively few countries have taken management actions to control increases in fishing effort despite the repeated recommendations of the GFCM (Caddy, 1993). Furthermore, when a rule to limit the increase of the fishing effort has been implemented (limiting the number of boats or the time at sea), the increase in fishing mortality due to technological progress has not been taken into account. A major problem concerning management is the low level of enforcement of the legislation.

In some Mediterranean countries there are closed areas for trawling, usually the 3 first nautical miles from the coast or up to 50 m depth. Some seasonal closures that postpone the age at first encounter with the trawl have experienced considerable success (the so called "Cyprus effect", Garcia and Demetropoulos, 1986). However, other cases do not seem especially successful, as in the subsidised seasonal closures in Spain.

It is generally considered that managing Mediterranean fisheries means managing the trawl. Almost all the management pilot projects carried out in the Mediterranean involve trawl as the main target. However, only three such projects seem to have reached some success: the *Plan Castelló*, in Spain (Suau, 1979; Lostado *et al*. 1999), the management of Cyprus fisheries (Garcia and Demetropoulos, 1986), and the Golfo de Castellammare (Sicily) management project (Pipitone *et al*., 1996, 1998). Implementation of pilot projects (Boutet, 1996) allowing small or medium scale management regulations to be developed and analysed from the biological, economic and social point of view is perhaps the best way to develop management tools in the Mediterranean.

ASSESSMENT

The availability of appropriate data is considered one of the main shortcomings in the assessment of Mediterranean fisheries. There is a large amount of reliable data, but they do not always fit the data needs of the standard assessment methods. However, scientists have tried to assess the fisheries with several tools, using the data available. Mediterranean scientists have often used the methods developed for tropical fisheries (Le Fur, 1998) for assessment and parameter estimation, not only because of the scarcity of suitable data, but also because of the complexity of the multi-species artisanal fisheries.

Another element contributing to the uncertainty of the assessments is the fishery on recruits affecting some important species. As is well known, the recruitment process is much more uncertain than the adult life in fish and studies in this direction are scant (or lacking) in the Mediterranean.

In general, no long time series of size/age composition of catches are available, because such data have been obtained from on-going research projects, and until recently few monitoring plans have been implemented. Consequently, growth, length/age relationship, etc., are usually taken as constant along time for different assessments.

Population dynamics

The main problems for the application of analytical methods are that age composition or size frequency data are regularly collected only for few species, and there is a general lack of sampling schemes for monitoring year class abundance (Caddy, 1993).

Analytical methods based on population dynamics have been applied to different stocks of demersal, small pelagics and large pelagics. The first approach was the application of production models under equilibrium (Oliver, 1983; Charbonier and Caddy, 1986); in some instances this model was fitted to a set of species rather than a single one. Lleonart (1993) discussed the possibilities of applying different population dynamics methodologies to the Mediterranean and concluded that surplus production models are not particularly useful because of the difficulties in effort estimation: The independent variable (effort) does not always present enough contrast to carry out reliable regressions. Since the late 1980s length cohort analysis (LCA) and yield per recruit using Thompson and Bell's approach (Thompson and Bell, 1934) have been used, mainly because the lack of catch-at-age data does not allow more standard VPA procedures to be applied. These methods have been applied to all kinds of species (demersals, large and small pelagics) but only to a quite limited number because of the lack of appropriate data. Abella *et al*. (1997) have analysed the problem of different natural mortalities at age on LCA assessments. Some demersal species present extended spawning and recruitment seasons (e.g. hake), so the recruitment and growth estimations are uncertain.

In the Second Session of the Sub-committee on Stock Assessment (GFCM, 2000, FAO, 2000b) the assessments made in the last decade were gathered. The results are summarized in Table 2.

In the Third Session of the Sub-committee on Stock Assessment (GFCM, 2001, FAO, 2001) specific assessments for GFCM were presented (Table 3). In both tables (2 and 3) it can be seen that the state of most stocks is over or fully exploited.

Small pelagics assessments

Small pelagics surveys based on acoustics are being routinely performed in European countries (Abad *et al*., 1996; Patti *et al*., 2000; Guennegan *et al*., 2000). They assess the biomass of anchovy and sardine, but, as occurs in other assessments few or no management actions are taken from these assessments.

TABLE 2. – Assessments available for the Mediterranean, produced during the period 1985-1999, concerning the eight most important demersal and small pelagic species (GCFM, 2000)

Species	Number of assessments	State of resources Over-fished	Fully-fished	Under-fished	Comments
Merluccius merluccius	36	28	7	1	general growth overfishing
Aristeus antennatus	10	6	3	1	
Mullus barbatus	32	18	14		
Mullus surmuletus	8	2	4	2	
Micromesistius poutassou	4	3	1		
Engraulis encrasicolus	14	2	8		risk of recruitment overfishing
Sardina pilchardus	7	2		2	3 without results
Sardinella aurita	never evaluated				unknown
Thunnus thynnus	see ICCAT 1999				over-fished
Thunnus alalunga	never evaluated				unknown
Xiphias gladius	see ICCAT 1999				unknown

TABLE 3. – Assessments presented at SAC in 2001 (no assessments were presented for large pelagics due to lack of data). GFCM 2001

Species	Number of assessments	State of resources Over-fished	Fully-fished	Under-fished	Comments
Merluccius merluccius	4	4			Growth overfishing. Risk of recruitment overfishing. Reduce effort. Improve the selectivity of trawl
Mullus barbatus	3	2	1		Closure of coastal zone to protect juveniles. Use artificial reefs. Seasonal closure. Reduce effort Enforce current management measures
Solea aegyptiaca	1		1		
Diplodus annularis	3		3		
Pagellus erythrinus	3		3		
Nephrops norvegicus	1			1	
Aristeus antennatus	2	1	1		
Engraulis encrasicolus	3	1	2		Risk of recruitment overfishing Set the minimum legal size to that of 1st maturity
Sardina pilchardus	3	1	2		
Trachurus trachurus	1		1		Keep fishing effort at current level
Boops boops	1		1		Keep fishing effort at current level

Daily Egg Production Methods (DEPM) have been used in the Mediterranean several times but they are not employed routinely on a year-by-year basis. These methods have been applied mainly to anchovy but also to sardine in some instances (Chavance, 1980; Regner, 1990; Palomera and Pertierra, 1993; Garcia and Palomera, 1996; Somarakis and Tsimenides, 1997; Casavola *et al*., 1998; Casavola, 1999; Quintanilla *et al*., 2000). A comparison between the results of DEPM, acoustic surveys and population dynamics models showed that the results were quite similar (Pertierra and Lleonart, 1996).

Trawl Surveys

Trawl surveys constitute a useful tool in assessment of demersal fisheries and have been used in several Mediterranean countries, especially Italy (Ardizzone and Corsi, 1997). Since 1994 the MEDITS project has been being performed in the four European Mediterranean countries, with extensive trawl surveys at the end of spring carried out in all European waters (Bertrand *et al*., 1998, Abella *et al*. 1999; Abelló *et al*., 2002). The main source of error in this case is the difficulty of intercalibration of the trawl surveys between the different vessels and countries.

The main objective of MEDITS is to obtain abundance indices that are comparable between the different studied areas. This has been made possible by the standardisation of the methodology (location of the trawl stations, same gear operated in the same way by each participant, common format for the computer files, etc.). Some results have been published and gathered in monographic issues (Bertrand and Relini (Coords.) 1998; Relini *et al*., 1999). To date, the results of trawl surveys have not been coupled to population dynamics models to tune the indirect assessments (as in the standard VPA).

TABLE 4. – List of references about assessments carried out in the Mediterranean, indicating the species assessed and the area involved.

Author	Year	Species	Area
Aldebert and Recasens	1996a	*Merluccius merluccius*	Gulf of Lions
Aldebert and Recasens	1996b	*Merluccius merluccius*	Gulf of Lions
Aldebert *et al*.	1993	*Merluccius merluccius*	Gulf of Lions
Ardizzone	1998	*Merluccius merluccius, Mullus barbatus*	Seas of Italy
Arneri and Jukic	1996	*Mullus barbatus*	Adriatic Sea
Ben Mariem and Garbi	1996	*Merluccius merluccius*	Tunisia
Ben Mariem *et al*.	1996	*Mullus surmuletus*	Tunisia
Bouaziz *et al.*	1998a	*Merluccius merluccius*	Algeria
Bouaziz *et al.*	1998b	*Merluccius merluccius*	Algeria
Bouchereau *et al*.	1986	*Sardina pilchardus*	Balearic Islands and Gulf of Lions
Chavance *et al*.	1986	*Engraulis encrasicolus, Sardinella aurita, Trachurus trachurus*	Western Mediterranean
Cingolani *et al*.	1996	*Engraulis encrasicolus*	Adriatic Sea
Cingolani *et al*.	1998	*Engraulis encrasicolus, Sardina pilchardus*	Adriatic Sea
Colloca *et al.*	1998	*Aristeus antennatus*	Tyrrhenian Sea
Demestre and Lleonart	1993	*Aristeus antennatus*	NW Mediterranean
Demestre and Martin	1993	*Aristeus antennatus*	NW Mediterraenan
Demestre et. al.	1997	*Mullus barbatus*	Western Mediterranean
Djabali *et al*.	1991	*Sardina pilchardus, Engraulis encrasicolus, Trachurus trachurus, Scomber japonicus, Boops boops, Nephrops norvegicus, Merluccius merluccius, Mullus barbatus, Pagellus acarne, Helicolenus dactylopterus*	Béni-Saf (Algeria)
Fiorentino *et al*.	1996	*Merluccius merluccius*	Ligurian Sea
Fiorentino *et al*.	1998	*Aristeus antennatus*	Ligurian Sea
Flamigni	1984	*Merluccius merluccius*	Adriatic Sea
Giovanardi *et al*.	1986	*Merluccius merluccius*	Adriatic Sea
Hadjistephanou	1992	*Mullus barbatus, Mullus surmuletus, Spicara smaris, Boops boops, Pagellus erythrinus*	Cyprus
Karlou and Vrantzas	1989	*Mullus barbatus*	Saronikos gulf, Aegean Sea
Lembo *et al*.	1998	*Merluccius merluccius*	Tyrrhenian Sea
Levi *et al*.	1993	*Mullus barbatus*	Sicily channel
Lleonart *et al*.	1999	*Coryphaena hippurus*	Western Mediterranean
Martin and Sánchez	1992	*Merluccius merluccius, Mullus barbatus, Eledone cirrhosa*	Catalan Sea
Oliver and Morillas	1992	*Merluccius merluccius, Mullus surmuletus*	Balearic islands
Oliver	1993	*Merluccius merluccius*	Balearic islands
Oliver *et al*.	1995	*Merluccius merluccius*	Balearic islands
Orsi-Relini and Arnaldi	1986	*Mullus barbatus*	Ligurian Sea
Orsi-Relini and Relini	1998	*Aristeus antennatus*	Ligurian Sea
Papaconstantinou	2000	*Merluccius merluccius*	Greek seas
Papaconstantinou and Stergiou	1995	*Merluccius merluccius*	Eastern Mediterranean
Pertierra and Perrotta	1993	*Sardina pilchardus*	Catalan Sea
Ragonese and Bianchini	1996	*Aristeus antennatus*	Strait of Sicily
Recasens	1992	*Merluccius merluccius*	Catalan Sea
Santojanni *et al*.	1999	*Sardina pilchardus*	Adriatic Sea
Sardà and Lleonart	1993	*Nephrops norvegicus*	Catalan Sea
Sinovcic	1998	*Engraulis encrasicolus*	Adriatic Sea
Spedicato *et al*.	1995	*Aristeus antennatus*	Tyrrhenian Sea
Stergiou *et al*.	1992	*Mullus barbatus, Mullus surmuletus*	Greek waters
Tursi *et al*.	1994	*Mullus barbatus*	Ionian Sea
Tursi *et al*.	1996	*Merluccius merluccius, Mullus barbatus*	Ionian Sea
Ungaro and Marano	1996	*Merluccius merluccius*	Adriatic Sea
Ungaro *et al*.	1992	*Merluccius merluccius*	Adriatic Sea
Ungaro *et al*.	1994	*Mullus barbatus*	Adriatic Sea
Vassilopoulou and Papaconstantinou	1992	*Mullus barbatus*	Aegean Sea
Vidoris and Kallianiotis	2000	*Engraulis encrasicolus*	Thracian Sea
Voliani *et al*.	1998	*Mullus barbatus*	North Tyrrhenian Sea
Vrantzas *et al*.	1992	*Mullus barbatus*	Saronikos gulf, Aegean Sea
Yahiaoui *et al*.	1986	*Aristeus antennatus, Parapenaeus longirostris*	North Tyrrhenian Sea

Other approaches

Regression analysis, generalised linear models (GLM) and time series analysis have been used by several authors to analyse particular fisheries, in particular series of catches and CPUEs (Stergiou and Christou, 1996; Stergiou *et al*., 1997a; Daskalov, 1998, 1999; Goñi *et al.*, 1999; Lloret *et al*., 2000, 2001). They have been used to obtain estimates of fishing power and relationships to environmental variables. The data necessary for these purposes should be very disaggregated and of a very high quality, which is not frequent in the Mediterranean.

Fiorentini *et al*. (1997) analysed the trends of landings in 285 species or groups of species and found more rising trends than declining ones. However, landings do not represent the state of the resources as well as CPUE does; they are a combination of the biomass at sea and the fishing mortality applied.

As catches are often made up of a large number of species, the calculations for a single species are of limited value for management. Mediterranean fisheries would require an integrated multi-species approach to management measures (Caddy, 1993). In spite of the multi-species characteristics of most Mediterranean fisheries, to date it has not been possible to consider this aspect in assessments.

There have been some attempts to carry out ecosystem simulation on Mediterranean fisheries. Some preliminary results were presented by Stergiou and Koulouris (2000) and Tudela (2000).

Almost no assessments have been made considering the space or the particular geographic constraints of the Mediterranean. Charbonier and Garcia (1985) published an Atlas of fisheries of the western and central Mediterranean. The FIGIS (Le Corre, 2000) and MEDITS projects (Bertrand and Relini, Coords., 1998) have generated cartographies and GIS utilities of the most important resources. These tools, although promising, are still far from being completely applicable for assessment purposes.

The use of computer simulation for the evaluation of management strategies has been useful in cases where, as in the Mediterranean, several gaps and shortcomings impeded the scientific management of the fishery. The procedure consists of the computer simulation of the entire process of data collection, fishery assessment and management and its projection into the future. This has been applied successfully by the International Whale Commission (Kirkwood, 1998). Some attempts at using this procedure in the Mediterranean have been started, but the incorporation of economics (as one of the main management tools in the Mediterranean) is an essential requirement (Placenti and Rizzo, 1998; Lleonart *et al*., 2002).

State of the resources

According to the results gathered by the Scientific Advisory Committee (SAC) of the GFCM (GFCM, 2001; FAO, 2001), hake is overexploited in almost all parts of the Mediterranean. The status of other demersals (red mullet, red shrimp and blue whiting) is not so clear. The small pelagics assessments give very diverse results, depending on the species and the area. Swordfish and bluefin tuna are the large pelagics regularly analyzed by ICCAT, but assessment of large pelagics was not presented to the last meeting due to lack of data. There are no conclusive results for any of these species, although the overexploitation of both species seems quite clear.

It has been argued that the Mediterranean fisheries have reached a sort of "overfishing steady state". With the available data presented above it is difficult to find arguments against this, but, in our opinion, this is not true for most species. Technological improvements in catch methods are increasing and a continuous decline in the CPUE of some demersal stocks can be detected. Furthermore, the recent introduction of new fishing procedures (such as modern longliners in the NW Mediterranean) has eliminated the "spawning refugia" of some species such as hake.

As a consequence of this change in strategy in Mediterranean fisheries, overfishing is also changing. Traditionally, two types of overexploitation have been described, according to their impact on the fishery system: Growth overfishing and recruitment overfishing (Cushing, 1996).

It seems that recruitment overfishing might affect the NW Mediterranean anchovy stock, because the pattern of exploitation has changed in recent years. The fishing season has been extended to practically the entire year and currently a significant amount of the population of species with a short life span is caught before they reach the first reproduction. On the other hand, some demersal stocks have traditionally been subject to growth overfishing, because the effort was mainly directed at the juveniles of the population. Some species, like hake, might have begun to suffer locally from recruitment overfishing, as their parental fraction has started to become available for exploitation, while the effort directed at juveniles has increased. Thus, the risk of a stock collapse for hake is increasing, and could lead to important changes of the whole ecosystem. These ecological changes (which could be defined as a third type of overfishig, or ecosystem overfishing) might already have started (Caddy *et al*., 1995), as demonstrated by the continuous increase of landings of planktivorous species with short life spans, such as small pelagic fish (e.g. sardines), cephalopods and small benthic crustaceans (FAO 2000a). The degradation of a large part of the coastal zone, in part due to pollution and tourism, but also to bad fishing practices, has caused the disappearance of large extensions of *Posidonia oceanica* and other marine phanerogam meadows.

PERSPECTIVES AND CONCLUSIONS

In the Mediterranean, the management is reactive, never adaptive and still less, precautionary. There is a lack of feedback among the three main agents for an adaptive management: administration, fishermen and scientists. The social pressure on the administration regarding needs for assessment is almost null. Acquisition of data suffers from the same lack of interest of all sectors involved. Furthermore, due to narrowness of the continental shelf, few stocks (excluding the large pelagics) are shared by two or more countries, which helps to minimise the international concerns about the fishery resources. As has been described by Kirkwood (1998), all of this results in a vicious circle: the data are unreliable, so the assessments and the scientific advice are likely to be unreliable, and it would be unwise and possibly politically counterproductive to impose management based on such unreliable advice.

To overcome the limitations in the assessments of Mediterranean fisheries, a set of measures should be implemented taking into account the international cooperation. GFCM and ICCAT should play a central role in such a task, although other bodies like CIESM have also an important role.

Some actions that should be implemented to improve the assessment and management of Mediterranean fisheries are:

- Integration of the countries around the Mediterranean regarding data collection, assessment, and management co-ordination. Reinforcement and promotion of the GFCM.

- International scientific review of the assessments, even for non-shared stocks. Standardisation of the presentation of the assessment, including the basic data.

- Development of specific methods of data collection for the Mediterranean, that take into account the use of data easy, cheap to obtain, and geographic (country-to country, region to region, etc.) differences.

- A multi-species approach to assessment, incorporating measures of uncertainty both in the data and the process.

- Development of simulation methods integrating biological and economic aspects.

- Development and enforcement of a common Mediterranean policy.

- Implementation of adaptive management schemes, which should establish close relationships between data gathering, assessment and management, and between administrators, fishermen and scientists.

- Implementation of management pilot projects, community based management, and marine protected areas.

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