DEMERSAL RESOURCES OF THE GULF OF LIONS (NW MEDITERRANEAN). IMPACT OF EXPLOITATION ON FISH DIVERSITY

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DEMERSAL RESOURCES OF THE GULF OF LIONS (NW MEDITERRANEAN). IMPACT OF EXPLOITATION ON FISH DIVERSITY

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SPECIES DIVERSITY
ELASMOBRANCHS
FISHING IMPACT
LONG-TERM CHANGES
NW MEDITERRANEAN
GULF OF LIONS

ABSTRACT. – This paper examines long-term changes in groundfish diversity in relation to the evolution of trawl fishery in the Gulf of Lions (NW Mediterranean). Two different data sets were used for this purpose, viz. data collected during bottom trawl surveys over the period 1957 to 1995 and landings statistics from the Sete auction market for years 1970 to 1995. They led to convergent results. 70 % of the 167 demersal or benthic species collected during the whole surveys may be considered as permanent. However, major changes occurred for elasmobranchs, sharks and rays. Within this systematic group, a clear decline of commercial species took place since the middle eighties, firstly on the continental shelf, later on the slope. No decline was observed for non-commercial species. Landings from the trawl fleet were analysed for twenty species. Multivariate analyses showed a high time gradient related to the increase of fishing intensity and to the consequences of technological modifications of the fishing gear. All elasmobranchs species identified in the landings showed similar declining trend.

BIODIVERSITÉ
SÉLACIENS
IMPACT DE L'EXPLOITATION
CHANGEMENTS À LONG TERME
MÉDITERRANÉE
GOLFE DU LION

RÉSUMÉ. – L'étude vise à mettre en évidence les modifications intervenues dans la diversité des espèces ichtyologiques démersales du golfe du Lion, en liaison avec les changements des modes et des niveaux d'exploitation au cours des dernières décennies. Elle est basée sur deux types de données complémentaires : pêches expérimentales au chalut de fond réalisées dans le Golfe du Lion entre 1957 et 1995, débarquements de Poissons de fond à la criée de Sète de 1970 à 1995. 70 % des 167 espèces benthiques ou démersales récoltées sur l'ensemble de la période peuvent être considérées comme permanentes. Parmi celles qui n'ont plus été capturées au cours des campagnes récentes figurent surtout des Sélaciens. Les diagrammes rang-fréquence établis pour les 30 espèces de Sélaciens (squales et raies) identifiées dans le golfe du Lion montrent une forte réduction du nombre d'espèces, surtout sensible à partir du milieu des années 80, affectant progressivement le plateau continental puis le talus. Ils traduisent aussi une meilleure conservation des espèces peu ou pas commercialisées. Les séries de débarquements commerciaux des chalutiers ont été utilisées pour les 20 espèces ou genres démersaux suffisamment bien identifiés. Une ACP et une classification hierarchique effectuées sur l'ensemble des espèces montrent l'existence d'un fort gradient temporel des débarquements, lié aux profondes modifications des conditions d'exploitation des ressources démersales intervenues depuis 1970. L'analyse des séries chronologiques monospécifiques a permis de grouper les espèces selon quatre types de tendances. Pour les Sélaciens identifiés dans les débarquements, les résultats corroborent ceux obtenus sur la base des données de campagnes expérimentales : la tendance générale est à la baisse des apports allant même jusqu'à la disparition des espèces les plus fragiles.

INTRODUCTION

Exploitation of demersal resources has reached a high level in the Gulf of Lions. At the moment, demersal resources are exploited both by a trawler fleet (nearly two hundred units including Spanish boats) and by numerous small-scale fishing vessels using various gear, such as trammel nets, gillnets, longline... The trawler landings make up at least two thirds of the total catch. The demersal fishery presents the typical Mediterranean characteristics, i.e. a multispecific exploitation, rarely targeted on a single species due to the lack of highly dominant stocks (Oliver 1983, Campillo 1992).

During the last decade, several studies were carried out on the exploitation of some of the main demersal fish species such as hake *Merluccius merluccius* (Aldebert and Recasens 1993, 1996), sole *Solea vulgaris*, bass *Dicentrarchus labrax* and gilthead bream *Sparus aurata* (Farrugio and Le Corre 1995). These studies concluded in most cases that the concerned stocks were at least fully exploited if not overexploited. Similar conclusions can be found in a review of French Mediterranean fisheries (Campillo 1992). Furthermore, an economic study of the Sete trawler fishery (Meuriot *et al.* 1987) pointed out the very important changes that had occurred in conditions of exploitation since 1970. Those changes resulted in an increased fishing effort.

In this context, the impact of exploitation on demersal resources and on fish diversity in the Gulf of Lions becomes a relevant question. Various studies have related exploitation to long-term trends of fish assemblages in overfished areas such as the North Sea. According to Greenstreet and Hall (1996) changes in diversity were subtle; in particular, the non-target species assemblage remained relatively unchanged when data from 1929-50 were compared to data from 1980-93. Conversely, Sherman (1991) reported that a range of target species was reduced by half, while a good survival and sometimes an extension could be observed for non-commercial species. Gomes *et al.* (1995) showed that the distribution patterns of the groundfish assemblages remained relatively stable from 1978 until 1987 on the Newfoundland-Labrador shelf; since then dramatic changes could be observed, changes in the distribution patterns of individual species anticipating changes at the community level. Gislason (1994) considers that, due to the lack of convenient methods, a large part of uncertainty remains in scientific results.

The present study was carried out in order to give initial answers to this question for the Gulf of Lions. It must be considered as the first part of a larger study on long-term variations in the demersal fish in the Gulf of Lions, taking into account the variations in the environmental factors.

Two different types of data were collected independently but used complementarily as a base for our analyses :

— data from bottom trawl surveys in the Gulf of Lions between 1957 and 1995,

— commercial landings from the demersal fishery in the port of Sete from 1970 to 1995.

The results of a preliminary examination of survey data led us to retain elasmobranchs as a most interesting group according to the principal aim of the study. More detailed analyses focused on this systematic group.

The time series of landings statistics is shorter than the survey data but still sufficient to point out long-term trends, due to high changes in exploitation within the period. General information on the evolution of the trawler fleet and gear in Sete during the last four decades is available. This could help to understand the changes which have occurred in the species composition of the landings.

MATERIAL AND METHODS

General trends of trawler fleet and exploitation in Sete since 1957

Several phases in the evolution of the fishery can be distinguished. They are based on the data obtained from the local Fishery Administration or collected by the Sete Fishery Laboratory (Giffard 1967, Meuriot *et al.* 1987, Campillo 1992, Taquet *et al.* 1997). These phases can be summarised as follows :

— 1957-61 : small scale fishery with small size and low horsepowered boats (27 vessels, total nominal horsepower 2 700 hp in 1961); traditional trawl gear with 2 panels and a small vertical opening; restricted fishing area on the continental shelf.

— 1962-70 : increase of the number of vessels, of their size and horsepower (28 units in 1962, total nominal horsepower 2 800 hp; 45 units in 1970, 12 720 hp). Traditional gear; fishing areas extending more offshore.

— 1971-73 : fishing effort still increasing in spite of the limitation of trawler number (fishing licenses) and of individual maximum horsepower (430 hp); 46 units, total nominal horsepower 13 270 hp in 1971, 14 180 hp in 1973.

— 1974-87 : increase of the total fishing power of fleet, technical improvements (fish detection, net drums...); 44 units in 1974, total nominal horsepower 14120 hp; 48 units in 1984, 19 940 hp. New types of trawlnets with 4 panels and a vertical opening as high as 6 m in 1974 and 11 m in 1980. Higher catch of small pelagic fish.

— 1988-94 : partial displacement of fishing effort towards small pelagic fish (up to 50 % of the trawler fleet according to years); the apparent decrease of fishing effort on demersal resources being balanced partly by a real increase of the fishing power of trawlers. About 45 units with a smooth trend to decrease for the recent years. New types of pelagic trawls with very high vertical opening up to 20 m in 1988 and to 40 m high since 1992, these gear being used close to the bottom.

It must be noticed that since the middle eighties, the nominal horsepower of trawlers could be no more considered as a satisfying index for fishing effort : some of the trawlers were fit out with more powerful governed engines (up to 1 000 hp) while varying pitch propellers and nozzles became of general use. These improvements resulted in an increase of the real fishing power of the trawler fleet.

Table I. – Distribution of experimental trawl hauls in the Gulf of Lions from 1957 to 1995.

Period	Research vessel	Number of hauls	< 150 m	>= 150m
1957-60	Pt T. Tissier, Thalassa	64	27	37
1966-70	Ichthys	180	175	5
1971-76	Ichthys	257	254	3
1980-84	Ichthys	230	95	135
1985-87	Roselys II	214	200	14
1988-89	Roselys II	206	186	20
1992	Roselys II	69	67	2
1994-95	L'Europe	139	109	30
Total		1359	1113	246

Bottom trawl survey data and analyses

Data collected by the Fisheries laboratory (ISTPM/IFREMER) are available from 1957 to 1995. All surveys were carried out using bottom otter trawls with two panels, a small vertical opening (between 1 and 3 m high), the mesh size in the codend being 40 or 20 mm. However, due to differences between sampling conditions (boats, gear or hauls duration) and the main goals of the surveys, these data are rather heterogeneous. In the earlier period, the surveys focused mainly on prospecting of fishing grounds or were aimed at specific studies for one or few demersal species. Since 1983, routine stratified sampling surveys were carried out to estimate abundance indexes of demersal resources in the whole continental shelf and the upper part of the slope of the Gulf of Lions. This was needed for national projects (Chalist surveys) or European projects (Reclio and Medits surveys). Consequently, the data are only directly comparable for the last period. When considering the entire period, geographic and bathymetric sampled areas may differ so that any direct quantitative comparison could be biased.

Data from 1359 tows were examined. For each haul, the minimum information available consisted of a faunistic list of species including the number of fish caught and their total weight. Also, as the hauls were quite unevenly distributed all along the period with gaps of several consecutive years, the data were grouped into short periods in order to obtain rather representative samples. In the same way, only two bathymetric strata were taken into account so as to obtain reliable data bases for analyses. The isobath 150 m was chosen as a rather convenient and realistic limit between the continental shelf and the slope in the Gulf of Lions, the shelf break occurring between 120 and 160 m depth. Also, the upper limit of the slope corresponds to major changes in the species composition as well as in groundfish assemblages (Maurin 1968, Gaertner 1997). The repartition of haul data available within each period for the continental shelf (from the coast to 150 m depth) and for the slope (150-800 m depth) is given in table I.

Firstly an exhaustive list of fish species caught on the continental shelf and on the slope was established. Altogether, 198 species of fish were identified for the whole period. Information was collected from literature (Bauchot and Pras 1980, Fischer *et al.* 1987, Quero 1984, Whitehead *et al.* 1986), in order to characterise each species according to its geographical area of distribution, bathymetric distribution, behaviour and main type of habitat (substratum). Thirty-one species were excluded from the previous list, their occurrence being thought casual due to their pelagic (or mesopelagic) behaviour or to an exclusively inshore distribution.

Descriptive analyses, mainly based on the presence/absence of fish species, were carried out so as to show general trends of each species : continuous occurrence, stable, increasing or decreasing frequency. Rank-frequency diagrams (Frontier and Pichod-Viale 1991) were used to point out modifications both in absolute frequency and in relative rank of species for sharks and rays (one species of Chimaeridae being included as well). In these diagrams, frequency is equal to the number of positive hauls against the total number of hauls, expressed as a percentage. Major attention was focused on data from three periods where sampling effort had been high both on the continental shelf and the slope :

— years 1957-60 which constitutes the initial reference in spite of a rather low number of hauls,

— years 1980-84 including the first stratified sampling survey (Chalist-1) on the continental shelf and several surveys for prospecting of fishing grounds of the slope,

— years 1992-95 including three recent stratified sampling survey i.e. Chalist-5 (1992), Medits94 and Medits95.

Data for other periods, being quite restricted, were used only as additional information sources.

Landings statistics and analyses methods

For the present study, only landings of demersal fish from the Sete auction market were taken into account. Sete is the main fishing port on the French Mediterranean coast, accounting for more than a third of the total landings from the coast. The landings from this port can be considered as a good indicator for the general trends. It is also the first place whose the auction market was computerised (1970) so that a time series of 25 years of landings is now available. Statistics include the landings from almost the entire trawler fleet and from a few of the small-scale fishing vessels. The choice of this time series was justified by sufficient detail in the recording of the species composition of the landings; e.g. several elasmobranch species or genera could be identified despite their small landings. However, several demersal species could not be taken into account, because they were included in mixed commercial categories. These constraints excluded some systematic groups, such as Triglidae and almost Sparidae, in spite of their interest from a biodiversity point of view. Data from twenty species or genera could be used, the list of which is given in table II. Landings for these species represented 53 to 70 % of the total demersal fish landings in individual years (mean over years 65 %). As shown in figure 1, a similar evolution

Table II. – List of scientific and common names of fish species and genera used for landings analyses (nomenclature from Whitehead *et al.* 1984-86). Codes : abbreviated names for Principal Component analysis.

Scientific name	English name	code for PCA
Conger conger	European conger	Cong
Dicentrarchus labrax	European seabass	Dice
Lepidorhombus boscii	Fourspotted megrim	Lepm
Lophius spp (L.budegassa, L. piscatorius)	Angler	Loph
Merluccius merluccius	European hake	Merl
Mullus spp (M. barbatus , M. surmuletus)	Red mullet	Mull
Mustelus spp (M. mustelus, M. asterias)	Smooth hound	Must
Myliobatis aquila	Common eagle ray	Myli
Pagellus acarne	Axillary seabream	Paca
Pagellus erythrinus	Common pandora	Pery
Raja asterias	Starry ray	Rast
Raja clavata	Thornback ray	Rcla
Raja oxyrinchus	Longnose skate	Roxy
Scyliorhinus canicula	Dogfish	Scyc
Scyliorhinus stellaris	Nurse hound	Scys
Solea vulgaris	Common sole	Sole
Sparus aurata	Gilthead seabream	Spar
Squalus spp (S. acanthias, S. blainvillei)	Spurdog	Squa
Trisopterus minutus capelanus	Poor cod	Cape
Zeus faber	John dory	Zeus

of the two series can be evidenced on the timescale of 25 years, allowing further analyses on the restricted series.

Two types of analyses were performed taking into account either all species jointly or separately.

Multivariate analyses (Lebart *et al.* 1984) were applied to annual landings for years 1969 to 1994 considering all the species together. The procedure included successively a principal components analysis (PCA), hierarchical classification with final partition of the dendrogram and description of classes. SPAD.N software (Lebart *et al.* 1993) was used to perform the analysis. The PCA was carried out using centred but not normalised values of landing data in order to keep the variability of every species. However, landings were expressed in logarithms so as a single species could not have too much influence on the constitution of the axes. Two of the 20 species, *Scyliorhinus canicula* and *Raja oxyrinchus,* were used only as supplementary variables. Also year 1969 was considered as a supplementary individual, due to a lower reliability of data.

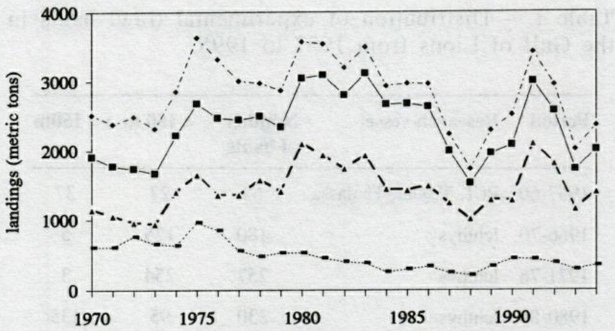

Fig. 1. – Yearly landings from the Sete auction market from 1970 to 1994. (— - — ▪ : total demersal species. ____ ■____ ■ : total demersal fish. – ▲ – ▲ : analysed fish species. – . . . – . . . : molluscs and crustacean).

Monospecific time series analyses (Box and Jenkins 1976) were based on monthly data available for the same period. Several procedures from Statgraphics-Plus software were used to point out general trends, seasonal cycles and even pluriannual cycles in some cases (Palm 1992). Considering the main objective of the study, major attention was focused on the trend analysis. The Trend Analysis procedure was developed initially for forecasting purpose. It fits a linear or quadratic line, exponential power curve or S-curve through the time series data. Each of the four fitting methods estimates a function Z(t) where t represents the time index.

RESULTS

Survey data analyses

Given the above reservations, 167 species of demersal or benthic fish were identified in the area sampling hauls on the whole (Table III). No significant change could be observed in the total number of species caught, considering the differences of sampling effort at each period. Ninety-one species (54 %) were fished all along the period and can be considered as permanent. This

Table III. – Number of fish species identified in experimental hauls at different periods according to their main bathymetric distribution.

	Time periods								
Main habitat	1957-60	1966-70	1971-76	1980-84	1985-87	1988-89	1992	1994-95	1957-95
inshore area	0	3	4	2	2	3	0	1	9
shelf	43	48	46	46	45	49	36	41	66
shelf +slope	41	44	33	52	44	44	36	37	59
slope	23	3	13	25	13	13	5	22	34
total number	107	98	96	125	104	109	77	101	167

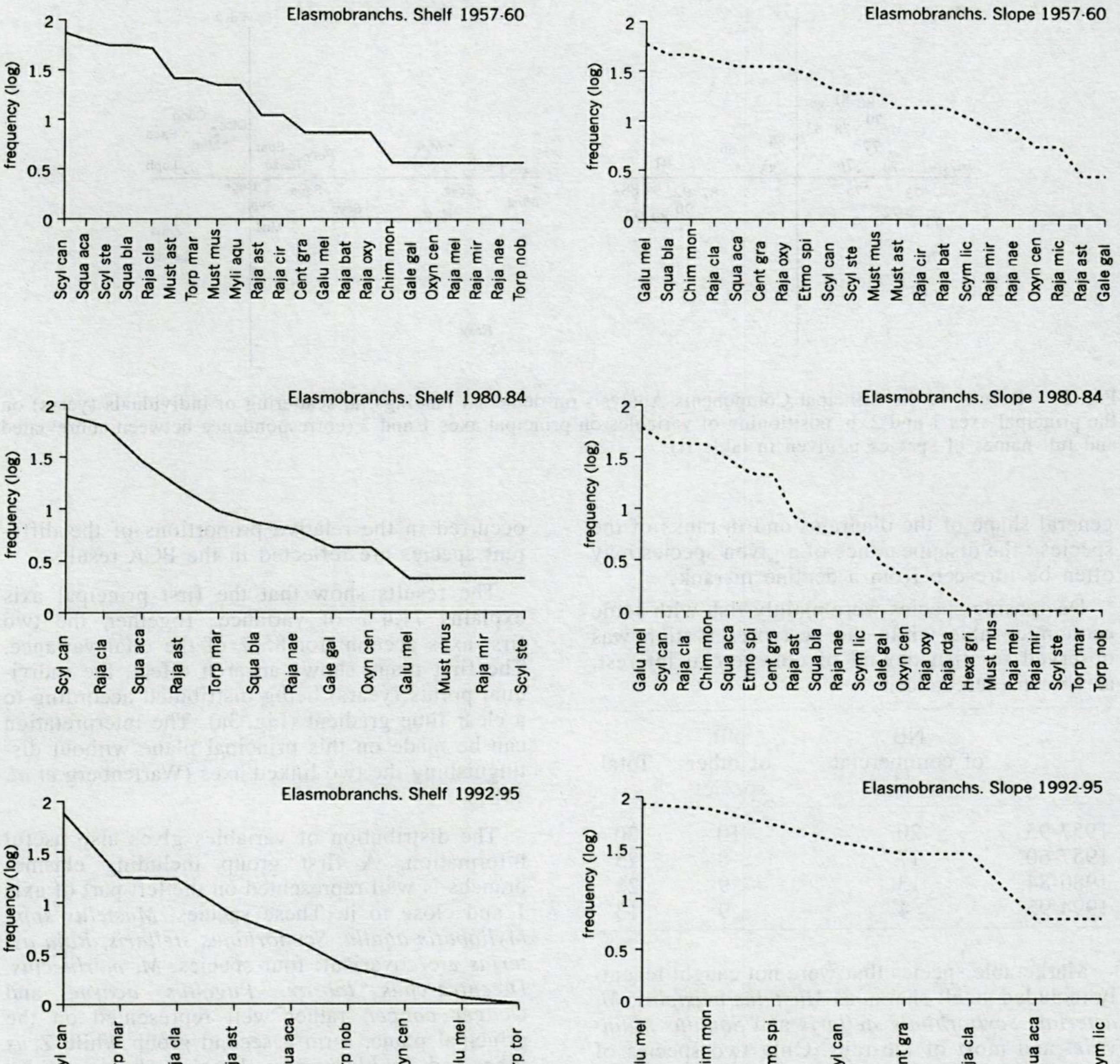

Fig. 2. – Rank-frequency diagrams for elasmobranch species on the continental shelf and on the slope of the Gulf of Lions. Correspondence between abbreviated and full names is given in appendix 1.

number may be extended to 126 (70 %) when taking into account different factors : species not described or looked for in the early years; low level of frequency possibly linked to sampling methods; occurrence related to specific patterns of distribution.

However, it is worth considering more carefully species whose occurrence was restricted to the early period. From a systematic point of view, these species are mainly elasmobranchs, thus justifying its further analyses.

The list of the 30 elasmobranch species identified in total and their occurrence at each short time period is given in appendix 1. It shows clearly a gradual decrease in their number. Rank-frequency diagrams describe more accurately the general trends, both on the continental shelf up to 150 m depth and on the slope (more than 150 m). During the initial period, about twenty species were caught either on the shelf or the slope. The decline of elasmobranchs began on the continental shelf as far back as the sixties and was quite obvious in the year 1980-84. The species diversity was preserved for a longer period on the slope, but recent surveys show the same evolution pattern as on the continental shelf (Fig. 2). Also, changes can be observed in the

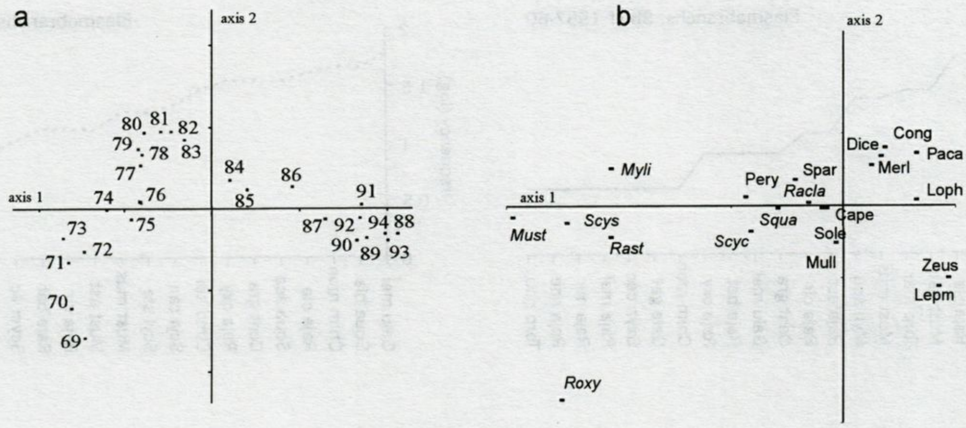

Fig. 3. – Results of the Principal Components Analysis on demersal landings. a, scattering of individuals (years) on the principal axes 1 and 2. b, positioning of variables on principal axes 1 and 2 (correspondence between abbreviated and full names of species is given in table II).

general shape of the diagrams and in ranks of the species : the disappearance of a given species may often be foreseen from a decline in rank.

Decreasing species were mainly fish with some economic value while the best preservation was observed for fish devoid of commercial interest, as shown thereunder :

	NB of commercial species	NB of other species	Total
1957-95	20	10	30
1957-60	17	8	25
1980-84	13	9	22
1994-95	4	9	13

Marketable species that were not caught recently included small sharks as *Mustelus mustelus, M. asterias, Scyliorhinus stellaris* and *Squalus blainvillei* and most of the rays. Only two species of rays, *Raja clavata* and *R. asterias*, being the most abundant and frequent in the area, could be fished during recent years. Conversely, a good resistance of poorly or non commercial species could be verified even in cases of a low level of initial abundance, e.g. the three species of electric rays *Torpedo marmorata, T. torpedo, T. nobiliana* or *Oxynotus centrina.* Equally, the dogfish, *Scyliorhinus canicula* on the continental shelf and the blackmouth catshark *Galeus melastomus* on the slope, seemed to take the lead over all other elasmobranchs.

Landings statistical analyses

Multivariate descriptive analyses

The total landings of demersal fish in the port of Sete remained relatively steady throughout the years 1970-1994 (Fig. 1). The changes that have occurred in the relative proportions of the different species are reflected in the PCA results.

The results show that the first principal axis explains 71.4 % of variance. Together, the two first axes account for 85 % of the total variance. The first plane shows an arch effect, the individual points (years) being distributed according to a clear time gradient (Fig. 3a). The interpretation can be made on this principal plane without distinguishing the two linked axes (Wartenberg *et al.* 1987).

The distribution of variables gives also useful information. A first group including elasmobranchs is well represented on the left part of axis 1 and close to it. These species, *Mustelus spp., Myliobatis aquila, Scyliorhinus stellaris, Raja asterias* are covariant; four species, *M. merluccius, Dicentrarchus labrax, Pagellus acarne* and *Conger conger,* rather well represented on the principal plane, form a second group while *Zeus faber* and *Lepidorhombus boscii* make up a third one (Fig. 3b).

The dendrogram issued from hierarchical classification points out logically clusters of years with a pattern similar to PCA scattering of individuals. The final partition of the population is defined by cutting the dendrogram. The choice of cutting level had to be done above the low aggregations, which bring together the elements that are very close one to another, and under the highest aggregations (Lebart *et al* 1984). Also the purpose of the study, i.e. the impact of exploitation on fish diversity, had to be taken into consideration.

The dendrogram shows a clear partition into two main clusters corresponding to the periods 1970-1986 and 1987-1994 (index of hierarchical tree 58 %). As shown in figure 4, final partition was obtained by cutting the aggregation tree to

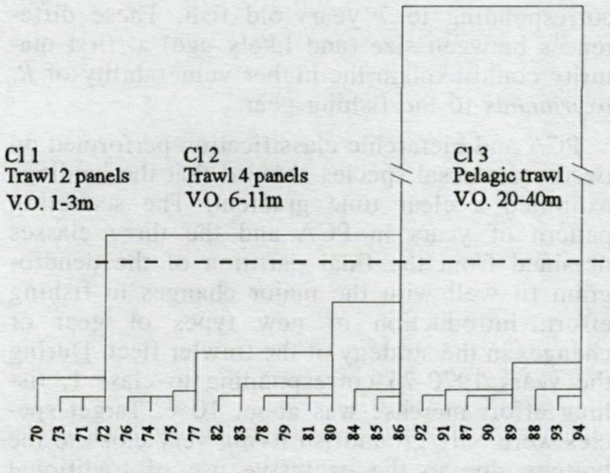

Fig. 4. – Hierarchical classification of demersal landings. (– –: level of partition of the dendrogram. V. O. : vertical opening of trawl).

three main classes corresponding to the time periods, 1970-73, 1974-87 and 1988-94. This cut corresponds to the second higher level of aggregation of the hierarchical tree (index 14 %) and it fits quite well with the different phases that have been distinguished in the evolution of the fishery.

Class 1 is characterised positively by various elasmobranchs (*Raja oxyrinchus, R. asterias, Scyliorhinus stellaris*...) and negatively by *M. merluccius, P. acarne, Conger conger* and *D. labrax*. Class 2 is poorly defined by any species, viz. *Z. faber* and *L. boscii* being negative characteristics. Conversely, these two species are positive characteristics of class 3, while most of the elasmobranchs can be found in a large list of negative characteristic species. Types of gear were added to figure 4 as an illustration of the main fishery technical changes.

Time series analyses

For the present study, the results are examined only from general trend point of view. The analyses of the landings show four different trends :

— species declining continuously since 1970. These species are mainly elasmobranchs : *R. oxyrinchus* was not landed after year 1976; also a clear decrease was observed for *R. asterias, Mustelus spp., S. stellaris* and later for *M. aquila* (Fig. 5a). *Squalus spp.* decrease began only during the eighties but not in so high proportion. Other species can be connected to this group in spite of a softer slope of the catch curve;

— steady species despite occasional important annual variations. It is the case of *D. labrax, Solea vulgaris, Trisopterus minutus capelanus, Mullus spp.* (Fig. 5b). In this group one might put *S. canicula* whose landings are determined by sale conditions;

— for *M. merluccius*, *P. acarne* and *C. conger,* the catch curve shows a rising period initiated during the middle seventies; recently a stable or even slightly decreasing trend may be observed (Fig. 5c);

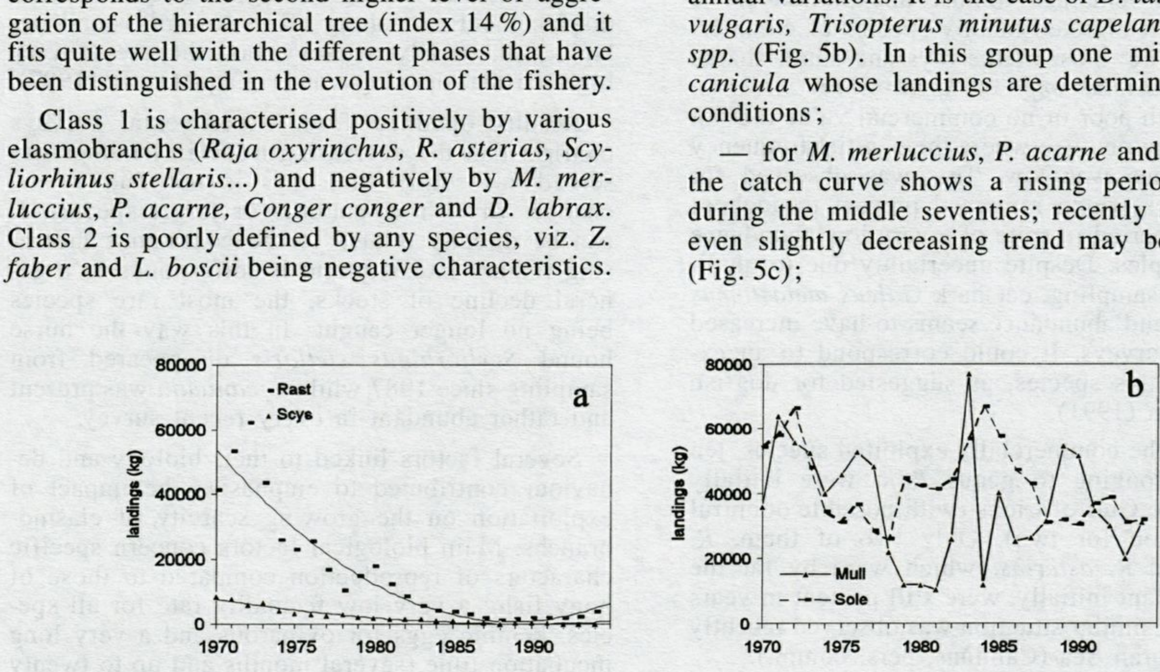

Fig. 5. – Time series analysis from demersal landings at the Sete auction market from 1970 to 1994. a, declining trend. b, no trend. c, dome shaped trend. d, rising trend (correspondence between abbreviated and full names of species is given in table II).

— time series showing an increasing trend during the last decade. It is the case for *Lophius spp., Z. faber, L. boscii* (5d).

DISCUSSION

Due to the qualitative value of surveys data base, only descriptive methods were available to point out and to describe possible changes in groundfish diversity.

The total number of species fished in the Gulf of Lions was quite stable throughout the time period. However, with regards to the elasmobranchs, the analysis of trawl survey data showed clear evidence of changes. Within this group, the number of species caught in recent years was less than half of the species caught the earlier period. The reduction occurred first on the continental shelf and then, more recently, on the slope, an area which remained almost unexploited for a long time. It affected mainly species of commercial value, i.e. most of the rays and small sharks such as *Mustelus spp.* or *Scyliorhinus stellaris.* Species with poor or no commercial value did not appear to lessen even where their initial frequency or abundance was low. This was observed for electric rays which remained present throughout the whole period in spite of a very low abundance in the samples. Despite uncertainty due to qualitative data sampling, catshark *Galeus melastomus* frequency and abundance seems to have increased in recent surveys. It could correspond to an extension of this species, as suggested for dogfish by Sherman (1991).

Among the commercially exploited species, ten species belonging to genus *Raja* were initially found in the Gulf of Lions (with possible doubtful determination for two). Only two of them, *R. clavata* and *R. asterias,* which were by far the most abundant initially, were still present in years 1992-95. A similar situation was observed recently in the Alboran Sea (Camiñas, pers. comm.).

Analyses of landings data led to rather convergent results concerning elasmobranchs species. The general pattern of each time series shows a similar decreasing trend, initiating more or less early according to species; so, *R. oxyrinchus* disappeared from catch statistics in year 1976 while *R. clavata* decrease could be noticed only since the middle eighties. Differences in life history strategy, as well as initial abundance, could explain the earlier decline of the former species. In the Mediterranean, according to Capapé (1986), the size at first maturity is about 120 cm for *R. oxyrinchus* (maximum length 150 cm). For *R. clavata* females, the first maturity was observed between 73 and 85 cm (maximum length 110 cm), corresponding to 7 years old fish. These differences between size (and likely age) at first maturity could explain the higher vulnerability of *R. oxyrinchus* to the fishing gear.

PCA and hierarchic classification performed on twenty demersal species showed that the landings exhibited a clear time gradient. The scattering pattern of years in PCA and the three classes obtained from the final partition of the dendrogram fit well with the major changes in fishing effort, introduction of new types of gear or changes in the strategy of the trawler fleet. During the years 1970-73 corresponding to class 1, fishing effort increase was about 10 %. Target species were only groundfish living very close to the bottom, due to the exclusive use of traditional trawl. Class 2 corresponds to an increase of fleet fishing power (total nominal horsepower from 14 120 to 20 640 hp *i.e.* a 46 % increase within the period) and to the introduction of trawls with 4 panels, that became of general use within the period. Class 3 should be characterised by major changes in the fishing strategies with the partial displacement of fishing effort towards small pelagic fish, mainly anchovy, and the use of very high vertical opening trawls (Taquet *et al.* 1997).

Results obtained from experimental surveys confirm that the decreasing trend in landings observed for sharks and rays is not due to the changes of fishing patterns or target species. It can be directly related to the continuous increasing fishing intensity and it corresponds to a general decline of stocks, the most rare species being no longer caught. In this way the nurse hound *Scyliorhinus stellaris* disappeared from sampling since 1987 while *S. canicula* was present and rather abundant in every recent survey.

Several factors linked to their biology and behaviour contributed to emphasise the impact of exploitation on the growing scarcity of elasmobranchs. Main biological factors concern specific characters of reproduction compared to those of bony fish : a very low fecundity rate for all species, benthic eggs for oviparous and a very long incubation time (several months and up to twenty two months in the case of genus *Squalus*). Also large size or shoaling behaviour are factors to account with as far as they may increase fish vulnerability. Quero (1995), in an historical study of the effect of fisheries in Arcachon marine waters identified the same factors as facilitating a complete disappearance of several large sized sharks or rays. As soon as 1974, Holden had pointed out these specific characteristics of elasmobranchs. The author concluded that "by the time young of any species of elasmobranch have reached a commercially exploitable size, the number of female fish in the population is only sufficient to provide constant recruitment and that any sustained exploitation of the female part of the stock will reduce its abundance very considerably". This conclusion was verified in the Gulf of Lions as well as in other areas.

All information analysed in the present study results from experimental or commercial trawling. This may introduce a bias in interpretation of results; areas not accessible to trawls (rocky grounds, canyons, etc.) may act as natural preservation sites for rare species, as shown by occasional catch of a few individuals with small-scale gear. Also the period of reference is rather short from a biological point of view. Until now, no attention could be given to the environment. Environmental factors may be of capital importance with regard to long-term variations of stocks : stock collapses firstly imputed to overfishing proved afterwards to be correlated to environmental anomalies (Jakobson 1992).

Despite all these reservations, the impact of exploitation on fish diversity appears to be rather clear for elasmobranchs which show a declining trend in the Gulf of Lions. It will be necessary to follow their landings and their occurrence in trawl surveys during the next years. This will allow the estimation of the impact of partial reallocation of fishing effort towards pelagic fish (since 1988). A reduction of fishing effort on groundfish might led to a reversal of trends and a possible recovery of the declining stocks.

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Appendix 1. Elasmobranch species collected during bottom trawl surveys from 1957 to 1995 (nomenclature from Whitehead *et al.* 1984-86). Occurrence according to time periods. Correspondence between full scientific name and Rubin code.

Species	57-60	66-70	71-76	80-84	85-87	88-89	92	94-95	habitat	Rubin code
Scyliorhinus canicula	—	—	—	—	—	—	—	—	shelf + slope	Scyl can
Squalus acanthias	—	—	—	—	—	—	—	—	shelf + slope	Squa aca
Torpedo marmorata	—	—	—	—	—	—	—	—	shelf	Torp mar
Raja clavata	—	—	—	—	—	—	—	—	shelf + slope	Raja cla
Torpedo nobiliana	—	- -	—	—	—	—	—	—	shelf	Torp nob
Raja asterias	—	—	—	—	—	—	- -	—	shelf	Raja ast
Chimaera monstrosa	—	—	- -	—	—	—	—	—	slope	Chim mon
Centrophorus granulosus	—	- -	- -	—	—	—	—	—	slope	Cent gra
Galeus melastomus	—	- -	- -	—	—	—	—	—	slope	Galu mel
Etmopterus spinax	—	- -	- -	—	—	—	- -	—	slope	Etmo spi
Scymnorhinus licha	—	- -	- -	—	- -	- -	- -	—	slope + shelf	Scym lic
Oxynotus centrina	—	—	—	—	—	—	—		shelf + slope	Oxyn cen
Torpedo torpedo		—	—	- -	- -	—	—		shelf	Torp tor
Mustelus mustelus	—	—	—	—	- -	—			shelf	Must mus
Raja naevus	—	—	- -	—	—	—			shelf + slope	Raja nae
Raja miraletus	—	- -	—	—	- -	—			shelf + slope	Raja mir
Scyliorhinus stellaris	—	—	—	—	—				shelf	Scyl ste
Squalus blainvillei	—	- -	- -	—	—				shelf + slope	Squa bla
Galeorhinus galeus	—	- -	- -	—					slope	Gale gal
Myliobatis aquila	—	—	—						shelf	Myli aqu
Mustelus asterias	—	—							shelf + slope	Must ast
Raja melitensis	—	- -	- -	—					shelf + slope	Raja mel
Raja oxyrinchus	—	- -	- -	—					slope	Raja oxy
Raja montagui					—	—			shelf + slope	Raja mon
Hexanchus griseus				—	—				slope + shelf	Hexa gri
Raja polystigma						—			slope + shelf	Raja pol
Raja radula				—					shelf + slope	Raja rad
Raja batis	—								shelf + slope	Raja bat
Raja circularis	—								shelf	Raja cir
Raja microocellata	—								shelf + slope	Raja mic