Research Article

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Bathymetric and longitudinal distribution analyysis of the rockfish *Helicolenus Dactylopterus* (Delaroche, 1809) in the southern Tyrrhenian Sea (central Mediterranean)

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Abstract

This study provides information on bathymetric and longitudinal distribution heterogeneity of the rockfish Helicolenus dactvlopterus in the southern Tyrrhenian Sea. Data were drawn from experimental bottom trawl (1996-2002) plus bottom trap (2001-02) surveys. The frequency of occurrence and mean relative density (N/km2) and biomass (kg/km2) indexes were calculated for two survey seasons (spring and autumn), four geographic sectors and three depth strata. MANOVA was used to test fish abundance among years, sectors and strata. Analysis of the length-frequency distributions was carried out by two-way (gears and depths) ANOVA, post hoc multiple comparisons for testing differences among depths and Student's t test for testing differences between gears. Length-weight relationship was also estimated and the allometric coefficient was tested with the Student's t test. The results showed a significant positive bathymetric gradient of sizes both for trawl and trap surveys; at same depths, fish caught by traps were significantly longer than those caught by trawl. In spring surveys, significant differences were found among strata for both abundance indexes; in autumn surveys, significant differences between depth strata were found only for density indices. The distribution and abundance patterns of H. dactylopterus along the southern Tyrrhenian Sea was homogeneous among sectors. Length-weight relationship showed a significant positive allometric growth.

Keywords: *Helicolenus dactylopterus;* Deep-sea rockfish; Bottom trawl; Bottom traps; Tyrrhenian Sea; Central Mediterranean.

Introduction

The blue-mouth rockfish *H. dactylopterus* (Delaroche, 1809) (Pisces: Scorpaenidae) is a bathydemersal deep-sea fish widely distributed in the eastern Atlantic Ocean and in the Mediterranean Sea, at depths of 100-1000 m (MASSUTI *et al.,* 2001; RELINI *et al.,* 1999). Its bathymetric distribution has been studied in the central Atlantic (CARDADOR & PESTANA, 1995; FIGUEREIDO *et al.,* 1995), the north-eastern Atlantic (KELLY *et al.,* 1999), the North Sea (HEESEN *et al.,* 1996), the western (MASSUTI *et al.,* 2001) and northern Iberian Peninsula (RIBAS *et al.,* 2006) and the north-western Ionian Sea (D'ONGHIA *et al.,* 1992, 1996). Age and growth have been studied in the Ligurian Sea (PEIRANO & TUNESI, 1986; RAGONESE, 1989), the Straits of Sicily (RAGONESE & REALE, 1995), the south-western Adriatic (UNGARO & MARANO, 1995), the north-eastern Ionian Sea (D'ONGHIA *et al.,* 1996), the south-western Adriatic (ROMANELLI et al., 1997) and off the Iberian Peninsula (MASSUTÍ *et al.,* 2000); reproductive biology in the north-western Mediterranean by MUÑOZ *et al.* (1999, 2000, 2002a, 2002b); diet by FROGLIA (1976), MACPHERSON (1979) and NOUAR & MAURIN (2000); exploitation rate by RAGONESE & REALE (1992) and UNGARO & MARANO (1995). Notwithstanding the several studies in the Mediterranean Sea, scanty information on *H. dactylopterus* is available from the southern Tyrrhenian Sea, mostly coming from experimental bottom trawl surveys carried out in the framework of both national (GRUND; RELINI, 2000) and international (MEDITS; BERTRAND *et al.,* 2002) programmes. In this area, the blue-mouth has a high commercial value and is caught by bottom set-nets and trawl fisheries; the former uses long-lines, trammel net and traps, and exploits mainly adult specimens (between 300 and 400mm in total length), whereas the latter catches mainly smaller specimens (between 120 and 150 mm). Since data collected by experimental trawl survey are not representative of the whole population structure of this fish, in this paper we aimed at analyzing the spatial distribution by using data collected by two different gears: trawl net and traps.

Materials and Methods

Distribution and abundance data of *H. dactylopterus* in the area between Cape S. Vito and Cape Vaticano (southern Tyrrhenian Sea), coming from MEDITS (spring-summer; 163 total hauls) and GRUND (autumn; 324 total hauls) experimental bottom trawl surveys carried out from 1996 to 2002, have been analysed. An *ad hoc* designed trawl net (GOC 73) with a 2.9 m vertical opening and 20 mm of stretched mesh size was employed within the MEDITS project (MED). A typical Italian commercial trawl net with 36 mm meshes in the cod-end was utilized for autumn surveys (GRUND project; GRU). Four geographic sectors were identified *a priori* inside the sampling area according to hydrographic conditions and expected degree of fishing exploitation (Fig. 1): S-1, from Cape S. Vito to Cape Zafferano (n. hauls: 24 MED; 55 GRU), S-2, from Cape Zafferano to the Gulf of Patti (n. hauls: 51 MED; 97 GRU), S-3, from the Gulf of Patti to Cape Milazzo (n. hauls: 40 MED; 87 GRU); S-4, from Cape Milazzo to Cape Vaticano (n. hauls: 48 MED; 85 GRU). In each sector, five depth strata were considered: 10-50 m (*stratum* A; n. hauls: 22 MED; 54 GRU); 51-100 m (str. B; n. h: 24 MED; 54 GRU); 101-200 m (str. C; n. h: 34 MED; 60 GRU); 201-450 m (str. D; n. h: 39 MED; 78 GRU); 451-700 m (str. E; n. h.: 44 MED; 78 GRU). The distribution and

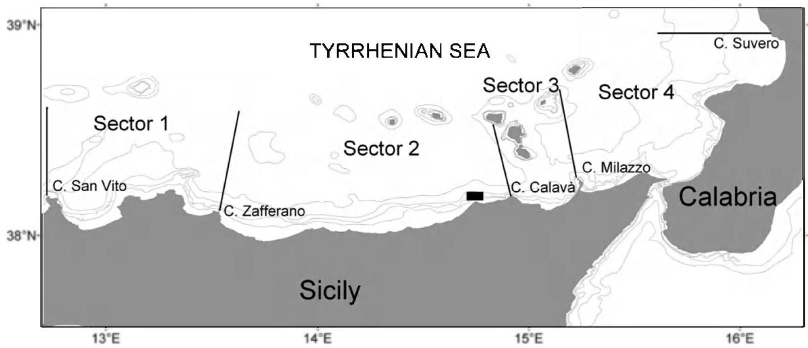

Fig. 1: Study area with the considered geographical sectors evidenced. The black rectangle shows the trap fishing area.

abundance of *H. dactylopterus* was analyzed by survey typology, sector and *stratum* by estimating the Frequency of Occurrence (number of hauls in which the species appeared in relation to the total number of valid hauls), the Density (DI; N/km^2) and Biomass Index (BI; kg/km^2), with the corresponding coefficient of variation (CV % = s.d./mean*100). In particular, both indices of abundance were estimated according to the swept area method and the estimators based on the overall swept area in each *stratum* (BERTRAND *et al.,* 2002).

MEDITS bottom trawl data were integrated with those obtained by an experimental bottom trap survey carried out in non-trawlable grounds, given the presence of submarine canyons and valleys (CASTRIOTA *et al.,* 2004).

The trap survey was carried out with a small scale fishing boat (7.38 GRT, 120 hp) from April 2001 to April 2002, excluding May and September (boat maintenance and fishing ban). In particular, 1 m high cylindrical traps of 70 cm base diameter, supported by a vertical wood frame reinforced with iron rings and provided with a 1 cm mesh polypropylene net, were employed. A funnel-shaped opening allowed the entrance of animals through each cylinder base. To permit the recovery of trapped animals, a 25 cm diameter circular opening was also created on the cylinder's lateral surface. The bait used consisted of fishes linked to each other and suspended centrally inside each trap by a nylon line. Two lines of 30 traps each, connected through a ground line and spaced at about 20 m from each other were set. One line was placed in an area usually exploited by this fishery (101-300 m, area a), whereas the other line was used in unexploited bottoms (301-500 m, area b), every month over a period of one year. These study areas are both located in Sector 2 (Fig. 1). The traps were kept at the bottom for 24 hours and then re-set for five consecutive days, subject to weather conditions. Data were then grouped by the bathymetric strata considered for trawl surveys.

As concerns size, specimens from bottom traps and MEDITS surveys were measured to the nearest 1 mm (total length, TL) and weighed to the nearest 0.1 g (total body weigh, TW).

Multifactor analysis of variance (MANOVA) was used to test fish abundance and biomass variances among years, sectors and strata. The analysis was carried out separately for the two trawl surveys, to remove the likely efficiency heterogeneity of the used gears (FIORENTINI *et al.*, 1999).

Analysis of the length-frequency distributions was carried out by two-way (gears and depths as factors) analysis of variance (ANOVA), *post hoc* multiple comparisons (Dunnett's test) for testing differences among depths and Student's t test for testing differences between MEDITS gear and trap.

Length-weight relationships, grouping all data from both gears, were calculated by the power regression, $TW = a*TL^b$, where b represents the allometric coefficient. Student t-test was computed to determine the significance of the deviations of the allometric coefficient from the theoretical value for isometric growth (b = 3).

Results

H. dactylopterus was found in 53 hauls (32.5% of total hauls) for the MED surveys and in 104 hauls (32.1%) for the GRU surveys, while it was always present in the bottom traps samples.

In the trawl surveys, *H. dactylopterus* occurred at the outermost edge of the shelf (101-200 m; C stratum) and upper slope (201-700 m; D and E strata). The highest frequency of occurrence was observed for both survey typology at depths ranging from 201 to 450 m (Foc = 62% and 70% respectively). In the GRU surveys, the species was more numerous at D stratum of Sector 4 (318 N/km^2; CV = 45.2) than in any other strata, while the highest biomass was obtained at E stratum of Sector 4 (24.0 kg/km^2; CV 22.30). In the MED surveys, the highest abundance indices were also recorded in Sector 4 (174 N/km^2; CV = 25.4) at D stratum and (24.0 kg/km^2; CV= 35.02) at E stratum respectively. The Density (N/km^2) and Biomass (kg/km^2) indices for both surveys, are shown in Figure 2.

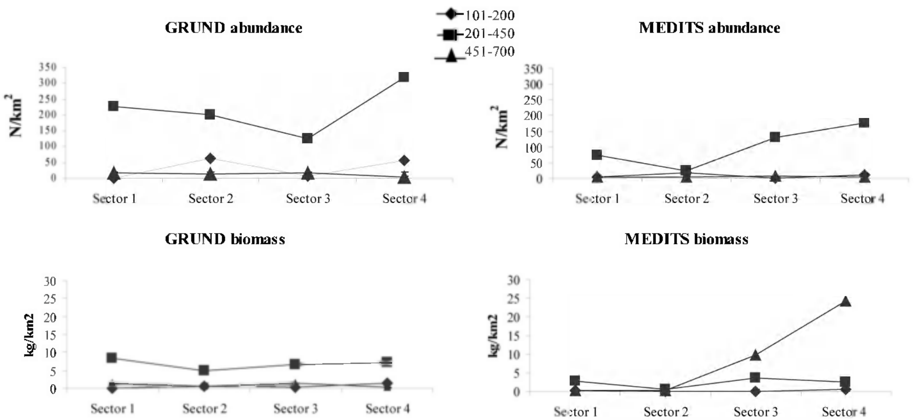

Fig. 2: Indices (great mean of the survey's year mean) of *H. dactylopterus* by sector and depth *stratum*.

Significant differences were found among strata for both DI and BI, in the MED survey ($F_{8,17}$=18.41 and $F_{8,17}$=3.90 respectively, $P < 0.001$). No significant differences were found between years and sectors. Also in the GRU survey, significant differences between depth strata were found, but only for DI ($F_{2,56}$ = 14.25, $P < 0.001$).

The number of individuals, their length range, mean and standard deviation *per stratum,* are showed by MED bottom trawl and traps, in Table 1, whereas, the Length-Frequency Distributions, grouped by stratum separately for each gear, are shown in Figure 3.

Two-way ANOVA calculated for length-frequency distributions showed significant differences between gears ($F_{(1,1241)}$ = 196.5, $P < 0.001$) and among depths ($F_{(2,1241)}$=184.9, $P < 0.001$). All post hoc multiple comparisons among depths showed significant results ($P <$ 0.05), the lengths increase with depth for both gears. At the same depth stratum, the specimens collected with bottom traps were longer than those caught by trawl (stratum C: $T_{(245)}$=28.9, P <0.001; stratum D: $T_{(952)}$=22.5, $P < 0.001$; stratum E: $T_{(44)}$ = 5.2, $P < 0.001$).

Finally, the length-weight scatterplot and corresponding relationship (Fig. 4)

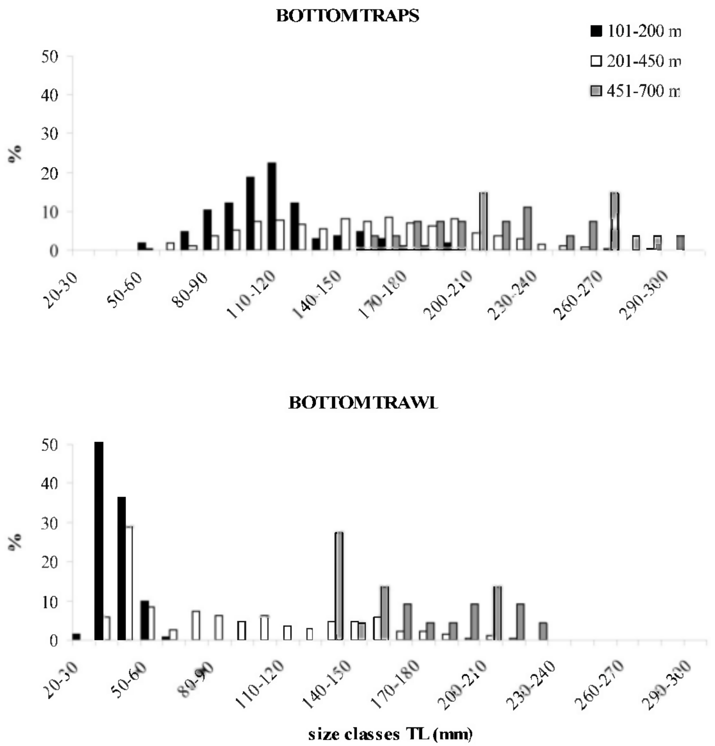

Fig. 3: Length Frequency Distributions of *H. dactylopterus* (sex combined) in the different depth *strata:* a) bottom traps; b) bottom trawl.

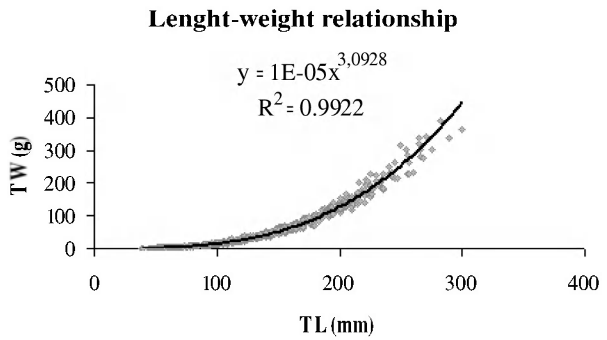

Fig. 4: Length-weight scatterplot and resulting positive allometric relationship of *H. dactylopterus* (sex combined).

Table 1
Number, length range (mm), mean total length (mm) and standard deviation (s.d.) of *H. dactylopterus* (sex combined) by depth, *stratum* and gear. No specimen was caught in the 10-50 and 51-100m depth *strata*.

Depth strata (mm)	MEDITS Bottom trawl				Bottom trap			
Depth strata (m)	number	TL range mm	TL mean mm	sd	number	size range mm	mean TLmm	SD
	n	lenght range (mm)	mean TL (mm)	SD	n	lenght range (mm)	meadn TL (mm)	SD
C: 101-200	140	35-75	49.8	9.35	107	58-200	114.72	26.73
D: 201-450	433	35-230	106.6	47.66	519	56-282	154.40	44.39
E: 451-700	22	135-235	173.3	32.80	27	160-300	225.33	38.93

resulted in a significant (Student's t test, $T_{(982)}=10.57$, $P < 0.001$) positive allometry (TW = 1E-05 TL $^{3.0928}$; $R^2 = 0.99$).

Discussion

The distribution pattern of *H. dactylopterus* along the southern Tyrrhenian Sea was homogeneous among the sectors examined both for MED and GRU surveys. The maximum abundance was obtained at depths from 201 to 500 m in both trawl surveys, according to data from the literature in the central Atlantic (CARDADOR & PESTANA, 1995) and in the Mediterranean Sea (STEFA-NESCU *et al.,* 1994; MASSUTI *et al.,* 2001).

The analysis of trawl and traps derived Length Frequency Distributions revealed an increasing trend of sizes with depth for both gears, confirming data from the literature (KELLY *et al.,* 1999; MASSUTI *et al.,* 2001). However, in submarine canyons the average sizes of

H.dactylopterus recorded were significantly higher than those found in trawlable bottoms at same depths. The trend observed in bottom trawl samples could be due to different features: a portion of stock is not accessible to trawl because is outside the professional fleet range (below 800 m) or it occurs on rough bottoms unsuitable for trawl. Even if the large size specimens were available and accessible to the trawl, they were less vulnerable given their greater avoidance ability. However, for sedentary rockfish the most likely cause of disappearance of larger fish in the trawl catches could also be related to the low interchange rate between high and low or not all exploited fishing grounds.

The presence of small fish at low depths could represent a consequence of species recruitment, according to RAGONESE & REALE (1995); they are supposed to migrate down the slope as they become older and larger (KELLY *et al.,* 1999), also in canyons where such a pattern was also found. In fact, ther could be a sort of dilution of fishing mortality in submarine canyons depending on the degree of interchange between trawlable and non-trawlable areas.

H. dactylopterus may be found down to 1000 m depth, as also reported in areas neighboring our study area (BOMBACE & SARÁ, 1972; PÉRÈS & PICARD, 1964; RAGONESE & REALE, 1995); at such a depth it could be exploited by specific gears like long-lines which would allow the catch of larger sizes than those collected at shallower depths (SOUSA *et al.,* 1999).

Moreover, in these grounds the recorded average length of *H. dactylopterus* was significantly higher than that found in trawlable bottoms at the same depths. These results could indicate that zones of the Gulf of Castellamare (Sector 1) and the Gulf of Patti (Sector 3), which have undergone closure, did not have any significant protection or enhancement effects for *H. dactylopterus.* On the contrary, Sectors 2 and 4 (characterized by high incidence of untrawlable areas), where both trawling and set nets fisheries are supposed to be lower than other counterparts, show the highest abundance indices (although not significant differences).

The analysis of length-weight relationship showed positive allometric growth, in accordance with that reported for H. dactylopterus from other Italian seas (D'ONGHIA *et al.,* 1992, 1996; PEIRANO & TUNESI, 1986; RAGONESE & REALE, 1995; UNGARO & MARANO, 1995). Moreover, the 'b' coefficient value obtained in this study is higher than that reported for specimens sampled in other Italian seas, suggesting better growth performances of the specimens living in the southern Tyrrhenian Sea.

Our results stress the usefulness of integrating different sampling methods aiming at the analysis of fish population structure, when particular conditions such as different bottom morphology in the same area do not allow a sufficient representation.

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