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Long term observations of *Aristeus antennatus*: Size-structures of the fished stock and growth parameters, with some remarks about the "recruitment"

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SUMMARY - A brief history of the attempts that have been made to derive growth parameters for *A. antennatus* is given. Length/frequency distributions are often incomplete, given that the locations of shrimps change with age and, apparently, also with geographical factors, a fact which is reflected in the available growth estimates. Initially the life span was taken to be short, while in the most recent studies it is estimated to be 4-5 years. In summer 1987, a very abundant group of small individuals appeared in the Gulf of Genoa. The growth of these "recruits" was followed up over a period of three years and a growth rate of about 5 mm CL per year was recorded. The validated segment of life points to maximum life span of about 10 years. A comparison of the size-structures of the fished stock before and after the 1987 "recruitment" makes it possible to discuss the recruitment in *A. antennatus*, making inferences about the migratory abilities of the red shrimp. The 1987 recruits ranged in size from 20 to 44 mm CL and were almost all spawners. If the group had age 1, the prerecruitment growth must have been very fast; if they were composed of age 1 + N, the first aggregation of spawners must have gathered elsewhere and migrated to the Gulf of Genoa fishing grounds after N - 1 years. The 1988 peak of catches and the evolution of the size-structure in the following years with decreasing numbers of the youngest shrimps may represent the first biological evidence of long-term cycles in the population, which are reflected in the fluctuating success of the fishery.

Key words: *Aristeus antennatus*, length/frequency distributions, growth, recruitment.

RESUME - "Observations à long terme de *Aristeus antennatus*: structures de taille du stock pêché et paramètres de croissance, avec quelques remarques sur le recrutement". On présente une brève histoire des tentatives de dériver des paramètres de croissance pour *A. antennatus*. Les distributions longueur/fréquence souvent sont incomplètes car il existe une localisation des crevettes liée à l'âge, et, apparemment, aussi à des facteurs géographiques, un fait qu'on peut visualiser dans les estimations de croissance connues. Dans les premières approches, la durée de la vie a été considérée courte, alors que les approches les plus récentes indiquent une durée de 4-5 ans. A l'été 1987, un groupe très nombreux de recrues a fait son apparition dans le golfe de Gênes; la croissance a été étudiée pendant trois années et elle est résultée, dans l'ensemble, de 5 mm LC/an. Le segment ainsi validé de vie indique une durée totale de 8-9 ans au moins. La comparaison des structures de taille entre le stock pêché avant le recrutement de 1987 et celui pêché après, donne l'opportunité de discuter le recrutement d'*A. antennatus* et de tirer des inférences sur la capacité migratoire de la crevette rouge. Les recrues de 1987 varient en taille de 20 à 44 mm LC et sont presque tous reproducteurs. Pour le groupe à l'âge d'1 an, la croissance pendant le pré-recrutement est très rapide; pour 1 + N ans, la première agrégation de reproducteurs s'est réunie ailleurs et elle a migré vers les fonds du golfe de Gênes où elle est arrivée depuis N - 1 ans. Le pic des captures enregistré en 1988 et l'évolution de la structure de taille dans les années suivantes avec une progressive diminution du nombre des crevettes les plus jeunes, met en évidence du point de vue biologique la possibilité de cycles à long terme de la population, qu'on constate à propos des succès fluctuants de la pêche.

Mots-clés : *Aristeus antennatus*, distributions longueur/fréquence, croissance, recrutement.

Introduction

Growth parameters of the red shrimp *A. antennatus* (Risso, 1816) can be derived only from an analysis of length-frequency distributions. The correct preparation of these, i.e., samplings in which shrimp sizes are exhaustively covered, can be problematic in bathyal species, given their broad distribution space.

The size-structures of bathyal shrimp populations vary according to vertical and horizontal gradients. Vertical distribution seems regulated by light, varying with diel and seasonal rhythms. Furthermore, the overall vertical distribution changes with age: in the range of trawlable bottoms in the

Mediterranean (mostly between 450 and 700 m), red shrimps are smaller near the epibathyal level and larger at the mesobathyal level. The same vertical distribution has been registered for *A. varidens* (Holthuis, 1932) on the East Atlantic slope (Burukowsky, 1978).

Horizontal or geographical gradients have been reported for *Pleoticus robustus* (Smith, 1885) on the Western Atlantic slope (Anderson and Lindner, 1971) and for *Haliporoides sibogae* (De Mass, 1907) in E. Australia (Baelde, 1992); in both cases larger shrimps were found in the northern areas.

From a brief inquiry promoted by Sardà (1989), *A. antennatus* proved to be at its largest size in the Ligurian Sea, medium-sized in Sicily, Sardinia and Catalonia and smallest in Murcia and Algarve. Recent research in the Ionian Sea has shown the largest sizes along the Apulian coast and the smallest on the Calabrian side (D'Onghia *et al.*, 1996).

Sampling at landings can be biased by the movement of the fishing fleet along the slope. In this connection Sardà (1993) suggests using for red shrimps the "annual return matched samples method" which Sparre *et al.* (1989) have proposed for migratory stocks. Also a stratified sampling at sea may prove incomplete because of the difficulties of taking into account all the above-mentioned causes of variability.

The "history" of growth parameter calculations for *A. antennatus* (Table 1) reflects the above-mentioned differences in l/f distributions. The first attempt was made with shrimps caught in the fishing grounds off Portofino (Ligurian Sea) (Fig. 1). Apparently they were divided into two ages groups and reached very large sizes. Their growth parameters therefore were considered similar to those of coastal Peneids. The second estimate, made by Sardà and Demestre (1987), was carried out on Catalan samples in which the proportion of small shrimps is high (Fig. 2); it was supposed that the first annual group was missing in the Ligurian samples and the life span was extended to 3-4 years. The most recent estimates posit a life span of 4-5 years (Table 1). The general trend seems to be towards paying more attention to the young shrimps and towards a decrease in size at age 1. It is not clear, however, on what basis age 1 is to be extracted from l/f distributions.

In fact, in most of the l/f distributions available from the literature, modal progressions are absent or in some way blurred. Two recent studies on this subject are available: in the first (Ragonese and Bianchini, 1996) a small sample of shrimps from the Strait of Sicily shows small individuals (modal CL 28 mm) in summer and these were followed up to 44 mm CL after one year. In the second study (D'Onghia *et al.*, 1997) "recruits" (this term is proposed by the Authors) appear in the Ionian Sea in September (23 or 25 or 27 CL) and were followed to the next July (43, but also 37 or 47 mm CL).

It is well known that clear modal progressions can be obtained with particularly strong cohorts which remain distinguishable over a period of time. This was the case of the 1987 cohort in the Ligurian Sea, on the basis of which we have recently developed a new interpretation of the life span of *A. antennatus* (Orsi Relini and Relini, 1996). The link with real time, i.e., the validation of at least a segment of life, concerned a period of three years. The 1987 recruitment also gave us the opportunity to discuss the concept of recruitment for *A. antennatus*.

Materials and methods

The Gulf of Genoa has at its centre a system of two submarine canyons, corresponding to the two rivers which flow into the sea at Genoa, the Polcevera and the Bisagno. The latter canyon has an eastern branch towards the Portofino Promontory. Shrimp fishing grounds are located both on a steep wall of this lateral branch and on an adjacent deep plateau (Fig. 3). Shrimps in commercial quantities are now present in the 480-700 m range; in the past, during the winter, they were fished even at epibathyal levels and very occasionally also at the edges of the shelf.

The demographic structures of fished stock were recorded on board trawlers operating out of the port of S. Margherita (Portofino Promontory). Large numbers of shrimps, corresponding to 1 haul or several hauls of the same day's fishing on the above-mentioned steep bottom, were sexed and measured in term of carapace length (CL) with calipers. In addition, their reproductive condition was assessed: in males the presence or absence of spermatophores in the terminal ampoules of *vasa deferentia*, in the female the ovarian maturative stage in terms of storage of carotenoproteins (white, pink, light violet, dark violet ovary, according to Relini Orsi and Relini, 1979).

Table 1. Chronology of growth estimates for *A. antennatus*

Year	Source	Area	Estimated life span (years)	Growth parameters		Carapace length (mm) at age (years)							
				L ∞	K/y	T $_0$	1	2	3	4	5		
1985	Orsi Relini and Relini	Ligurian Sea	2.25	63	1.71	0.44	37	59					
1987	Sardà and Demestre	Catalan Sea	3-4	76	0.3	-0.07	29.4	39.8	53				
1994	Campillo	Gulf of Lion	5	63.57	0.525	-0.259	30.7	44.15	52.08	56.77	59.55		
1994	Dos Santos and Ribeiro Cascalho	Algarve		75.4	0.36	-0.3	28.2	42.5	52.4	59.4	64.2		
1995	Spedicato <i>et al.</i>	South Tyrrhenian	-	66.81	0.558	0.2337	33.2	47.6	55.8	60.5	63.2		
1994	Yahiaoui	Algeria	4-5	65-70	0.33-0.37	-	-	-	-	-	-		
1996	Ragonese and Bianchini	Strait of Sicily	4	69.1	0.53	0	29	44	56	63	-		
1996	Martínez-Baños	Murcia	5	71-75	0.38-0.4	-0.08/-0.05	25	35	44	51	57		

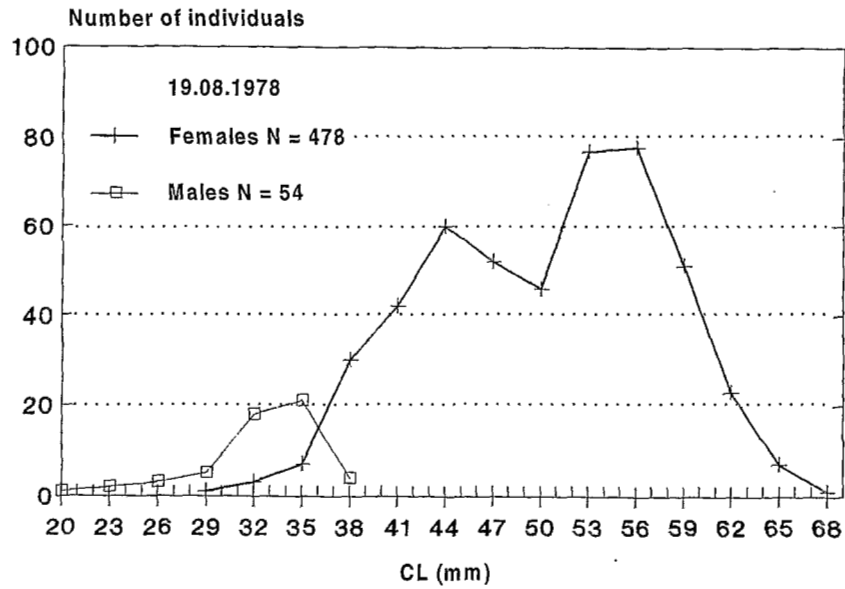


Fig. 1. Length/frequency distribution recorded in the seventies on Portofino fishing grounds.

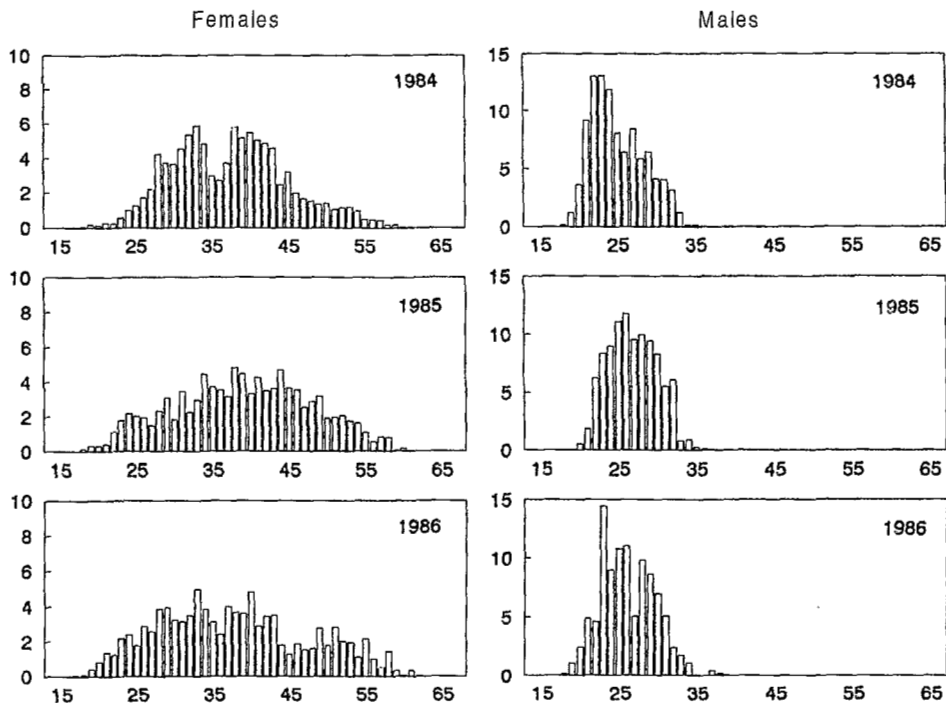


Fig. 2. Length/frequency distributions recorded in the eighties off the Catalan coast (from Demestre and Martin, 1993).

In 1972-1975, studies began mainly on the qualitative aspects of the bathyal community, with the support of the Consiglio Nazionale delle Ricerche. From 1976 to 1981 studies of red shrimps were conducted within the framework of a CNR programme "Oceanografia e Fondi Marini, Risorse biologiche". Sampling was carried out by the trawler "Lavoratore Secondo", using a net with meshes of 40 mm opening at the cod end. However, after 1980 it was no longer possible to obtain substantial samples of the population in this area because in the meantime shrimps had become extremely

scarce (Relini and Relini Orsi, 1987), to the extent that commercial fishery was discontinued. In 1985 and 1986 fishing activity returned to moderate levels and samples were obtained by the same trawler. In 1987 a massive recruitment of red shrimps took place during spring-summer and a period of flourishing activity began for the S. Margherita fleet. In previous years trawling for red shrimps had always taken a winter break; from summer 1987 onwards, it became continuous throughout the year and involved a larger number of trawlers. Measurements of shrimps were effected in summer 1987, winter, spring, summer, autumn 1988, spring and summer 1989 and summer 1990, again on board the above-mentioned trawler.

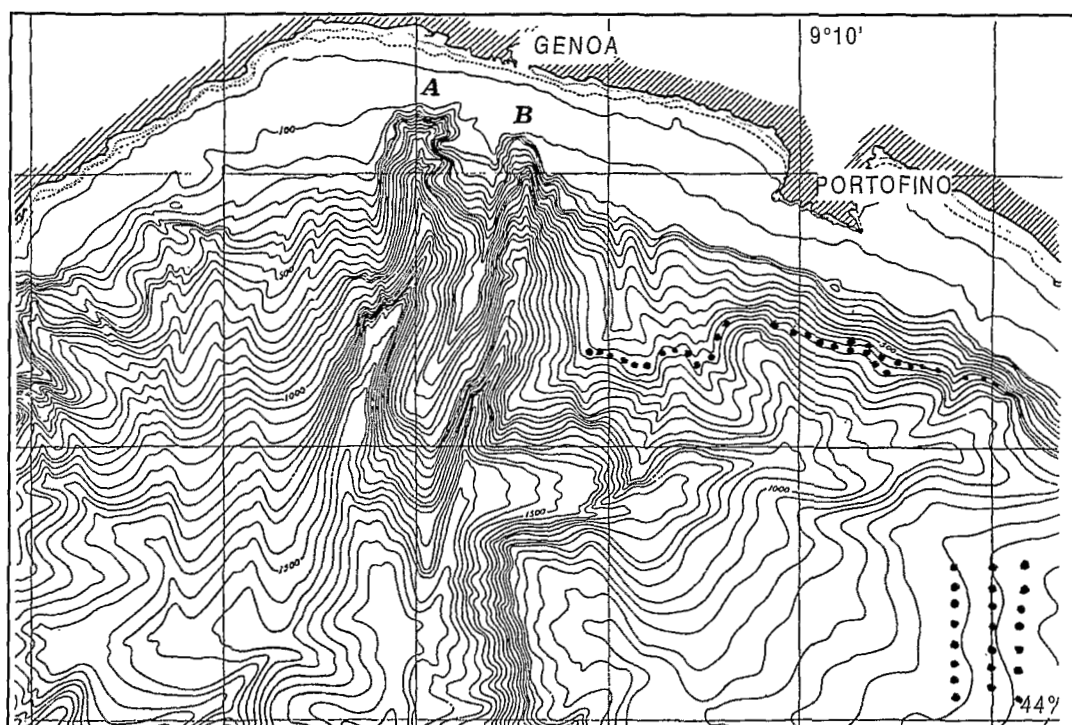


Fig. 3. The Portofino fishing grounds for red shrimps are represented by black dots. The marine canyons of Polcevera (A) and Bisagno (B) are indicated.

In the meantime, 1985 saw the beginning of a new research plan (Ministero Marina Mercantile, Valutazione delle risorse demersali, survey plan in Relini, 1985). The trawler "Elisabetta" was used, with fishing gear similar to the previous one. In the first period (1985-87) sampling consisted of two seasonal trawl surveys each year and in the second period (1990-93) of four seasonal surveys, including fishing for red shrimps at the 500-520 m and 640-650 m levels.

Results and discussion

The appearance of a large number of small shrimps in 1987

In the seventies and at the beginning of the eighties, commercial concentrations of shrimps were mostly made up of large-sized females (Fig. 4). After the period of absence of commercial fishery, the 1985 and 1986 catches showed a demographic structure virtually unchanged from previous years (Fig. 4), i.e., the catches consisted mainly of large females.

In 1987 large quantities of shrimps became available. This was recorded both in the present study area and about 150 km to the west, in the Ventimiglia Canyons. These new shrimps were so different in sizes (Fig. 4) that on the market a second category of "small red shrimps" was designated.

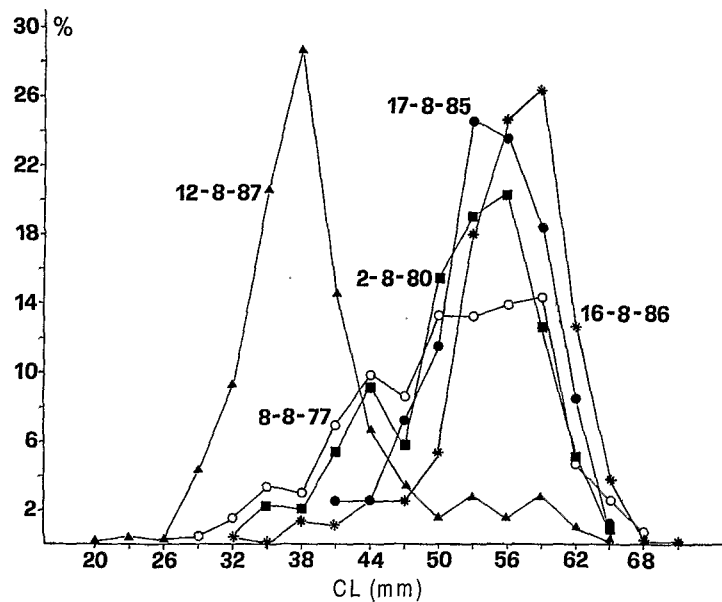


Fig. 4. Length/frequency distributions of females *A. antennatus* recorded in Portofino area. Place, boat, skipper, gear remained unchanged in the indicated period of time (from Orsi Relini and Relini, 1988).

What is the recruitment in *Aristeus antennatus*?

The detailed size-structure of fished stock recorded in the Portofino area during summer 1987 is shown in Fig. 5. The coloured bands show the reproductive condition of these females. The new shrimps mainly belong to the size range 21-44 mm CL and from 24 mm CL upwards they can be mature females. The group peaks at 38-40 mm CL in August. In the most straightforward interpretation we must assign age 1 to the block of new shrimps. In fact, in summer 1986 they were absent (Fig. 4), and one year later they formed the main share of the fished stock. We have called these shrimps recruits in the sense that they were entering the fished stock and represented the smallest individuals found in the area; however they were adults for their reproductive status and this fact is rare in the Mediterranean fisheries where recruits are generally young immature animals. More in general, every concentration of red shrimps on the fishing grounds concerns mainly the adult and not the juvenile fraction of the population; and the use of the term "recruits" by some Authors, e.g., D'Onghia *et al.* (1997), is not different from ours, indicating the small shrimps recently arrived, albeit mature. The size structure of the block of the Ligurian 1987 recruits, showed a polymodal pattern in which we recognized at least six instars (Orsi Relini and Relini, 1996).

If they had been born in 1986 (an hypothesis we named "scenario a"), these recruits would have experienced fast growth (38 mm CL in one year, i.e., a figure similar to that indicated in Table 1 as size at age 1 in the 1985 approach). However, in the light of observations on growth, this scenario must be discarded.

Alternative hypotheses assign to the 1987 recruits the age 1 + 2 (scenario b) or 1 + 2 + 3 (scenario c). The b scenario is closed to the inferences for l/f distributions made by Sardà and Demestre (1987), Martínez-Baños (1996), D'Onghia *et al.* (1997). Both the b and c scenarios pose the question about the previous location of the red shrimps. In fact, if the Ligurian recruits were at least in part age 2, these must have been spawners at age 1 in some unknown location from which they moved to Portofino to join with the "local" age 1 recruits. The same can be repeated for age 3 shrimps.

As already noted, the 1987 recruits were a spawning aggregation (Fig. 5). Their reproductive activity lasted until early autumn, and the following year (1988) proved earlier (i.e., spring-summer instead of summer-autumn) than the reproductive sequence registered in the seventies (Relini Orsi and Relini, 1979).

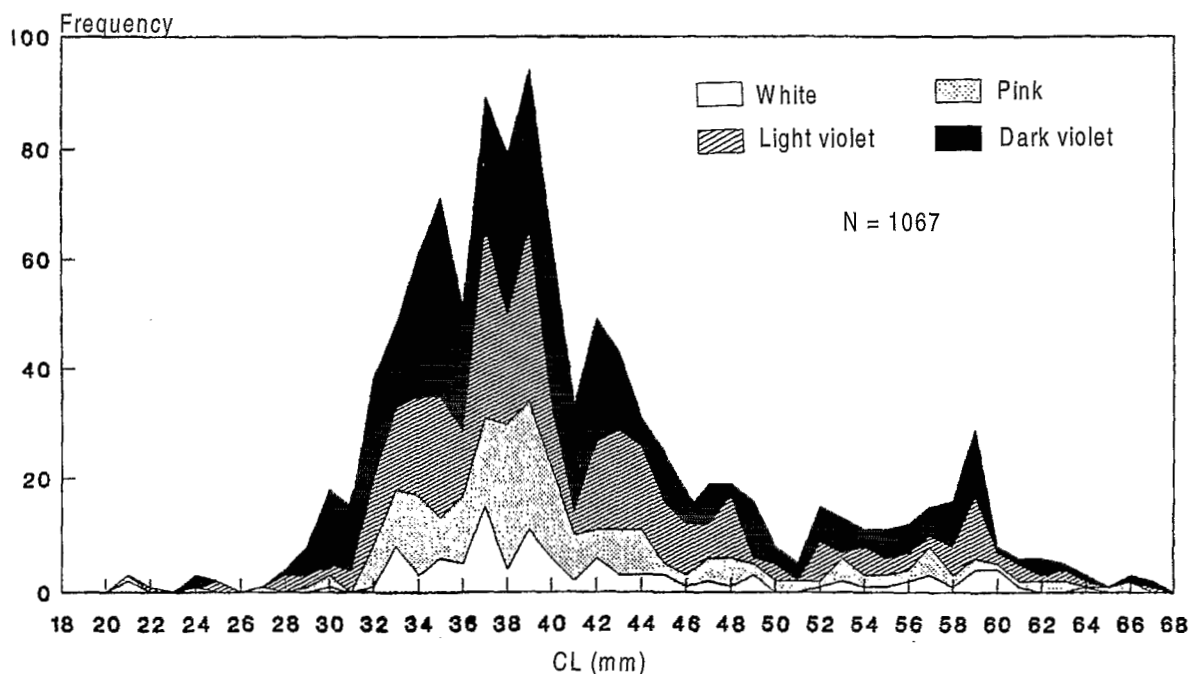


Fig. 5. Detailed size-structure and reproductive stages of females *A. antennatus* in August 1987 (from Orsi Relini and Relini, 1996).

Growth of the 1987 cohort

The 1987 main sub cohort (38 mm CL as modal size) was followed (Fig. 6) for three years (detailed biological notes in Orsi Relini and Relini, 1996). In 1988 growth was registered in late winter, with two moults in February and March, and reached 44 mm CL. In 1989 growth was registered in spring (two estimated moults) with a final length of 51 mm CL. In 1990, during August, carapace length was 53 mm (apparently after 1 moult). In 1991 the group could no longer be distinguished in terms of *l/f* distributions; however, it is possible that from 53 mm CL upwards, only one growth moult occurs per year.

The maximum length registered in the area (during summer 1986) is 71 mm CL. If the shrimps take three years to grow 15 mm CL, it is reasonable to assume that in the final segment of life they cannot have a faster growth rate ($\Delta CL/\Delta t = 15 \text{ mm}/3 \text{ years} = 5 \text{ mm/year}$) and thus the growth from 53 to 71 mm ($\Delta CL = 18 \text{ mm}$) will take more than three years. (Obviously 71 mm CL is a size which is very rarely reached).

These observations suggest a maximum life span of about nine or ten years.

Growth parameters

The growth parameters, derived from sampling on the Portofino fishing grounds (FISAT package by Gayanilo *et al.*, 1996, curves forced to 0 with the assumption that $CL = 0.1$ at 0.01 years) are:

Scenario a	fast prerecruitment growth	$L_{\infty} = 65.05$	$K = 0.52$	$t_0 = -0.12$
Scenario b	slow prerecruitment growth	$L_{\infty} = 71.2$	$K = 0.317$	$t_0 = -0.047$
Scenario c	very slow prerecruitment growth	$L_{\infty} = 76.99$	$K = 0.21$	$t_0 = -0.019$

The growth curves are shown in Fig. 7.

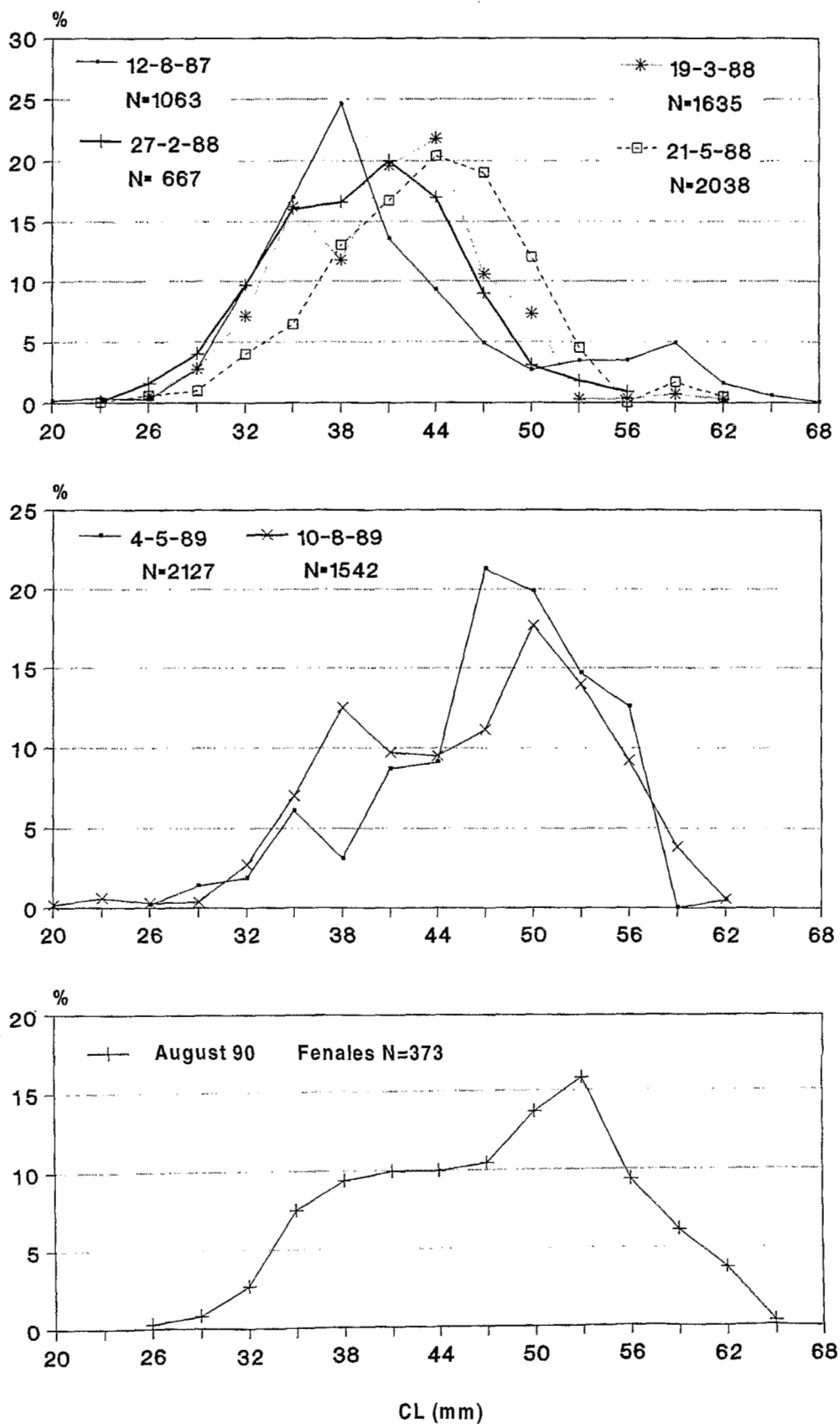


Fig. 6. Growth of the 1987 cohort in Portofino area (from Orsi Relini and Relini, 1996).

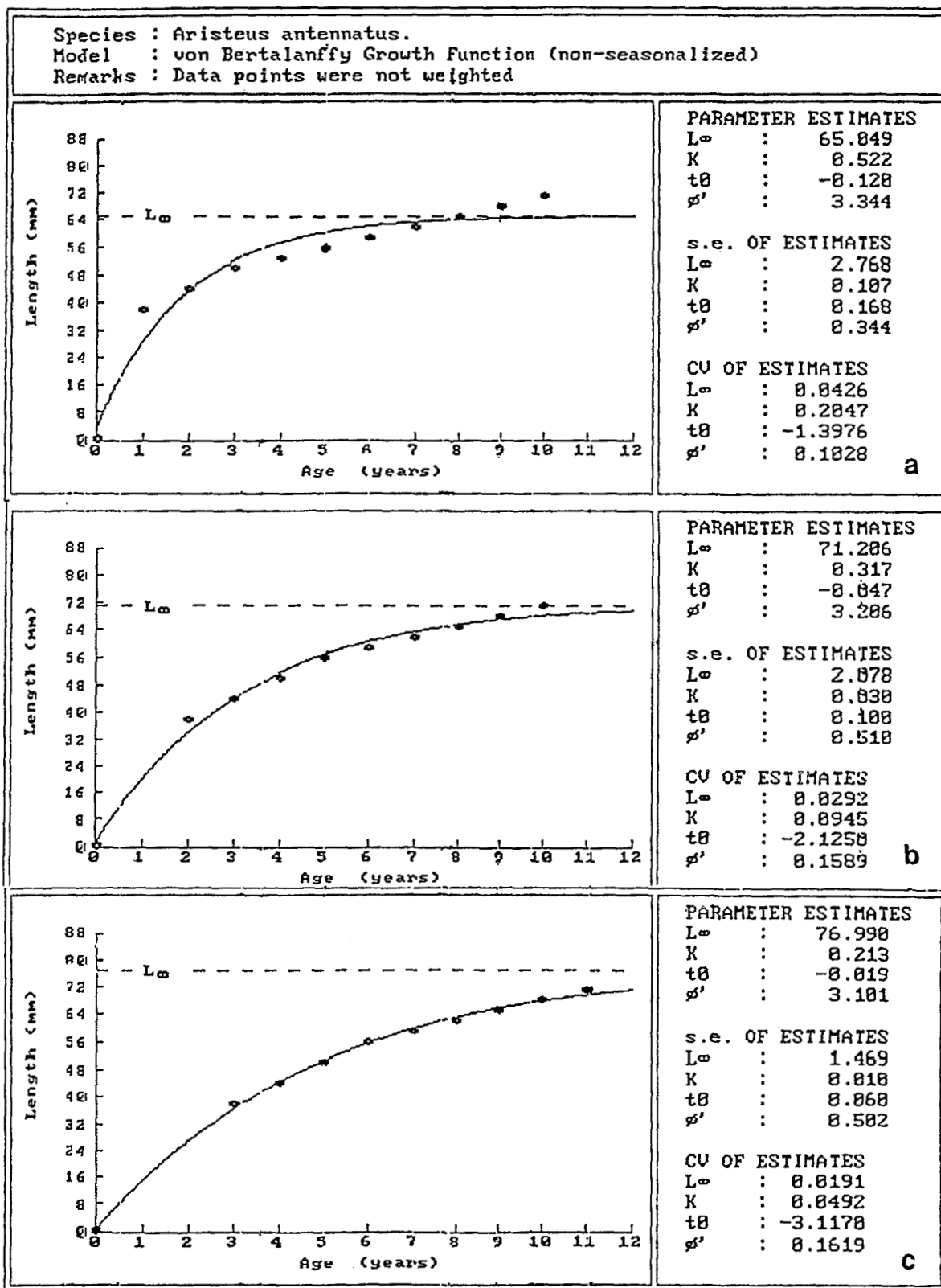


Fig. 7. Growth curves for three scenario a (fast prerecruitment growth) b and c = (slow and very slow prerecruitment growth) (from Orsi Relini and Relini, 1996).

Evolution of the structure of the fished stock 1987-1996

Commercial catches reached a maximum in 1988 and in the following years showed a slow decline.

The demographic structure of the catches, considered on an annual basis, was dominated for years by small sizes, corresponding to 25-45 mm CL, i.e., appeared very similar to those registered in the eighties off the Catalan coast (Fig. 2 and Fiorentino *et al.*, this volume, Fig. 4).

The present size structure recorded in August on Portofino fishing grounds for sake of comparison with the temporal series of Fig. 4, is shown in Fig. 8. The importance of large sizes is increased, in respect of the 1987, with a balance between shrimps smaller and larger of about 43 mm CL. However the largest size is only 61 mm CL. Other samples have been examined in the last days preceding the present Dynpop Session (total N = 1,400), with the recording of one individual of 63 mm CL. Apparently nine years, elapsed from 1987 recruitment, were not sufficient to reach the maximum sizes of the eighties. Probably the increased fishing effort has a part in reducing the individuals of advanced ages.

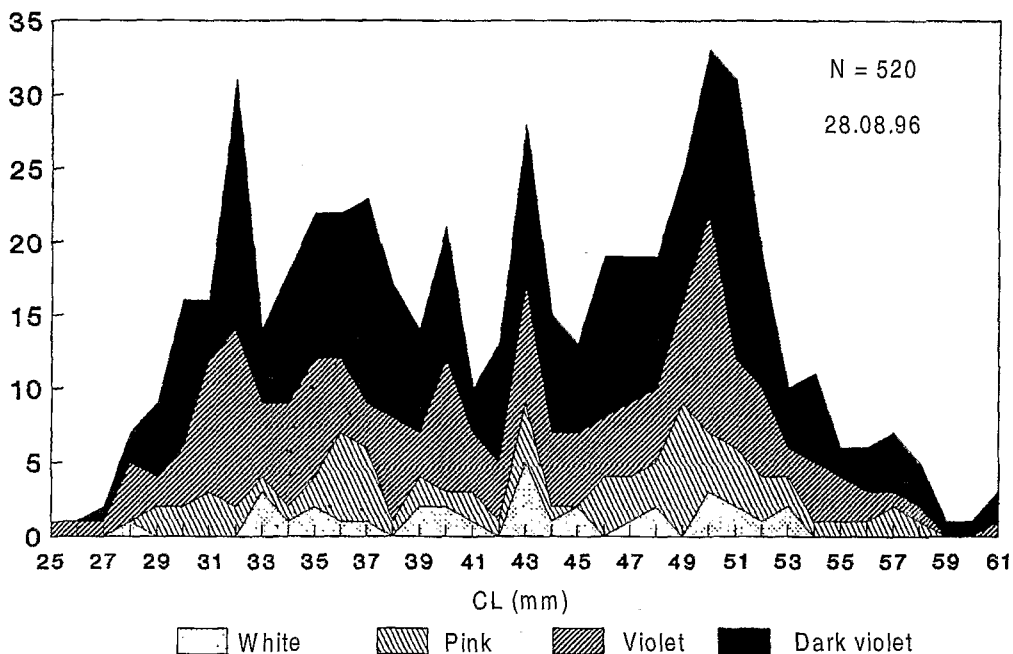


Fig. 8. Up to date length-frequency distribution recorded in August on Portofino fishing grounds.

Conclusive remarks

The long temporal series of l/f distributions registered in the Portofino area suggests some remarks.

A. antennatus is a species with a long life span whose growth from 38 to 53 mm CL lasts 3 years. Different scenarios can be suggested for the previous and following segments of life; in any case the maximum life span is at least about 9 years.

The scenario of early fast growth seems to be unrealistic. If it is accepted that 1987 recruits were two years old or more, this means admitting the possibility of large migrations of *A. antennatus*, as observations of fishing activities had previously suggested (Orsi Relini *et al.*, 1986; Orsi Relini and Relini, 1986).

It is interesting to note that the 1987 recruitment brought into the Gulf of Genoa the same kind of shrimps (in terms of size range and reproductive season) which had apparently been characteristic of Sicily, Sardinia and Catalonia (Sardà, 1989).

Thus, the difference in size which previously appeared to be connected to a latitudinal gradient now proved to be linked rather to a temporal factor. In a given area the size-structure of the fished stock can slowly evolve from small to large (probably as long as fishing pressure is not too heavy). This kind of evolution seems due to the combined effect of decreasing recruitment (Fiorentino *et al.* this volume) and long life span. At present, nine years after the 1987 recruitment, the size structure of fished stock includes specimens with 63 mm CL as a maximum. Recruitment seems to be the most important factor in the success of fishery; unfortunately in the present study area it is also the most aleatory.

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Addendum

Mura, Orrù and Cau have recently (1997) published a note about juvenile growth of *A. antennatus*. In length/frequency distributions of shrimps smaller than 24 mm CL, trawled on Sardinian fishing bottoms, they recognized two cohorts and followed their growth month by month, in a period of one year. Their conclusion is that sexual maturity may be achieved both by females of 20 mm CL, whose age is about 13 months in August (this is the first cohort), and by females of 24 mm CL, whose age is about 2 years in July-August (the second cohort).

This interpretation of juvenile growth gives support to our hypothesis of a very slow pre-recruitment growth.

Mura M., Orrù F. and Cau A. Osservazioni sull'accrescimento di individui in fase pre-riproduttiva di *Aristeus antennatus* e *Aristaeomorpha foliacea*. *Biol. Mar. Medit.*, 4 (1): 254-261.