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GROWTH OF *SCORPAENA ELONGATA* CADENAT, 1943 (*Osteichthyes Scorpaenidae*) IN THE STRAIT OF SICILY (MEDITERRANEAN SEA) BY USING BACK CALCULATED AND INDIVIDUAL SIZE AT AGE

SUMMARY

Age of *Scorpaena elongata*, Cadenat, 1943, of the Strait of Sicily (Central Mediterranean Sea) was investigated using sliced otolith and back calculation analysis. Specimens ranging from 100 to 550 mm total length (TL) were gathered during experimental surveys carried out in the Strait of Sicily (1985 – 1987). A total of 82 otoliths were analysed. Fish (TL) – whole otoliths (OL) length relationship were computed resulting in no sex related differences. The sliced otoliths showed only one consistent false ring (check) associated to the settlement phase. The zones (age related rings) resulted to be well discernible in the first years (5-8 years), more packed thereafter and stacked at the edge of the slice. The distance between each zone's edge and the core was measured by applying the Optimas image plus software and size at age backcalculated in fish and otoliths lower than 370 mm TL and 15 mm OL, respectively, given the disharmony in otoliths. Back calculated (0.5-8.5y) and individual (9.5-30.5y) size at age classes were interpolated according to the von Bertalanffy Growth Formula. On the base of the resulting parameters (TL_∞ = 561.2mm; ky^{-1}= 0.090; t_0= -0.92y) *S. elongata* conforms to the "*Sebastes* deep life history pattern", i.e., quick growth rate in the first phase of life, slow growing thereafter and high longevity.

RIASSUNTO

Crescita di Scorpaena elongata*, Cadenat, 1943, (Osteichthyes Scorpaenidae) dello Stretto di Sicilia integrando stime derivate con il retrocalcolo ed individuali.* L'età di *Scorpaena elongata*, Cadenat, 1943, dello Stretto di Sicilia (Mediterraneo centrale) è stata analizzata sulla base di sezioni di otoliti e applicando tecniche di retro calcolo. 82 esemplari, di lunghezza totale compresa da 100 a 550 mm, sono stati campionati durante le campagne di ricerca con rete a strascico svolte nello Stretto di Sicilia fra il 1985 e il 1987. La relazione fra lunghezza del pesce e dell'otolite intero è stata calcolata per sessi combinati (non risultando differenze significative) e gli otoliti sezionati per la lettura degli anelli di accrescimento. Gli anelli appaiono ampi e ben distinguibili sino a 5-8 anni, ma poi divengono più impacchettati e difficili da individuare; il primo, vicino al nucleo è stato associato al momento dell'insediamento sul fondo. La distanza fra gli anelli e il nucleo è stata misurata tramitre il software Optimas image plus ed utilizzata per il retrocalcolo limitatamente ai pesci inferiori a 370 mm di lunghezza, data la discontinuità nella sezione dell'otolite. Le taglie retrocalcolate per classe di età (0,5-8,5 anni) sono state integrate con le stime individuali (9,5-30,5 anni) ed interpolate tramite la curva di crescita di von Bertalanffy. I risultanti parametri (TL_∞ = 561,2mm; ka^{-1}= 0,090; t_0= -0,92a) indicano *S. elongata* come conforme al pattern di vita dei *Sebastes*, cioè una crescita rapida nella prima fase di vita seguita da un rallentamento prolungato che si associa ad una elevata longevità.

INTRODUCTION

The family Scorpaenidae (Scorpionfish or rockfish) is represented by 14 species in the Mediterranean Sea (QUIGNARD & TOMASINI, 2000). Some species are endemic and are rarely caught (such as *Scorpaenodes arenai* Torchio, 1962), whereas others (such as *Pterois miles* Bennett, 1828, and *Trachyscorpia cristulata echinata* Koehler, 1896) are exotic intruders through the Suez Canal or the Strait of Gibraltar, respectively (RAGONESE & GIUSTO, 1999; FROESE & PAULY, 2007). However, the most common and valuable scorpenids for the Mediterranean small scale and bottom trawl fisheries are represented by *Scorpaena spp.* and *Helicolenus dactylopterus dactylopterus* (RAGONESE & REALE, 1992; RELINI *et al.*, 1999; MASSUTÍ *et al.*, 2001; FROESE & PAULY, 2007). All these rockfish are sedentary, slow-growing, long living and sensitive to high fishing pressure (BOMBACE & SARÀ, 1972; CAMPILLO, 1992; MASSUTÍ *et al.*, 2001; REÑONES *et al.*, 2001), although spatial heterogeneity might avoid stock collapse (cfr. RIBAS *et al.*, 2006). Exploited Mediterranean rockfish include also *Scorpaena elongata* CADENAT, 1943, a large (up 590 mm of total length, TL, DUCLERC, 1970) subtropical fish occurring from the Gulf of Cadiz down the coasts of Senegal and Mediterranean Sea (RELINI *et al.*, 1999; FROESE & PAULY, 2007). Recognised as "Slender rockfish", it occurs on muddy bottoms next to rocky outcrops, from the outermost edge of the continental shelf down to the upper slope, preferably between 100 and 700m of depth (DUCLERC & ALDEBERT, 1968; MARINARO *et al.*, 1970; RELINI *et al.*, 1999; FROESE & PAULY, 2007). In the past, the Slender rockfish was traditionally considered uncommon (although not rare) and almost exclusively associated with the Western Mediterranean (cfr. MAURIN, 1970). However, such a limited distribution mainly derived from misclassification with the congener *S. scrofa* (DUCLERC & ADELBERT, 1968) given that both historical (GFCM, 1970; SCACCINI *et al.*, 1970) and recent (ANONYMOUS, 1984; GOLANI, 1996) reports indicate a wider distribution of the species within the Mediterranean Sea. Although some literature exists on the biology and growth of the Mediterranean stocks of *Scorpaena* species and *Helicolenus d. dactylopterus* (RELINI *et al.*, 1999; MASSUTÍ *et al.*, 2001; MORALES-NIN, 2001), very scanty information is available for *S. elongata* (DUCLERC & ALDEBERT, 1968; DUCLERC, 1970; MARINARO *et al.*, 1970; RELINI *et al.*, 1999; RAGONESE *et al.*, 2003; RIZZO *et al.*, 2003; FROESE & PAULY, 2007). According to the available specific references, the most relevant biological traits of *S. elongata* can be summarized as follows: a) positive relation between mean size and depth (due to the shelf preference of juveniles); b) mean length reduction in the exploited grounds (Sicilian fishermen considered the size of rockfish in a trawl catch as a good index of local exploitation pressure; BOMBACE & SARÀ, 1972); c) slight prevalence of females on males (52-69% of sexed specimens); d) but with comparable size range (90-570; 95-565 mm; TL); e) slight negative length-weight allometry (b about 2.9) with no sex related difference; f) reproduction peak between summer (when females show a better condition) and the beginning of autumn; g) length at 50% of sexual maturity (TL_m) ranging from 290 up to 325 mm; and h) relatively slow growth according to the von Bertallanfy Formula ($TL_\infty \approx 530$ mm; $ky^{-1} \approx 0.10$). As concerns the otolith, in particular, both whole and sliced *sagittae* resemble the typical rockfish otolith features (MASSUTÍ *et al.*, 2001; MORALES-NIN, 2001): ellipsoid shape, well-defined, but not prominent rostrum, antirostrum divided from the rostrum by an inconspicuous excissura, well-defined core, clear *sulcus acusticus*, well discernible zones next to the core, which successively become more packed and stack at the outermost margin of the section (Fig. 1). For the otolith description refer to the recent publication of TUSET *et al.* (2008).

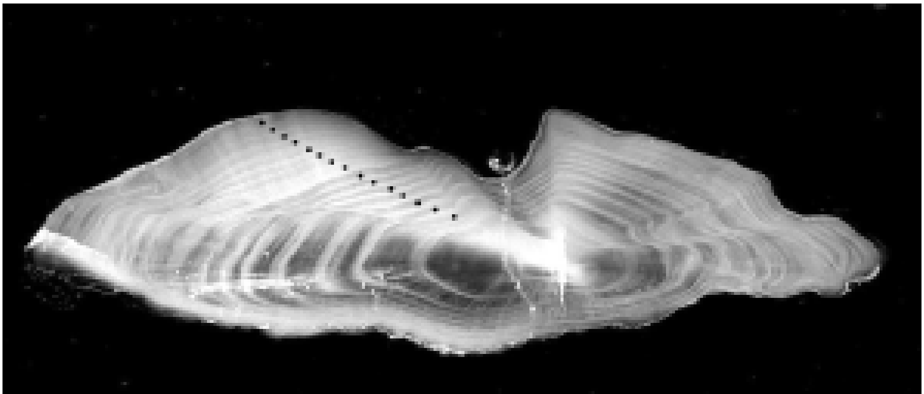

Fig. 1 — Otolith thin section of a male of *Scorpaena elongata* from the Strait of Sicily (TL=370mm), age class 17.5 years, with evidenced the zones close to the *sulcus acusticus*.

In the Strait of Sicily (Central Mediterranean Sea), noticeable captures (535 kg/km^2) of large sized *S. elongata* were gathered during the first experimental bottom trawl surveys carried on by the Institute of Mazara between 1985 and 1987 (Fig. 2; RAGONESE *et al.*, 2003). These captures occurred in limited spots close to rough bottoms, not yet exploited by fishermen since the limitation of the navigation equipment in use at that time; these hauls resulting in severe damage to the gear and were no further covered by experimental trawl surveys. A limited set of otoliths was taken from the fish sampled in the first two cruises and successively recovered for preliminary analysis (RAGONESE *et al.*, 2003; RIZZO *et al.*, 2003). Given the relevance of growth estimations, as a suitable index of resilience to fishing pressure, for species for which scanty information exists, the aim of the present note was to improve the preliminary von Bertalanffy Growth Formula (VBGF) estimates available by implementing back calculation technique (see FRANCIS, 1990; PANFILI *et al.*, 2002, for a general review) on the same set of "historical" otoliths.

Fig. 2 — Noticeable capture of *Scorpaena elongata* obtained during the first experimental bottom trawl survey carried out in the Strait of Sicily (26th May 1985). The haul was invalidated due to the severe damages incurred to the gear.

MATERIALS AND METHODS

Eightytwo left *sagittae* of *S. elongata* sampled in the Strait of Sicily between 1985 and 1987 exploratory bottom trawl surveys (RAGONESE *et al.*, 2003) were measured (0.01 mm) according to their total length (OL: from the anterior tip of the rostrum to the posterior projection); fish total length (TL; mm) and sex was also determined resulting in 61 females (100-550mm) and 21 males (105-550mm), respectively. Fish – otoliths linear length relationship (OL vs. TL) was performed according to the dummy variable approach (KLEINBAUM & KUPPER, 1978; pages 190-192) to evaluate any sex effect according to the model:

$$OL_{(i)} = a + b * TL_{(i)} + c * Z + d * (TL_i * Z)$$

where Z, c and d denote the dummy variable (related to the sex of fish, 0 and 1 for females and males, respectively), the parallelism coefficient and the intereaction coefficient, respectively. The *sagittae* were thereafter embedded in Implex resin and a thin (0.5 mm) transverse section cut through the primordium (otolith terminology and definition after the glossary in PANFILI *et al.*, 2002) with a Buhler® Isomet ™ low-speed saw using a double diamond blade. Sections were mounted on glass slides using thermoplastic cement and polished with n°3 allumina. Otolith sections were examined with reflected light under a dissecting microscope (25x) under a dark background, by reading the translucent rings on the proximal internal side along an axe next to the *sulcus acusticus*. A zone was considered "true" (i.e. age related) only when it was clearly distinguishable in both side of the sulcus, otherwise it was considered as a check, i.e. marks reflecting occasional stress or "ontogenig" crucial moments such as hatchling, settlement or spawning (RIJNSDORP & STORBECK, 1995; MORALES-NIN, 2001). "Blind" readings were independently performed twice by each author in successive times. In case of divergence, the same section was read again and the two new counts compared. In case of persistent divergence, the otolith was rejected and only those counts in fully agreement were maintained for the successive analysis. The distance between the outermost limit of the reading field in each section (otolith edge; OE) and each zone (Z_i) and the core was measured on the base of the image captured with a high resolution camera and processed by using the computer program Optimas image plus. Previous analysis (RIZZO *et al.*, 2003) have shown a discontinuity in the otoliths features starting in fish larger than 370-400 mm TL; OL vs. OE relationship reflected such a disharmony, and consequently only the relationship related to fish less than 370 mm TL was used to perform the back calculation; in particular, the scale proportional hypothesys (SPH) and

Hile's formula (BCF) were adopted (FRANCIS, 1990; 1995; COLLOCA *et al.*, 2003) resulting in the following BCF:

$$TL_i = -\left(\frac{a}{b}\right) + \left[\left(TL_c + \frac{a}{b}\right) * \left(\frac{R_i}{R_c}\right)\right]$$

where TLi is the fish length at the formation of the i zone or check, TLc is the fish length at the time of capture, Ri is the distance of the zone or check n from the core, Rc is the otolith edge at the capture, a and b are the slope and the intercept of the fish length–otolith edge relationship. Neither validation of periodicity of zone deposition nor marginal increment analysis (FRANCIS, 1995; CAMPANA, 2001; PANFILI *et al.*, 2002) was available for *S. elongata* (even from the data set at hand given the low number of otoliths by season and measured specimens). Putative age classes were hence assigned assuming that one zone would be deposited each year, as the general case for other Mediterranean deep fish (MASSUTÍ *et al.*, 2000; MORALES-NIN, 2001). Back calculated and individual size at ages were combined and used to estimate, by implementing the Solver routine in Excel, the von Bertalanffy growth formula (VBGF) parameters (TL_∞, ky^{-1}, and t_{oy} defined according to FRANCIS, 1995). Goodness of fit of the considered models was assessed on the base of the determination coefficient (r^2), mean square error (MSE) value and analysis of residual plot.

RESULTS

The overall otolith length-fish lenght plot looked linear although some heteroscedasticity was appreciable at the rightmost side of the plot. Both H0: d=0 (intereaction test) and H0: c=0 (parallelism test) were not rejected (p=0.355 and p=0.416, respectively) showing no significant difference between males and females. The combined linear fit was OL=3.44043+0.02911*TL (N=81; r^2=0.962; MSE=0.435). OE vs OL plot reflected the disharmony previously described, hence, the linear fit was hence successively repeated by excluding otoliths of large fish starting from 400 mm towards the smaller size class. The best linear fit was achieved for TL < 370, OL < 15, and OE < 1.02 mm; in this range, OL and OE resulted higly linear related (r^2= 0.99); the final coefficients used to derive the BCF were OL=2.90667+0.03146*TL (N=60; r^2=0.96; MSE=0.228). As concerns the microstructure interpretation, no regular check was identified with the exception of the 1st wide translucent ring next to the core, which was assumed to represent the "settlement" (or "demersal") check also according to the smallest specimens ever recorded in the Mediterranean (40-60 mm TL; DUCLERC, 1970). The fish size corresponding to the settlement check and each "zone" was back calculated and the resultant descriptive statistics estimated and presented in Table 1, togheter with the individual specimens estimates used to integrated the growth curve fit. The combined (i.e. back calculated and individual fish) size at age plot is represented in Fig. 3; the Solver routine converged consistently on VBGF estimates of 561.2mm, 0.09 and -0.92 for TL_∞, ky^{-1}, and t_{oy}, respectively (N=273; MSE=1009.6).

DISCUSSION

In spite of the available information, sliced otoliths analysis and back calculation methodology revealed to be useful to improve the growth estimation of *S. elongata* of the Strait of Sicily and, contemporarily, to attempt some comparisons with the other related Mediterranean and Atlantic rockfish. First of all, it is worth remarking the contrast between the linear correspondence of fish length and whole otolith length *versus* the discontinuity in the other otoliths features in fish larger than 370mm of TL (RIZZO *et al.*, 2003). Large otoliths, in fact, are very robust and show a thickening pattern, likely as consequence of deposition of additional material in the internal surface during the late growth life phase as evidenced also in other rockfish (CHILTON & BEAMISH, 1982; ECHEVERRIA, 1987; NEDREAAS, 1990); this otolith growth pattern supports the choice, in the present paper, of the *sulcus acusticus* as the elective field to detect the zones (CHILTON & BEAMISH, 1982).

Also the "discontinuity" evidenced by the microstructure analysis, i.e. the abrupt decrease in the thickness of the opaque increments after some

Table 1

Descriptive statistics of size (total length, TL, mm) at age class (year) estimated after back calculation (a) and individual ageing (b) of Scorpaena elongata *from the Strait of Sicily. N, M and V denote number of cases, mean TL and corresponding coefficient of variation (sd/M%), respectively. The following single individual length at age estimates were not included in the table for the insufficient room: 410 (12.5), 475 (13.5), 535 (27.5), 550 (29.5), and 550 (30.5).*

	Age class (year)																
St	a) Back calculated estimations									b) Individual estimations							
	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	14.5	15.5	18.5	20.5	21.5
N	37	37	37	36	34	23	14	12	5	6	3	7	2	3	2	3	2
M	55	117	157	188	217	248	279	297	311	320	330	358	453	415	493	483	468
V	33	21	19	18	18	17	14	11	8	5	10	6	2	10	5	1	13

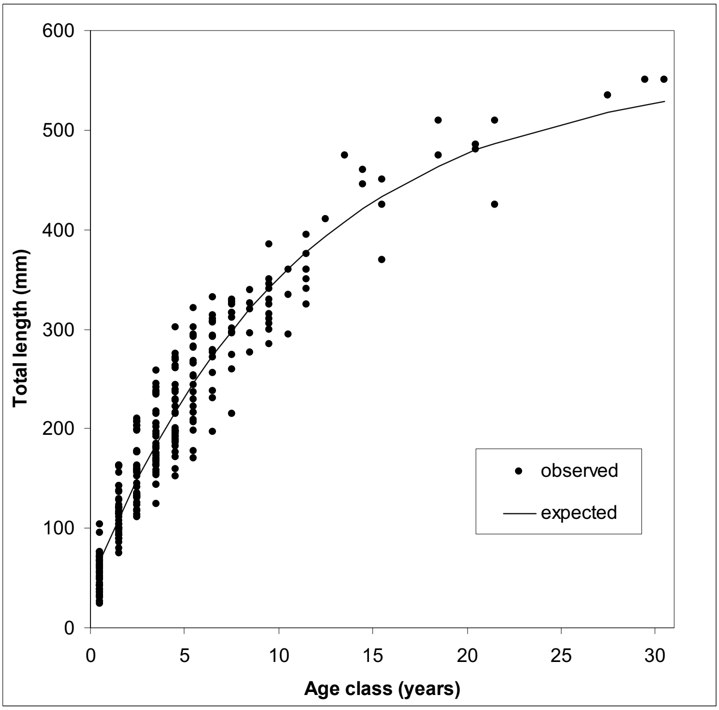

Fig. 3 — Size at age plot with overimposed the von Bertalanffy Growth Formula (VBGF) fit for *Scorpaena elongata* (sex combined) by pooling individual and back calculated size at age group. The estimated parameters were: TL∞ = 561.2mm; ky^{-1}=0.090; t_{oy}=-0.92 (N=273; MSE=1009.6).

zones laid down next to the core, has been already described in other Mediterranean deep water scorpenids (cfr. MASSUTÍ *et al.*, 2000; ABECASIS *et al.*, 2006) and related by some Authors (for example, MASSUTÍ *et al.*, 2000) to the onset of sexual maturity. Available length at 50% of sexual maturity (TL_m) for *S. elongata* (290–325 mm TL; RAGONESE *et al.*, 2003; FROESE & PAULY, 2007) might be coherent with the hypothesys that otolith microstructure discontinuity might be related to the achievement of fully maturity, however, specific studies should be required to confirm this hypothesis (cfr., BECKMAN & WILSON, 1995; MORALES-NIN, 2001; PANFILI *et al.*, 2002). First of all, sexual maturity in fish is usually achieved along a trajectory of age and size which depends on demographic condition (Alm's hypothesys in STEARNS & CRANDALL, 1984); further, there are evidences that reproduction itself might be induced by other kind of physiological stress in fish, and that the different energy allocation (the so called "reproductive drain hypothesys" which might explain the reduction in otolith growth given the different energy allocation) is not compatible with most of marine species (PAULY, 1998). As concerns the sex related differences in Mediterranean scorpenids, considered in the present study only for TL-OL relationship (with no significant result), a conclusive answer could not be given: no significant difference was detected in *Scorpaena scrofa* (CAMPILLO, 1992), whereas females (*S. porcus*, RELINI *et al.*, 1999) or males (*Helicolenus d. dactylopterus,* MASSUTÍ *et al.*, 2000) show an higher size than the other sex respectively. For the Atlantic stocks of *H. d. dactylopterus*, in particular, a lower maximum size in females has been associated to the ovo-viviparity habit, which might implies an higher cost of reproduction (MASSUTÍ *et al.*, 2000), but no significant difference was recently found in other Atlantic stock by ABECASIS *et al.*, 2006; these Authors remarked the likely influence of sampling and methodology variability in such analysis. In contrast with other related rockfish, such as gurnards (cfr. COLLOCA *et al.*, 2003), no well discernible systematic spawning check (*sensu* WILLIAMS & BEDFORD, 1974) has been so far detected in otoliths of the Mediterranean deep water scorpenids, which typically show a growth ring pattern with numerous and irregular dispersed checks as a likely consequences of multiple interacting physiological factors such as temporal variations in food resources or habitat changes (MASSUTÍ *et al.*, 2000) different from settlement. Sea water temperature, on the contrary, is not considered a relevant factor for the Mediterranean stocks given the omeothermy (13-15 °C) condition below 100-150 m depth (MORALES-NIN, 2001).

No clear "natal" (or hatching) check was also identified in *S. elongata*; for this species, only morphology and egg size (ovoid, about 1mm diameter without oil drop; MARINARO *et al.*, 1970) is known. Generally, in scorpaenids spawning occurs through the extrusion of gelatinous floating ribbons, each with thousand of eggs and embryos at different development stages (NELSON, 1994). Mediterranean scorpaenids larvae hatch at about 2.4-2.8 mm and underwent a pelagic life before settlement (RELINI *et al.*, 1999; FROESE & PAULY, 2007); consequently, natal check, if any, might be obscured during the successive otolith development (cfr. the accessory nucleus described by MASSUTÍ *et al.*, 2000). On the contrary, it is biological sounding that the 1^{st} wide translucent band next to the core (corresponding to back calculated mean *S. elongata* size of 55 mm; Table 1) might represent the "settlement" or "demersal" check. This is in agreement both with the smallest specimens recorded in the Mediterranean (40-60 mm TL; DUCLERC, 1970) and what has been already proposed and observed for other Mediterranean rockfish (MASSUTÍ *et al.*, 2000; MORALES-NIN, 2001). As concerns the back calculation methodology, different hypothesis or approaches have been discussed and compared in literature, but yet there is no general agreement about the most suitable or preferable alternatives (CAMPANA, 2001; FRANCIS, 1990; 1995; PANFILI *et al.*, 2002). In the present study, the choice was also based on the positive application obtained by COLLOCA *et al.* (2003), for a related rockfish. As concerns the growth estimates, it is worth to remark the asymptotic size, which resulted slight higher than the previous preliminary (based on the Ford-Walford plot) estimate (RAGONESE *et al.*, 2003), but still lower than the maximum size reported for the species (590 mm TL; DUCLERC, 1970). This discrepancy, however, is expected in fish larger than 500 mm (MATHEWS & SAMUEL, 1990; BEVERTON, 1992) and coherent with the probability distribution function interpretation of this parameter (FRANCIS, 1995). The VBGF parameters estimated in the present note are conform to the growth pattern of Mediterranean deep water scorpenids stocks (CAMPILLO, 1992; RELINI *et al*, 1999; MASSUTÍ *et al.*, 2000; MORALES-NIN, 2001; FROESE & PAULY, 2007) and to the typical "Sebastes deep life history pattern" (BEVERTON, 1992; CAILLIET *et al.*, 2001): otoliths with discernible zones, despite the supposed stable environment in which these fish live, quick growth rate in the first phase of life, slow growing thereafter and high longevity. The pile up of several age groups in the reproduction life span, as consequence of the large longevity, should ensure a buffer capability of the stock against recruitment failures due to the deep water critical habitat (LEAMAN & BEAMISH, 1984). According to this growth pattern, the presence of large specimens of *S. elongata* in the historical samples mainly reflected an accumulation of biomass; these large sized fish were less accessible to fisheries given the lack of efficient equipment for controlling the geographical position of the vessel during the haul operation. No official landing statistic are available for *S. elongata* of the Strait of Sicily, but nowdays all the Sicilian trawlers are able to exploit more efficiently rough bottoms thanks to the modern GPS tools. Although the present results are based on limited information, it is unlikely that classic fishing effort limitations could protect efficiently *S. elongata* in a context of developed and multispecific fisheries such those of the Mediterranean Sea. Taking into account both the limited data context (WALTERS, 2001) and evidences gathered for other Mediterranean deep water rockfish (MASSUTÍ *et al.*, 2001; REÑONES *et al.*, 2001; RIBAS *et al.*, 2006) the establishment of no taken zones or marine refuges, preferably around rough bottoms (BIANCHINI *et al.*, 2006) might be a suitable management tool to guarantee the conservation of *S. elongata* stocks of the Strait of Sicily waiting for further data to improve the life history knowledge of this species.

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