



Spear fishing in the Balearic Islands (west central Mediterranean): species affected and catch evolution during the period 1975–2001

J. Coll^{a,*}, M. Linde^a, A. García-Rubies^b, F. Riera^a, A.M. Grau^a

^a Direcció General de Pesca, Govern de les Illes Balears, C/Foners 10, 07006 Palma de Mallorca, Illes Balears, Spain

^b Centre d'Estudis Avançats de Blanes, C.S.I.C., C/Camí de Sta. Bàrbara s/n., 17300 Blanes, Girona, Spain

Received 31 December 2003; received in revised form 14 May 2004; accepted 14 May 2004

Abstract

Catch and effort records of spear fishing competitions since 1975, in the Balearic Islands, have been used as a tool to study the temporal evolution of rocky littoral fishery resources. Competition spear fishing affected over 30 species, among which the most abundant were *Diplodus sargus*, *Symphodus tinca*, *Labrus merula* and Mugilidae. A decreasing trend over time for the mean CPUE (kg fisherman⁻¹ h⁻¹) was shown. *Epinephelus marginatus* was a key species in the evolution of the CPUE, since individuals weighing more than 4 kg diminished drastically after 1987. The species recorded as largest specimens clearly changed since this date, showing a serial depletion process. These results taken as a whole describe a situation of overfishing for some target fish inhabiting rocky bottoms between 0 and 40 m. Both recreational and competition spear fishing seem to have had an important effect on these resources and probably contributed to the lack of profitability of some traditional and highly selective fishing gears.

© 2004 Elsevier B.V. All rights reserved.

Keywords: Spear fishing; Rocky littoral fisheries; Catch per unit of effort; Temporal evolution; Overfishing

1. Introduction

Spear fishing is a very popular activity in most of the western Mediterranean countries, where it is practised at recreational and competition levels. In Spain,

an individual licence is required but the use of SCUBA diving equipment and the commercialisation of the catches have been prohibited since 1963 (B.O.E, No. 34, 8/02/1963).

On the coasts of the Balearic Islands, the environmental conditions can be considered optimal for the practice of this sport throughout the year. Coastal waters reach to minimum temperatures of 13–14 °C in winter and maximum ones of 27–28 °C in summer;

* Corresponding author. Tel.: +34 971 17 61 04;
fax: +34 971 17 61 57.

E-mail address: jcoll@dgpesca.caib.es (J. Coll).

visibility normally exceeds 25 m and rocky bottoms are abundant. Moreover, spear fishing in the Balearic Islands increased significantly after the 1960s due to the international success of the local spear fishermen. At present, there are 2128 spear fishing licences registered, although these represent only around two-third of the real number practising the sport.

Spear fishing is normally practised in the littoral zone and it partially overlaps with the traditional fishing area of the professional artisanal fleet. This fleet made up of 450 vessels, with length that ranges from 6 to 12 m, represents 84% of the total fishing fleet of the Balearic Islands (according to data from the Fisheries Department of the Government of the Balearic Islands). This overlap and the effectiveness of spear fishermen at catching certain species forced the Fisheries Department to establish a rule limiting the catches to 5 kg plus one fish per spear fisherman per day, as well as limiting the minimum size of some species. However, there are still certain problems such as the illegal selling of the catches or the opposition of spear fishermen to the prohibition of fishing in the newly protected areas of the Balearic Islands.

As a consequence of the multifactorial nature of the impacts that affect the littoral zone and the lack of data concerning the specific impact of each activity on resources, the fishermen's associations rejected many of the measures that should be established for fishery management. The destruction of coastal habitats, pollution, overfishing, climatic change and spear fishing appear as the main causes of impact on endangered species in the Red Data Book of the fishes of the Balearic Islands (Mayol et al., 2000). However, isolating the effect of a single factor from the rest is not an easy task, although the existing literature in the western Mediterranean indicates that spear fishing is an important factor that can affect the composition of fish communities (Bell, 1983; García-Rubies and Zabala, 1990; Moranta et al., 1997; Reñones et al., 1997) and the structure of certain fish populations (Harmelin and Marinopoulos, 1993; García-Rubies, 1997; Zabala et al., 1997; Coll et al., 1999; Harmelin and Harmelin-Vivien, 1999; Reñones et al., 1999; Jouvenel and Pollard, 2001).

The aim of the present paper is to determine which species were most affected by competition spear fishing, and, furthermore, to evaluate the health of fish resources by means of describing the evolution of catches

from 1975 to the present day. Both objectives have been approached on the basis of information registered in official spear fishing competitions that have taken place in the waters of the Balearic Islands.

2. Methods

2.1. Field framework and database

Spear fishing competitions are usually held on the rocky shores of almost any area of the Balearic Islands, in a bathymetric depth range from 0 to 40–45 m (Fig. 1). Currently, the location where the competition is going to take place is previously studied by the Fisheries Department to prevent the same area being used consecutively year after year, which has been a measure used since the early seventies.

The practice of this activity is excluded in the 26,900 ha, which make up the marine reserves of Cabrera National Park, north of Minorca and Ibiza and Formentera Straits. In the marine reserves of the Bay of Palma and the south of Majorca, with 19,453 ha, spear fishing is allowed only on certain days for certain species, and the minimum length of some vulnerable species is limited. However, competitions are absolutely forbidden in these areas (Goñi and Coll, 2003).

Spear fishing competitions are based on the catch of the maximum number of fishes and the maximum weight in a period of 5 or 6 h. The evolution of the fishing technique in the last 25 years, always apnoea diving, has been minimal. During the 1970s, the Tahitian speargun, propelled by rubber bands, was introduced and it totally replaced the less effective air-compressed spearguns.

Spear fishing competitions include certain specific rules, which are more restrictive than in recreational spear fishing. Except for conger eels (*Conger conger*), moray eels (*Muraena helena*) and groupers (*Epinephelus* spp.), which must have a minimum weight of 2 kg, fishes weighing at least 300 g are considered valid. The rule of the 2 kg was established in 1994, although in 1987 an agreement had been reached in order to invalidate groupers weighing less.

The data used to undertake this study were extracted from the files that the Balearic Federation of Subaquatic Activities (FBDAS) has registered for

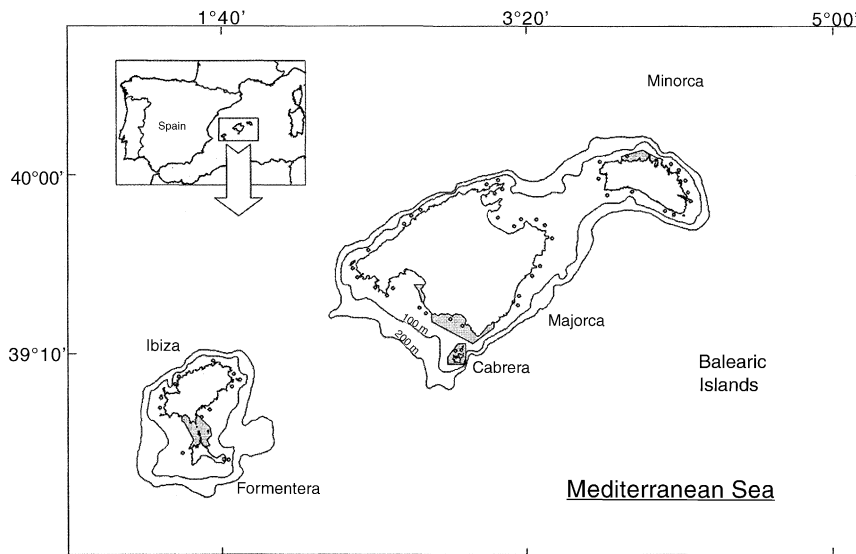


Fig. 1. Localization of the zones where spear fishing competitions were carried out between 1975 and 2001. The areas noted in grey are marine reserves where spear fishing is forbidden (Ibiza and Formentera strait, north of Minorca, Cabrera) or regulated (Majorca).

most of the spear fishing competitions since 1975. The available data corresponded to three different series with different details. The first database collected the total annual results of the competitions that took place in the Balearic Islands (number of participants, total number of fish caught and total weight) from 1975 to 2001. The second database included the same yearly information, separated by competition and by participant as well as the species and the weight of the largest specimen of each participant from 1975 to 2000. However, these two databases are not complete, since they include only data from the years 1975, 1977 and 1980, and from 1985 to 2001. Finally, since 1994, the FDBAS added to the classification data a detailed list of all the species caught in each competition and the number of fish for each species. In these lists, the species are recorded by their common name. Due to the fact that the data relate to official competitions, the validity of the information is guaranteed and therefore can be considered useful and of great interest for examining the evolution of the affected resources during the last 25 years of the 20th century.

From the detailed data available for each competition and participant, we selected only those competitions that had been taking place over a long time series on an approximately annual basis. Therefore,

we considered only the local, regional and between-islands competitions. This means that data were available from 95 competitions between the years 1975 and 2000. Higher-level competitions, such as the Spanish, European or World championships, were excluded because they were not held on a regular basis and because the level of the participants was much higher than that of regional competitions. Similarly, it is clear that not all participants have the same experience. It is also obvious that the best spear fishermen are the ones who catch greater number of fishes and largest fishes. This is why the best-classified participants in each competition can be considered as the best estimators of the state of the resource they are exploiting. Therefore, and to avoid excessive variations in the catches, depending on the number of participants, only the results of the participants classified in the first 10 places in each competition were considered, thereby obtaining a database of 950 record registers.

To obtain a representative sample of the specific composition of the catches in the different islands, we have taken into account only those competitions in which the number of fish was relatively high ($n > 20$). With these data, obtained from 71 competitions and 11,272 fishes caught during the period 1994–2000, it was possible to check which part of the littoral marine

ichthyofauna was the most affected by competition spear fishing.

2.2. Data treatment of species involved

From the list obtained by the federation (FBDAS), the common names of the species, which are well known in the Balearic Islands, were translated to the corresponding scientific names using manuals written by local authors (Massutí, 1980; Riera et al., 1995). In some cases, it was not possible to identify the taxonomic level of species and the family level had to be used. For instance, the family level was used in the case of Mugilidae, where the name “Ilissa” was used for three different species (*Chelon labrosus*, *Liza ramada* and *L. aurata*) and in the case of the large Serranidae that, except for the dusky grouper (*Epinephelus marginatus*), are denominated, using doubtful criteria, as “anfós llis”, “xerna” or “anfós bord”, which includes the species *Epinephelus costae*, young specimens of *E. caninus* and *Mycteroperca rubra*. In the case of “barracuda” (*Sphyraena* sp.), only the genus was determined, which included *Sphyraena sphyraena* and *Sphyraena viridensis*. The group of Labridae called “tords” referred to two species (*Labrus merula* and *Symphodus tinca*), which were designated together as *L. merula*–*S. tinca*. The rest of the species included in the study had a clear correspondence between the common name and the scientific name.

To detect the existence of possible differences in the specific composition of catches, depending on the zone or the year (from 1994 to 2000), a hierarchic grouping analysis was carried out, based on the matrix formed by the number of fishes of each species caught in each competition. With the aim of avoiding chance dissimilarities, the species that appeared with a frequency lower than 4% were not considered. As a result, an initial matrix of 35 species, or higher-level taxa, was reduced to one made up of 29 taxa. Measurement of similarity between samples was determined by the “percentage similarity” index ($Psi = 1 - 0,5 \sum |P_{xi} - P_{yi}|$), with P_{xi} being the probability of occurrence of the species i in the sample X, and P_{yi} the probability of occurrence of the species i in the sample Y, according to Kohn and Riggs (1982). The hierarchic grouping of the samples was carried out by means of the grouping algorithm UPGMA (Legendre and Legendre, 1984).

2.3. Treatment of the temporal evolution of the catches

The relative values of the absolute data, i.e., the mean number of fish and the mean weight of the catch by participant as well as the mean weight per fish were calculated. The temporal evolution (from 1975 to 2001) of these variables was analysed by means of a linear regression (Sokal and Rohlf, 1979; Zar, 1984).

Using the detailed registers of each competition (second data series), the catch weight of each of the first 10 classified participants was divided by the competition length of 6 h. In this way, an estimation of the multispecies catch per unit of effort (CPUE, expressed in $\text{kg fisherman}^{-1} \text{h}^{-1}$) was calculated, which was compared to other calculations already existing in the literature (Dazell, 1996 and references therein). The mean CPUE per competition, per year, and the one corresponding to each of the first ten classified participants were the dependent variables in relation to time (independent variable) for a linear regression model (Underwood, 1997). Due to the fact that the location of the competition varied every year, both the total data and the data referring to the first ten classified participants were considered as independent samples.

The weight frequency distribution and the annual mean weight of the largest specimens, captured by the first ten classified participants, were also calculated. The frequency of large fish in the catches can be considered as a good indicator of the state of the population because these are the ones that tend to become scarcer more quickly when the pressure upon the resource increases (Jennings and Lock, 1996; García-Rubies, 1997).

3. Results

3.1. Species affected (period 1994–2000)

In total, 71 competitions from 1994 to 2000 were analysed. In these competitions, 11,272 fish belonging to 31 species and 4 major taxa (Serranidae, Mugilidae, *Sphyraena* spp. and Labridae (*S. tinca*–*L. merula*)) were captured. Among these taxa, the majority of the spatial and trophic ecological groups were represented, except for the small pelagic planktivores (Harmelin, 1987) (Table 1). In spite of the extensive spectrum of

Table 1
Percentage species abundance (%N) captured in spear fishing competitions carried out in the Balearic Islands from 1994 to 2000

Species	Majorca (n = 8661)	Minorca (n = 1918)	Ibiza and Formentera (n = 693)
Coastal pelagic species			
<i>Oblada melanura</i> ^a	0.16	0.10	0.29
<i>Lichia amia</i> ^a	0.21	0.21	–
<i>Seriola dumerili</i> ^a	0.84	4.43	1.30
<i>Sphyraena</i> sp. ^a	0.28	0.42	–
<i>C. hippurus</i>	–	0.26	–
Medium-large home-range demersal species			
<i>B. carolinensis</i> ^a	1.80	0.36	0.14
<i>D. volitans</i> ^a	5.40	0.42	1.01
<i>Dentex dentex</i> ^a	0.50	0.16	–
<i>Dicentrarchus labrax</i> ^a	1.02	0.89	0.43
<i>Lithognathus mormyrus</i> ^a	0.22	–	0.43
<i>L. piscatorius</i>	0.01	–	–
Mugilidae ^a	10.61	12.77	12.41
<i>M. surmuletus</i>	0.07	0.10	–
<i>Pagellus erythrinus</i>	0.05	–	0.14
<i>S. aurata</i> ^a	1.10	0.94	0.14
<i>Spondyllosoma cantharus</i> ^a	0.12	0.05	0.58
<i>Trigloporus lastoviza</i>	–	0.10	–
<i>Z. faber</i>	0.02	–	–
Low-medium home-range demersal species			
<i>Diplodus puntazzo</i> ^a	0.01	–	–
<i>Diplodus cervinus</i>	0.83	0.52	0.72
<i>D. sargus</i> ^a	40.04	37.96	33.04
<i>D. vulgaris</i>	0.08	0.21	–
<i>E. marginatus</i> ^a	1.14	1.72	1.73
<i>Epinephelus</i> spp. ^a	0.31	–	0.72
<i>L. viridis</i> ^a	5.70	4.48	4.76
<i>S. tinca</i> – <i>L. merula</i> ^a	11.30	13.35	9.96
<i>S. salpa</i> ^a	4.69	8.55	7.79
<i>U. cirrosa</i>	0.08	0.36	–
Low home-range benthic species			
<i>C. conger</i>	0.51	0.47	0.72
<i>M. helena</i> ^a	1.97	1.56	2.31
<i>P. phycis</i> ^a	2.22	0.78	3.32
<i>Scorpaena porcus</i>	0.13	–	0.14
<i>S. scrofa</i> ^a	3.82	3.39	6.06
<i>S. umbra</i> ^a	4.75	5.42	11.83
<i>U. scaber</i>	0.01	–	–

^a Species catalogued as largest specimens from 1975 to 2000.

ecological niches represented, the greater proportion of catches corresponded to *Diplodus sargus*, a demersal omnivore species that shows vertical and horizontal intermediate diel displacements. *D. sargus* comprised 30–40% of the catches, irrespective of the island (Table 1). Large labrids (*S. tinca* and *L. merula*) and

the Mugilids (*C. labrosus* and *Liza* spp.) showed similar importance in the catches and their abundance percentage was greater than 10%. The rest of the species represented less than 10% of the catches and the most abundant ones in this group were *Sarpa salpa*, *Sciaena umbra*, *Labrus viridis*, *Scorpaena scrofa* and *Phycis phycis* (Table 1).

Abundance shifts of these species were not related to spatial (island) or temporal (year) factors. The two major groups that presented a greater similarity in the dendrogram (groups 1 and 2) contained samples from different zones, which were collected in different years (Fig. 2). The differences between the two main groups seemed to be related to the diversity of the samples, which was highly correlated with the number of fish captured ($R^2 = 0.79$; $P < 0.001$). Groups 3 and 4 were composed of only one competition. These competitions were differentiated from the rest due to the punctual abundance of unusual species, such as *Dactylopterus volitans* and *P. phycis*, respectively.

3.2. Temporal evolution for all competitions registered from 1975 to 2001: without selection of participants

During the period, between 1975 and 2001, the number of participants registered in spear fishing competitions taking place in the Balearic Islands were 7692, and they captured 45,695 fish with a total weight of 27,097 kg (FBDAS data). The relative data, i.e., the number of fish and catch by participant (NFP and CP, respectively) as well as the mean weight of fish (MWF), showed a progressive temporal decrease. The NFP fitted a linear function ($NFP = 6.860 - 0.111 \times \text{time}$; $R^2 = 0.39$; $P < 0.01$) that responded to the pronounced decline observed from 1975 to 1990 (Fig. 3a). The CP showed a similar tendency, also with a notable decrease from 1975 when the maximum value of 8.2 kg/participant was observed until 1996, after which it stabilised between 2.7 and 3.2 kg/participant (Fig. 3b). Globally, this variable showed a decreasing tendency that fitted a regression line defined by the equation: $CP = 5.391 - 0.122 \times \text{time}$ ($R^2 = 0.45$; $P < 0.001$). The MWF decreased significantly and linearly with time, showing a marked slope with respect to the former variables, $MWF = 789.720 - 7.554 \times \text{time}$ ($R^2 = 0.42$; $P < 0.01$). From the seventies to the early nineties, mean weights of over 700 g/fish were

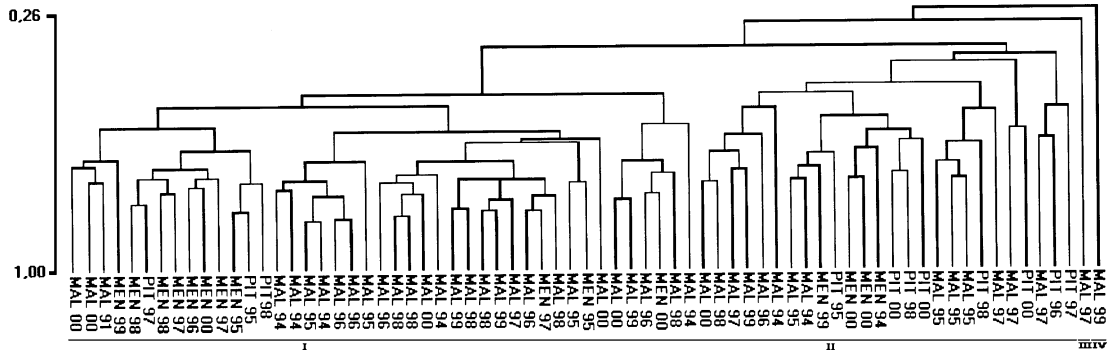


Fig. 2. Dendrogram based on the cluster analysis of 71 competitions performed between 1994 and 2000 in the Balearic Islands.

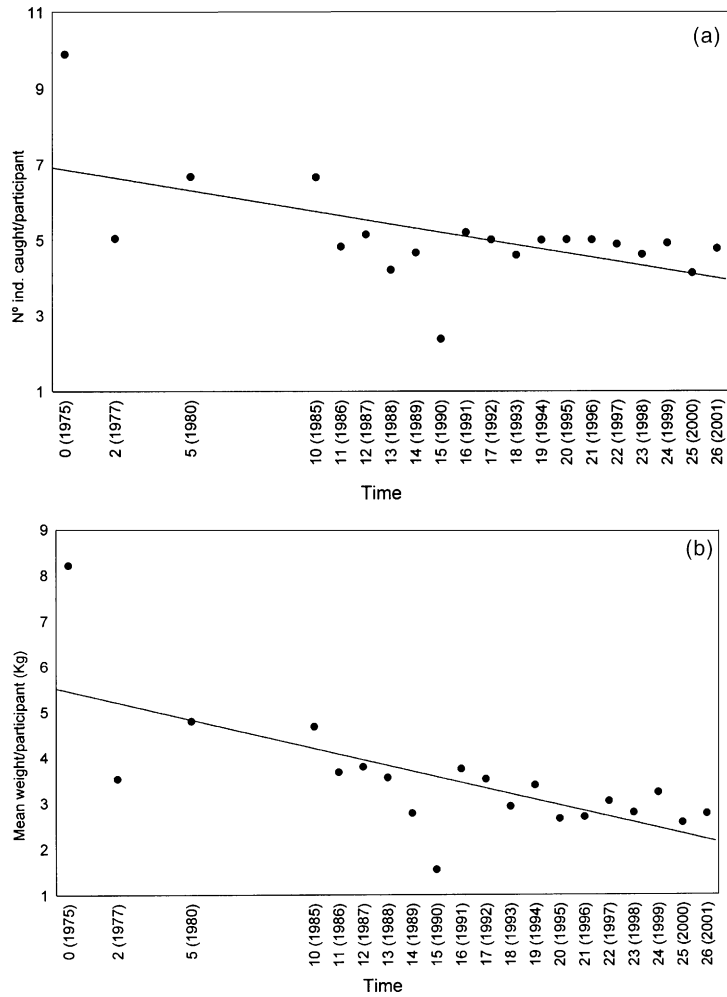


Fig. 3. Temporal patterns of (a) number of fish by participant (NFP); (b) catch by participant (CP); and (c) mean weight of fish (MWF) for all competitions and all classified spear fishermen, analysed by means of a linear regression.

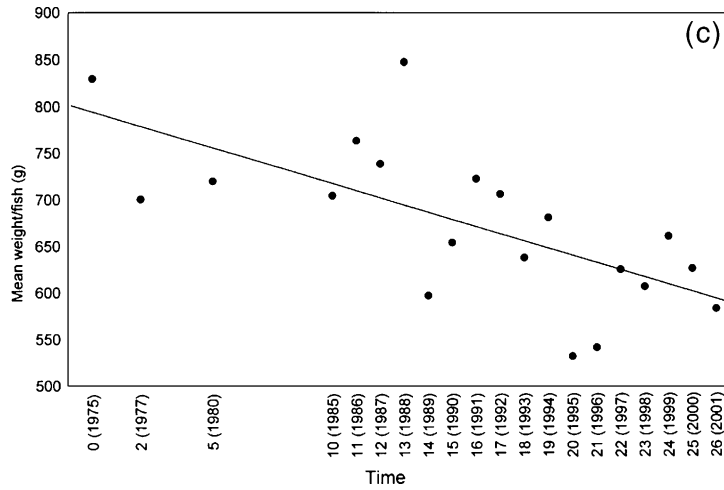


Fig. 3. (Continued).

frequently observed, but these values were not reached between 1995 and 2001. The greatest annual difference was observed between the maximum values observed in 1988 and the decrease of 1989, although these cases did not affect the overall pattern for the 27-year period studied (Fig. 3c).

3.3. Temporal evolution for regional competitions: with selection of the first 10 classified

These filtered data, referring only to the first 10 classified participants of each competition, showed a more accurate approximation to the evolution of resources

Table 2

Mean value and standard deviation of the number of fish (MNFP) and catch (MWC) by a participant and the mean weight of fish (MWF) from 1975 to 2000 for the first ten classifieds of each competition

Year	MNFP	S.D.	MWC (kg)	S.D.	MWF (kg)	S.D.	n
1975	16.46	9.44	19.07	15.37	1.24	0.81	50
1977	8.34	3.63	8.19	10.09	1.01	0.98	70
1980	13.16	6.23	12.76	8.69	1.12	0.91	50
1985	14.00	7.56	11.88	7.80	0.92	0.66	50
1986	11.90	6.41	10.65	6.05	1.09	0.85	40
1987	9.96	5.04	9.11	5.15	1.06	0.80	50
1988	10.98	5.02	8.73	5.38	0.86	0.68	50
1989	11.18	5.86	7.23	4.11	0.65	0.20	40
1990	8.25	4.93	6.70	5.12	0.80	0.41	20
1991	10.57	4.61	8.75	6.17	0.85	0.67	30
1992	9.90	4.69	7.82	5.97	0.79	0.33	50
1993	7.76	4.52	5.61	5.32	0.72	0.40	80
1994	11.12	7.27	8.84	13.08	0.78	0.76	70
1995	14.78	12.24	7.37	6.17	0.52	0.13	50
1996	13.65	11.48	6.84	5.74	0.57	0.20	40
1997	13.55	6.85	9.85	6.80	0.77	0.42	80
1998	11.18	5.59	6.90	4.14	0.65	0.41	50
1999	12.47	6.34	6.92	4.13	0.61	0.55	30
2000	8.95	6.37	5.15	4.87	0.64	0.26	50

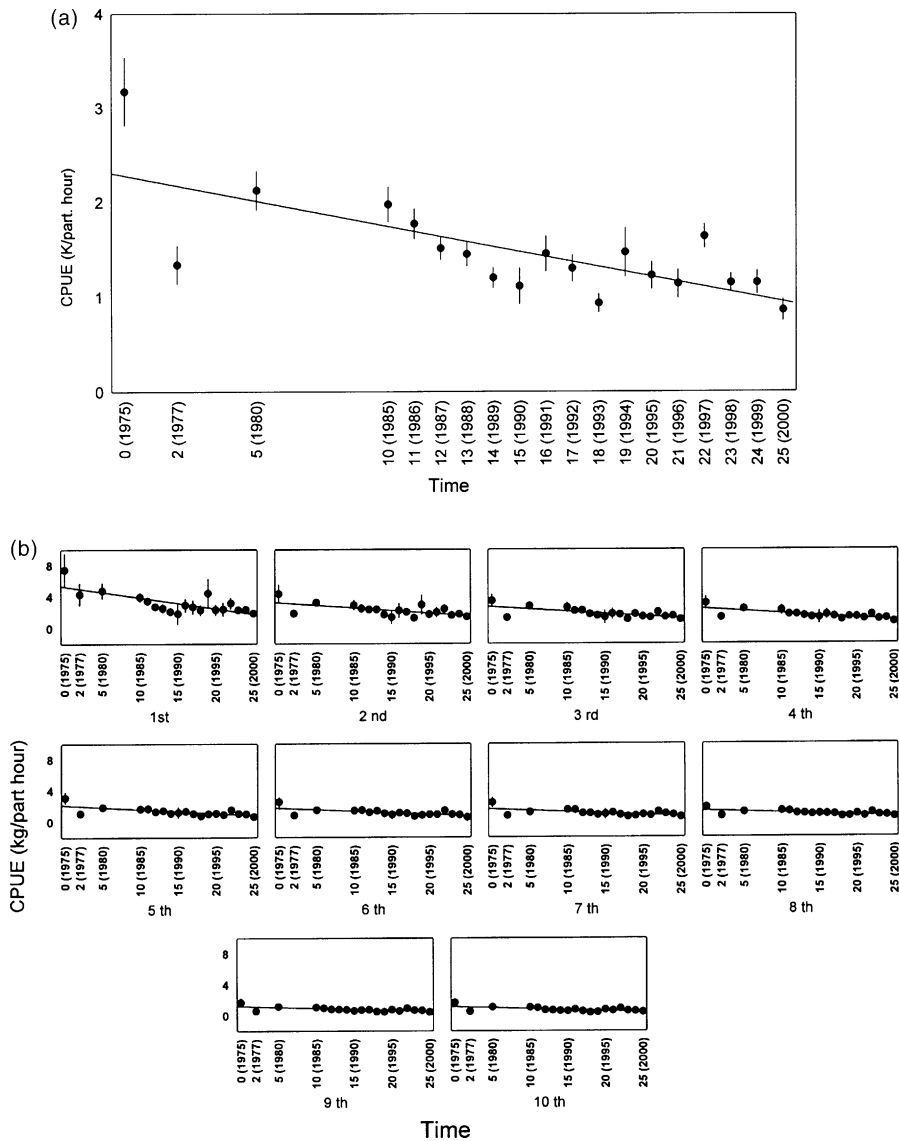


Fig. 4. Temporal patterns of the catch per unit of effort (CPUE) grouped by the first 10 classified spear fishermen (a) and for each of the 10 places (b) for the regional competitions.

targeted by spear fishing competitions described above. The mean number of fish by participant (MNFP) did not show a clear temporal pattern, while the mean weight of the catch (MWC) tended to decrease during the period studied ($MWC = 577660 - 285.8 \times \text{time}$; $R^2 = 0.14$; $P < 0.001$). This decrease was due to the progressive decrease of the MWF as a function of time ($MWF = 48464 - 23.94 \times \text{time}$; $R^2 = 0.25$; $P < 0.001$) (Table 2), sup-

porting the results obtained from the global data. The decrease of the MWC led to a progressive reduction of the CPUE ($\text{kg participant}^{-1} \text{h}^{-1}$), as shown by the significant negative slope of the regression in Fig. 4a. The mean CPUE for each of the first 10 classified competitors showed a decrease over time, especially for the first classified, which had a regression line with a greater slope (Fig. 4b and Table 3).

Table 3
Regression equations for the mean CPUE (kg fisherman⁻¹ h⁻¹) by time and total for the first 10 classified per competition

CPUE	Regression equation	R ²	P-level
1st	5.293 – 0.140 × time	0.53	<0.001
2nd	3.235 – 0.067 × time	0.36	<0.004
3th	2.687 – 0.058 × time	0.36	<0.002
4th	2.400 – 0.058 × time	0.55	<0.001
5th	2.134 – 0.053 × time	0.47	<0.001
6th	1.744 – 0.039 × time	0.39	<0.003
7th	1.600 – 0.037 × time	0.36	<0.005
8th	1.331 – 0.028 × time	0.39	<0.003
9th	1.223 – 0.027 × time	0.39	<0.003
10th	1.167 – 0.027 × time	0.39	<0.003
Total	2.281 – 0.053 × time	0.50	<0.001

E. marginatus seemed to be the key species in spear fishing competitions. Due to its sedentary character, the great size that it can reach and its relative frequency in the Balearic Islands, this species was frequently the largest specimen of the better fishermen (Fig. 5). From 1987, the dusky grouper became less important as the largest specimen and there was an increase in the percentage of other species. In parallel to the disappearance of groupers of less than 2 kg (due to an unofficial

prohibition imposed from this date), the medium and large specimens also became less important, especially since 1988 (Fig. 6 and Table 4). After this date, the competitions carried out were characterized by the presence of sub-adults, most of them weighing between 2 and 4 kg. The presence of specimens larger than 6 kg was sporadic and quite rare after 1995.

4. Discussion

4.1. Species affected

Spear fishing is a highly selective activity. In fact, it is the only modality in which the fisherman can choose exactly the prey that will be captured. This implies that valued species and individuals of large sizes will be the preferred preys (Dalzell, 1996). The selectivity of spear fishing is accentuated when it is competitive, since in this case, only fishes that weigh more than 300 g are valid. This limitation means that the catches are biased towards those species that normally exceed a total length of 25 cm (Morey et al., 2003). The 41 species that comprise the catches of competitions analysed in

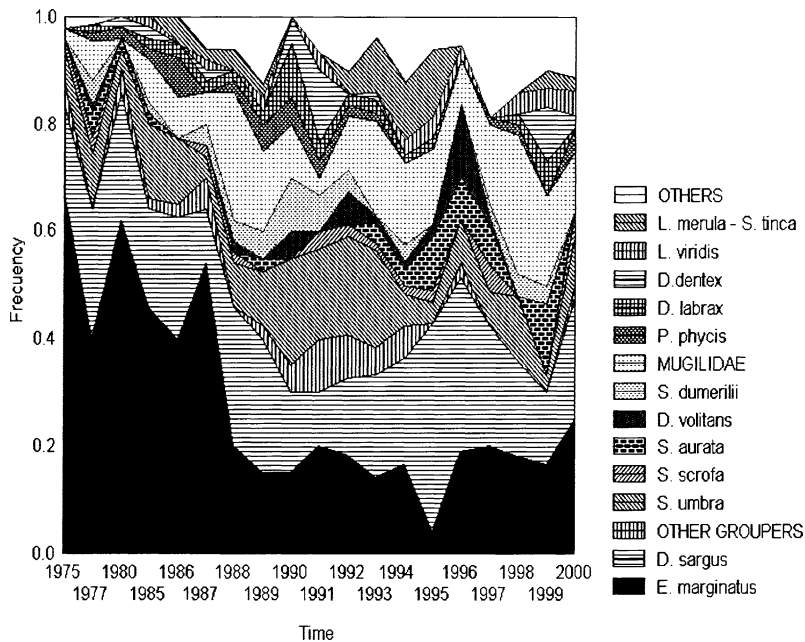


Fig. 5. Temporal evolution of the relative frequency of species, which were the largest specimens for the regional competitions and the first 10 classified spear fishermen.

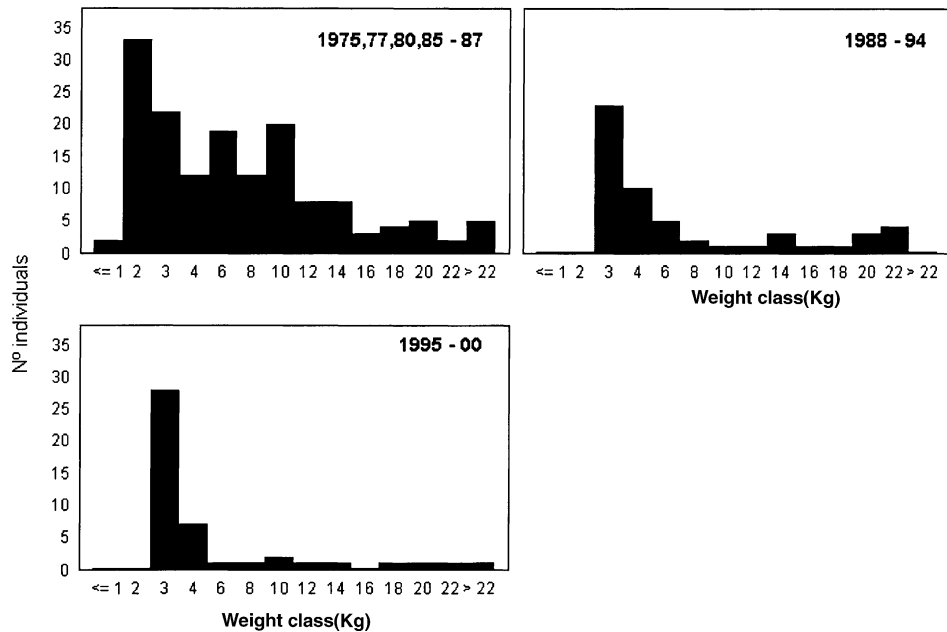


Fig. 6. Weight frequency distribution of the largest specimens of the species *E. marginatus* for three time intervals.

Table 4

Mean, maximum and minimum weights (kg) of *E. marginatus* and mean number of fishes of this species in the catch of larger fishes collected by the first 10 classified by year

Year	Mean weight	Minimum weight	Maximum weight	S.D.	<i>n</i>	Mean no. individuals	S.D.	No. of competitions
1975	9.30	0.80	27.50	5.87	32	6.40	3.44	5
1977	6.73	1.00	20.15	5.50	27	3.86	2.48	7
1980	7.18	1.19	22.60	6.63	30	6.00	3.32	5
1985	7.13	1.37	23.00	7.13	23	4.60	2.07	5
1986	5.71	1.12	14.50	4.75	16	4.00	2.94	4
1987	4.37	1.13	17.35	3.93	27	5.40	2.41	5
1988	9.28	2.29	21.50	7.19	10	2.00	2.00	5
1989	3.07	2.36	4.69	1.00	5	1.25	0.50	4
1990	6.09	2.21	12.12	5.29	3	1.50	0.71	2
1991	10.25	2.31	20.75	8.57	6	2.00	2.00	3
1992	3.51	2.28	5.50	1.01	8	1.60	1.14	5
1993	6.25	2.01	20.75	7.13	11	1.38	1.41	8
1994	7.31	2.08	20.15	6.96	10	1.43	1.27	7
1995	2.99	2.32	3.67	0.95	2	0.40	0.55	5
1996	3.39	2.01	8.50	2.30	7	1.75	2.36	4
1997	7.92	2.04	22.50	7.44	12	1.50	1.20	8
1998	5.35	2.35	19.00	5.33	9	1.80	1.48	5
1999	5.27	2.32	16.30	6.17	5	1.67	0.58	3
2000	2.62	2.15	3.66	0.50	11	2.20	1.10	5

this study represent only 50% of the species visually censused on the rocky bottoms of the Balearic Islands (García-Rubies, 1993; Moranta et al., 1997; Reñones et al., 1997).

Gobiidae, Blenniidae and small Labridae, amongst many others, are not subject to competition catches for obvious reasons of size. Other relatively abundant species, which are an active target, catch for non-competitive spear fishing, such as *Diplodus vulgaris* or large individuals of *Serranus scriba* (J. Coll., pers. obs.) are practically absent in competitions. Larger individuals of *S. scriba* rarely surpass 200 g, while *D. vulgaris* reaches 300 g when it attains length of over 26 cm and is five years old (Gonçalves et al., 1997; Gordo and Molí, 1997; Morey et al., 2003). The frequency of *D. vulgaris*, larger than 26 cm in the populations of open fishing areas of the western Mediterranean, is rather low (García-Rubies, 1997; Ballesteros et al., 2000; Coll et al., 2000) and hardly represents 1% in competition total catches. Other species with low presence in competition catches, such as *Coryphaena hippurus*, *Lophius piscatorius*, *Trigla lastoviza*, *Zeus faber*, *Umbrina cirrosa* and *Uranoscopus scaber*, can be considered as unusual on Mediterranean rocky littoral bottoms.

On the other hand, some species that are normally refused in non-competitive spear fishing because of their zero or low gastronomic value (e.g., Mugilidae, *S. salpa*, *D. volitans* and *Balistes carolinensis*), are usually caught during competitions due to their relatively large size. This selection due to size has an important effect on the clustering of differing samples related to island, locality or year factors in the dendrogram, and thus shows a high homogeneity of the exploited ichthyofauna.

Amongst all the species that can reach relatively large sizes, the main part of the catches relies on the more abundant ones. *D. sargus* and large Labridae, omnivorous species that are much more abundant than the strictly carnivorous species (large Serranidae, Scorpaenidae, conger eels and moray eels), dominate the composition of the competition catches in the period between 1994 and 2000.

4.2. Temporal evolution of the affected resource

Despite the bias inherent in competition rules, the data obtained since 1975 are a good sample of the tem-

poral evolution of the exploited resource. A progressive decline in number of fish caught and an even more notable decline of the mean weight catch per participant, as well as the mean weight per fish, have been shown. The total annual results are endorsed by the progressive decline of the mean annual CPUE of the ten first classified spear fishermen per competition, which is especially marked among the best fishermen. Thus, the mean annual CPUE of those classified first in 1975 (7.44 ± 4.73 kg person⁻¹ h⁻¹) could be compared to the maximum CPUEs from especially rich fish ecosystems such as coral reefs (8.5 kg person⁻¹ h⁻¹; according to Dalzell, 1996 and references therein). The mean CPUE of those classified first in the year 2000 (1.91 ± 1.09 kg person⁻¹ h⁻¹) would have hardly classified them in eighth position in 1975.

The analysis of the total data series indicates that the decline of the CPUE is due to the decline of the mean weight of fish (Fig. 3c), which is a variable greatly influenced by the demographic structure of the populations. It is also due to the decline in the number of fish, which is influenced, furthermore, by a large number of participants, the worst classified, that caught few or no fish in recent years.

The detailed analysis of the first 10 classified fishermen in regional competitions indicates that the decline of the mean fish weight is more important than variations in the mean number of fish for the temporal evolution of the CPUE. The constant decline of the mean fish weight is due to a notable scarceness of the largest size fish, which ultimately determines the first positions in the classifications. The dusky grouper *E. marginatus* is a key species for this observed pattern. This grouper, which can reach a size of 120 cm, surpassing a weight of 40 kg and an age of 50 years (Chauvet, 1988), is substituted by other species with much lower sizes and weights (e.g., *D. sargus*, *S. umbra*, *L. merula* and Mugilidae) in the marking as largest specimens since 1987 (Fig. 5). The progressive disappearance of *E. marginatus* specimens larger than 2 kg in the periods 1988–1994 and 1995–2000 endorses this pattern and indicates that the agreement of not catching groupers of lower weight had only a partial effect on CPUE evolution (Fig. 6). However, spear fishermen not taking part in competitions are still catching small groupers, a fact that indicates that the existing data show only a sample of the decline of this species in the Balearic littoral zone. This decline has been demon-

strated recently for a greater range of sizes by means of direct census in protected and unprotected areas (Coll et al., 1999; Reñones et al., 1999).

Competition spear fishing catches show the symptoms considered as classic in the over exploitation of a fishery resource. These are, the decline of the main species (*E. marginatus*) catches, partially forced by the agreement for a minimum weight limitation, and its substitution by other small sized and valued alternative species in order to maintain the yield, therefore clearly reaching what is known as a serial depletion process (Dugan and Davis, 1993).

Despite the importance of the dusky grouper, the fall of the CPUE was also notable between 1975 and 1987 (Fig. 3) and this was probably influenced by the mean weight decline of other valuable species, although this information is not detailed in the available database. Sport fishing and especially, spear fishing affect the mean density and size decrease of species such as *S. umbra*, *D. labrax* and the sparid fish *D. sargus*, *D. vulgaris*, *D. puntazzo* and *S. aurata*. This has been repeatedly demonstrated in marine reserves where this type of fishing has been prohibited (Bell, 1983; García-Rubies and Zabala, 1990; Francour, 1991; Harmelin et al., 1995; Jouvenel and Pollard, 2001). The effect of sport angling, both from the coast as well as by boat, impacts especially on the sparid fish mentioned, although their frequency in catches rarely surpasses 5% of fish (García et al., 2003). The implication of a wider number of species in the temporal CPUE decline can also be deduced according to Mayol et al. (2000), who included the species *E. costae*, *M. rubra*, *E. caninus*, *S. umbra*, *U. cirrosa*, *L. merula* and *L. viridis* under the concept of species threatened by spear fishing, trammel nets and long lines, following the UICN (1994) and Hudson et al. (1996) criteria.

4.3. Is spear fishing the main impact source?

The results extracted from our data allow us only to explain the temporal evolution of resources and not to empirically attribute it to any supposed external factor. Thus, implying that the progressive decline of the most sought after species was solely due to spear fishing could be critical. In fact, the area where this activity is carried out is partially shared with the low scale professional fleet, although important reasons exist for thinking that the impact of this fleet on the main

valuable rocky species between depths of 0 and 40 m is secondary or, in any case, indirect. Together with the species mentioned by Mayol et al. (2000) there is evidence that proves a high *E. marginatus* population recovery in marine protected areas of the western Mediterranean, where only sport fishing, including spear fishing, has been prohibited (Coll et al., 1999; Culioli and Quignard, 1999; Reñones et al., 1999; Vacchi et al., 1999).

The low scale fishing fleet in the Balearic Islands has decreased from 698 vessels in 1970 (Alemany, 1980; Llabrés and Martorell, 1984) to currently not more than 450 (Fisheries Department of the Balearic Islands data). There does not exist any historical and specific catch data series for this fleet, parallel to that obtained for sportive spear fishing. Nevertheless, contextual data about the targets and fishing grounds of this fleet (Table 5) show that the specific techniques that actually share areas and species with spear fishing are those related to the cuttlefish *Sepia officinalis* and to the red mullet *Mullus surmuletus*. These types of fishing are carried out by means of trammel and gill nets, respectively, from the coast down to a depth of 50 m, on soft or seagrass bottoms, where spear fishing is not effective. The effect of these gears and, coincidentally, the use of bottom long lines on coastal rocky bottoms deeper than 40 m, could be to prevent adult recolonization of shallower rocky zones.

Recent studies carried out in the Balearic Islands indicate that the most vulnerable species to spear fishing represent less than 5% of trammel net catches (Coll et al., 2000; Morey et al., 2000) and less than 2% of gill net catches (González-Serrano et al., 1996; Román et al., 2000). Only *S. umbra* and *L. merula* appear with values of 7.5 and 6.1% with respect to the total catch biomass in the islands of Formentera and Menorca, respectively (Morey et al., 2000).

Historically, it is significant that several highly selective traditional gears focused on the same resources as spear fishing have progressively disappeared since the middle of the 20th century. These professional gears, which operated in the rocky littoral zone, were directly focused on catching groupers (fish baited traps, small hook lines or spears used onboard during the night) or on *D. sargus*, *S. aurata* and other sparid fish (bottom-surface long lines baited with sea-cucumber) (Prats, 1997; J. Coll, pers. obs.). It should be underlined that the effectiveness of such

Table 5

Use of fishing gears by small scale vessels in the Balearic Islands (Iglesias and Martorell, 1992; Iglesias et al., 1994; González-Serrano et al., 1996; Massutí, 1998)

Target species	Period of fishing	Fishing gear	Bathymetry (type of bottom)
<i>Aphia minuta</i>	December–March	Jonquillera	0–35 m (sand—seagrass)
<i>S. officinalis</i>	February–June	Trammel net	0–50 m (sand—seagrass)
<i>Palinurus elephas</i>	April–August	Trammel net, fish trap	40–100 m (rocky—calcareous algae)
<i>M. surmuletus</i>	September–November	Gill net	0–50 m (patched of sand, seagrass and rock)
<i>C. hippurus</i>	September–November	Llampuguera	>70 m (Pelagic)

gears was largely dependent on large fish density and that they were profitable when resources were better than at present. In other words, when the situation was closer to that observed in the early seventies than in the late nineties. Dichotomy between the effectiveness of hook or spear gears related to their density dependence can be inferred from the study by Hansen et al. (2000), which demonstrated that spear fishing increased the proportion of the population caught (not the total catch) per unit effort, in fact, when fish density declined.

The present study demonstrates that CPUE data obtained from sportive competitions are a good tool to evaluate the health of some fish populations and that this health has significantly declined in the last quarter of the 20th century. Many impact factors have converged in the Balearic sublittoral zone during this time period, although published articles concerning fish populations within and outside marine protected areas point out that spear fishing has had an important impact on a specific group of species in a very precise stratum of the Balearic littoral ecosystem, namely, the sublittoral rocky zone between 0 and 40 m. Overall, this should be taken into account in any management measure that affects littoral rocky resources in Balearic waters and, especially, in the management of marine protected areas where conservation of all fish communities is the main goal.

Acknowledgement

We thank the Balearic Federation of Subaquatic Activities (FBDAS) for their collaboration related to the competition spear fishing data register, which is being improved year by year. Likewise, we wish to thank Dr E. Ballesteros, Dr E. MacPherson and two anonymous reviewers for their useful comments on the text.

References

- Aleman, B., 1980. La flota pesquera balear. Primeras jornadas de pesca de las Islas Baleares. Consell General Interinsular, Palma de Mallorca, Spain.
- Ballesteros, E., Garcia-Rubies, A., Cebrián, E., Coll, J., 2000. Estudi sobre la cartografia, biodiversitat i efecte reserva en tres reserves de les Illes Balears. Technical Report, CEAB-CSIC, Blanes, Spain.
- Bell, J.D., 1983. Effects of depth and marine reserve fishing restrictions on the structure of a rocky reef fish assemblage in the north-western Mediterranean Sea. *J. Appl. Ecol.* 20, 357–369.
- Coll, J., García-Rubies, A., Moranta, J., Stefanni, S., Morales-Nin, B., 1999. Efectes de la prohibició de la pesca esportiva sobre l'estructura poblacional de l'anfós (*Epinephelus marginatus* Lowe, 1834. Pisces Serranidae) en el Parc Nacional de Cabrera. *Bol. Soc. Hist. Nat. Balears* 42, 125–138.
- Coll, J., García-Rubies, A., Ballesteros, E., Riera, F., Grau, A.M., Linde, M., 2000. Estudi de les comunitats bentòniques i de la ictiofauna a la costa d'Artà, N.E de Mallorca. Informe preliminar per a la creació d'una reserva marina. Technical Report, Fisheries Department of the Government of Balearic Islands, Palma de Mallorca, Spain.
- Culioli, J.M., Quignard, J.P., 1999. Suivi de la démographie et de la territorialité des mâles de mérous bruns *Epinephelus marginatus* (Lowe, 1834) (Pisces, Serranidae) du site du pèlu (Réserve naturelle des îles Lavezzi, Corse, Méditerranée N.O.). Mémoires de l'Institut océanographique Paul Ricard. Symposium International sur les Mérous de Méditerranée, novembre 1998. Embiez, France, pp. 29–36.
- Chauvet, C., 1988. Étude de la croissance du mérou *Epinephelus guaza* (Linné 1758) des côtes tunisiennes. *Aquat. Living Resour.* 1, 277–288.
- Dalzell, P., 1996. Catch rates, selectivity and yields of reef fishing. In: Polunin, N.V.C., Roberts, C.M. (Eds.), *Reefs Fisheries*. Chapman & May, London, pp. 161–192.
- Dugan, J.E., Davis, G.E., 1993. Application of marine refugia to coastal fisheries management. International symposium on marine harvest refugia. *Can. J. Fish. Aquat. Sci.* 50, 202–204.
- Francour, P., 1991. The effect of protection level on a coastal fish community at Scandola. Corsica. *Rev. Ecol. (Terre Vie)* 46, 65–81.
- García, C., Moranta, J., Morales-Nin, B., 2003. Avaluació d'alguns aspectes de la pesca recreativa a l'illa de Mallorca. Technical Report, IMEDEA-CSIC, Esporles, Mallorca, Spain.

- García-Rubies, A., 1993. Distribució batimètrica dels peixos litorals de substrat rocós a l'illa de Cabrera. In: Alcover, J.A., Ballesteros, E., Fornós, J. (Eds.), *Història Natural de l'Arxipèlag de Cabrera*. Moll Publishers, Palma de Mallorca, Spain, pp. 645–661.
- García-Rubies, A., 1997. Estudi ecològic de les poblacions de peixos litorals sobre substrat rocós a la Mediterrània occidental: efecte de la fondària, el substrat, l'estacionalitat i la protecció. Tesis Doctoral, Universitat de Barcelona, Barcelona, Spain, p. 262.
- García-Rubies, A., Zabala, M., 1990. Effects of total fishing prohibition on the rocky fish assemblages of Medes Islands marine reserve (NW Mediterranean). *Sci. Mar.* 54, 317–328.
- Gonçalves, J.M.S., Bentes, L., Lino, P.G., Ribeiro, J., Canário, A.V.M., Erzini, K., 1997. Weight-length relationships for selected fish species of the small-scale demersal fisheries of the south and south-west coast of Portugal. *Fish Res.* 30, 253–256.
- González-Serrano, J.L., Mas, J., Pastor, F., Ortega, R., Mediavilla, M., 1996. Proyecto para la construcción e instalación de un arrecife artificial en el Levante mallorquín. Technical Report, M.A.P.A. Secretaría General de Pesca Marítima, Madrid, Spain.
- Goñi, F.R., Coll, J., 2003. Les Reserves Marines de les Illes Balears. *Quadern de pesca 76*, Conselleria d'Agricultura i Pesca, Govern de les Illes Balears, Palma de Mallorca, Spain, p. 119.
- Gordoa, A., Molí, B., 1997. Age and growth of the sparids *Diplodus vulgaris*, *D. sargus* and *D. annularis* in adult populations and the differences in their juvenile growth patterns in the north-western Mediterranean Sea. *Fish Res.* 33, 123–129.
- Hansen, M.J., Beard, T.D., Hewett, S.W., 2000. Catch rates and catchability of walleyes in angling and spearing fisheries in northern Wisconsin lakes. *N. Am. J. Fish Manage.* 20, 109–118.
- Harmelin, J.-G., 1987. Structure et variabilité de l'ichtyofaune d'une zone rocheuse protégée en Méditerranée (Parc national de port Cros France). *P.S.Z.N.I.: Mar. Ecol.* 8, 263–284.
- Harmelin, J.-G., Marinopoulos, J., 1993. Recensement de la population de corbs (*Sciaena umbra* Linnaeus, 1758: Pisces) du Parc National de Port-Cros (Méditerranée, France) par inventaires visuels. Scientific reports of the Port-Cros national park, France 15, 265–276.
- Harmelin, F.J.-G., Harmelin-Vivien, F.M., 1999. A review on habitat, diet and growth of the dusky grouper, *Epinephelus marginatus* (Lowe, 1834). Mémoires de l'Institut océanographique Paul Ricard. In: Proceedings of the Symposium International sur les Mérous de Méditerranée, Novembre 1998. Embiez, France, 1999, pp. 83–94.
- Harmelin, J.-G., Bachet, F., Garcia, F., 1995. Mediterranean marine reserves: fish indices as tests of protection efficiency. *P.S.Z.N.I.: Mar. Ecol.* 16, 233–250.
- Hudson, E., Mace, G., Baillie, J., Sobel, J., Punt, A., Safina, C., Vincent, A., Roberts, C., Sadovy, Y., Hall, H., 1996. Threatened fish? Initial guidelines for applying the IUCN red list criteria to marine fishes. In: Proceedings of Workshop on Marine Fish and the IUCN Red List of Threatened Animals, IUCN/WWF/ZSL, London, May 1996.
- Iglesias, M., Martorell, J.M., 1992. La pesquería de góbidos en las Islas Baleares. Informes técnicos del Instituto Español de Oceanografía 116, 1–18.
- Iglesias, M., Massutí, E., Reñones, O., Morales-Nin, B., 1994. Three small-scale fisheries based on the island of Majorca (N.W. Mediterranean). *Bol. Soc. Hist. Nat. Balears* 37, 35–58.
- Jennings, S., Lock, J.M., 1996. Population and ecosystem effects of reef fishing. In: Polunin, N.V.C., Roberts, C.M. (Eds.), *Reefs Fisheries*. Chapman & May, London, UK, pp. 193–219.
- Jouvenel, J.-Y., Pollard, D.A., 2001. Some effects of marine reserve protection on the population structure of two spear fishing target-fish species, *Dicentrarchus labrax* (Moronidae) and *Sparus aurata* (Sparidae), in shallow inshore waters, along a rocky coast in the northwestern Mediterranean Sea. *Aquat. Conserv.: Mar. Freshwater Ecosyst.* 11, 1–9.
- Kohn, A.J., Riggs, A.C., 1982. Sample size and dependence in measures of proportional similarity. *Mar. Ecol. Prog. Ser.* 9, 147–151.
- Legendre, L., Legendre, P., 1984. *Écologie Numérique, Tome 2. La structure des données écologiques*. Masson, Paris et les Presses de L'Université du Québec. Québec, Canada, p. 260.
- Llabrés, M., Martorell, J.M., 1984. La pesquería de artes menores. Islas Baleares. Comunidad Autónoma de las Islas Baleares, Spain.
- Massutí, M., 1980. La pesca deportiva en Mallorca. Editorial Cort, Spain.
- Massutí, E., 1998. Biology of *Coryphaena hippurus* Linnaeus, 1758 (Pisces: Coryphaenidae) in the western Mediterranean. Doctoral Thesis, University of the Balearic Islands, Spain.
- Mayol, J., Grau, A.M., Riera, F., Oliver, J., 2000. Llista vermella dels peixos de les Balears. *Quadern de Pesca*, 4. Govern de les Illes Balears, Spain.
- Moranta, J., Reviriego, B., Coll, J., 1997. Contribución al conocimiento de la estructura de la comunidad íctica asociada a los fondos rocosos litorales de las islas del Toro y d'Es Malgrat (suroeste de Mallorca, islas Baleares). *Publ. Espec. Inst. Esp. Oceanogr.* 23, 143–152.
- Morey, G., Moranta, J., Morales-Nin, B., 2000. Projecte de seguiment de l'efecte de les mesures de protecció sobre la comunitat íctica de les reserves marines de les Illes Balears. Technical Report, Spanish Council for Scientific Research (CSIC).
- Morey, G., Moranta, J., Massutí, E., Grau, A.M., Linde, M., Riera, F., Morales-Nin, B., 2003. Length-weight relationship for littoral to lower slope fishes from the western Mediterranean. *Fish. Res.* 62, 89–96.
- Prats, A., 1997. La pesca d'abans a les Pitiüses. Consell Insular d'Eivissa i Formentera. Conselleria de Cultura, Spain.
- Reñones, O., Moranta, J., Coll, J., Morales-Nin, B., 1997. Rocky bottom fish communities of Cabrera Archipelago National Park (Mallorca western Mediterranean). *Sci. Mar.* 61, 495–506.
- Reñones, O., Goñi, R., Pozo, M., Deudero, S., Moranta, J., 1999. Effects of protection on the demographic structure and abundance of *Epinephelus marginatus* (Lowe, 1834). Evidence from Cabrera Archipelago National Park (west-central Mediterranean). Mémoires de l'Institut océanographique Paul Ricard. In: Proceedings of the Symposium International sur les Mérous de Méditerranée, Embiez, France, pp. 155–164.
- Riera, F., Oliver, J., Terrassa, J., 1995. Peixos de les Balears. Conselleria d'Obres Públiques i Ordenació del territori, Govern de les Illes Balears, Spain.
- Román, F., Marhuenda, M., Aracil, M.S., Pérez, E., Serrano, P.A., Devesa, D., Sánchez, M., Gallego, C., Martín, J., Artigues, B., Alemany, J.F., 2000. Seguimiento del arrecife artificial del lev-

- ante mallorquín. Technical Report, Mediterráneo Servicios Marinos S.L., Spain.
- Sokal, R.R., Rohlf, F.J., 1979. In: Blume (Ed.), *Biometría*. Madrid, Spain.
- UICN, 1994. Categorías de las listas rojas de la UICN. Preparadas por la comisión de supervivencia de las especies de la UICN. Gland, Suiza.
- Underwood, A.J., 1997. *Experiments in Ecology. Their Logical Design and Interpretation Using Analysis of Variance*. Cambridge University Press, Cambridge.
- Vacchi, M., De La Mesa, G., Finoia, M.G., Guidetti, P., Busotti, S., 1999. *Misure di protezione e giovanili di cernia bruna *Epinephelus marginatus* (Lowe, 1834) (Pisces, Serranidae) nella riserva marina dell'Isola di Ustica (Mar Mediterraneo)*. Mémoires de l'Institut océanographique Paul Ricard. In: *Proceedings of the Symposium International sur les Mérous de Méditerranée*, Embiez, France, pp. 177–185.
- Zabala, M., Lousy, P., García-Rubies, A., Gracia, V., 1997. Socio-behavioural context of reproduction in the Mediterranean dusky grouper *Epinephelus marginatus* (Lowe, 1834) (Pisces, Serranidae) in the Medes Islands Marine Reserve (NW Mediterranean Spain). *Sci. Mar.* 61, 79–89.
- Zar, J.H., 1984. *Biostatistical Analysis*. Prentice-Hall, Englewood Cliffs, NJ.