

An overview of the history, knowledge, recent and future research trends in Mediterranean fisheries*

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SUMMARY: The Mediterranean sea is an area which has a longlived oceanographic tradition. Since the remote antiquity, it has been the object of observations and descriptions in which maritime activities and fishing hold a paramount place. This paper presents a synthetic view on the history of the fisheries research and its evolution in the area. The very rich mediterranean fauna and the highly multispecific nature of the catches certainly favoured the fact that the first works were mainly oriented towards attempts of exhaustive descriptions of the vital cycles and biological parameters of a given species. The passage from marine biology sensu-stricto to fisheries research is relatively recent in the Mediterranean; the first attempts to apply some mathematical population dynamics models to the exploited stocks were realized in France and Spain in the last sixties. Most of these analyses used the "global production models" which come out to be quite disappointing when applied in the area. Several mediterranean work programmes are now oriented towards the use of "direct evaluations" and "analytical" methods of modelling of the exploited stocks. Quantitatively, the mediterranean state of knowledge about fisheries is not far from what we can find in many atlantic european fishing grounds. A recent innovation in the research about mediterranean fishing is to take in account the activity of the "small-scale" fleets and their interactions with other types of fisheries. Catch and effort statistics remain a weak point, as the official statistical data are still often very far from reflecting the reality. To avoid this situation, the latest works in the area have consisted in perfecting sampling and assessment strategies. There is also an increasingly generalized awareness of the socio-economic importance of fishing, and of the fact that the effects of the anthropic coastal activities should be taken into account, as at a mundial level there is a general tendency to redirect the target of the fisheries science from resources to entire ecosystems equilibriums. The success of this evolution will depend mostly on a new wave of investment in a multidisciplinary fundamental research which might lead to a new start in the evolutive dynamics of the finalised research depending on it. So the growing interest in semi-industrial and small-scale fisheries which is expressed today at an international level can make mediterranean fisheries research a valuable model.

Key words: Mediterranean, fisheries science, history, research trends.

RESUMEN: UNA REVISIÓN SOBRE LA HISTORIA, EL CONOCIMIENTO Y LAS TENDENCIAS PRESENTES Y FUTURAS DE LA INVESTIGACIÓN EN LAS PESQUERÍAS DEL MEDITERRÁNEO. — El mar Mediterráneo es un área con una larga tradición oceanográfica. Desde la remota antigüedad, ha sido objeto de observaciones y descripciones en las que las actividades marítimas y pesqueras han jugado un papel primordial. Este artículo presenta una visión sintética de la historia de la investigación de las pesquerías y su evolución en el área. La gran riqueza de la fauna mediterránea y la naturaleza pluriespecífica de las capturas han favorecido el hecho de que los primeros trabajos fueran principalmente orientados hacia intentos de descripciones exhaustivas de los ciclos vitales y los parámetros biológicos de las especies. El paso de la biología marina "sensu-stricto" a la investigación en pesquerías es relativamente reciente en el Mediterráneo; los primeros intentos de aplicar algunos modelos matemáticos de dinámica de poblaciones se realizaron en Francia y en España a finales de los años sesenta. La mayoría de estos análisis usaban los modelos globales de producción, los cuales resultaron bastante decepcionantes cuando se aplicaron a este área. Algunos programas de trabajo en el Mediterráneo están ahora orientados hacia el uso de evaluaciones directas y métodos analíticos de modelización de los stocks explotados. Cuantitativamente, el estado de conocimiento sobre las pesquerías no está lejos del que se puede encontrar en la mayoría de los bancos de pesca atlánticos. Una innovación reciente en la investigación de las pesquerías mediterráneas es tener en cuenta la actividad de las flotas de artes menores y sus interacciones con otros tipos de pesquerías. Las estadísticas de capturas y esfuerzo siguen siendo un punto débil, así como los datos estadísticos oficiales que a menudo están lejos de reflejar la realidad. Para evitar este problema, los últimos trabajos en el área han consistido en perfeccionar el muestreo y las estrategias de evaluación. Hay, igualmente, un incremento generalizado de la conciencia de la importancia socio-económica de la pesca, y del hecho de que deben considerarse los efectos de las actividades antrópicas en la costa, así como, a nivel mundial hay una tendencia general a redirigir el objetivo de la ciencia de las pesquerías desde los recursos hacia el estudio global de los ecosistemas en equilibrio. El éxito de esta evolución dependerá de una nueva inversión en investigación básica multidisciplinar que llevará a un nuevo inicio de la dinámica evolutiva de la cual dependerá la investigación realizada. Así, el creciente interés en las pesquerías de pequeña escala o semi-industriales que se expresa hoy a nivel internacional puede llevar a considerar la investigación de las pesquerías mediterráneas como un valioso modelo.

Palabras clave: Mediterráneo, ciencia de la pesquería, historia, tendencias en la investigación.

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INTRODUCTION

The Mediterranean is a semi-enclosed sea "biologically poor" compared to the large oceanic areas with which its exchanges of water masses are very limited. Its continental shelf is most frequently reduced to a narrow coastal fringe. From the fisheries biologist point of view, two of the fundamental features of this sea are the presence of a very large variety of species, which represent 5.5% of the world marine fauna (MAURIN, 1962; QUIGNARD and FARRUGIO, 1982; TORTONESE, 1987; BOMBACE, 1990; FREDJ *et al.*, 1992) and the absence of large monospecific "stocks" comparable to those which inhabit some wide areas of the open oceans.

Therefore, unlike those areas, the Mediterranean Sea has not been the theatre of the development of an "industrial fishing" in the conventional meaning of these words. Although it comprises only 0.8% of the world hydrosphere (CHARBONNIER *et al.*, 1990) it is the site of a very old fishing activity resulting of a mosaic of very diversified structures spread over more than 40000 km of coasts and whose characteristics put the scientific research on fisheries in the particularly complex context of the so-called "composite fisheries".

THE ARTISANAL CHARACTERISTICS OF THE FISHERIES

The word "artisanal" generally applies to any small-capital exploitation, most often the fishermen's property, in contrast to "industrial fishing" which implies important investments made by companies or financial groups.

Artisanal fishing is often coastal in character, and thus located on the continental shelf or very close to it, and exploiting 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 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.

Except in a few cases due to the recent evolution of some fleets toward a nearly "industrial" type of activity — especially in the northwestern part of the

area — most Mediterranean fisheries can therefore be considered as "artisanal" and "coastal".

Nevertheless, Mediterranean 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 differences are due not only to the ecological and geographical factors which control the biotopes and the exploited animal populations but also to the social, economic and historical contexts of the neighbouring countries.

THE HISTORICAL ROOTS OF MEDITERRANEAN FISHERIES SCIENCE

The Mediterranean Sea is an area which has a long-established oceanographic tradition. The exploitation of marine living resources started several thousand years ago, which explains that, ever since remote antiquity, it has been the object of observations and descriptions in which maritime activities and fishing hold a paramount place (MARGALEF, 1989).

The oldest documents are anthropological accounts by travelers and humanists, dealing with all aspects of Mediterranean culture and civilization, and the first faunistic inventories were compiled in remote times (LINNÉ, 1758; BONNATERRE, 1787; DELAROCHE, 1809; RISSO, 1810, 1826; BONAPARTE, 1834; CANESTRINI, 1875). Except for a few ancient attempts to explain some ecological phenomena of importance to Mediterranean fisheries management, such as tuna migrations (ARISTOTLE, 384-322 B. C.), the first researches specifically oriented towards fishing date back to the XVIII th century. Since then, descriptions of fishing activities have appeared continuously particularly concerning the western Mediterranean Sea. This abundant literature, whose diverse origins complicate its compilation, nevertheless, explicitly reports the evolution of the (great) technological, economic and social aspects of Mediterranean fishing over nearly eight centuries.

Thus syntheses of this literature by Mediterranean historians, geographers and biologists always include long chronologies of details and enable us to understand and interpret this evolution in a remarkable way (SALVADOR I RIERA, 1722; DUHAMEL DU MONCEAU, 1769, SAÑEZ REGUARD, 1791-1795; BERTHELOT, 1868; GOURRET, 1894; DELGADO, 1923; LLEO, 1923; FRANCO and SALINAS, 1923; MIRANDA, 1923; THOMAZI, 1947). They also point out the diversity of Mediterranean fishing activities which still

retain many archaic features nowadays. Finally, they show that, even since the Middle Ages, the few great types of fishing which gave birth to the Mediterranean populations of fishermen have prevailed. Coral fishing in particular, a monopoly of the Catalans until the end of the XIVth century, then of Genoa until the early XIXth century, employed thousands of people, and led to the migration of Genoese fishermen and to their settlement along the European and African coasts of the western Mediterranean (MORI, 1950; BORGHESI, 1985). Those people remained there by adopting new activities, after economic and political events had caused the decline of coral fishing.

Another great area of fisheries research at the time, which allows us to draw a continuous fresco of several centuries, is tuna trap fishing, a speciality of Italians, Spaniards and French, and generated important changes leading to high employment, the led to and creation of fishermen's communities and of a great number of settlements along the Mediterranean coast (PAVESI, 1889; PARONA, 1919; HELDT, 1931; BELLOC, 1961).

Equally well-known is the evolution of the Spanish fisheries, particularly those specialized in surface longline fishing until the early 1900's on the Catalan coasts, and the evolution of the Neapolitan small pelagic fisheries, which caused the migration of thousands of fishermen who founded colonies along the European, North African and Eastern coasts of the Mediterranean Sea.

Not as much is known about the evolution of the ancestral types of fishing in the eastern waters, but ethnographic and historical research point out the importance of some activities like sponge fishing in the genesis of the fishing populations of that area, and allow a description of the chronology of the technological and strategic changes until today (DOUMENGE, 1968, 1984).

Finally, ever since the Greek and Latin authors of the Antiquity, bibliographic materials (QUIGNARD and ZAOUALI, 1980, 1981) have accumulated continuously concerning population settlements and lagoon fisheries around the Mediterranean, which hold an important place in the traditions of the area. Several centuries of history are also well-known for these environments, especially concerning the evolution of the management methods along the Spanish, French, Italian and North African coasts. The main lines of their management systems (ARDIZZONE *et al.*, 1988), economic and social evolution can also be followed (particularly through the fluctuations of the eel trade), as well as the urban development of those ar-

chas and the problems linked to it, such as tourism, pollution etc... (D'ANCONA, 1955; AMANIEU, 1973; ARDIZZONE, 1984).

OCEANOGRAPHY AND FISHERIES: BIOLOGICAL ASPECTS

The "naturalist" period

Since the XIXth century, the invention and adoption of new fishing techniques, trawling and purse-seining in particular, their rapid spread in a cultural area where the exchanges were made easier by the fishermen's seasonal migrations, motorisation of the boats and mechanization of fishing gear have been the landmarks of a turning point in the history of Mediterranean fisheries.

This "technological revolution" coincides with a reinforced concern felt in the western world for physical oceanography, marine biology, and with the orientation of scientific research towards global surveys. The latter were further stimulated by the results of great exploratory cruises of the first European research vessels, among which some of the most famous took place in the Mediterranean (HELDT, 1921; LE DANOIS, 1925).

It is to that time that we can trace the advent of oceanography in its modern sense. It was marked on Mediterranean coasts by the establishment of numerous research stations whose activities in the marine field were varied. These institutes developed particularly in Spain, France, Italy and in the coastal African countries (Stazione Zoologica di Napoli created in 1872, Laboratoire Arago of Banyuls, 1881, Laboratorio Biológico Marino de Baleares, 1908, Musée Océanographique de Monaco, 1910, Station océanographique de Salammbô, Station d'aquiculture et pêche de Castiglione, 1921 ...). The research programmes which first took place there were fundamental to basic knowledge of the hydrographic, sedimentological and faunistic characteristics of this sea.

Then, more or less connected to fishing activities, research evolved towards a number of studies describing fishing techniques, gear and boats on the one hand, the biology and physiology of the main (marine animal) species on the other hand. As a whole it can be said that these studies are characterized by a strictness and accuracy linked to the serenity which prevailed during this research, as it was not subject to the delivery of short-term results. As already mentioned at that time by a few observers, the possibility of the fishing resources running short was not yet effectively

topical, and the public authorities showed little concern for the protection of large areas of production, for the competitive will was then limited to a reduced geopolitical scale.

That situation, the very rich Mediterranean fauna and the highly multispecific nature of the catches certainly favoured the fact that the biologists divided their attention between numerous species and various aspects of their biology. The "zoological-character" of this research is quite clear, as is their monographic tendency, for they were mainly oriented towards exhaustive descriptions of the vital cycles and biological parameters of given species. In those days, the chief preoccupation was to discover as many fundamental characteristics of the whole marine fauna as possible. The research programmes were not yet submitted to political demands, and as a result, the species which were studied in detail were not necessarily the most important ones economically speaking, while on the contrary the ecology of some "commercial" categories of the fauna were only studied occasionally. A very large bibliography (more than 5000 references) these topics (taxonomy, physiology, spawning, habitat, distribution, etc...) appears in a check-list of the European fish fauna published under the auspices of UNESCO (HUREAU and MONOD, 1973).

The advent of modern fisheries research

Little by little systematic research developed with the aim of contributing to fisheries management. These works started principally in the countries of the northwestern Mediterranean, after the end of the second world war. Therefore, the passage from marine biology *sensu-stricto* to fisheries research, a conjunction of traditional qualitative zoology and statistical theories, is relatively recent in the Mediterranean Sea. This new scientific orientation undoubtedly comes from the generalization of "fishing theories" and from the concept of "optimal exploitation" and "over-exploitation" of marine living resources. These theories were initially developed in some large monospecific industrial fisheries of the Atlantic and Pacific Oceans after several major exploited stocks had collapsed. A new awareness of the dimension of these risks, associated with a will to explore opportunities of increasing productivity in the fisheries sector, urged national administrations to exert some pressure over the research institutes to make them intensify their work in that field, including the Mediterranean fisheries.

Here we must point out the important role of the

international commissions whose fields of competence cover the Mediterranean area. The main ones are CIESM (International Commission for the scientific exploration of the Mediterranean) created in 1916, the GFCM (General Fisheries Council for the Mediterranean) created in 1949 by FAO, and the IC-CAT (International Commission for the Conservation of Atlantic and adjacent seas Tunas) created in 1966. Their actions have increased opportunities of collaboration between fisheries scientists sharing the same goal, and have introduced the use of population dynamics methods in the Mediterranean.

Initially, research was oriented towards the evolution of yields and the demographic composition of catches. Then the first attempts to apply some mathematical population dynamics models to the stocks exploited in the Mediterranean were undertaken in France and Spain in the late sixties (OLIVER, 1983).

As in most parts of the world, that process consisted in using the existing patterns without questioning the basic concepts and hypotheses. In those days assessment was designed only with concern for managing resources, and the main preoccupation of the national administrations and scientists was to avoid the fish being caught prematurely, before they had enough time to grow and spawn. Despite their social and economic weight, the "small-scale" fisheries caused only slight interest in the administrations, which explains why most attempts at fisheries modelling were, until recently, oriented mainly towards trawling, small pelagic and tuna fisheries.

Most of the early analyses used "global production models". These models of classic use in fisheries exploiting monospecific resources by means of a single type of gear, and for which they were designed, turn out to be quite disappointing when applied in the Mediterranean Sea.

Considering the multispecific nature of the catches and the diversity of the present fleets and gear (several scores of fishing techniques), many difficulties appeared in using and interpreting those models whose strong theoretical restrictions and insufficient statistical data made the construction even more uncertain. From a compilation of studies based on this theme, what particularly comes out is a unanimous acknowledgement of powerlessness to define a quantitative unity which would allow an efficient standardization of the various components of the fishing effort in the Mediterranean area. In general, as in many Atlantic multispecies fisheries, global modelling also found it impossible to distribute a global — or approximately global — effort in a likely way among the different species on which it applies simultaneously.

The lack of consistent time series of catch and effort data have led to some attempts to use the so called "composite production models" (GARCÍA, 1983; CADDY and GARCÍA, 1984). But these models work under a geographical homogeneous productivity hypothesis which turns out to be rare in the Mediterranean. So they have been used in very few cases (CHAVANCE and GIRARDIN, 1985). These models were used last year for a preliminary analysis of the data on research trawl surveys in Italian waters.

Moreover, in the Mediterranean, marked cyclical fluctuations in abundance of some species of demersal and pelagic fishes have been observed (SELLA, 1929; RODRÍGUEZ-RODA, 1960; FARRUGIO, 1981; ASTUDILLO and CADDY, 1986; RELINI and ORSI-RELINI, 1987; VUCETIC and ALEGRÍA-HERNÁNDEZ, 1988; ABAD *et al.*, 1991; OLIVER and CARBONELL, 1992; BENÉ, 1992; Biagi, pers.comm.). Those fluctuations which do not seem to be linked only to exploitation complicate the situation even more and make "classic" analyses valueless.

Faced with this situation, many Mediterranean biologists were reluctant to a systematic and unreasonable use of the global and indirect methods of population dynamics. They started a reorientation towards more direct methods and a probing into the fundamental knowledge concerning the ecological parameters of the exploited populations or the technical parameters of the fishing gear. The works of several laboratories, particularly in Spain and Italy, have also turned towards the prospection and direct evaluation of fish biomasses, starting from cruises applying experimental fishing (LEVI, 1985; MINISTERIO MAR. MERC., 1988), echosounding and echointegration (GFCM, 1982; AZZALI and LUNA, 1988; OLIVER *et al.*, 1988; ABAD *et al.*, 1991; PALOMERA and PERTIERRA, 1993), or methods for the evaluation of planktonic eggs and larval densities (DICENTA and PICCINETTI, 1977; PICCINETTI and SPECCHI, 1984; PALOMERA and PERTIERRA, 1993).

This attitude has often been criticized as a negative reaction to new methods, whereas it was often the result of a deep knowledge of the specific problems of the fisheries concerned.

Periodical updatings of research activities dealing with Mediterranean fisheries were made by GFCM from 1970, during working groups and technical consultations at a regional level. These have been regularly published in the "GFCM Studies and Reviews" and "FAO Fisheries Reports", and give a fairly complete panorama of the situation (GFCM, 1985a,b, 1986b, 1987, 1988). Apart from that, progress in the field of more fundamental biological and dynamical

aspects of the marine species are published by the Committee of Marine Vertebrates and Cephalopods of the CIESM in the "Rapports et Procès-Verbaux" of this commission.

Concerning demersal stocks, a general conclusion of these studies is that, except in a few cases, whatever methods have been used, diagnoses of biological full exploitation, or even overexploitation have been obtained and confirmed in an obvious way by the evolution of the rates of production. This situation is the result of both the conditions of the exploited populations and the exploitation patterns which are traditionally applied to them. It limits today's catches approximately to the peak of the global production models, which can only forecast a transition to a state of overfishing, in the best case, if the general increase in effort of the various fishing activities is carried out according to the pattern prevailing during the recent past.

In most of the cases a decreasing trend in individual lengths of the fish caught per unit of effort (of the boats) is observed. In general, juveniles are under the most important fishing pressure. This results essentially from the fact that the sizes at first catch are very often similar to those at which fish recruit.

An evolution can be noted in the total production statistics of Mediterranean fisheries; it seems that total fish production of the Mediterranean is increasing, and perhaps more than we can deduce from the official statistics. Recent data (GFCM, 1991) show that the total production of the Mediterranean increased 42.6% from 1977 (803, 401 tonnes) to 1989 (1,145,761 tonnes). This increase seems to be due partly to some corrections of catch statistics (particularly in the case of Turkey). But if we consider the three large GFCM divisions of the Mediterranean, we can note during the period 1977-1989 a 14% increase of the production in the western area, a 6% increase in the eastern Mediterranean, and a 179% increase in the eastern area. So while in 1977 the contribution of the western area to the total catch was 43%, it was only 35% in 1989. The contribution of the central Mediterranean has changed from 45% to 42% and that of the eastern fisheries increased from 11% to 22%.

A strange observation concerns the durability of some fisheries which are largely based on massive catches of juveniles of some species. This situation can be explained with an hypothesis of a good stock-recruitment relationship for low levels of spawning stock biomass. Some spawning stocks seem to be spared from fishing activities because they are suspected to live beyond the traditional fishing areas, at

least during a large part of the year (SBRANA and BELCARI, 1992). But apparently it is not always the case and the hypothesis needs further testing.

Another hypothesis is based on the existence of an anthropogenic eutrophication of the Mediterranean (CADDY and GRIFFITHS, 1990). In some areas like the Adriatic, this eutrophication may contribute to increased the primary production and consequently to increased benthic and demersal biomass via the food chain (BOMBACE, 1990).

Concerning the small pelagic resources, the assessments resulting from egg and larval and acoustic surveys indicate that they are not fully exploited everywhere. Among the large pelagic species, bluefin tuna is considered fully exploited, and juveniles of this species are submitted to heavy fishing pressure, while albacore is not a Mediterranean target species (ICCAT, 1991).

Relying—at least officially—partly on today's scientific knowledge about fisheries, the current arsenal which has been elaborated for the regulation of fishing by the Mediterranean countries' central administrations is quite typical of this situation. It is composed of a series of measures of a very general kind, largely restrictive and coercive, and concerns particularly the use of some kinds of gear in space and time, the power and number of boats, the meshsizes of nets and the legal commercial sizes of the species (MEURIOT and DREMIÈRE, 1986; OLIVER, 1991).

Although several infringements of these laws have occurred, even since their origin, the generalized lack of respect for these restraints by fishermen has been manifest for a long time. We may wonder if the countries' administrations have the necessary means to enforce the respect of these regulations. In fact it seems that we are in the presence of a maladjustment of these management measures whose geographical fields do not fit the fisheries structures, a result of the failure of attempts to analyse the system through the mere transposition of "foreign" patterns. So it seems necessary to adapt the regional scientific approach and to find some alternative solutions (CADDY, 1990).

RECENT TRENDS OF MEDITERRANEAN RESEARCH

Exploited stocks and fisheries dynamics

Mediterranean scientific institutions have gradually become aware of the above situation. As a result, what has followed for about fifteen years is a series of

syntheses to evaluate knowledge of the available biological and dynamics parameters for the main stocks (for example DREMIÈRE, 1979; QUESADA, 1992; CAMPILLO, 1992). This work has allowed all the useful information to be put together for evaluation of the resources in the Mediterranean Sea. A certain number of syntheses dealing with the state of the stocks have also been achieved. These revisions are based on already existing publications or on the use of information which had not yet—or only partially—been used (GFCM, 1967; LEVI and TROADEC, 1977; OLIVER, 1983; IVANOV and BEVERTON, 1985).

There is also a trend, in quite a number of subjects, to elaborate and update common databases which can produce increasingly reliable work tools (FAO SPECIESDAB, MEDIFAUNE, EEC-FAR programmes in course). Here also the international organizations continue to play an important role to which the federating action of the European Economic Community has recently been added.

GFCM and EEC have edited, in collaboration with fisheries research institutes and biologists from all Mediterranean countries, a series of species identification sheets for fisheries purposes. This document facilitates the identification of exploited species and provides general information on their fundamental characteristics and exploitation (FISHER *et al.*, 1987).

Thanks to the international cooperation cited above, GFCM and EEC have also published an atlas of the fisheries of the western and central Mediterranean (CHARBONNIER and GARCÍA, 1985). This document provides a cartographic synthesis of the main groups of species from the Straits of Gibraltar to the Adriatic coasts. It should be noted that this mapping ensues mainly from data on fishing activities with the addition of few biological criteria. In particular, some variations which can be noted in the atlas from one area to another can simply reflect differences in the fishing intensity of the various fleets. So it is not a population mapping in the biological understanding of this word. In fact, from an ecological point of view, reliable information about the horizontal distribution of Mediterranean fish populations is scarce (RELINI *et al.*, 1986; BIAGI *et al.*, 1989).

A recent innovation in the research on Mediterranean fishing is to consider that demersal stocks are not only subjected to trawling—unjustly considered in most cases as independent "industrial" or "semi-industrial" units—but also to the activity of the "small-scale" fleets, completely ignored until the recent years. For decades, researchers have "buried their heads in the sand" in this field, due to a feeling

of powerlessness in front of the enterprise represented by the elaboration of reliable series of data on this activity, and the absence of "readymade" methods adapted to the study of these fisheries. This attitude has recently been replaced by a new awareness by a growing number of Mediterranean scientists (CHARBONNIER and CADDY, 1986; FARRUGIO and LE CORRE, 1989). Now the activity of these fleets is increasingly fully taken into account in the Mediterranean countries and, according to their importance, they are studied specifically, or tentatively integrated in analyses of interactive fisheries when they share the exploitation of some stocks with other fleets (FARRUGIO and LE CORRE, 1987; ALDEBERT and CARRIES, 1990).

Moreover, the increasing acuteness of the economic conflicts between fleets in some areas, following competition for space, resources and markets, forces new demands on Mediterranean research.

Although such competition has always existed (LÓPEZ-LINAGE *et al.*, 1991), it can be noticed that their importance has grown in a remarkable way in several regions during the last few decades with the modernization of fishing, which research has favoured in many fields. Technological innovation has allowed fleet efficiency to improve. Its effects have been a greater rapidity and safety in navigation which have allowed "small" and "big" fishermen to extend notably their fields of action relative to their ports of registry. Technical progress has also made modern prospection and positioning equipment commonplace, while improving considerably the quality and efficiency of fishing gear and its deployment.

But this progress is not bereft of adverse effects: it has played a large part in increasing the scarcity of resources in the various fleets' traditional areas of activity. All the conditions permitted the fleets to enlarge their respective territories. Interactions and interferences between national and international fleets have often increased considerably, with a corollary from the fishing point of view: a growing complexity to understand and follow the evolution of the biological equilibria (or disequilibria) of the marine ecosystems and of the fisheries which exploit them.

Thus today's study of Mediterranean fisheries (and particularly the coastal ones) multiplies the number of evolutions to be integrated and increases the plurality of the issues to be resolved. All this requires new analytical concepts. This approach presupposes first of all the understanding of the present

structure of the fisheries to define units of exploitation, assessment and management and consequently the stratification corresponding to each level (DURAND *et al.*, 1989). Secondly it also implies an understanding of the behaviour of the fisheries, to explain their strength, their inner dynamics and consequently, the choices upon which it would be possible for managers to act. Eventually, it requires adopting some analytical or surveying methods.

However, if all Mediterranean research centers have scientific teams capable of studying the biological and dynamic parameters of the most important stocks, as well as the fleet dynamics and interactions, catch and effort statistics remain the main weak point. In several countries, suggestions have been made to improve these data (BAZIGOS *et al.*, 1984; CINGOLANI *et al.*, 1986; MARTORELL and OLIVER, 1986). But most statistical data are still often very far from reflecting reality. According to the case, both underestimate of catches (frequently suspected to represent not more than a third of reality), and overestimate of some stocks are detected. This situation is directly linked to the fact that an important part of Mediterranean production often eludes the traditional circuits for information gathering (auctions, markets...).

As for the fleet inventories, it leaves much to be desired in most countries. The statistics do not describe well the structure and capacity of the fleets, which depend on heterogeneous factors such as the depth of the fishing grounds, the type of fishing activity, the economic level of the fishermen, shipbuilding, traditions, etc... Particularly as regards the small-scale fleets, the files available in the national administrations are generally quite incomplete. An underestimate of about 50% compared to the real figures is not rare and of course it can introduce important biases in the analysis.

To avoid this situation, the latest works in the area have consisted in perfecting sampling and assessment strategies, particularly fit for Mediterranean fisheries. This type of investigation has developed during the last five years in several countries of the western Mediterranean (FARRUGIO and LE CORRE, 1984; LAHNIN *et al.*, 1989; ZOGHLAMI, 1991). The basic principles of these works consist in applying methods of stratified random sampling in space and time. The gathering of information depends entirely on the installation of networks of observers on the coasts. This requires a considerable investment in human and financial resources, and although they are only beginning, scientists are confronted with the problem of elaborating routine strategies, which will

enable them to obtain information at lower cost (CADDY and BAZIGOS, 1985).

Moreover, some Mediterranean experiments on the use of remote sensing to obtain direct information on fishing and surface marine life activities in large survey areas, or on the geographical distribution of marine communities have recently been conducted (FARRUGIO and LE CORRE, 1985; XIMENES, 1989; PETIT *et al.*, 1990; FREDJ *et al.*, 1990).

The main lessons that Mediterranean scientists have already been able to draw from these new approaches are similar in all the areas where they have been developed. In particular, contrary to a "traditional" postulate still largely admitted in some scientific and administrative circles, these experiments have demonstrated the possibility of operating studies which respect the statistical demand. Abundant flows of valuable information can be obtained, and their generalisation render possible a new and complete approach to the dynamics of the main stocks and fisheries, as well as to their interactions.

The problem of readjusting Mediterranean fisheries is going through the classical pattern of decisions in these circumstances: whatever the motivation for the choice of option, and the nature of the questions asked, the formulation of opinions or advice takes on a predictive character for the consequences, in terms of quantities, of the adoption of a new management regime.

It is in this direction that the programmes of several Mediterranean laboratories of fisheries research are now oriented. On the one hand, they continue to perform routine assessments of global indexes of resource abundance by trawl or hydroacoustic surveys. On the other hand, they implement "analytical" methods of modelling of the exploited stocks, mainly cohort or virtual population analysis (VPA) and yield per recruit models. They operate also the techniques of computerized simulation of fisheries' evolution under various hypothetical scenarii of exploitation. By making it possible to take into account simultaneously several species exploited by several kinds of gear, these techniques to some extent eliminate the handicaps linked to multispecificities problems and interactions between national and international fisheries. The first applications of analytical modelling achieved to date in the Mediterranean have had promising results in the fields of tuna fishing and demersal fisheries (FARRUGIO, 1981; FARRUGIO and LE CORRE, 1987; ALDEBERT and CARRIES, 1990; LLEONART, 1990; ARDIZZONE *et al.*, 1990; OLIVER, 1991; RECASENS, 1992; ALDEBERT *et al.*, 1993; DEMESTRE and LLEONART, 1993).

The main drawback of these analyses is the considerable number of basic data which must be available to start. The higher the number of fleets and species concerned, the larger the quantity (hence price) of information required. This is why a hierarchical organization and a geographical and specific selection of priority objectives must be the first preoccupation of this new research.

Here we must emphasize two important considerations: first of all, the fact that some biological or exploitation parameters are sometimes not perfectly known with a very high precision should not be considered an insuperable obstacle which prohibits any attempt to assess a stock or to study a fishery. Sensitivity analysis techniques allow the study of the impact of such uncertainties and their quantification, to evaluate the variance of results. Also, the lack of long historical series of annual catches and length frequency data should not be considered as a major problem for applying the VPA techniques to reach to a fairly good idea of a fisheries' dynamics. Very efficient computer programs already exist to run these analyses starting from "pseudo-cohorts" which need only a few — or even only one — year of demographic sampling of the catches. Some of them allow one to perform VPA on demographic age or length structures of stocks exploited with several kinds of gear and to analyse the transition situations and the sensitivity to the various parameters (LLEONART and SALAT, 1992). Some "rectified VPA" techniques exist too, which take into account a vector of fishing effort while performing the pseudocohort analysis (LAUREC and SANTARELLI, 1988). When effort time series during the period prior to the demographic sampling is available, this allows one to reduce the weight of the constant exploitation hypothesis.

A second important point is that, despite the apparently very complex situation which the multispecies nature of Mediterranean catches seems to show, some "target species" can be identified as priority indicators of the status of composite stocks. For example one can define, for the northwestern Mediterranean fisheries, a group of 13 species which constitute the "basic production" (OLIVER, 1992). These species are, in order of weight, sardine, anchovy, hake, red mullet, poor cod, sole, anglerfish, pandora, octopus, squid, cuttlefish, red shrimp and Norway lobster. Even if imperfect, the catch statistics show that this group represents respectively 68%, 65%, 43% and 40% of the total catch for France, Spain, Italy and Greece.

It should be noted that these proportions would certainly increase if it were possible to know the real

composition of the item "various species" of the official statistics, which include parts of the catches of those species.

Quantitatively, such a situation is similar to that we find in many European Atlantic fishing grounds. In fact, during the period 1974-1989, in a group of 20 species under EEC regulation in the Atlantic and North Sea, 8 of them did not reach 1% of the catches and 7 other species lay between 3% and 5%. The relative proportion of the last 5 species is around 12%, except for the cod which is 17% of the total catch (COMMISSION OF EUROPEAN COMMUNITIES, 1991).

These considerations have recently generated a multinational EEC program in which several scientific institutes from Spain, France and Italy participate. Started in 1990, this programme, whose first phase has just been completed (FARRUGIO *et al.*, 1992), is aimed as a first approach to some basic elements about the demersal fisheries production system on a regional scale (northwestern Mediterranean area). Its main objectives are the following:

- to compile a common data base on catches, effort, and biological and economical information,
- to improve knowledge of demographic and biological characteristics of some target species of major economic value,
- to improve knowledge of fleet dynamics, fishing effort, and capacities,
- to reflect on methods and techniques for future common assessment and management of western Mediterranean fisheries.
- to model some of the most characteristic problems regarding the demersal fisheries of the countries associated in the project, to demonstrate use of the database.

Some other recent European programmes still active on a regional scale (northwestern Mediterranean) concern the migration patterns, distribution and assessment of large and small pelagic species (TSIMENIDES *et al.*, 1992; GARCÍA, 1992).

Socio-economy

With a production reaching today more than nine-hundred thousand tons, Mediterranean fishing is only a small proportion of world production, which is about ninety-five million tons (FAO, 1989). But average prices of the products of this fishing, intended almost exclusively to be consumed when fresh, are five to ten times higher than in many other fishing areas (STAVROU, 1985).

Also, from the European point of view, Mediterranean fishing is far from being marginal since it represents nearly 20% of the weight and 35% of the value of the community's production of fish at present.

In addition, Mediterranean fishing and activities linked to it have a considerable social weight, since they represent several hundred thousand jobs (EUROPEAN PARLIAMENT, 1991). So fishing community dynamics are considered an integral part of the "fisheries production system", in the same way as fish population ecology or dynamics.

Conscious of the indisputable importance of these elements, some Mediterranean scientists have for a long time held the view that the analysis and management of fishing should not be based only on biological considerations, but should also take into account a great number of economic and social parameters. This concept has frequently been stated since the XIXth century. Nevertheless, the number of strictly socio-economic studies of Mediterranean fishing is small compared with those concerning ecology or technology. This is mostly the result of a preference amongst regional sociologists and economists for more traditional themes, such as agriculture and commerce (whose economic weight is far more important than that of the fisheries sector). It also indicates a lack of communication between research disciplines until quite recently.

If wide gaps still exist in the biological knowledge and in the catch and effort statistics as we have seen, we know even less about employment, the organization of the trade, its preservation, the effects of fishing on the socioeconomic environment and the industrial structure of the different Mediterranean areas. Very few studies (most of them mainly descriptive), and those very limited in space and time, are available about these questions (TEMPIER, 1986; PLACENTI *et al.*, 1988; ALEGRET, 1989; GARRABE *et al.*, 1989; REY, 1989; FRANQUESA and LOSTADO, 1991).

However, the small number of studies achieved must not overshadow the existence of permanent questioning by teams specialized in this field. A certain number of priorities have already been identified and multidisciplinary efforts have been made, both at the national (especially in Spain, Italy and France), and international levels (FAO, 1985; GFCM, 1986a).

So far, the results of these efforts have led to a new and increasingly generalized awareness of the socio-economic importance of fishing, and of the fact that the range of patterns of the fishing populations' dynamics, as sophisticated as they may be, can only

represent a link in the chain of fundamental knowledge required for a rational application of research to the management of fishing and fisheries.

In order to be fully useful, the use of the techniques of simulation and prediction of the catches, mentioned earlier, must be extended to estimates of the social and economic interest of the various balances which can be envisaged. To reach this goal, it becomes necessary to define and follow the evolution of relevant indicators of the fisheries' conditions which also largely depends on operational and political constraints, whose analysis is not within the biologists' competence. Undoubtedly, the definition of such indicators is not easy. In the Mediterranean as in other regions, economy and human sciences meet with a major difficulty which presents some analogy with the problems of multispecificity, stock fluctuations and diversity of exploitation strategies well-known to biologists. In fact, they address fishing populations which are particularly dense, and cause group conflicts. The complexity of the system also comes from the fishermen's capacity to evolve, rapidly in response to favourable or unfavourable outside incentives (fluctuations of biomass, costs of energy and money, assistance schemes markets, innovation, legal measures, etc).

This analogy can also be found in recent reflexions on the possibilities of using "bioeconomic" models for the study of Mediterranean fisheries. However, models of this type which are beginning to be used normally refer to unsophisticated fisheries (or made more simple by a set of suitable hypotheses), and usually consider the exploitation of a single species by a homogenous fleet. Because of its past failures in the field of biological modelling of the fisheries, research about Mediterranean fishing is now quite prudent concerning an immediate application for these new bio-economical tools, which are poorly suited to the analysis of composite fisheries so typical of this region. In this field, the need for an original conceptual approach is clearly perceptible through the reflexions which are developing on this theme (PANAYOTOU, 1982).

Another fundamental set of themes which concerns the allocation of marine resources is also beginning to acquire an increasingly large audience among Mediterranean researchers. This concept attributes the failure of the present fishing regulations and the multiplication of conflict situations to an inadequacy of the definition of the rights of access to the resources (TROADEC, 1982, 1990). The competition between individuals for the appropriation of a naturally limited production may lead to an overcatching ca-

capacity, resulting progressively in a degradation of productivity and a complete wasting of potential profits. As long as the access to the resources is free, it can only favour competition between the various participants, for the fisherman remains persuaded (rightly, as experience shows) that what he does not catch will be caught by someone else (DURAND *et al.*, 1989).

As a whole, we can consider that we have reached the stage of an advanced reflexion, but that there is still a long way ahead to overcome quite a number of scientific or administrative reluctances, harmonise the methodologies, define new strategies of approach.

FROM REFLEXION TO APPLICATION: THE REQUIREMENTS OF FUTURE RESEARCH

Evolution towards a pluralistic analysis of fishing realities in the Mediterranean implies that the orientation of future research can meet the demands of the concepts above mentioned, as far as improving knowledge and acquiring new data are concerned. We must remember that the target of fisheries science is not to manage resources or the fisheries, but to produce elements useful for this management.

So the success of this evolution will depend mostly on a new wave of investment in multidisciplinary fundamental research which might lead to a new start in the evolutive dynamics of research.

This view of the future goes against the current of increasing pressure that local, national or international authorities exert on researchers to obtain short term scientific advice. At different levels, and for various motives, this situation prevails equally in industrialized countries and in developing ones.

Yet the achievement of real progress in the "systemic" understanding of the structure and dynamics of Mediterranean fisheries will only be made possible at this price.

Given the topical preoccupations of fisheries science in all coastal countries, one of the main lines of future research in this field concerns the study of the typology of the resources and trades which lead to the definition of well individualized units of exploitation and management. In this perspective, it is obvious that Mediterranean fisheries scientists should be able to participate in the development or adjustment of methods allowing the analysis of the interactions between stocks and between fisheries.

The realization of these analyses and their generalization requires improvement of the quality of the statistics in general. It requires also particularly, for a certain number of species, an improvement of our knowledge of the biological parameters (age, growth, fecundity), and of the biogeographical characteristics (migrations, distribution, spawning areas, nurseries). Studies of interspecific and trophic relationships also seem to be fundamental (MACPHERSON, 1977, 1981; SARTOR, 1993), as well as understanding of the mechanisms of biomass fluctuations in space and time. Still at the fundamental level, studies which increase understanding of recruitment and its links to the environment, and those of fleet dynamics become of paramount importance too.

In such a perspective, the building of Mediterranean Geographical Information Systems databases will be of a great help for the understanding of the situation as a whole.

From a socio-economic point of view, the regular survey of several indicators like the evolution of investments and capital, of employment and salaries, seems indispensable. Future research should also start dealing with —or extending— studies of the price of production factors and the profitability of fishing in the Mediterranean, about which only sketchy knowledge is available.

Finally, it goes without saying that the scientific approach to past and future evolution of fishing in the Mediterranean should take into account the indisputable effects of agricultural, industrial, urban and touristic developments (pollution, eutrophication, equipment of the coast, diversions of rivers, development of aquaculture...). Whether they are harmful in one place, or beneficial in another, they among other factors, have an influence on the environment, the biological productivity and the exploitation strategies in this sea, whose water renewal rate is low, and where fishing remains greatly dependent on the condition of the coastal fringes and on artisanal practices (BEN TUVIA, 1973; QUIGNARD and FARRUGIO, 1982;; SARÀ, 1983; FAO/UNEP, 1985). During the last decade there have been many examples of bad management of coastal areas. The Italian lagoon of Orbetello may represent an illuminating example of the final destiny towards eutrophication if intensive aquaculture, fishery needs, and above all domestic waste discharge do not take into account the protection of natural habitats (LENZI, 1992).

These aspects are acquiring more and more importance, as at a world level, there is a general tendency to redirect the target of fisheries science from resources to entire ecosystem equilibria.

CONCLUSIONS

Like the system that it tries to describe, fisheries research in the Mediterranean may seem slow in its evolution when compared (as is often done) with that of other fishing areas of the northern hemisphere, Atlantic Ocean and North Sea in particular.

But the balance of this research shows clearly the heterogeneity of the situations and problems characteristic of this sea, which are unrelated to the relative simplicity of large industrial fisheries. On the other hand, the characteristics of Mediterranean fishing, make it more similar to the so-called "coastal" or "semi-industrial" fisheries, especially in northern Europe, for which the poverty in knowledge and scientific enterprise is an acknowledged fact in a great number of countries and disciplines.

So, when it comes to comparisons, Mediterranean fisheries research can be considered nowadays in an advanced position in the field of reflexion and approach for the analysis of composite fisheries even if, as for Atlantic ones, only limited results are available at the moment. In fact, if it has long been treated as a poor relation by an international scientific community essentially concerned with industrial fishing, the growing interest in semi-industrial and small-scale fisheries which is expressed today can make a valuable model of it.

By force of circumstances, the stage of reflexion and mutation which some scientific groups are just entering these days in their first approaches of other composite fisheries has already been considerably penetrated by quite a number of Mediterranean scientists. So, if ever this movement can continue and be taken into account, the eclecticism of its approaches, its experiences, its questioning, its success and failures must indisputably play an innovating and pedagogical part in the general evolution of the modern fisheries research.

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