

Optimum exploitation of a demersal resource in the western Mediterranean: the fishery of the deep-water shrimp *Aristeus antennatus* (Risso, 1816)*

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SUMMARY: The evolution of the fishing of *Aristeus antennatus* during the last 15 years on the Catalan coast has been analyzed. Major components of catches, are mature individuals. The exploited length frequency distribution, as well as the mean size of catches remained stable during 1984-1991; the fishing effort directed to this species has undergone slight variations. The exploited sizes ranged between 15-66 mm carapace length for females and 17-38 mm for males. The exploitation of this species is limited to fishing grounds located in submarine canyons, between 400-800 m depth. Catches showed marked seasonality, with maximum values in spring-summer, during the reproduction period. Annual natural mortality rates M of 0.5 for females and 0.8 for males are proposed, values much lower than those estimated for other penaeids. Considering all these facts together, it appears that we are dealing with a bottom trawl fishing strategy close to the optimum.

Key words: *Aristeus antennatus*, deep bottom trawling, western Mediterranean.

RESUMEN: EXPLOTACIÓN ÓPTIMA DE UN RECURSO DEMERSAL EN EL MEDITERRÁNEO OCCIDENTAL: LA PESQUERÍA DE LA GAMBA *Aristeus antennatus* (Risso, 1816). — Se ha analizado la evolución de la pesca de *Aristeus antennatus* en los últimos 15 años en la costa catalana. Las capturas están compuestas mayoritariamente por ejemplares maduros. La distribución de tallas explotadas, así como la talla media de captura, se han mantenido estables durante el período 1984-1991; el esfuerzo aplicado sobre esta especie ha experimentado pequeñas variaciones. El rango de tallas explotadas fue de 15-66 mm de cefalotórax, en las hembras, y 17-38 mm en los machos. La explotación de esta especie se limita a caladeros situados en los cañones submarinos, entre 400-800 m de profundidad. Las capturas experimentan marcadas variaciones estacionales, con máximos en primavera-verano, coincidiendo con el período reproductor. Se proponen como valores anuales de la tasa de mortalidad natural M 0.5 para las hembras y 0.8 para los machos, valores muy inferiores a los estimados para otros peneidos. El conjunto de estos factores es indicativo de que nos encontramos ante una estrategia de pesca de arrastre cercana al óptimo.

Palabras clave: *Aristeus antennatus*, arrastre a gran profundidad, Mediterráneo occidental.

INTRODUCTION

The "gamba" shrimp *Aristeus antennatus* (Risso, 1816) (Decapoda: Dendrobranchiata) is one of the most important traditionally exploited demersal species in the western Mediterranean. It is considerable depths, caught at exclusively by bottom trawling, on muddy bottoms. With the exception of the Adriatic Sea, it is found throughout the Mediterranean, as well

as in the Atlantic, from southern Portugal to the Green Cape Islands (HOLTHUIS, 1980). Regular fishing appears to be limited to the western Mediterranean and southern Portugal.

On the Catalan coast (NW Mediterranean), fishing of *A. antennatus* is performed between 400 m and 800 m depth, on grounds where the continental shelf and the slope form submarine canyons. At present, annual catches are about 350 tonnes, that represent an income of around 13 million dollars (MARTÍN, 1991). Fishing activity is concentrated in fifteen ports. Only seven of them (Roses, Palamós, Blanes,

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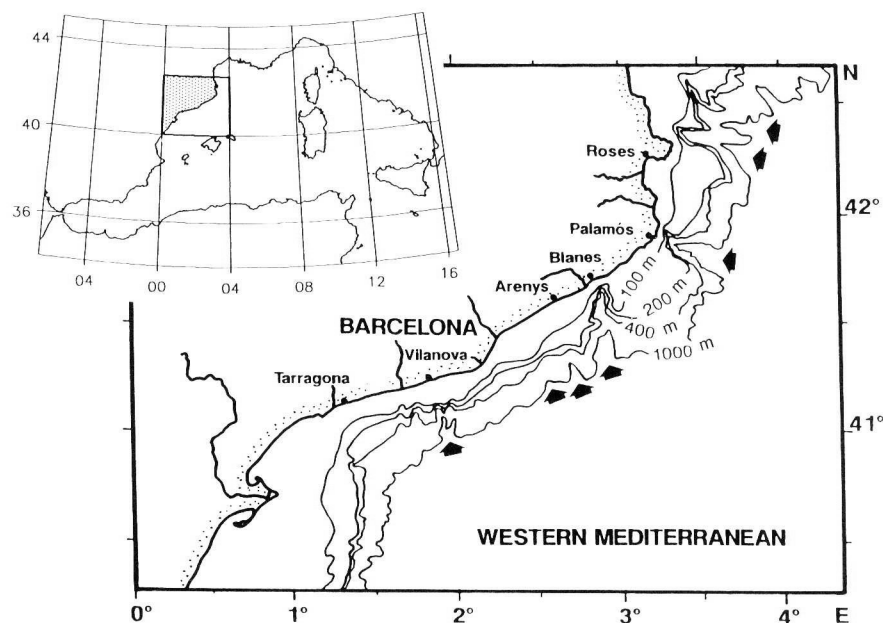


FIG. 1. — Study area showing the fishing grounds (arrows) of *Aristeus antennatus* and the fishing ports of the Catalan coast which regularly exploit shrimp.

Arenys, Barcelona, Vilanova and Tarragona) have developed regular fishing for this shrimp. The topography of the sea bed determines that the ports which obtain the highest yields (Palamós, Blanes and Arenys) are those located in front of submarine canyons. For these ports the shrimp is a resource of great local importance.

Early studies were based on morphology, fishing methods and distribution in the Mediterranean (BRIAN, 1931; HELDT, 1932; ARTÉ, 1952; MAURIN, 1965; BAS, 1966; MASSUTÍ and DAROCA, 1978). Later studies dealt with different aspects of the biology of the species (RELINI ORSI and RELINI, 1979; RELINI ORSI and PESTARINO, 1981; ARROBAS and RIBEIRO-CASCALHO, 1987; SARDÀ and DEMESTRE, 1987; DEMESTRE, 1990; DEMESTRE and FORTUÑO, 1992).

The present work defines the characteristics of the exploitation of *Aristeus antennatus* and analyses the evolution of the fishing pattern applied to the “gamba” shrimp during the last 15 years.

MATERIAL AND METHODS

The coast of Catalonia extends for about 550 km. The characteristic fishing grounds of *Aristeus antennatus* together with the harbours where this shrimp is regularly exploited are shown in Fig. 1.

Data on catches and fishing effort have been provided by the fishermen’s associations.

A survey of daily landings of the trawling fleet was conducted over a period of 2 years (from July 1981 to June 1983) in the main ports involved in shrimp fishing (Palamós, Blanes and Arenys). The sampling consisted in recording the composition and weight by species of the daily landings from vessels which operated on a single fishing ground during one day. The characteristics of the vessels (power and tonnage) were also recorded. Of the 564 observations which made up the daily catch monitoring, “gamba” shrimp was reported on 329 occasions.

A bottom trawler specialised in the *A. antennatus* fishing was monitored over a period of five years (1984 to 1988), and details of the daily shrimp catch and the fishing ground visited were recorded.

Size frequency distributions, by sex and year, were obtained from monthly samplings of commercial trawlers (from 1984 to 1991), standardized to the total catch (Table 1). The percentage of similarity (PS) was used as measure of resemblance of the annual length distributions:

$$PS = 2 \frac{\sum [\min(x, y)]}{\sum (x + y)} = 1 - \frac{\sum |x - y|}{\sum (x + y)}$$

where x, y are the length distribution vectors to be compared (GOODALL, 1978). Simultaneously with length sampling, monthly biological sampling was conducted, in which about 150 specimen were examined and, in each case, sex, carapace length (mm), weight (0.1 g), gonadal maturity stage, and the presence of spermatophore were recorded. In a previous study of gametogenesis, the different maturity stages

TABLE 1. – Mean size (MS), most frequent size (MFS), percentage of immatures (I) and sex-ratio (SR, female: male) from bottom trawl catches (1984-1991) of *Aristeus antennatus* (n=number of individuals measured, F = Females, M = Males).

Year	n		MS		MFS		I%		SR%
	F	M	F	M	F	M	F	M	
1984	4338	955	38	26	33	22	9	21	82
1985	1725	696	39	27	38	26	10	2	71
1986	757	344	38	27	33	23	13	9	69
1988	1981	698	34	25	28	22	18	21	74
1989	1766	799	36	26	38	28	14	11	69
1990	398	117	32	24	27	23	30	6	77
1991	1794	735	30	23	28	21	22	23	71

of ovary and testicle were characterised. Seven maturity stages in females and three in males were described (DEMESTRE and FORTUÑO, 1992). The size at first maturity was estimated for both sexes from the secondary sexual characters (thelycum, petasma, rostrum) and the development of the functional sexual characters (ovary maturity, presence of spermatophore in the thelycum and the presence of hemispermatozoa in the terminal ampulla of the testicle).

Indirect estimates of the natural mortality rate M were performed, for each sex separately, following the methods proposed by TAYLOR (1959), RIKHTER and EFANOV (1976) and PAULY (1980). These estimates were evaluated by considering biological characteristics of the species.

RESULTS

Aristeus antennatus fishing off the Catalan coast

The “gamba” shrimp *Aristeus antennatus* is one of the most important resources for the bottom trawl fishing fleet of the Catalan coast. Although the catches represent only 0.5% to 0.7% of the total for Catalonia, economically it represents between 7% and 8% of the income from fish marketing. This places it among the main species in terms of commercial importance, the others being anchovy (*Engraulis encrasicolus*), which represents 23%, hake (*Merluccius merluccius*), which represents 12%, and sardine (*Sardina pilchardus*) which represents 8 to 9% (DEMESTRE, 1990; MARTÍN, 1991).

The trawling fleet of the Catalan coast consists of about 450 vessels, and has undergone small variations during the last ten years. The vessels specialised in fishing for “gamba” shrimp are concentrated in Palamós (about 25), Blanes (about 10) and Arenys (less than 10). In general, the characteristics of these ves-

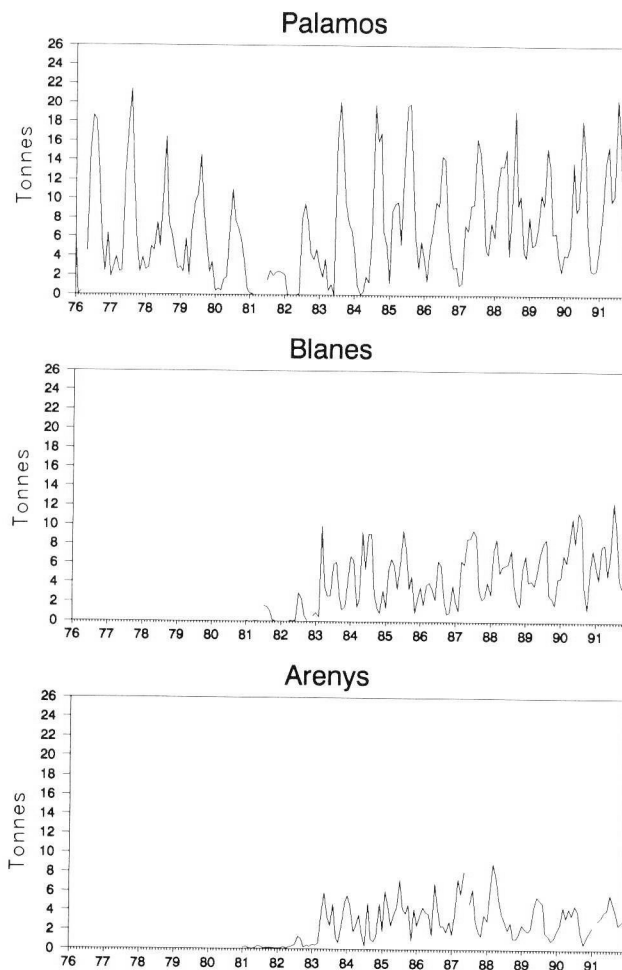


FIG. 2. — Monthly catches of *Aristeus antennatus* from the ports where the shrimp fishing is relevant (Palamós, Blanes and Arenys).

sels are a power of about 650 hp, and 85 gross registered tonnes. However, vessels with less power and tonnage are used sporadically for this type of fishing.

A. antennatus catches show marked seasonal changes, with maximum values from April to September. Palamós achieves the greatest yields of all the ports on the coast of Catalonia (Fig. 2). Maximum values are around 20 tonnes per month, and the minimum values about 2 tonnes per month. At the beginning of the eighties, minimum catches were observed. This decrease in catches coincided with that observed in other shrimp fishing grounds in the western Mediterranean (Ligurian Sea, Gulf of Lions). From 1983 a recovery in catches began, and in recent years the annual catch has stabilised at a level similar to that attained during the seventies. The maximum monthly catches in this harbour corresponded to daily shrimp landings of 1 tonne (fishing is performed 5 days per week), obtained from a reduced number of fishing grounds (see Fig. 1).

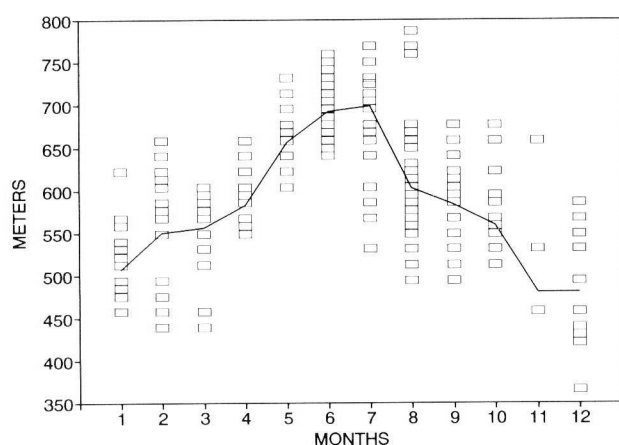


FIG. 3. — *Aristeus antennatus* fishing grounds visited during the year, data obtained from monitoring the activity of a commercial bottom trawler specialised in the exploitation of this species. The monthly mean depth of hauls is shown.

The “gamba” shrimp fishing grounds change during the year. In winter, from January to March, trawling is performed at depths of 450 to 600 m, whereas from April until July, fishing grounds located deeper, down to 750 to 800 m, are sought. At the end of the summer and beginning of autumn, trawlers operate mainly at 600-700 m depth, and later the fishing activity returns to the fishing grounds situated around 400-600 m in depth (Fig. 3).

Other co-occurring commercial species are the greater fork-beard (*Phycis blennoides*), and, to a lesser extent, large individuals of hake (*M. merluccius*), angler (*Lophius* spp.), conger (*Conger conger*) and blue whiting (*Micromesistius poutassou*). However, due to the gregarious behaviour of the species and its characteristic bathymetric distribution, the shrimp catches are “clean”, in the sense that this species is the main component of hauls. When *A. antennatus* is abundant, the total catch of those vessels specialised in the exploitation of this shrimp decreases, whilst the shrimp proportion in catches increases. Similarly, when the abundance of the “gamba” shrimp decreases, the total catch is increased considerably, which indicates clearly that the vessels turn to other more abundant and accessible resources, such as the blue whiting (Fig. 4). The daily catches can be as much as 100 kg during the months when the shrimp is most abundant.

Demography of the exploited population of *Aristeus antennatus*

The annual length frequency distributions, obtained from monthly samplings performed during the

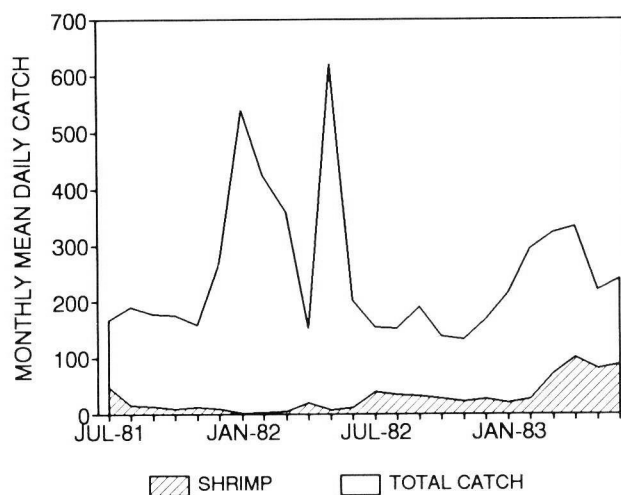
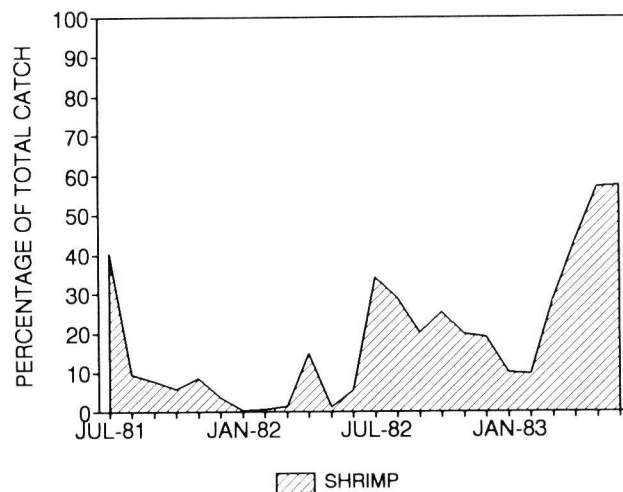


FIG. 4. — Monthly mean daily catches (kg) of bottom trawlers from Palamós, Blanes and Arenys, showing the *Aristeus antennatus* catch with regard to total catch (July 1981-June 1983).

period 1984 to 1991, showed stability in the range of exploited sizes, for both females and males. In the case of females, the carapace length lay in the range of 15 to 66 mm, the most common sizes being from 17 to 62 mm. For the males, the range of lengths was from 17 to 38 mm (Fig. 5). The female mean size remained constant, between 34 and 39 mm up to 1989, and after decreased to 30 mm in 1991. The male mean size followed a similar pattern, remaining stable between 25 and 27 mm until 1989, thereafter decreasing to 23 mm in 1991 (Table 1). In females, resemblance between the annual length distribution was high for the period 1984-1989 (PS between 0.70 and 0.83). On the other hand, size distributions obtained at the end of the period, 1990 and 1991, also showed a rather high similarity (PS between 0.64 and 0.73). Lower similarity was observed between the

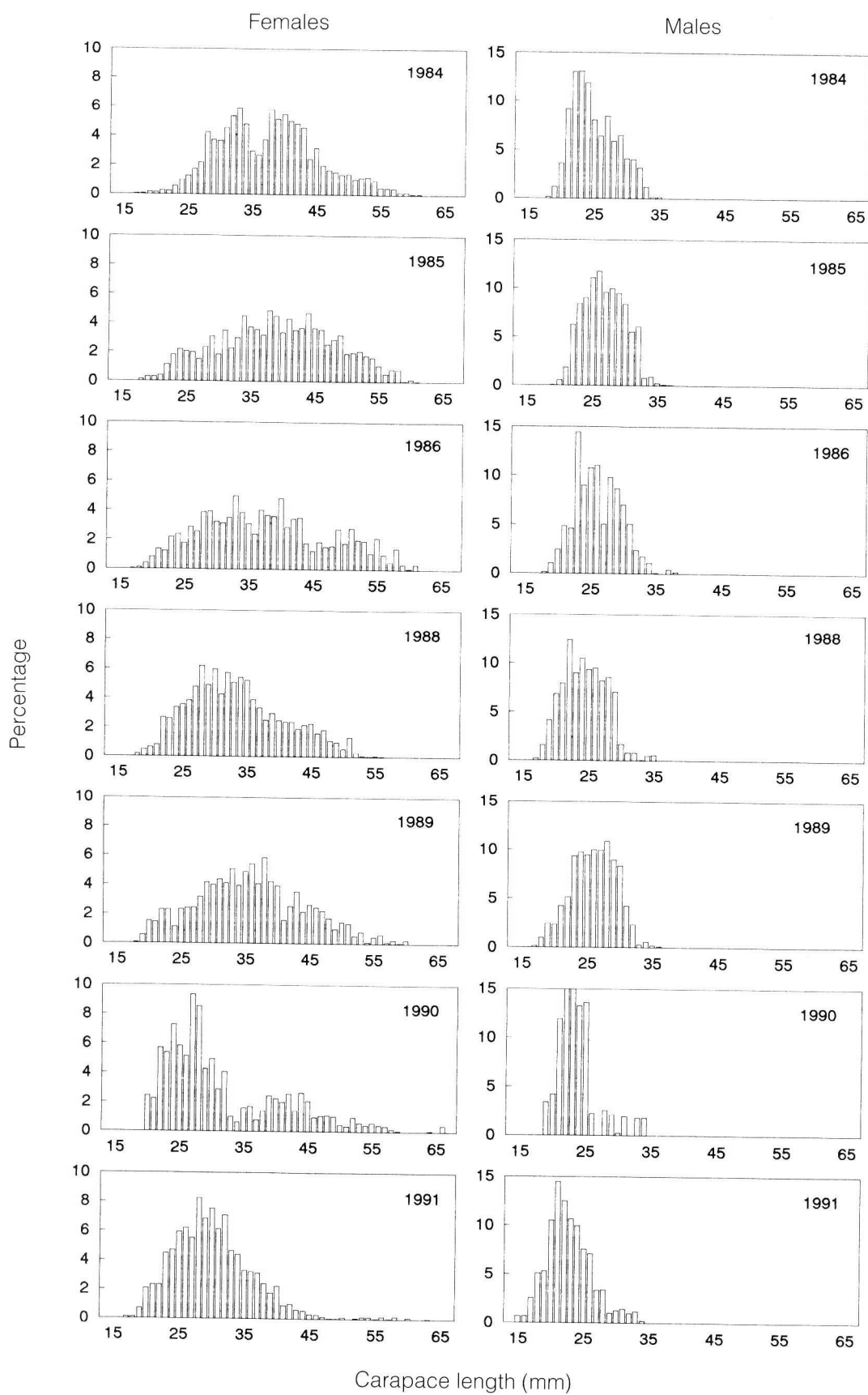


FIG. 5. — Annual length frequency distribution of *Aristeus antennatus*, by sex, from bottom trawl catches (1984-1991).

TABLE 2. — Estimated values of natural mortality rate (M) for *Aristeus antennatus*, by sex.

Method	Female	Male
TAYLOR, 1959	0.30	0.24
RIKHITER AND EFANOV, 1976	1.11	0.98
PAULY, 1980 (length)	0.44	0.42
PAULY, 1980 (weight)	0.59	0.59

size distributions at the beginning, 1984-1985, and at the end of the analysed period, 1990-1991, (PS between 0.53 and 0.59). Similarity among the annual size distributions in males was higher than that observed in females. PS reached values close to 0.90 in some cases. Lower similarity appeared when comparing 1985-86 with the end of the period (Fig. 6).

The proportion of immature individuals in catches is small, in general not exceeding 20 %. The size at first maturity was estimated according to the method previously described, and was found to be 26 mm in females, and 21 mm in males. According to these values, the proportion of immature females increased from 9 % in 1984 to 30 % in 1990, and that of immature males increased from 2 % in 1985 to 23 % in 1991. The sex ratio estimated from catches was very far from the relationship 1:1, females constituting the major part of the catch, between 69 and 82 % (Table 1). The reproduction period lasts several months, from May to October. The highest proportion of spawning females was found during June, July and August (about 40 %).

From the estimates of the annual natural mortality rate M by means of four methods, rather different values were obtained, similar for both sexes, oscillating from 0.30 to 1.11 in females, and from 0.24 to 0.98 in males (Table 2). Thus, to determine which value of M is the most suitable according to the biology of the species, additional studies related with factors affecting the natural mortality were performed (behaviour, life span, migration, parasitism, predation; DEMESTRE, 1990). Taking into account all these aspects, annual natural mortality rates M of 0.5 for females and 0.8 for males are proposed.

DISCUSSION

The fishing of *Aristeus antennatus* has certain characteristics which differentiate it considerably from other Mediterranean bottom trawling fisheries, to such an extent that it can certainly be considered as

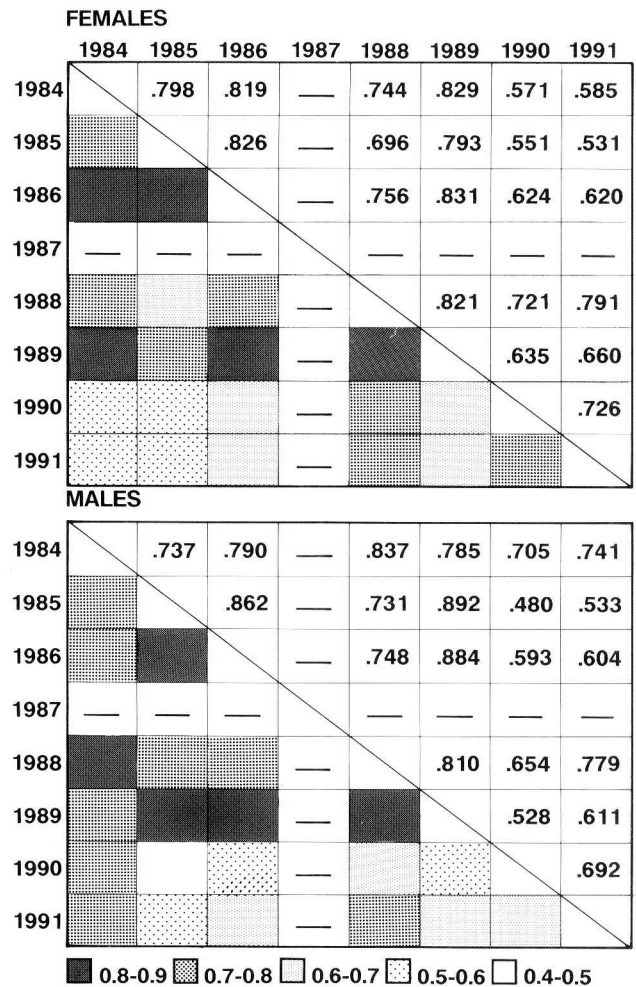


FIG. 6. — Annual size distribution to annual size distribution similarity-coefficient matrix (percentage of similarity) for the period 1984 to 1991, by sex.

a monospecific fishery. It is highly specialised; it is performed at depths where the abundance of other commercial species is very low, which means that this shrimp constitutes the major part of the catch. In addition, it is a very selective type of fishing, since it can only be carried out by certain vessels on particular fishing grounds.

Another characteristic which differentiates it from the exploitation of other demersal resources, is that in the fishing grounds, down to 800 m, there is no clear discrimination by size during the year. In *A. antennatus*, fishing effort can not be directed towards a certain size, as happens with some of the species exploited by bottom trawl on our coast. This is the case, for example, of the red mullet (*Mullus barbatus*) or octopus (*Eledone cirrhosa*). At a certain time of year exploitation affects only the recruits, which are just a few months old (MARTÍN and SÁNCHEZ, 1985; ORSI

RELINI *et al.*, 1985; MARTÍN, 1989; CAMPILLO *et al.*, 1990a; SÁNCHEZ and MARTÍN, 1991; SÁNCHEZ and PDPEM, 1991). Moreover, this shrimp is limited to some very specific fishing grounds, what makes accessibility to the resource rather difficult. Only a fraction of the population is exposed to exploitation, as shown by experimental fishing surveys. Small specimens (<15 mm carapace length) have been found at depths greater than 1500 m (CARTES, 1991), which are certainly inaccessible to the commercial trawlers. The presence of these small individuals leads to the conclusion that a fraction of the spawning stock remains, at least during the reproductive period that lasts for several months (DEMESTRE and FORTUÑO, 1992), at these depths. Also, consumer habits (preference for large specimens) have favoured the maintenance of the current fishing pattern.

Daily yields can reach maximum values of 100 kg in summer, on the deeper fishing grounds (750-800 m). These values are much higher than those obtained from other areas in the western Mediterranean (MINISTERO DELLA MARINA MERCANTILE, 1988; CAMPILLO *et al.*, 1990b; MARTÍNEZ-BAÑO *et al.*, 1990), but similar to those reported from southern Portugal (ARROBAS and RIBEIRO-CASCALHO, 1987).

The main factors considered to affect the mortality rate M in the great majority of penaeid shrimps (fast growth and exposure to strongly fluctuating environmental conditions) do not apply in the case of "gamba" shrimp. Its growth is much slower than that of other penaeids, which have high k values, between 1.8 and 3.6 per year. Previous estimates of k for *A. antennatus* gave a value of 0.3 for females and 0.25 for males (DEMESTRE, 1990). The indirect estimates of natural mortality rate M (Table 2) gave values much lower than those estimated for the great majority of Dendrobranchiata, which vary between 1 and 4 (GARCÍA and LE RESTE, 1981; GULLAND and ROTH-SCHILD, 1984; ROTHLSBERG *et al.*, 1985; RIBEIRO-CASCALHO and ARROBAS, 1987). The deep environment of the shrimp appears to be constant and scarcely fluctuating, unlike those which are inhabited by coastal species. Examination of the stomach contents of most of deep water species has given no evidence that the shrimp has any possible predators (RELINI ORSI and WÜRTZ, 1977; LLEONART, 1990). Furthermore, throughout the entire period of research, from 1984 to 1991, neither parasites nor any type of illness was encountered.

The fact that shrimp is fished between 400 and 800 m, and occurs as deep as 2000 m, indicates that the environmental conditions where *A. antennatus* lives are those of the Deep Water (temperature 12.8°C

and salinity 38.4). The shrimp population probably moves following this mass of water. At the beginning of winter, when the Deep Water is closer to the coast (FONT, 1987), the shrimps are found in the shallower regions of the canyons. Later in spring, the shrimps migrate to deeper fishing grounds. This relationship between the distribution of the species and Deep Water had already been mentioned by GHIDALIA and BOURGOIS (1961) and BOMBACE (1975).

A. antennatus catches are relatively low compared with the total production of the trawling fleet, but are of considerable importance at the harbours where the shrimp fishing is performed. The number of vessels specialised in this type of fishing has undergone slight changes in recent years, and shrimp catches off the coast of Catalonia have remained stable at about 350 tonnes per year. Furthermore, the length frequency distribution has remained constant during the period 1984-1991, as shown by the high values of the percentage of similarity attained. In males, these values were higher than those for females, which can be explained by the different size ranges exploited, smaller in males.

The fraction of the exploited population consists mainly of mature individuals, and the mean size in both sexes has always been larger than the size at first maturity. Also, the results of a Virtual Population Analysis on data from the period 1984-89 indicated that recruitment, mean size of catches and biomass have remained constant. In addition, yield per recruit analysis on the same set of data indicated that fishing effort applied to the "gamba" shrimp was close to the optimum (DEMESTRE and LLEONART, 1993). Considering these facts together, it appears that we are dealing with a bottom trawl fishing strategy close to optimal: the fishing effort has undergone small changes, and the length frequency distribution of the catches, as well as the yield, have remained stable during recent years. It is worth pointing out that by the end of the period considered in this research, a reduction in the mean size of catches was observed, although adults remain the main component of the catches. This may indicate a swing from the optimum level of fishing.

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REFERENCES

- ARROBAS, I. and A. RIBEIRO-CASCALHO. — 1987. On the biology and fishery of *Aristeus antennatus* (Risso, 1816) in the south Portuguese coast. *Investigación Pesq.*, 51(Supl. 1): 233-243.
- ARTÉ, P. — 1952. Datos biológicos sobre *Aristeus antennatus* (Risso, 1816) del "Sot de sa Gamba" de Blanes. (Crustáceos, Macrura Natantia). *Publ. Inst. Biol. Apl.*, 10: 145-149.
- BAS, C. — 1966. La gamba rosada (*Aristeus antennatus*). *Publ. Tèc. Junta Est. Pesca*, 5: 143-156.
- BOMBACE, G. — 1975. Considerazioni sulla distribuzione delle popolazione di livello batiale con particolare riferimento a quelle bentonectoniche. *Pubbl. Staz. Zool. Napoli*, 39(Suppl.): 7-21.
- BRIAN, A. — 1931. La biologia del fondo a "Scampi" nel Mar Ligure. 5. *Aristaeomorpha*, *Aristeus*, ed altri macruri natanti. *Boll. Mus. Zool. Anat. Comp. R. Univ. Genova*, 11: 1-6.
- CAMPILLO, A., Y. ALDEBERT, J.L. BIGOT and B. LIORZOU. — 1990a. Répartition des principales espèces commerciales du Golfe du Lion en fonction des saisons (et plus particulièrement des groupes 0 et 1). *FAO Fish. Rep.*, 447: 103-118.
- CAMPILLO, A., P.Y. DREMIERE, B. LIORZOU and J.L. BIGOT. — 1990b. Observations sur deux crustacés profonds du Golfe du Lion, *Aristeus antennatus* (R.) et *Nephrops novgicus* (L.) *FAO Fish. Rep.*, 447: 298—313.
- CARTES, J.E. — 1991. *Análisis de las comunidades y estructura trófica de los crustáceos decápodos batiales del Mar Catalán*. Ph.D. thesis, University of Barcelona, 627 pp.
- DEMESTRE, M. — 1990. *Biología pesquera de la gamba *Aristeus antennatus* (Risso, 1816) en el mar Catalán*. Ph.D. thesis, University of Barcelona, 443 pp. + XXXIV Lam.
- DEMESTRE, M. and J.M. FORTUÑO. — 1992. Reproduction of the deep-water shrimp *Aristeus antennatus* (Decapoda: Dendrobranchiata). *Mar. Ecol. Prog. Ser.*, 84: 41—51.
- DEMESTRE, M. and J. LLEONART. — 1993. The population dynamics of *Aristeus antennatus* (Decapoda: Dendrobranchiata) in the northwestern Mediterranean. *Sci. Mar.*, 57(2): 183-189.
- FONT, J. — 1987. The path of the Levantine Intermediate Water to the Alboran Sea. *Deep-Sea Res.*, 34(10): 1745-1755.
- GARCÍA, S. and L. LE RESTE. — 1981. Cycles vitaux, dynamique, exploitation et aménagement des stocks de crevettes pénaïdes côtières. *FAO Doc. Tech. Pêches*, 203, 210 pp.
- GHIDALIA, W. and F. BOURGOIS. — 1961. Influences de la température et de l'éclairement sur la distribution des crevettes des moyennes et grandes profondeurs. *Stud. Rev. Gen. Fish. Counc. Medit., FAO*, 16: 1-53.
- GOODALL, D.W. — 1978. Sample similarity and species correlation. In: H. Whittaker (ed.), *Ordination of plant communities*, pp. 99-149. Dr.W. Junk b.v. Publishers, The Hague.
- GULLAND, J.A. and B.J. ROTHSCILD. (eds.) — 1984. *Penaeid shrimps— their biology and management*. Fishing News Books, Farnham, 309 pp.
- HELDT, J.H. — 1932. Sur quelques différences sexuelles chez deux crevettes tunisiennes. *Bull. St. Océanogr. Salammbo*, 27.
- HOLTHUIS, L.B. — 1980. FAO species catalogue. Vol. 1. Shrimps and prawns of the world. An annotated catalogue of species of interest to fisheries. *FAO Fish. Synop.*, (125) Vol. 1: 261 pp.
- LLEONART, J. — 1990. *La pesquería de Cataluña y Valencia: descripción global y planteamiento de las bases para su seguimiento*. Comisión de las Comunidades Europeas, Dirección General XIV. Final Report, 1634 pp.
- MARTÍN, P. — 1989. *Dinámica de la pesquería de arrastre en Cataluña*. Ph.D. thesis, University of Barcelona, 358 pp.
- 1991. La pesca en Cataluña y Valencia (NO Mediterráneo): análisis global de las series históricas de captura y esfuerzo. *Inf. Tèc. Sci. Mar.*, 162: 43 pp.
- MARTÍN, P. and P. SÁNCHEZ. — 1985. Détermination des paramètres de la croissance du rouget (*Mullus barbatus* L. 1758) à partir des données de fréquence de taille. *Rapp. Comm. Int. Mer Médit.*, 29(8): 83-85.
- MARTINEZ-BAÑO, P., F. VIZUETE, J. MAS and F. FARACO. — 1990. Sobre la pesquería de la gamba roja (*Aristeus antennatus*, Risso, 1816) en el Sureste Peninsular: Rendimientos y esfuerzo pesquero. *FAO Fish. Rep.*, 447: 314-325.
- MASSUTI, M. and E. DAROCA. — 1978. Introducción al estudio de la biología de la gamba *Aristeus antennatus* de las pesquerías del sur de Mallorca. *Trab. Comp. Dep. de Pesca. (IEO)*: 264—277.
- MAURIN, C.L. — 1965. Répartition des crevettes profondes au large des côtes de Sardaigne et de Corse. *Rapp. P. — V. Réunion*, 18(2): 175-178.
- MINISTERO DELLA MARINA MERCANTILE. CONSIGLIO NAZIONALE DELLE RICERCHE (eds.). — 1988. *Valutazione risorse demersali. Atti Seminari per la Pesca e l'Acquacoltura III*. pp. 1019-1451.
- ORSI RELINI, L., L. TUNESI, A. PEIRANO and G. RELINI. — 1985. La pesca a strascico nella fascia costiera ligure: II. Distribuzione e incidenza nel pescato di forme giovanili di pesci. *Oebalia*, 11(2): 509-519.
- PAULY, D. — 1980. On the relationship between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *J. Cons. Int. Explor. Mer.*, 39(2): 175-192.
- RELINI ORSI, L. and M. PESTARINO. — 1981. Riproduzione e distribuzione di *Aristeus antennatus* (Risso, 1816) sui fondi batiali liguri. Nota preliminare. *Quad. Lab. Tecnol. Pesca*, 3(1 suppl.): 123-133.
- RELINI ORSI, L. and G. RELINI. — 1979. Pesca e riproduzione del gambero rosso *Aristeus antennatus* (Decapoda, Penaeidae) nel Mar Ligure. *Quad. Civica Staz. Idrobiol. Milano*, 7: 39.
- RELINI ORSI, L. and M. WÜRTZ. — 1977. Aspetti della rete trofica batiale riguardanti *Aristeus antennatus* (Risso, 1816) (Crustacea, Penaeidae). *Atti IX Congr. Soc. Ital. Biol. Marina Ischia*: 389-398.
- RIBEIRO CASCALHO, A. and I. ARROBAS. — 1987. Observations on the biology of *Parapenaeus longirostris* (Lucas, 1846) from the south coast of Portugal. *Investigación Pesq.*, 51 (Supl.1): 201-212.
- RIKHTER, V.A. and V.N. EFANOV. — 1976. On one of the approaches to estimation of natural mortality of fish population. *ICNAF Res. Doc.*, 76/VI/8: 12 pp. In: Jones, 1984. *FAO Fish. Tech. Pop.* (256): 118 pp.
- ROTHLISBERG, P.C., B.J. HILL and D.J. STAPLES (eds.). — 1985. *Second Australian National Prawn Seminar*. NPS2, Cleveland, Australia, 368 pp.
- SARDÀ, F. and M. DEMESTRE. — 1987. Estudio biológico de la gamba *Aristeus antennatus* (Risso, 1816) en el Mar Catalán (NE de España). *Investigación Pesq.*, 51(Supl.1): 213-232.
- SÁNCHEZ, P. and P. MARTÍN. — 1991. Talla de primera madurez y selectividad de algunas especies demersales de interés comercial del litoral catalán. *Inf. Tèc. Inst. Esp. Oceanogr.*, 100: 19-27.
- SÁNCHEZ, P. and PDPEM. — 1991. *Estudi de l'impacte de la pesca dels arrastres petits en els stocks d'espècies comercials de la costa catalana*. Generalitat de Catalunya. Final Report, 221 pp.
- TAYLOR, C.C. — 1959. Temperature and growth. The Pacific razor clam. *J. Cons.*, XXV: 93-101.