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Trawl gear selectivity on the deep-water rose shrimp (*Parapenaeus longirostris*, Lucas, 1846) in the Southern Tyrrhenian Sea (central Mediterranean)

Paola RINELLI[1], Daniela GIORDANO[1], Francesco PERDICHIZZI[1], Silvestro GRECO[2] and Sergio RAGONESE[3]
(1) *Istituto Sperimentale Talassografico- Section of Messina of IAMC-CNR, Sp. San Raineri, 86 - 98122 Messina, Italy, fax +39 090 669007; e-mail: paola.rinelli@iamc.cnr.it*
(2) *Istituto Centrale per la Ricerca Scientifica e Tecnologica Applicata al Mare (ICRAM), Via di Casalotti 300 00166 Rome, Italy*
(3) *Istituto di Ricerche sulle Risorse Marine e l'Ambiente (IRMA)- Section of Mazara of IAMC- CNR, Via L. Vaccara 61- 91026 Mazara del Vallo (TP), Italy*

Abstract: The deep water rose shrimp, *Parapenaeus longirostris* (Lucas, 1846), is one of the main target species of the Italian and Mediterranean demersal fisheries. In the Southern Tyrrhenian Sea, it represents one of the most valuable species for fishery markets. The exploitation pattern for this shrimp in the Southern Tyrrhenian area, however, has not been defined within a management plan; for example, according to the administrative autonomy of Sicily concerning fisheries regulations, fishermen have been allowed to mount a very fine diamond mesh size in the cod-end (31-36 mm stretched) in the past. Nowadays, Sicily is going to conform to the European Union legislation requirement of a minimum stretched mesh size of 40 mm in the cod-end of the trawl net, but no study has been performed to assess the selectivity performance of the rose shrimp fishery in the investigated area. The aim of this paper is to contribute to the exploitation control of this important resource, by analysing the used trawl gear cod-end selectivity, an important tool for the management of the commercial demersal resources. A selectivity experiment, using the "covered cod-end technique", was carried out in the Southern Tyrrhenian Sea. Fifty-four hauls were carried out between 10 and 800 m of depth from a commercial vessel equipped with the "Italian Tartana" commonly used for both commercial fishery and experimental survey in this Mediterranean area. 36 and 20 mm diamond (stretched) mesh size were mounted in the cod-end and a cover respectively. On the basis of shrimp carapace length structure, observed both in cod-end and cover, a logistic model was used in order to estimate the retention length at 50%, the selection factor and the selection range. The selection process showed to be highly affected by the bottom location, in the shelf and in the slope. In any case, present selection performance seems to be inadequate for a sustainable and efficient exploitation of the resources. However, The selection parameters obtained were comparable to those found in other Mediterranean and Atlantic areas.

Résumé : *Sélectivité de capture de la crevette rose de profondeur* Paraneaeus longirostris *(Lucas, 1846) dans le sud de la Mer Tyrrhénienne (Méditerranée centrale)*. La crevette rose de profondeur *Parapenaeus longirostris* (Lucas, 1846) est une des principales espèces cibles des pêcheries démersales méditerranéennes, notamment italiennes. Dans le sud de la Mer Thyrrhénienne, elle représente une des espèces les plus nobles des marchés. Le schéma d'exploitation de cette crevette en Mer Tyrrhénienne n'a toutefois pas été défini dans un plan de gestion ; par exemple, en raison de l'autonomie administrative de la Sicile pour la régulation des pêches, les pêcheurs ont eu dans le passé la possibilité d'utiliser une maille très fine (31-36 mm étirée). Actuellement, la Sicile se conforme à la législation de l'Union Européenne qui exige une maille minimum de 40 mm étirée, mais aucune étude n'a été réalisée pour tester la sélectivité de la pêcherie de crevette rose dans cette

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zone. L'objectif de ce papier est de contribuer au contrôle de l'exploitation de cette ressource importante, en analysant la sélectivité de l'engin de pêche, un outil important pour la gestion des ressources démersales commerciales. Une expérience de sélectivité, au moyen d'une maille de recouvrement supplémentaire, a été menée dans le sud de la Mer Tyrrhénienne. Cinquante quatre traits ont été réalisés entre 10 et 800 m de profondeur à bord d'un bateau professionnel équipé de l'*Italian Tartana*, communément utilisé à la fois pour les pêches commerciales et pour les pêches expérimentales dans cette partie de la Méditerranée. Des mailles de 36 mm et 20 mm (étirées) ont été montées respectivement pour le cul du chalut et la nappe de recouvrement. A partir des structures de taille (longueur de carapace) observées sur les deux mailles, un modèle logistique a été développé pour estimer la taille de capture à 50%, le facteur de sélection et la sélectivité. La sélection des tailles est fortement affectée par la localisation, sur le plateau continental ou sur le talus. Dans tous les cas, la sélectivité observée semble incompatible avec une exploitation rationnelle et durable des ressources. Toutefois, les paramètres de sélectivité mesurés sont comparables à ceux trouvés dans d'autres régions de Méditerranée et d'Atlantique.

Keywords: Trawl net selectivity, *Parapenaeus longirostris*, Deep-water rose shrimp, Southern Tyrrhenian Sea

Introduction

The deep water rose shrimp *Parapenaeus longirostris* (Lucas, 1846) is one of the most important commercial shrimp in the Italian seas. *P. longirostris* lives between 20 and 700 m of depth throughout the Mediterranean, but it is more common and abundant on sand-muddy bottoms between 100 and 400 m (Relini et al., 1999). The size structure and the sex ratio of the exploited population, related to the depth were described (Ribeiro-Cascahlo & Arrobas, 1987; Ardizzone et al., 1990; Spedicato et al., 1996; Relini et al., 1999; Rinelli et al., 2000). On the deepest grounds, the largest specimens are more abundant and the males are dominant. Although mature females are caught all over the year (Levi et al., 1995), the reproduction starts in spring and the full maturity is reached during autumn and early winter (Spedicato et al., 1996; Relini et al., 1999). A continuous recruitment characterizes this species, although peaks were detected in some areas (e.g. in the Central-Southern Tyrrhenian Sea this occurs mainly in autumn; Lembo et al., 2000).

The aim of this paper is to contribute to the management of this important resource in this Mediterranean area, where two gulfs are already closed to trawl fishery, the Gulf of Patti and the Gulf of Castellammare, closed since 1990 above 500 m of depth (D'Anna & Badalamenti, 1995; Pipitone et al., 1996).

The exploitation pattern of the rose shrimp in the Southern Tyrrhenian area, however, has not been defined within a management plan; for example, according to the administrative autonomy of Sicily, concerning fisheries regulations, fishermen have been allowed to mount a very fine diamond mesh size in the cod-end (31-36 mm stretched) in the past. Nowadays, Sicily is going to conform to the European Union legislation (1994) requirement of a minimum stretched mesh size of 40 mm in the cod-end of the trawl net, but no study has been performed to assess the selectivity performance of the rose shrimp fishery in the investigated area.

In fact, one of the most useful tool for management of the shrimps exploitation is the selectivity of the trawl net. The effects of mesh size changes are very important for the deep-water rose shrimp as demonstrated by several research studies (Belveze et al., 1981; Nouar, 1985; Sobrino et al., 2000). Most of them have been conducted in the Mediterranean and in the Atlantic Sea to assess the trawl selectivity within shrimp fisheries (Vendeville, 1990; Ragonese et al., 2001; Ragonese et al., 2002), but not in the Northern coasts of Sicily.

The selection process can occur in every part of the net, but it is commonly accepted that it mainly takes place in the cod-end, where the specimens are conveyed during the trawl. For this reason, the method "covered cod-end technique" (Pope et al., 1975), was chosen for an experimental survey carried out during 1997 in the Southern Tyrrhenian Sea to test the selectivity of an "italian gear" commonly used for commercial shrimp fisheries in the Mediterranean Sea. The trawl surveys were carried out within the GRUND project (Evaluation of Demersal Resources in the Italian seas) funded by the Italian Ministry of Agricultural Policy.

The results of selectivity experiments were analysed to determine the retention length at 50% ($L_{50\%}$), the Selection Range (SR) and the Selection Factor (SF) of the deep-water rose shrimp.

Materials and Methods

During October 1997, 54 hauls were carried out in an area of the Southern Tyrrhenian Sea (Fig. 1), located between Capo Suvero (Calabria) and Capo San Vito (Sicily), between 10 and 800 m deep (Greco et al., 1998). A commercial vessel "Papà Carmelo" of 43 of GT and 300 Hp engine, equipped with a "traditional" commercial net having 36 mm of stretched mesh size (cod-end) was used (Fiorentini et al., 1998). A cover of 20 mm of mesh size was used, in each haul, for the selectivity experiments.

All specimens collected both in the cod-end (IN) and in

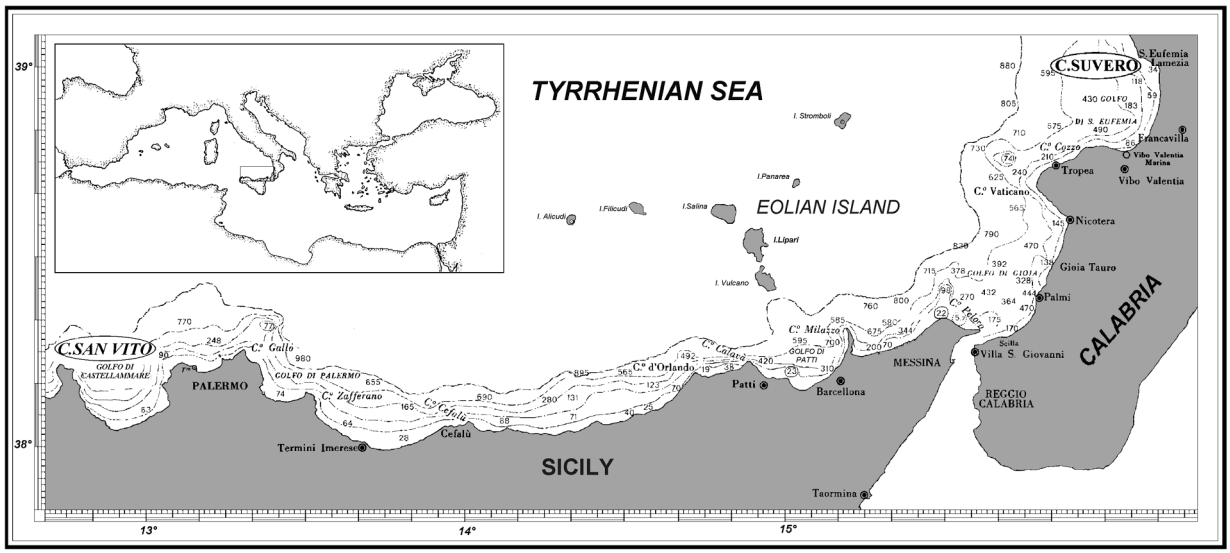

Figure 1. *Parapenaeus longirostris*. Study area. Capo Suvero and Capo San Vito represent the western and eastern limits (Depth record in m).

Figure 1. *Parapenaeus longirostris* Zone d'étude Capo Suvero et Capo San Vito représentent les limites occidentales et orientales (profondeur maximale en m).

the cover (OUT) were measured on board. The oblique length of the carapace (CL), from the posterior orbital sinus to the internal posterior margin of the carapace, was recorded with a watch calliper, to the nearest millimeter.

According to the depth range of the species in the Mediterranean Sea (Ardizzone et al., 1990; Relini et al., 1999; Rinelli et al., 2000), no rose shrimp was caught between 10 and 50 m of depth as well as in bottom deeper than 500 m.

Consequently, used data were divided in shelf (50-200 m) and slope (200-500 m) ones which were expected to show different features. These two bathymetrical macrostrata (shelf and slope) were interesting because of potential interactions between standing population and the gear. In order to assess any possible shelf-slope effect, the Length Frequency Distribution (LFD) for both cod-end and cover were analysed for both "macrostrata". In order to obtain an overall representation of the selection process and to facilitate a comparative analysis, however, the analysis was also performed on the whole bathymetrical range (50-500 m).

The hypothesis of the homogeneity between macrostrata was tested (p = 0.05) by a Kolmogorov-Smirnov (on the LFD) and a χ^2 tests (on the expected and observed "Selection Ratio", defined as 100 x OUT/(IN + OUT), which represents a rough index of the ability of the species to escape from the gear). For the second test in particular, the overall selection ratio was used to calculate the expected selection ratio in both macrostrata, hence the expected number of escaped specimens were compared with the corresponding observed values.

The probability of retention for each size class (p_L) was calculated as the ratio between the number of specimens (sex combined) collected in the cod-end and those collected in total (cod-end + cover).

Trawl selectivity was modelled using the logistic curve according to the following expression:

where p_{Li} is the retained proportion for each length class

$$pLi = \frac{\exp(a + bLi)}{1 + \exp(a + bLi)}$$

(L_i), a and b are the intercept and slope coefficients, respectively, after the logit linear transformation (Pope et al., 1975).

The fit was done following a maximum likelihood function, using logit coefficients as seed-values; in particular, all calculations were done using an "ad hoc" EXCEL worksheet (Leonori & Fiorentini, 1998). The following parameters were estimated by "macrostratum" and the overall investigated area as previously defined: length at first capture ($L_{50\%}$), Selection Range (SR= $L_{75\%}$- $L_{25\%}$), and Selection Factor (SF= $L_{50\%}$ / cod-end mesh size).

To further characterize the distribution pattern of the investigated populations and take into account the incidence of the gear selection on the "recruits", the ratio juveniles/adults was computed by macrostratum and overall, by

Table 1. *Parapenaeus longirostris*. Number of positive hauls, number of specimens retained (IN) and escaped (OUT), ratio juveniles /adults (J/A), Selection Ratio (100 x OUT /[IN + OUT]), range of size and mean carapace length (CL) of the specimens collected in the cod-end and cover.

Tableau 1. *Parapenaeus longirostris*. Nombre de traits efficaces, nombre de specimens retenus (IN) et non retenus (OUT), proportion juvéniles/adultes (J/A), Sélectivité (100 x OUT/[IN + OUT]), gamme de taille et taille moyenne de la longueur de carapace (CL) des individus récoltés sur les deux mailles.

	N° of positive hauls	N° cod-end (IN)	N° cover (OUT)	J/A	Sel. Ratio %	Range of size (CL) cod-end mm	Range of size (CL) cover mm	Mean CL cod-end mm	Mean CL cover mm
Shelf	15/28	2007	395	9.90	16.4	8.5-34.5	5.5-19.5	20.5	11.2
slope	13/26	3809	268	1.60	6.6	11.5-42.5	8.5-20.5	25.7	15.8
overall	28/54	5816	663	2.62	10.2	-	-	23.9	13.0

setting a size at sexual maturity of 26 mm of CL as threshold below which shrimps are considered "juveniles" (Lembo, 2003).

Results

Over the 54 hauls carried out in all bathymetrical range, 28 were positive for the rose shrimp; all were located between 50 and 500 m, the typical depth range of the Mediterranean population (Relini et al., 1999). The number of retained (cod-end) and escaped (cover) specimens, as well as the positive hauls number for shelf, slope and overall, are reported in Table 1. On the whole, 6479 specimens of rose shrimp were collected, 5816 in the cod-end and 663 in the cover.

Both the sample length structure (LFD, Fig. 2a) and the rough selectivity results (Tab. 1) evidenced some differences in the selectivity process between the two macrostrata. Concerning the LFD, in spite of a similar shape, the juveniles (5-15 mm) were more represented in the first than in the second macrostratum, whereas the opposite was observed for the largest individuals (> 20 mm), which were totally retained by the used cod-end whatever the depth considered. A special remark deserves the middle size animals (15-20 mm); they showed a higher probability to escape in the second than the first macrostratum. The Selection Ratio, however, was 16.4% in the first and 6.6% in the second macrostratum *vs* an overall value of 10.2% (Table 1). The different presence of juveniles (most of them were able to escape) and behaviour of the middle size shrimps (which escaping ability was higher in the second macrostratum) might explain the mean length increase from the first to the second macrostratum: from 20.5 to 25.7 mm and from 11.2 to 15.8 mm of CL, for cod-end and cover respectively (Table 1).

The significance of the differences in both length structure and overall selection process was confirmed by the Kolmogorov-Smirnov (observed D = 0.536 versus critical D value of 0.035; $p < 0.05$) and χ^2 (16.45; $p < 0.05$) tests.

Concerning the selection by size estimates (Fig. 2b), it is worth to note a better correspondence between the observed p_{Li}, and the fitted logistic points in the shelf than in the slope.

The values of length at first capture ($L_{50\%}$), Selection Range (SR) and Selection Factor (SF), with the relative standard error (s.e.), obtained by maximum likelihood, are reported in Table 2. The length at first capture was higher on the slope (16.7 mm) than on the shelf (13.2 mm). The SR was quite similar in the two macrostrata (about 3.0 mm). Finally the SF was 0.37 on shelf and 0.46 for the deeper stratum (Table 2).

The overall selection parameters values ($L_{50\%}$ = 14.1 mm; SR = 4.0 mm; SF = 0.39) remained comparable to those observed in the Central Tyrrhenian Sea and in the Ionian Sea (Lembo et al., 2002), except for the SR which resulted higher (4.0 mm *vs* 2.9 and 2.4 mm, for the first and second zone respectively).

Finally, the ratio between juveniles (CL < 26 mm, Lembo, 2003) and adults (Table 1) detected higher values on the shelf (9.90) than on the slope (1.60).

Discussion

The selection process in a given gear is the result of many

Table 2. *Parapenaeus longirostris*. Length at first capture (L50%) and Selection Range (SR) with standard error (s.e.), Selection Factor (SF), derived through maximum likelihood procedure.

Tableau 2. *Parapenaeus longirostris*. Taille médiane de capture (L50%) et Sélectivité (SR) avec erreurs standards (s.e.), Facteur de sélection (SF), estimés par le maximum de vraisemblance.

	L50% max lik.	L50% s.e.	SR max lik.	SR s.e.	SF max lik.
shelf	13.2	0.14	3.0	0.15	0.37
slope	16.7	0.15	3.1	0.16	0.46
overall	14.1	0.13	4.0	0.14	0.39

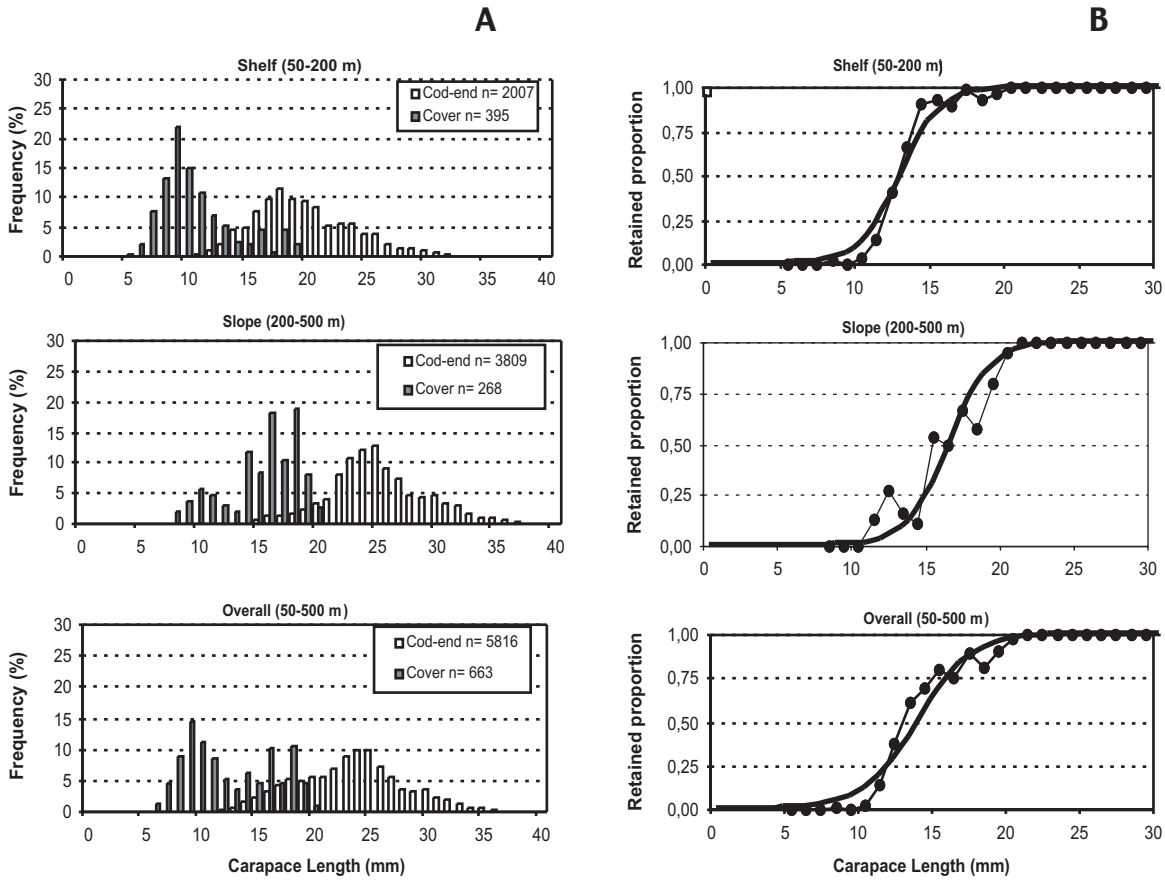

Figure 2. *Parapenaeus longirostris*. **A.** Length Frequency Distribution of sampled *P. longirostris* which evidenced the retained (cod-end: 36 mm mesh size) and escaped (cover: 20 mm mesh size) fractions. **B.** Observed (circles) and estimated (continuous line) individuals retained proportions as a function of individual size.

Figure 2. *Parapenaeus longirostris*. **A.** Distribution des fréquences de taille des individus échantillonnés mettant en évidence les fractions retenues (cul de chalut de 36 mm de maille) et non retenues (maille superposée de 20 mm de maille). **B.** Proportion observée (points) et estimée (courbe) d'individus retenus en fonction de la taille.

interaction factors such as gear geometry and performance, bottom topography (MacLennan, 1992) and the composition and size structure of both the investigated population and the assemblages encountered by the gear (Petrakis & Stergiou, 1997; Stergiou et al., 1997).

For the deep water rose shrimps, in particular, characterized by a short life span (2-3 years) and a high adult mortality (Sobrino et al., 2000), it is important to include in the analysis of any selectivity experience the likely changes of the LFD by depth. The increase of lengths related to greater depth is a well known phenomenon for the exploited deep-water rose shrimp populations in the Mediterranean (Ardizzone et al., 1990; Relini et al., 1999; Rinelli et al., 2000).

One interesting result of the present paper, however, consists in having highlighted the presence of a sensible fraction of specimens bigger than 26 mm at depth lower than 100 m. Mainly present analysis has evidenced two aspects. First of all, there is a high overall similarity with other selectivity experiences, realised for the same species in other Mediterranean (Lembo et al., 2002) and Atlantic (Pestana & Ribeiro-Cascalho, 1991; Sobrino et al., 2000) areas: both the $L_{50\%}$ (14.1 mm) and SF (0.39) are very similar to those presented in literature. In particular, these SF values are in accordance to those obtained in Central (0.36) and Southern (0.39) Tyrrhenian Sea.

On the second hand, significant differences on the selectivity of the trawl net were observed at different bathymetrical levels. These "bottom level related effects" may raise some perplexities at a first step; in fact, any unique judgment about the cod-end performance seems to be difficult: the Selection Ratio is higher on the shelf than on the slope, but the opposite occurred for the size at first capture. As a

matter of fact, the contradiction is only apparent, if the different LFD structure (*i.e*. juveniles are more abundant in the shelf) and bionomic features of the bottom (shelf bottoms are more heterogeneous than the slope bottoms as concerns the biogenesis) are taken into account. Consequently, it is likely that the high presence of juveniles and more heterogeneous assemblages determine a higher cod-end "saturation" in the shelf than in the slope, resulting also in a minimization of the escaping probabilities for the middle size shrimps.

On the basis of the previous interpretation, the used cod-end performs better in the slope than in the shelf likely as a consequence of a complex interaction between the gear, species and assemblages features. Whatever the interaction was, however, the better "selectivity" must be considered with caution. In fact, it is still not adequate since even the "best" $L_{50\%}$ estimation (16.7 mm), obtained for the fraction of the population exploited in the slope, remains lower than the size at sexual maturity (26 mm) recorded in the same area (Lembo, 2003).The results obtained in the present and other related papers indicate that, in order to achieve a more sounding exploitation pattern of the resource, the mesh in use (36 mm) in the investigated area should be increased to about 48-56 mm, i.e.15- 20% over the proposed European Union legal mesh size (40 mm) to obtain a length at 50% near or equal to length of maturity of this species (26 mm, Lembo, 2003), at least in the slope bottoms where mature females are more abundant.

Such an increase of mesh size, which cause an immediate economic loss for fisheries harvesting penaeids, must be introduced gradually considering that the deep-water rose shrimps are short life span and fast growing species (Sobrino et al., 2000).

As concern the shelf bottoms, such a change should be considered with more caution, given the technical (i.e. small sized vessels) and multispecies (i.e. fishermen tend to exploit a mix of heterogeneous valuable animals) features of the Mediterranean fisheries (Caddy, 1990). For these bottoms, the adoption of the legal mesh (40 mm) might represent the best temporarily solution, postponing the decision about any further increase when a new "equilibrium" will be achieved.

Stressing that the change of mesh size must be considered as only one plausible technical tool to be implemented within a more complex management plan, the enforcement of two different mesh size by shelf and slope bottoms for the deep rose shrimp might appear as a non practical solution, but it is coherent with an adaptive management in which the spatial heterogeneity of both the fishery activities and the related exploited resources is taken into account in the attempt to achieve a more sounding sustainable exploitation pattern.

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