Characterisation and standardisation of a red shrimp, *Aristeus antennatus* (Risso, 1816), fishery off the Alicante gulf (SE Spain)*

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SUMMARY: The red shrimp (*Aristeus antennatus*) is a target species of a deep trawl fishery in the Gulf of Alicante. This paper describes the fishery by following the activity of this trawl fleet between 1992 and 1999. Principal Components Analysis (PCA) of specific catch compositions identified five main components that explained 92% of the variability, and the catches were grouped into three main species: red shrimp, hake and blue whiting. Hierarchical Clustering Grouping of the percentage species catch composition allowed the fleet to be considered as two main groups, according to monthly landings and by differentiating the origin of the catches (slope or shelf). The species composition of the catch and the red shrimp catch rates (CPUE) differed between the two fleet groups. The application of Generalised Linear Modelling (GLM) to the CPUE series gave consistent indices of abundance. The fleet group, year and season had significant effects on shrimp catch rates, with the fleet group being the most important, and these models explained up to 62% of the total deviance. The abundance indices showed little variation from 1992, although 1994 had the highest value and 1997-1998 the lowest. Comparison with survey indices showed similar trends, while mean uncorrected CPUE differed. Monthly variations of shrimp indices showed a lower abundance in summer, which was attributed to the reproductive patterns of the species. As a result, the use of some fleet grouping techniques is recommended before standardising CPUEs to obtain trends or to calibrate assessment in a fishery.

Key words: abundance indices, trawl fisheries, *Aristeus antennatus*, Mediterranean Sea.

RESUMEN: CARACTERIZACIÓN Y ESTANDARIZACIÓN DE LA PESQUERÍA DE LA GAMBA ROJA, *ARISTEUS ANTENNATUS* (RISSO, 1816) EN EL GOLFO DE ALICANTE (SE DE ESPAÑA). – La gamba roja (*Aristeus antennatus*) es la especie objetivo de la pesquería de arrastre profundo en el Golfo de Alicante. En este estudio se describe la pesquería siguiendo la actividad de la flota de arrastre entre 1992 y 1999. El Análisis de las Componentes Principales (PCA) de la composición de especies de las capturas, identificó cinco componentes principales que explican el 92% de la variabilidad, agrupándose las capturas en torno a tres especies principales; gamba roja, merluza y caballa. El agrupamiento jerárquico (Clúster) de las contribuciones porcentuales de las especies en cada desembarco, permite considerar la flota en dos grupos principales en función de sus capturas mensuales, diferenciando el origen de las capturas según procedan de la plataforma o del talud. La composición de especies en las capturas, así como las tasas de captura (CPUE) de gamba roja, resultan diferentes en los dos grupos de flota identificados. La aplicación de Modelos Lineales Generalizados (GLM) a la serie de CPUE de gamba roja proporciona índices de abundancia consistentes. El grupo de flota, el año y la estación tienen efectos significativos en las tasas de captura de gamba, siendo el grupo de flota el factor más importante, explicando los modelos más del 62% de la desviación total. Los índices de abundancia muestran pequeñas variaciones a lo largo del periodo estudiado, resultando 1994 el año de valor más alto y 1997-1998 los años de valores más bajos. La comparación con índices de abundancia obtenidos en Campañas de prospección muestra tendencias similares mientras que, si los comparamos con las CPUE sin estandarizar, se observan diferencias. Las variaciones mensuales de los índices de abundancia muestran los valores más bajos en el verano, pudiendo atribuirse a patrones del comportamiento reproductivo de la especie. Como conclusión se recomienda el uso de técnicas de agrupamiento en la flota antes de estandarizar las CPUEs, tanto para obtener tendencias como para utilizarlas en la calibración de evaluaciones en una pesquería.

Palabras clave: índices de abundancia, pesquerías de arrastre, *Aristeus antennatus*, mar Mediterráneo.

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INTRODUCTION

The red shrimp (*Aristeus antennatus*) is a demersal species that is found on the muddy bottoms of the continental slope. Its distribution area is very wide, since it is found in the Mediterranean Sea and Atlantic Ocean south of the Iberian peninsula, reaching as far as the Portuguese coasts (Arrobas and Ribeiro-Cascalho, 1987). In the Spanish Mediterranean, it is a species exploited fundamentally in the Ibiza Channel, Catalonia, the Alicante Gulf, the Vera Gulf and the Balearic Islands. It is the target of a very specific fishery, due to its great market value, since, although it does not usually contribute more than 5% of the landings by weight, it can amount to 50% of the landings by value in some ports. In recent years, *Aristeus antennatus* has been the object of some yield per recruit (Y/R), length cohort (LCA) and virtual population (VPA) analyses based on its exploitation in some neighbouring areas (Demestre and Lleonart, 1993; Demestre and Martín, 1993; Demestre *et al.*, 1994; Martínez-Baños, 1997; García-Rodriguez and Esteban, 1999; 2000). The results indicate that stocks are close to equilibrium or slightly overexploited, although the resource can withstand some variations in the fishing effort without any yield variations. However, these assessments were carried out on pseudocohorts and the VPAs were not calibrated with catch per unit effort (CPUE) or survey abundance indices.

CPUE data from commercial fishing vessels are frequently used to calculate biomass indices for stock assessment purposes (Large, 1992) as well as to calibrate Virtual Population Analysis (VPA) (Laurec and Shepherd, 1983; Pope and Shepherd, 1985). Their use is based on the assumption that the CPUE is proportional to abundance and requires accurate data series. Nevertheless, fishing power (P) differs between vessels or can change with time, and measurements based on this parameter must therefore be standardised (Gulland, 1956; Beverton and Holt, 1957). Multiplicative models for CPUE have been used as an alternative to the P index, by considering the effect of factors such as area, season, year and fishing power. These effects are treated as analysis of variance classifications, taking CPUE to be log-normally distributed (Gulland, 1956; Robson, 1966; Gavaris, 1980). This kind of analysis, based on catch and effort data, has been frequently used in other areas (Kimura, 1981; Large, 1992; Mejuto and García, 1996; Hoey *et al.*, 1996; Kimura and Zenger, 1997) to derive indices of relative abundance in fisheries.

In the Mediterranean Sea, Goñi *et al.* (2000) applied a Generalised Linear Model to a hake data series from the port of Castellón and compared the abundance index obtained with survey estimates. The results highlighted the fact that modelling catch rates from trawl fisheries offered a promising method for obtaining standardised abundance indices of groundfish stocks in the western Mediterranean.

In general, such models relate the catch rate of a certain vessel type to the catch rate of a reference vessel. Additionally, they can accommodate effects such as time, area, fishing power and other target species in the catch, and the model coefficients can be estimated by using Generalised Linear Modelling (GLM) techniques (Hilborn and Walters, 1992). This approach allows the factors that influence catch rates to be identified and a standardised abundance index to be computed. In some models, fishing power effects have been removed by categorising vessels into groups (Large, 1992; Goñi *et al.*, 2000; Álvarez *et al.*, 2001). In a multi-species fishery, the target species of each group must be identified as a first step. Subsequent identification can then be undertaken by Principal Components Analysis (Biseau and Gondeaux, 1988; Laurec *et al.*, 1989) or by the analysis of the catch composition in relation to the relative fishing effort applied (Biseau, 1998), thereby obtaining a small number of groups composed of vessels that fish in a similar way, according to the species fished.

In our case, though Mediterranean trawl fisheries are considered as multispecific with up to 104 species recorded in commercial hauls in some areas (Massutí *et al.*, 1996), the red shrimp fishery can be considered as monospecific, since it does not suffer discards due to its high commercial value (Demestre, 1993; Carbonell *et al.*, 1997). Nevertheless, some landings, where the presence of red shrimp is obvious, often contain other species that cannot be considered as characteristic of the red shrimp fishing grounds. This can seriously distort the results of a possible catch per unit effort analysis. On the other hand, the relationships found between the physical characteristics of the vessels in the fleet can result in low covariance values (maximum value; Length-GRT, r^2=0.57), since the GRT represents the vessel characteristic that most explains the variance (59%) for the hake trawl fleet in the port of Santa Pola (Álvarez *et al.*, 2001) and this fact must be taken into account in further analyses.

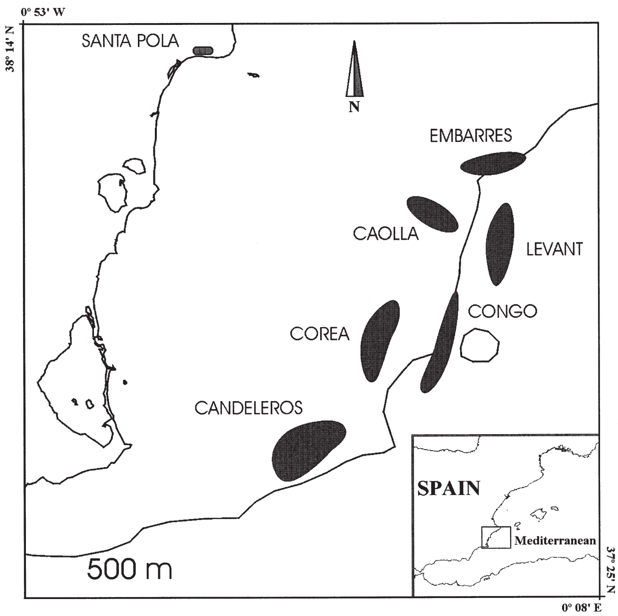

FIG. 1. – Location of the study zone, pointing out the principal fishing grounds in the area.

Consequently, this study describes an *Aristeus antennatus* trawl fishery, characterising its activity, standardising the catch rates and obtaining trends of abundance index, in order to give a more complete account of this deep water trawl fishery in the Spanish Mediterranean.

MATERIALS AND METHODS

The data used in this study came from records of monthly landings of the red shrimp (*Aristeus antennatus*) in the port of Santa Pola from vessels operating in the Alicante Gulf area, from Cape San Antonio to Cape Palos (Fig. 1). The port of Santa Pola is one of the most important on the Spanish Mediterranean coast by volume of sales, and acts as a focal point for landings of vessels from other ports that fish in the area. The port has a very extensive and powerful fleet with some 150 boats that have a total of 5,500 grt and an average of 52.18 grt. The fleet use different types of gears but are mainly dedicated to trawling (82 boats) and the trammel net (50 boats), with a few boats (approximately 28) devoted to pot and long-line fishing; the trawlers land approximately 90% of the total landings.

In order to obtain an overview of the development of the catches landed in recent decades, data collection from the annual landings of *Aristeus antennatus* was also undertaken in the port of Santa Pola, thus providing a historical record of the yearly shrimp catches landed from 1976 to 1999. The data for this section came from the annual records of the Santa Pola Fishermen's Association. For the main objectives of this study, monthly landing data, cumulated by boat and species, was collected from vessels that landed shrimps in the port of Santa Pola during 1992 to 1999 and this was compiled by the Information and Sampling Network of the Spanish Institute of Oceanography (Instituto Español de Oceanografía). The data were obtained for the monthly activity of each vessel, with both catches and fishing days being recorded. Each vessel was identified and its technical characteristics (GRT, HP, length, etc.) were also recorded. As a first step, uncorrected monthly red shrimp catch rates (CPUE) were calculated as the ratio of the recorded monthly shrimp landings to the monthly number of days the vessel fished. All the records of CPUEs below 1 kg/boat/day were discounted for further analysis.

In order to explore different fishing strategies within the Santa Pola shrimp trawl fleet (or métiers; Biseau, 1998), a Principal Components Analysis (PCA) was performed on a file containing the percentage contribution of each species to the total monthly catch, by vessel, for the studied period. The file used contained 2,669 rows (monthly landings by boat) and considered 52 species. The S-Plus routine for PCA with scaling on the covariance matrix was used. This analysis provides information about the relative importance of the main species in the catch composition, as well as on the variance explained by the single components obtained (Álvarez *et al.*, 2001).

In addition, cluster analysis was applied to assess the existence of different fishing strategies or métiers in the Santa Pola trawl fleet, which could help to identify groups of observations (vessel-months) with different strategies with respect to red shrimp fishing. The final goal of the analysis was to extract the vessel-month group observations that more clearly corresponded to the fishery for a red shrimp set of annual CPUE data that best represented the fishery in the Alicante Gulf area. The same file used for PCA was also used for the input data for the cluster analysis. Cluster analyses were performed using the S-PLUS 2000 package; an Agglomerative Hierarchical Analysis was applied, making successive pairwise agglomerations of elements (Ward, 1963), and the Euclidean distance was used as measure of similarity. The maximum distance (>750) at combinations in the dendrogram was used to select the number of groups to be analysed. The grouping results obtained, based on the similarity between catch species composition and its percentage contribution, were used to identify and classify each monthly-landing (vessels) in each corresponding group, by grouping together the vessels that fished in a similar way during the period. The specific composition of the landings of each group obtained were thus compared.

To analyse the variation of the CPUE for the target species selected (*Aristeus antennatus*) with factors such as vessel group, year and month, a Generalised Linear Model (McCullagh and Nelder, 1989; Chambers and Hastie, 1992) was used, applying the corresponding subroutine of the S-PLUS 2000 package (Becker *et al.*, 1988) on a file that considered the vessels identified for each group, their characteristics and the red shrimp CPUE obtained. Since the frequency distribution of the red shrimp catch rates was skewed, 63 % of the values being between 1 and 25 kg/day, and the variances of the catch rates were not independent from the mean, being proportional to near the square of the mean (log (cpue variance) = 1.6065 log (cpue mean) + 0.1312), the gamma variance ($V(\mu) = \mu^2/v$) and a logarithmic link function (log (μ) where μ is the mean and v determines the shape of the distribution ($v = \sigma^{-2}$) where σ is the coefficient of variation) were used to relate the expected CPUE to the predictors, in a similar way to that used by Stefansson (1996), Goñi *et al.* (2000) and Alvarez *et al.* (2001) for modelling different fisheries. The independent variables (vessel class, year, month) were introduced as factors.

The model chosen was:

$$\mathrm{Ln}\,\mu_{cym} = \alpha + \delta_c + \theta_y + \lambda_m + \varepsilon_{cym}$$

where μ_{cym} is the expected catch rate obtained by Vessel class c in year y in month m; α is the catch rate obtained by vessel class 1 in January 1992; δ_c is the efficiency of vessel class c relative to class 1; θ_y is the abundance in year y relative to 1992; λ_m is the abundance in month m relative to January and ε_{cym} is the deviation between the observed catch rates and the expected value for *cym*. An analysis of deviance was carried out in order to evaluate the significance of the factors, as well as interactions, in the model. Deviance represents the variation present in the data and its analysis gives a table that summarises the information related to the sources of variation in the data, in a similar way to ANOVA. A model with main effects and another considering interactions by pairs were used to compare the different models obtained by excluding one term at a time (Goñi *et al.*, 2000). Finally, the derived indices were compared with survey-based indices from the International Bottom Trawl Surveys in the Mediterranean (MEDITS_ES).

RESULTS

The active trawling fleet was numerous, with an average of 65 boats sailing daily, and landing 4,000 mt/year, 100 of which belonged to red shrimp caught in the Alicante Gulf, mainly in the area between Cape of Palos and Cape of Santa Pola (Fig.1). The principal species caught were blue whiting (*Micromesistius poutassou*), hake (*Merluccius merluccius*), octopus (*Octopus-Eledone*), red shrimp (*Aristeus antennatus*) and red mullet (*Mullus* spp.), besides various other species. Almost all the fishing activity was carried out in the fishing grounds of the Alicante Gulf, alternating with the fishing grounds of the Ibiza Channel where approximately 25 vessels usually trawled. A yearly mean of

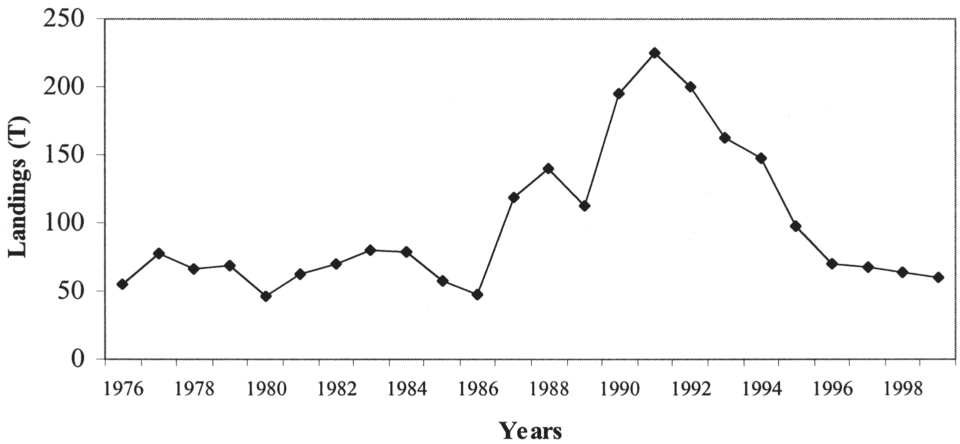

FIG. 2. – Historical series of annual landings for *Aristeus antennatus* in the port of Santa Pola between 1976 and 1998. Data from the Fishermen's Association.

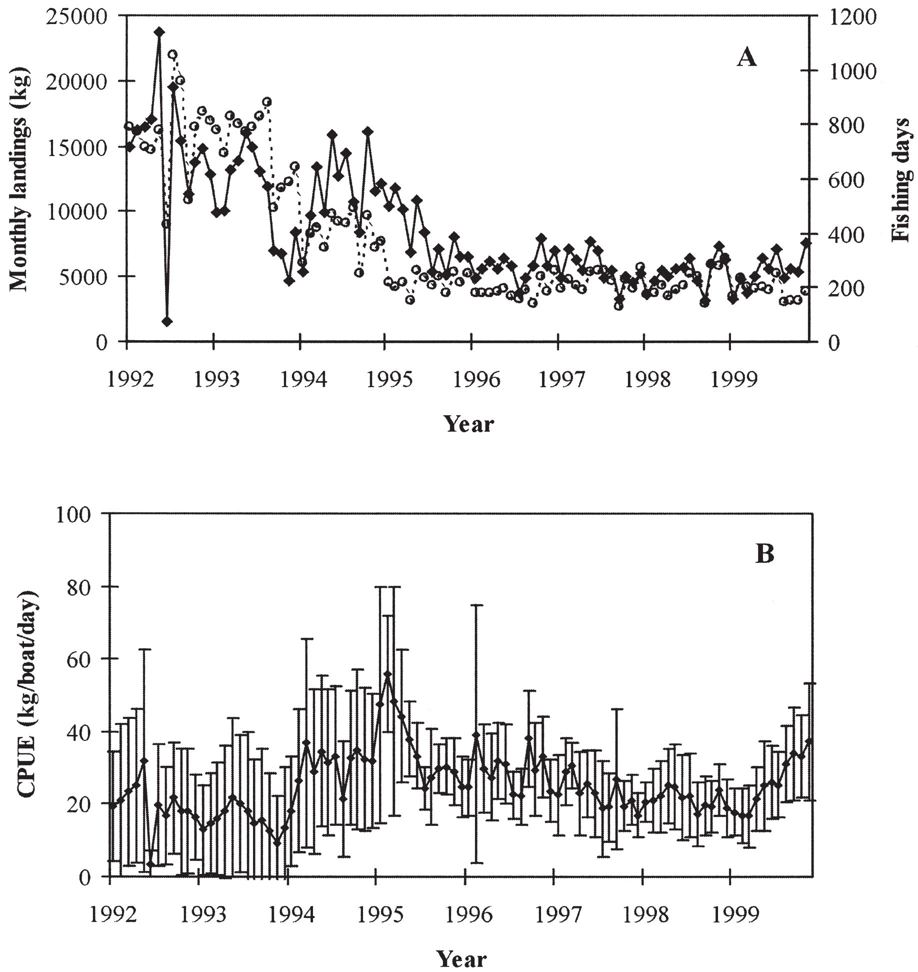

FIG. 3. – Monthly landings (solid line) and effort (dashed line) (A) and uncorrected CPUE (kg/boat/day) evolution (B) for *Aristeus antennatus* in the port of Santa Pola during 1992-1999. Data from RIM-IEO for the shrimp trawl fleet.

40 vessels had fishing activities directed towards the red shrimp in the Alicante Gulf fishing grounds during the period considered.

As shown in Figure 2, the total annual landings for the historical series from these ports considered together fluctuated around an annual average of 100 t between 1976 to 1999. The landings increased from 1986 to 1991 and were higher than the mean in the period between 1987 and 1995, although they started to decline slowly but continuously from 1992 and 1998. The maximum volume of landings was reached in 1991 with 225 t, and the minimum occurred in 1986 with 47 t.

The monthly values of the shrimp landings compiled during the 1992 to 1999 period for the Santa Pola trawling fleet (Fig. 3) showed large fluctuations, but did not indicate any seasonal pattern. The mean monthly catch was 7.01 t, whereas the catch by unit of effort (CPUE) was 27.7 kg/boat/day, based on the data compiled throughout the period considered (Fig. 3). The correlation between catches and CPUE was positive but low ($r^2 = 0.37$), mainly due to the existence of monthly variations in the total number of boats operating in the area (mean = 22 boats/month).

At least three groups of fishing strategies could be distinguished from the biplot resulting from the Principal Components Analysis carried out on the catch species composition (Fig. 4). One was dominated by blue whiting (*Micromesistius poutassou*), another by the red shrimp (*Aristeus antennatus*) and the third by hake (*Merluccius merluccius*). The bulk of the observations, however, fell in the centre between these axes. The results showed that over 90% of the variability was explained by the first five principal components. The first component grouped all landings composed by *M. poutassou*, *M. merluccius* and horse mackerel (*Scomber spp.*) but was negatively related to *A. antennatus* and red crab (*Geryon longipes*). In the second component, the

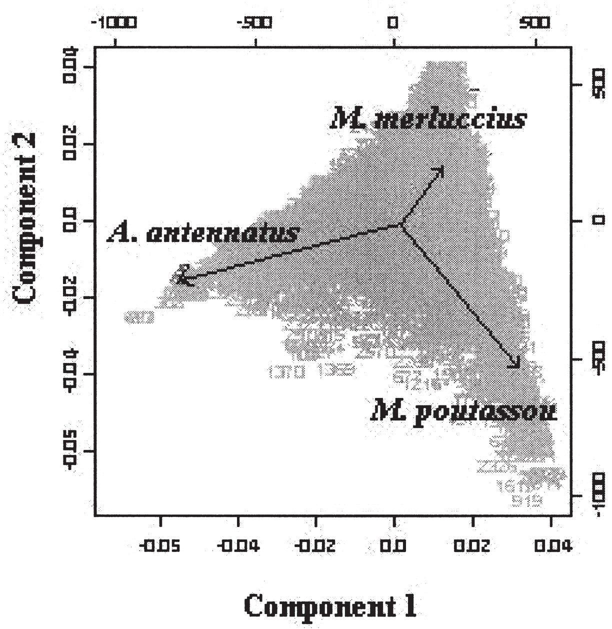

FIG. 4. – Principal Components Analysis (PCA) results; biplot from the PCA showing the grouping of the species. Data for the Santa Pola red shrimp fleet landings 1992-1999.

TABLE 1. – Loadings (covariation values) of the main species for the five principal components (* = absent).

Species	Component 1	2	3	4	5
A. antennatus	-0.846	-0.326	-0.237	-0.152	0.200
M. merluccius	0.180	0.300	-0.596	-0.629	-0.220
M. poutassou	0.457	-0.822	-0.206	*	*
G. longipes	-0.140	*	0.203	0.179	-0.799
Phycis blennoides	*	0.002	0.103	*	-0.186
Scomber spp.	0.002	0.211	-0.109	0.159	0.304
L. caudatus	0.001	*	0.690	-0.613	0.213
Octopus-Eledone	*	0.238	*	0.358	0.278

landings were composed of *M. merluccius*, octopus (*Octopus* and *Eledone*) and *Scomber spp*., negatively correlated with the presence of *M. poutassou* and *A. antennatus*. The other three components were similarly arranged (Table 1).

Grouping results from the Agglomerative Hierarchical Analysis are represented in Figure 5 and they showed two main groups based on the proportions of the species in the landings. The results obtained for the Group 1 fleet showed (Fig. 6 top) a catch composition in which the dominant species represented 67% of the total. The composition was characterised by *M. poutassou*, *M. merluccius* and *Scomber spp*., as well as forkbeard (*Phycis blennoides*), scabbardfish (*Lepidopus caudatus*) and *A. antennatus*. This species composition suggested that the landings of the vessels comprising this group were obtained in a wide bathymetric range, trawling on the shelf and upper part of the slope. Catches landed by the fleet that formed Group 2, represented in Figure 6 (bottom), showed a typical slope species composition, with *A. antennatus* (37%), *P. blennoides* (9%), *G. longipes* (8%), etc. The octopuses were mainly *E. cirrhosa*, and the group denominated "*others*" represented approximately 24%. The sizes of some species, such as *P.*

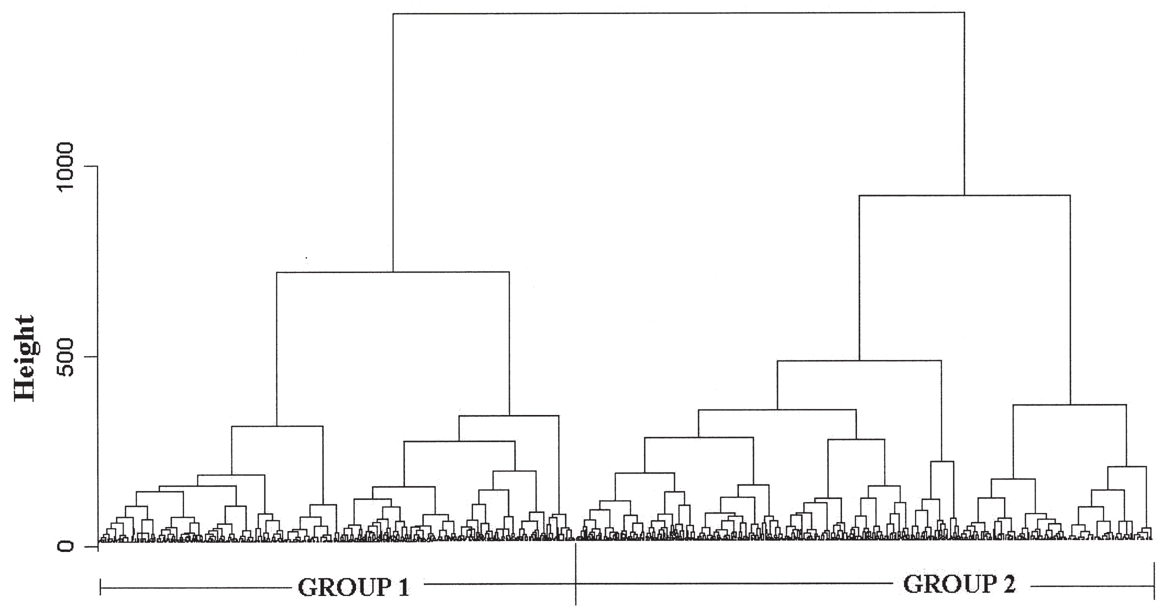

FIG. 5. – Results of the Agglomerative Hierarchical Clustering on the specific landing composition for the red shrimp fleet in the port of Santa Pola.

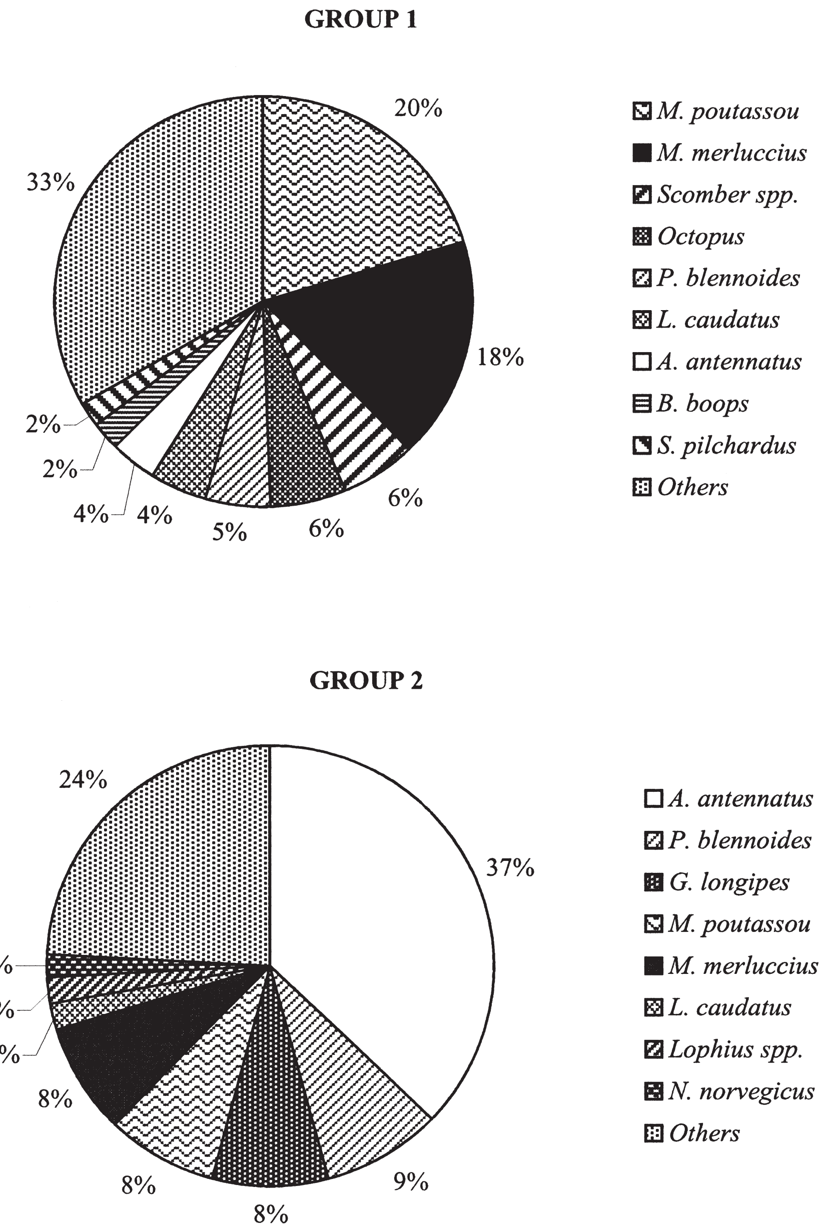

FIG. 6. – Catch species composition as a percentage for Vessel Group 1 (upper) and Vessel Group 2 (lower). Data for the Santa Pola red shrimp fleet landings 1992-1999.

blennoides, *M. merluccius* and *M. poutassou*, were dominated by the large commercial category, with the medium category also being well represented. Both groups present similar mean technical characteristics, with Group 1 constituted by a higher number of boats than Group 2. The mean uncorrected CPUE obtained for the target species (*A. antennatus*) was much smaller in Group 1 than in Group 2 (Table 2).

As a result of the application of the model to standardise the catch rates (GLM), an influence of the different factors was seen (Fig. 7A) as a difference in *Aristeus antennatus* CPUEs between the classes in which the vessels were grouped. The catch rates were lowest in vessels of Group 1 and highest in vessels of Group 2.

TABLE 2. – Mean characteristics of the two vessel groups for the 8-year period considered

Mean	Group 1	Group 2
Boats (n)	83	67
HP	377	367
Length	18.9	18.5
GRT	70.9	69.2
GT	94.5	76.9
CPUE red shrimp	9.62	36.47

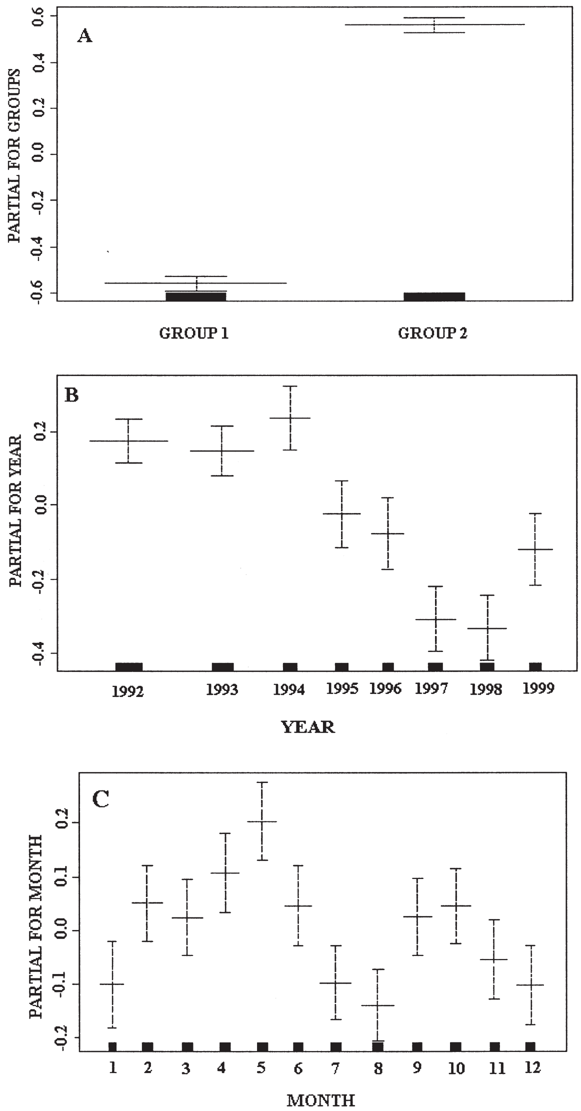

FIG. 7. – Results of Main Effects Model. Each plot represents the contribution of the corresponding variable to the fitted linear predictor for Vessel Groups (A), year (B) and month (C). The fitted values are adjusted to average zero and the dashed bars indicate S.D. The width of the solid bars at the base of the plots is proportional to the number of observations at each level of the factors.

From the model coefficients presented in Table 3, expected catch rates for Group 2 vessels were only 1.8 times higher than those of Group 1 vessels, as opposed to the 3.8 times found in the mean uncorrected CPUE. The yearly evolution of the estimated abundance coefficients showed a decrease after the high value of 1994 (Fig. 7B), with a small recovery in the final year (1999). The years between 1992 to 1994 showed abundance indices that were higher than the mean values, whereas from 1997 to 1999 the values were lower than the mean. However, the range of the variations observed was small and was considered almost constant between years. Seasonal

TABLE 3. – Analysis of deviance results for GLM fitted to red shrimp trawl catch rate data from the period 1992-1998 in the port of Santa Pola. Coefficients express the difference between each level of the factors at the first level (*).

Coefficient	Estimate	Standard error
Vessel Class 1-1992-January*	2.885	0.0159
Vessel Class 2	0.559	0.0160
1993	-0.015	0.0248
1994	0.025	0.0176
1995	-0.053	0.0132
1996	-0.042	0.0110
1997	-0.067	0.0083
1998	-0.051	0.0072
1999	-0.012	0.0067
February	0.028	0.0367
March	0.011	0.0208
April	0.035	0.0149
May	0.024	0.0120
June	-0.002	0.0100
July	-0.011	0.0080
August	-0.019	0.0069
September	-0.002	0.0064
October	-0.006	0.0056
November	-0.0028	0.0053
December	0.005	0.0046

variations of the abundance coefficients showed that, for the consolidated monthly results, two main seasons of abundance could be identified (Fig. 7C). These were spring and to a lesser extent autumn, whereas in winter and especially summer the expected values were much lower. The estimated month effects by year showed (Fig. 8) that the year-month interaction pattern seemed to be similar to the general pattern (Fig. 7C) in the period between 1994 and 1998, whereas 1999 appeared to be clearly different to the general pattern.

The results obtained from the analysis of deviance showed that the Models chosen explained 52% of the variation observed (Table 4). In the Main Effects Model, the Vessel factor explained up to 36%, and was followed in importance by the year and month effects. By considering only vessels from Group 2, the Main Effects Model explained 62% of the variability, with the same order of importance as in the General Model, but with more importance attached to the year effect.

The yearly abundance index obtained could be transformed into a corrected CPUE expressed in kg/boat/day, in order to compare it with other indices. Figure 9 shows the red shrimp corrected CPUE compared with the MEDITS_ES Experimental Trawl Survey abundance index, expressed as kilograms of red shrimp obtained by hour of trawl, and also with mean uncorrected CPUEs. It was shown that, except for the 1994 and 1999 values, the trend for the other years was very similar between

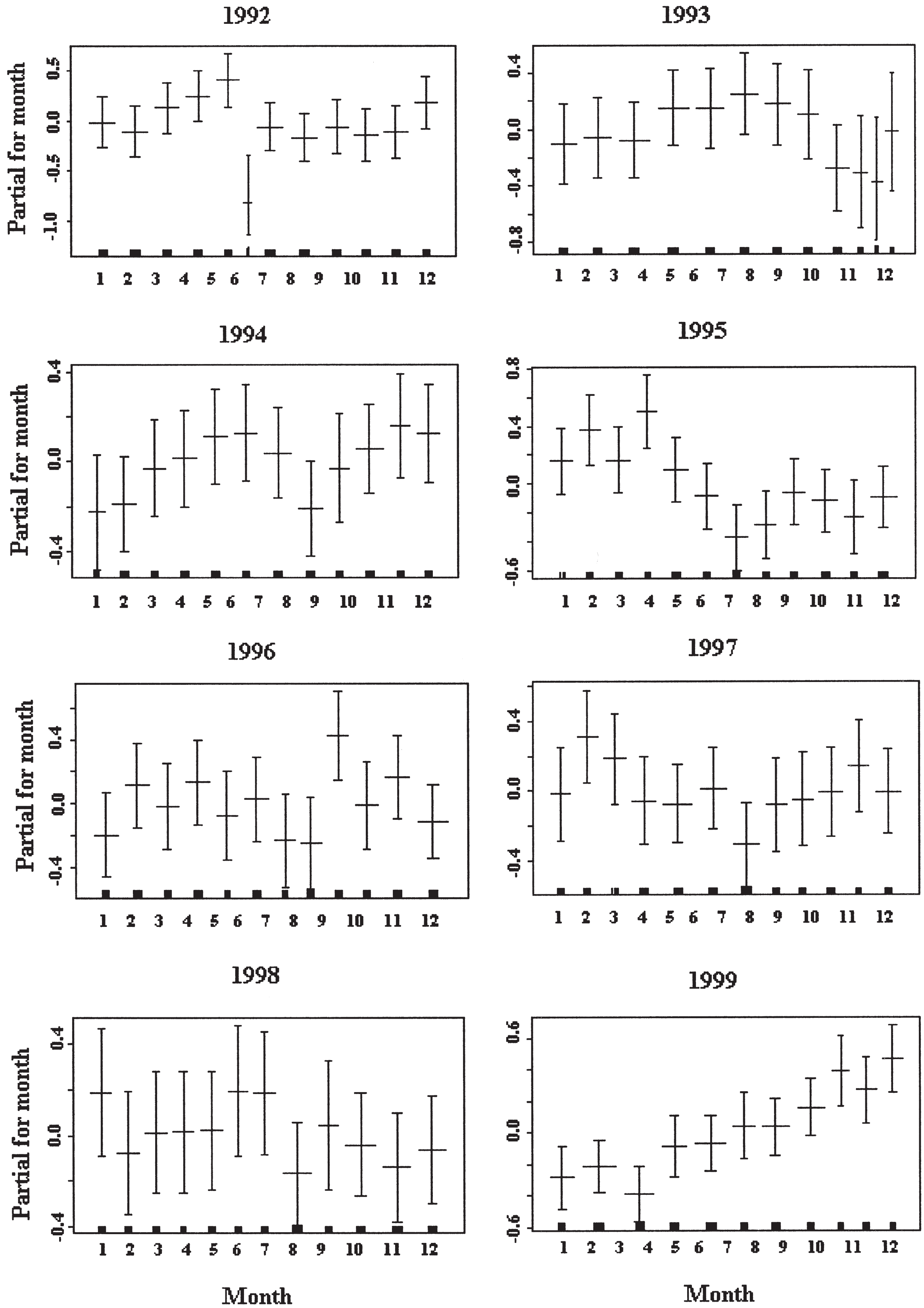

FIG. 8. – Evolution of the relative monthly catch rates by year; GLM Main Effects Model: The fitted values are adjusted to average zero and the dashed bars indicate S.D. The width of the solid bars at the base of the plots is proportional to the number of observations at each level of the factors.

TABLE 4. – Analysis of deviance results for GLM fitted to red shrimp trawl catch rate data from the period 1992-1998 in the port of Santa Pola. For each model, values of deviance of each factor, degrees of freedom (d.f), percentage of the total deviance explained by each factor, residual deviance and residuals degrees of freedom, as well as values of F and probability (P), are shown.

Source of variation	Deviance	df.	% explained	Res. deviance	Res. df.	F	P
General Model							
NULL				1151.07	2322		
Main effects							
Vessel class	653.39	1	36.21	1804.46	2323	1200.86	0.000
Year	90.22	7	7.27	1241.29	2329	23.69	0.000
Month	12.20	11	1.05	1163.27	2333	2.04	0.022
Interactions							
Vessel class: Year	9.13	7	0.85	1071.35	2235	2.59	0.012
Vessel class: Month	6.75	11	0.64	1062.21	2239	1.22	0.270
Year: Month	72.38	76	6.38	1134.59	2304	1.89	<0.001
TOTAL			52.40	88.86	94		
Residual				1062.21	2228		
Group 2 Model							
NULL				306.12	1166		
Main effects							
Vessel	69.00	65	29.78	231.67	1148	8.10	0.000
Year	56.67	7	25.84	219.34	1090	61.8	0.000
Month	10.50	11	6.06	173.16	1094	7.28	<0.001
TOTAL			61.68	143.46	83		
Residual				162.66	1083		

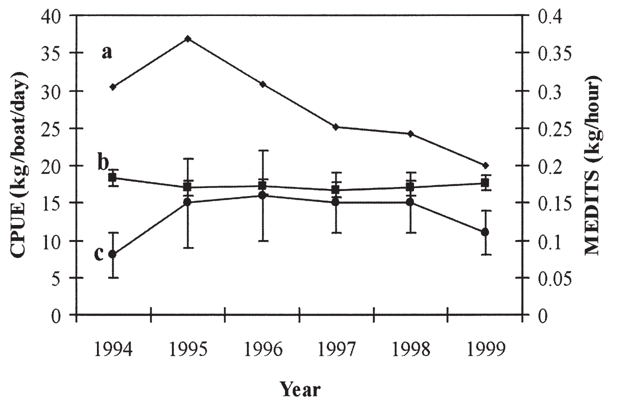

FIG. 9. – Comparison between uncorrected CPUE (a), corrected CPUE (b), and the MEDITS Survey abundance index (c). Data for the Santa Pola red shrimp fleet landings 1994-1999 and MEDITS Survey data 1994-1999.

the standardised CPUEs and the Survey abundance index. They showed a positive correlation (r^2 = 0.86), with a slightly recovering trough during the considered period. However, large differences could be observed when the mentioned indices were compared against mean uncorrected CPUEs.

DISCUSSION

Principal Components Analysis detected three groups of fishing strategies, one dominated by *M. merluccius*, the second by *M. poutassou* and the third by *A. antennatus,* with over 90% of the variability explained by the first five principal components. Since the resulting classes of vessels by PCA are based on catches of the most discriminant species, which do not necessarily include the targeted one, the CPUEs calculated within each group of vessels cannot be considered as actual directed CPUEs (Biseau, 1998). Consequently, it was considered better not to use these results to group vessels into an "activity group" for calculating red shrimp CPUEs, but rather to consider that the PCA results provided a clear description of the fishery.

Grouping made by means of Clustering provides better results. The area that the vessels in Group 1 trawl comprises the shelf and the first part of the slope (from 150 m to 350 m). It is characterised by large catches of *M. merluccius* and *M. poutassou*, with the cephalopod *E. cirrhosa* and some crustaceans like the Norway lobster (*Nephrops norvegicus*), as well as species such as pink shrimp (*Parapenaeus longirostris*), scabbardfish (*L. caudatus*), argentine (*Argentina sphyraena*), pouting (*Trisopterus spp.*), anglerfish (*Lophius* spp.) and John dory (*Zeus faber*). Fishes represent the bulk of the discards from this deep stratum, mainly due to the lack of commercial interest in their sizes (Carbonell *et al.*, 1997). The part of the fleet that constitutes Group 2 mainly trawls on the deepest slope (from 350 m and deeper) and is characterised by catches of decapods such as the Norway lobster (*N.*

norvegicus), red shrimp (*A. antennatus)* and some gadids such as the forkbeard (*P. blennoides*) and large sized hakes (*M. merluccius*). Discards in this stratum are negligible and are due to null commercial interest species (*Galeus melastomus, G. longipes*, etc.) (Carbonell *et al.*, 1997). Despite the fact that they have to sail further than Group 1 to reach their fishing grounds, the mean characteristics of the vessels included in Group 2 seem to indicate that they are not different from Group 1. Nevertheless, their shrimp mean uncorrected CPUEs are much higher than those of Group 1. Model coefficients of expected catch rates for vessel Group 2 also give higher values than for Group 1, but the difference between them is smaller than those observed when using uncorrected mean CPUE. Nevertheless, we must consider that one specific vessel can be allocated into one group or another depending on the type of activity carried out during a particular month. However, in general, two different fishing patterns can be distinguished with respect to red shrimp, one in which red shrimp is fished sporadically (Group 1) and one in which red shrimp is fished as a target species (Group 2).

The yearly evolution of the estimated abundance coefficients shows a small decrease during the period studied, with a recovery in the final year. Nevertheless, the range of the variations observed is small and was considered almost constant between years, which contrasts with the variations obtained by the mean uncorrected CPUEs. Seasonal variations of the abundance coefficients show two main seasons of abundance, spring and autumn, whereas in both winter and summer expected values are much lower. The importance of the model with interactions is explained by the year-month interaction, the only significant one, whose significance level indicates that monthly variations in catch rates are not the same in all years.

The general model chosen explains 52% of the variance observed, with vessel, year and month in decreasing order of importance being the factors that need to be taken into account. All three cases are significant, which means that variations in catch rates are mainly due to the vessel considered, depending on the year and to a lesser extent on the season. In the model for the Group 2 fleet, 62% of variance was explained, with the factors arranged in the same order of importance as in the general model. In similar studies, the vessel effect, or vessel group, is also the most important factor. For instance, in other areas, Hoey *et al*. (1996) found 56% for vessels that fished for swordfish, and Large (1992) obtained 20% for a sole fishery. In the Mediterranean, Goñi *et al.* (2000) found 54% for the vessel category in a hake fishery in Castellón. In our case, the importance of the vessel group was not so great, mainly due to the prior selection of only the vessels that fished for shrimp. On the other hand, the importance of the Year effect, especially in the model for Group 2, is much greater than in the studies mentioned above. Seasonal variations of the abundance coefficients show higher abundance in spring and autumn than in winter and summer. However, Sardá *et al*. (1997) in Catalan coasts, reported high abundance of *A. antennatus* in spring and summer on the slope, and abundance was higher in late summer and winter in canyons. In the present case, seasonal variations could be attributed better to specific biological characteristics of the species rather than fleet variations or fishing strategies that change during the year, since we did not find any trend in the latter case. In nearby areas, reproduction takes place in summer, mainly from June to September, with special intensity in July-August (García-Rodriguez and Esteban, 1999; 2001). These facts could be more important than the observed variations of the abundance, since changes in the exploitation scheme were not detected.

The trend in standardised red shrimp CPUEs shows a similar pattern to the abundance indices obtained by direct methods, similarly to what happens in Mediterranean hake (Alvarez *et al*, 2001). Consequently, it can be concluded that clear differences exist between the use of an uncorrected CPUE and those obtained before characterisation of the fleet and standardisation of the CPUE were undertaken. However, we recommend the use of some fleet grouping techniques, such as agglomerative clustering, before standardising the CPUEs to obtain abundance trends or to calibrate fishery assessments.

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REFERENCES

Álvarez, F., R. Goñi, M. García-Rodriguez, M. Sbrana, P. Belcari, C. Viva, B. Reale, P. Sartor, P. Sánchez, M. Demestre, L. Recasens, J. Lleonart, F. Maynou, J.B. Perodou and S. Alderstein. – 2001. Factors affecting catch rates of north western Mediterranean trawl fleets and derivation of standardised abundance index. EU (DG XIV) Contract nº 98/053. Final Report. (mimeo).

Arrobas, I. and A. Ribeiro-Cascalho. – 1987. On the biology and fishery of *Aristeus antennatus* (Risso, 1816) in the south Portuguese coast. *Inv. Pesq*., 51(suppl. 1): 233-243.

Becker, R.A., J.M. Chambers and A.R. Wilks. – 1988. *The new S language. A programming environment for data analysis and graphics*. Wadsworth and Brooks/Cole Advanced Books Software, Pacific Grove, California. 702 pp.

Biseau, A. – 1998. Definition of a directed fishing effort in a mixed-species trawl fishery, and its impact on stock assessment. *Aquat. Living Resour*., 11(3): 119-136.

Biseau, A. and E. Gordeaux. – 1988. Apport des methodes d'ordination en typologie des flottilles. *J. Cons. Int. Explor. Mer,* 44: 286-296.

Beberton, R.J.H. and S.J. Holt. – 1957. On the dynamics of exploited fish populations. *Fish. Invest., Lond*. (2), XIX.

Carbonell, A., S. De Rainieri and P. Martín. – 1997. Discards of the trawl fisheries of the Western Mediterranean. EU (DG XIV). Contract nº 94/027. Final Report. (mimeo).

Chambers, J.M. and T.J. Hastie, (eds.). – 1992. *Statistical models*. Chapman and Hall, New York. 608 pp.

Demestre, M. – 1993. A study of the *Aristeus antennatus* fishery along the Catalan coast (western Mediterranean). BIOS. *Scien. Ann. of the Sch. of Biol*. Vol. 1, Nº 1.

Demestre, M., A. Carbonell and P. Martínez-Baños. – 1994. Analysis of the exploited population of *Aristeus antennatus* (Risso, 1816) in three adjacent zones in the Spanish Mediterranean. *In*: *Etùde pour l'amenagement et la gestión des peches en Mediterranee occidentale.* Rapport final. CEE FAR, 474 pp. (mimeo).

Demestre, M. and J. Lleonart. – 1993. Population dynamics of *Aristeus antennatus* (Decapoda: Dendrobranchiata) in the northwestern Mediterranean. *Sci. Mar*., 57(2-3): 183-189.

Demestre, M. and P. Martin. – 1993. Optimum exploitation of a demersal resource in the western Mediterranean: the fishery of the deep-water shrimp *Aristeus antennatus* (Risso, 1816). *Sci. Mar*., 57(2-3): 175-182.

García-Rodríguez, M. and A. Esteban. – 1999. On the biology and fishery of *Aristeus antennatus*, Risso 1818 (Decapoda, Dendrobranchiata) in the Ibiza Channel (Balearic Islands, Spain). *Sci. Mar*., 63: 27-37.

García-Rodríguez, M. and A. Esteban. – 2000. A comparison of the exploitation level of two populations of red shrimp from two close areas in the Spanish Mediterranean. In: F. Schram and Vaupel (eds.), *The biodiversity crisis and Crustaceans*. Vol. 2. A.A. Balkema, Rotterdam.

García-Rodríguez, M. and A. Esteban. – 2001. Length composition, growth and reproduction of a red shrimp (*Aristeus antennatus*, (Risso 1818) (Decapoda, Dendrobranchiata) population in the Alicante Gulf (S.E. Spain). *Rapp. Comm. inter. Mer Medit.,* (36).

Gavaris, S. – 1980. Assessment of the cod stock in NAFO Divisions 2J+3K. *NAFO,* SCR Doc. 80/VI/S 1, No. NI 35. 5pp.

Goñi, R., F. Alvarez and S. Alderstein. – 2000. Application of generalised linear modelling to catch rate analysis of Western Mediterranean fisheries: the Castellón trawl fleet as a case of study. *Fish. Res.*, 42: 291-302.

Gulland, J.A. – 1956. On the fishing effort in English Demersal Fisheries. *Fisheries Investigations*, London Series. Vol. 2. No. 20: 1-41.

Hilborn, R. and C.J. Walters. – 1992. *Quantitative Fisheries Stock Assessment. Choice, Dynamics and Uncertainty*. Chapman and Hall, London. 570 pp.

Hoey, J., J. Mejuto, J.M. Porter, H.H. Stone and Y. Uozumi. – 1996. An updated biomass index of abundance for North Atlantic Swordfish. ICCAT, S CRS/96/144. 9pp.

Kimura, D.K. – 1981. Standardized measures of relative abundance based on modelling log(CPUE), and their application to Pacific Ocean perch (*Sebastes alutus*). *J. Cons. Inter. Expl. Mer*, 39: 211-218.

Kimura, D.K. and H.H. Zenger. – 1997. Standardizing sable fish longline, survey abundance indices by modelling the log-ratio of paired comparative fishing CPUE's. *ICES J. Mar. Sci.*, 54: 48-59.

Large, P.A. – 1992. Use of a multiplicative model to estimate relative abundance from commercial CPUE data. *ICES J. Mar. Sci*., 49: 253-261.

Laurec, A. and J.G. Shepherd. – 1983. On the analysis of catch and effort data. *J.Cons. Explor. Mer,* 41: 81.84.

Laurec, A., A. Biseau, and A. Charuau. – 1989. Modelisation des interactions techniques. ICES MSM Symp. A:3.

Martínez-Baños, P. – 1997. *Dinámica de poblaciones de la gamba Aristeus antennatus (Crustacea, Decapoda) en las zonas de Murcia, Almería e Ibiza. Análisis global en el Mediterráneo Español.* Tesis Doctoral. Universidad de Murcia.

Massuti, E., O. Reñones, A. Carbonell and P. Oliver. – 1996. Demersal fish communities exploited on the continental shelf and slope off Majorca (Balearic islands, NW Mediterranean) *Vie Milieu*, 46(1): 45-55.

McCullagh, P. and J.A. Nelder. – 1989. *Generalized Linear Models* (2nd ed.). Chapman and Hall, London. 509 pp.

Mejuto, J., and B. García. – 1996. Standardized age specific catch rates for albacore *Thunnus alalunga* from the Spanish surface fleets in the Northeast Atlantic. 1981-1995. ICCAT, SCRS/96/081. 12pp.

Pope, J. and J.G. Shepherd. – 1985. A comparison of the performance of various methods for tunning VPAs using effort data*. J.Cons. Explor. Mer,* 42: 129-151.

Robson, D.S. – 1966. Estimation of relative fishing power of individual ships. *ICNAF Res. Bull.,* 3: 5-14.

Stéfansson, G. – 1996. Analysis of groundfish survey abundance data: combining the GLM and delta approaches. *ICES J. Mar. Sci*., 53: 577-588.

Ward, J. – 1963. Hierarchical grouping to optimise an objetive function. *J. Am. Stat. Assoc*., 58: 236-244.

Scient. ed.: F. Sardà