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ORIGINAL ARTICLE

Distribution and population structure of the fish *Helicolenus dactylopterus dactylopterus* (Delaroche, 1809) in the Central Mediterranean (Southern Tyrrhenian Sea)

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Conflicts of interest
The authors declare no conflicts of interest.

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Abstract

The blue-mouth, *Helicolenus dactylopterus dactylopterus* (Delaroche, 1809) (Pisces: Scorpaenidae), is a scorpionfish widespread in the whole Mediterranean basin, where it plays an important ecological role in deep-sea fish communities. The depauperation of this large-size sedentary and slow-growing fish can be an index of overexploitation. This species is found throughout all Italian seas; the juveniles are mainly located around 150–300 m depth, whereas the adult specimens are spread over a wider depth range from 200 m to as deep as 1000 m. The abundance in number and weight, the spatial distribution, the population structure, the growth and the recruitment pattern of *H. dactylopterus* were analysed in this study. The present paper integrates data from 11 bottom trawl surveys carried out in the Southern Tyrrhenian Sea (Central Mediterranean) along Calabrian and Sicilian coasts, within the framework of the MEDITS Project. A total of 1412 specimens of *H. dactylopterus* weighting 20.051 kg were caught. The species appeared in 40% of the 296 hauls analysed, throughout the whole depth range surveyed. The highest values of frequency of occurrence (>67%) were obtained in the slope, whereas in the shelf they fell to around 16%. On the continental shelf the species was found between 106 and 196 m depth, and in the slope between 400 and 645 m. The highest mean density index ($N{\cdot}km^{-2}$) value was obtained in the 100–200 m depth stratum, whereas the highest mean biomass index ($kg{\cdot}km^{-2}$) value was recorded in the deeper 200–500 m stratum. The length distribution of the specimens ranged between 2.5 and 24.5 cm. From the Von Bertalanffy growth model the following parameters for the whole population were obtained: L_∞: 30 cm; K: 0.16 $year^{-1}$; t_0: −0.02. The sampled population is composed mainly of the young-of-the-year fraction, which can reach up to 98% of the whole catch. Recruits (age 0+) and juveniles (age up 4 years) are limited to waters shallower than 500 m, whereas adults are present below this depth.

Problem

The blue-mouth, *Helicolenus dactylopterus dactylopterus* (Delaroche, 1809) (Pisces: Scorpaenidae), is a medium-sized scorpionfish widespread in the whole Mediterranean basin on the coarse and mud-sandy bottoms of the continental shelf and mostly on the slope as deep as 1000 m (Fischer *et al.* 1987). The blue-mouth is widely distributed in the Eastern Atlantic, from the Norwegian coasts to the south-west coast of Africa (Hureau & Litvinenko 1986). *Helicolenus dactylopterus*, common throughout all Italian seas (Relini *et al.* 1999), represents, among bathyal teleosts, more than a negligible fraction of the commercial catch in several Italian fisheries (IREPA, 2008). In particular, this species is exploited in deep-sea fisheries targeted at deep-water crustaceans. The study of *H. dactylopterus* population dynamics is important because the depauperation of this large-size sedentary and slow-growing fish can be an index of the overexploitation of fishing grounds. The life history of *H. dactylopterus* is well known in the Mediterranean Sea, both in the western and the central basin: (i) bathymetric distribution and population structure by D'Onghia *et al.* (1992) in the Ionian Sea and by Massutì *et al.* (2001) and Ribas *et al.* (2006) off the Iberian Peninsula; (ii) age and growth in the Ligurian Sea (Peirano & Tunesi 1986; Ragonese 1989), Strait of Sicily (Ragonese & Reale 1992, 1995), South-western Adriatic (Ungaro & Marano 1995), North-eastern Ionian Sea (D'Onghia *et al.* 1996), South-western Adriatic (Romanelli *et al.* 1997) and off the Iberian Peninsula (Massutì *et al.* 2000a,b); (iii) reproductive biology in the North-western Mediterranean by Muñoz *et al.* (1999, 2000, 2002a,b); (iv) diet by Froglia (1976) and Macpherson (1979); (v) exploitation rate by Ragonese & Reale (1992) and Ungaro & Marano (1995).

In the present paper, the abundance in number and weight, the spatial distribution, the population structure, the growth and the recruitment pattern of *H. dactylopterus* are discussed.

Material and Methods

Collection methods

Helicolenus dactylopterus dactylopterus specimens were collected during 11 bottom trawl surveys, carried out within the framework of international European MEDITS Project, from 1995 to 2005, in the southernmost part of the Tyrrhenian Sea (Central Mediterranean) along the Calabrian and Sicilian coasts (Bertrand *et al.* 2002).The surveyed area extended from Cape Suvero to Cape S. Vito, within the isobath of 800 m, for a total area of 7256 km^2 (Fig. 1).

Sampling procedures were the same in all surveys, according to the MEDITS project protocol (Bertrand *et al.* 2002, Anonymous 2007). Sampling was carried out randomly and the hauls were proportionately distributed in five bathymetric strata: stratum A: 10–50 m (622 km^2); stratum B: 50–100 m (1003 km^2); stratum C: 100–200 m (1224 km^2); stratum D: 200–500 m (1966 km^2); stratum E: 500–800 m (2441 km^2). An experimental sampling gear with a cod-end mesh size of 20 mm was used. The haul duration was 30 min in the shelf (10–200 m), and 60 min in the slope (>200 m).

In each haul, the number and weight of each were recorded, and the total length (TL, cm) of the specimens was measured to the nearest 0.5 cm. The sex was determined by macroscopic examination of the gonads.

Data analyses

With regard to distribution and abundance of the species, three indicators were estimated:

1 frequency of occurrence (FOC), as % of positive (*i.e.* with at least one specimen) hauls;
2 abundance, as density index (DI) expressed as N·km^{-2};
3 abundance, as biomass index (BI) expressed as kg·km^{-2}.

The mean abundance indices and their corresponding coefficient of variation (CV% = SD/mean) were estimated according to the classic swept-area approach (Gunderson 1993), but considering the area effectively trawled in the given stratum (Anonymous 2007).

The Spearman coefficient (r_0) was used to test the significance of the correlation between abundance values, both in number and weight, of the whole area, and years.

Density and biomass indices by year were interpolated using GIS software (ArcMap 9.2 by ESRI): data were mediated and normalized and then spatially elaborated by the deterministic interpolation method (IDW: Inverse Distance Weighting).

Moreover, given the extension of the studied area, the abundance in number and weight was analysed according to three geographic sectors distinguished by the homogeneity of their physiographic characteristics: (i) from Cape S. Vito to Cape Cefalù (Sicily); (ii) from Cape Cefalù to Cape Rasocolmo (Sicily); and (iii) from Cape Rasocolmo (Sicily) to Cape Suvero (Calabria) (Fig. 1).

ANOVA was used to check the null hypotheses that abundance and biomass do not change among years, sectors and depth strata. Before ANOVA, the assumptions of normality of data and homogeneity of variance were tested using one-way Kolmogorov–Smirnov (K–S) and Levene's tests, respectively. As a consequence of the non-normality of the DI dataset, the values were log-transformed [$\ln(x + 1)$] in all analyses. The Student–Newman–Keuls test was applied to verify which of the mean values of biomass and abundance indices were significantly different from the others.

The Spearman non-parametric test was applied to test differences in time of the median length. Length frequency distributions (LFDs) for each year were computed. The differences between years were tested with the Kruskal–Wallis test. LFDs were resolved into Gaussian components with Bhattacharya's method implemented in the software package FISAT II (Gayanilo *et al.* 2005). The separation of cohorts was used for the description of growth and to obtain numbers of recruits or the juvenile fraction of the population.

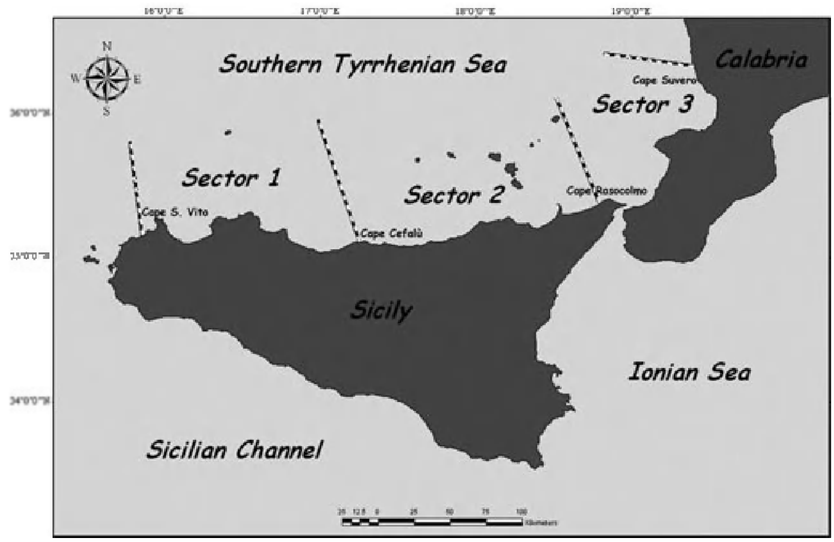

Fig. 1. Studied area with the relative sectors.

The Von Bertalanffy growth model was fitted after having assembled a series of length-at-age data using the length–age key provided by Massutì *et al.* (2001). Eight age classes were obtained. The growth performance index Φ' was employed to compare growth rate (Munro & Pauly 1983).

The density of young-of-the-year (yoy per km^2), defined as the first length class completely identified in each LFD, was obtained for each survey and stratum. To separate the yoy (in that case assimilable to recruits) from the older groups, cut-off values calculated for each survey were used (Table 1). These were derived by adding the mean length of the first group, obtained by Bhattacharya's separation, to the standard deviation. The yoy indices, calculated as the mean values of pooled years normalized to the highest value obtained in each survey, were represented graphically as 'bubble maps'.

Cluster analysis based on the resemblance between age composition by year, sector and stratum was applied to analyse differences in population structure. Only samples with more than 15 specimens were considered. The Bray–Curtis similarity index was used (Smith 2003). Analysis of similarity (ANOSIM) was carried out to test the null hypothesis that there were no differences in the age composition at different depth strata, sectors or years (Clarke & Green 1988). The statistical package PRIMER 5 was used to perform this analysis (Clarke & Warwick 2001).

Results

Abundance and spatial distribution

A total of 1412 specimens of *Helicolenus dactylopterus dactylopterus* weighing 20.051 kg were caught.

The species appeared in 40% of the 296 hauls analysed, throughout the whole depth range surveyed. The highest values of frequency of occurrence were obtained in the 100–200 and 200–500 m depth strata (Table 2). In the first two strata (A = 10–50 m and B = 50–100 m) the species was not collected at all. A positive, although not significant (Spearman test), temporal trend of FOC values was observed.

On the continental shelf *H. dactylopterus* was found between 106 and 196 m depth, whereas in the slope the species was caught from 400 to 645 m. The highest mean density index value (Table 2) was obtained in the depth stratum 100–200 m, whereas the highest mean biomass index value (Table 3) was recorded in the deeper stratum (200–500 m). At this depth the mean biomass values showed a clear increase in 2005 compared with the previous years. A direct correlation between abundance indices and years was observed, for both number and weight, only in the 100–200 m stratum ($r_0 = 0.752$;

Table 1. Mean total length, number of specimens (Nb), standard deviation (sd) of the component separated by Bhattacharya's method and cut-off values by year of *H. dactylopterus*.

year	mean length (TL, cm) of first group	SD	Nb	cut-off
1995	4.86	0.55	25.22	5.41
1996	4.77	0.58	29.43	5.3
1997*	–	–	–	–
1998	5.50	0.79	12.14	6.29
1999	4.31	0.50	78.71	4.81
2000	4.12	0.59	18.97	4.71
2001*	–	–	–	–
2002	5.58	0.99	35.52	6.57
2003	4.96	0.73	36.24	5.69
2004	3.67	0.56	149.02	4.23
2005	4.50	0.57	143.8	5.07

*Data not sufficient for analysis.

Table 2. Density Index (N/km^2), standard deviation (sd), coefficient of variation (CV) and percentage of positive hauls of *H. dactylopterus* by stratum and in the overall bathymetric range for each survey.

	year										
density (N·km^{-2})	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
C 100–200 m											
mean	14	0	0	10	327	17	3	127	139	776	455
SD	7	0	0	6	177	7	2	50	30	130	109
CV%	50	0	0	53	54	43	53	40	22	17	24
% positive hauls	17	0	0	17	50	33	17	60	60	100	100
D 200–500 m											
mean	99	127	62	106	97	169	54	51	62	69	431
SD	39	82	26	35	35	57	15	17	25	27	143
CV%	40	65	41	33	36	34	28	34	41	39	33
% positive hauls	75	86	71	86	86	100	88	67	50	67	100
E 500–800 m											
mean	33	7	10	2	2	2	0	11	6	2	2
SD	20	5	4	1	1	1	0	7	4	1	1
CV%	60	72	36	89	71	78	0	64	58	80	75
% positive hauls	50	29	57	14	17	14	0	33	33	17	17
overall 100–800 m											
mean	40	37	20	31	82	49	15	39	43	150	194
SD	13	22	7	10	31	16	4	10	9	23	43
CV%	31	61	35	31	38	32	27	26	20	15	22
% positive hauls	36	29	32	29	37	36	29	39	35	43	52

Table 3. Biomass Index (kg/km^2), standard deviation (sd), coefficient of variation (CV) of *H. dactylopterus* by stratum and in the overall bathymetric range for each survey.

	year										
biomass (kg·km^{-2})	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
C 100–200 m											
mean	0.03	0.00	0.00	0.03	0.38	0.04	0.03	0.50	0.49	0.92	0.66
SD	0.02	0.00	0.00	0.02	0.18	0.02	0.01	0.19	0.11	0.14	0.08
CV%	50.44	0.00	0.00	53.32	47.75	41.45	53.30	38.77	22.24	14.84	11.70
D 200–500 m											
mean	1.69	1.60	2.09	3.40	2.06	2.63	2.01	0.82	1.06	1.01	6.13
SD	0.66	0.51	0.98	0.90	0.70	0.88	0.58	0.35	0.50	0.53	2.62
CV%	39.07	31.50	46.90	26.34	33.92	33.28	28.95	42.54	47.66	52.88	42.79
E 500–800 m											
mean	1.19	0.51	1.05	0.12	0.00	0.08	0.00	1.08	0.39	0.00	0.10
SD	0.57	0.39	0.35	0.11	0.00	0.06	0.00	0.60	0.24	0.00	0.08
CV%	48.25	76.60	33.37	88.57	71.35	77.62	0.00	55.39	60.98	79.58	75.38
overall 100–800 m											
mean	0.86	0.60	0.92	0.97	0.62	0.75	0.55	0.67	0.50	0.43	1.80
SD	0.26	0.19	0.29	0.25	0.19	0.24	0.16	0.22	0.16	0.15	0.71
CV%	30.47	31.25	31.61	25.34	30.76	31.92	28.70	33.56	31.85	33.98	39.39

$\alpha = 0.05$ and $r_0 = 0.869$; $\alpha = 0.05$, $\alpha = 0.01$; for DI and BI indices, respectively).

Significant differences were found between sectors and strata for both density and biomass indices, but no significant variation between years was observed (Table 4). The density index showed highest values in sectors 1 and 3 in the 100–200 m depth stratum, whereas the highest biomass index value was obtained in sector 2 in the 200–500 m depth stratum (Fig. 2). The smaller individuals (recruits/juveniles) were observed in sector 3 in the 100–200 and 200–500 m depth strata, as determined by comparing DI and BI values (Fig. 2).

The spatial distribution of *H. dactylopterus* in the studied area was represented on GIS maps (Figs 3 and 4). The

Table 4. Summary of the statistic analysis to test the difference in fish biomass and density [ln (x + 1) transformed] between years (from 1995 to 2005), sectors (S1, S2 and S3) and strata (C, 100–200m; D, 200–500m and E, 500–800m). A) Test for homogeneity of variance Levene's test. B) Multifactor analysis of variance (ANOVA). C) Multiple range Student-Newman-Keuls test for density. D) Multiple range Student-Newman-Keuls test for biomass.

(A)

density	F = 0.17 (P = 0.05)
biomass	F = 0.81 (P = 0.05)

	SS			MS		F-ratio	
	$N \cdot km^{-2}$	$kg \cdot km^{-2}$	df	$N \cdot km^{-2}$	$kg \cdot km^{-2}$	$N \cdot km^{-2}$	$kg \cdot km^{-2}$
(B)							
main effects							
years (Y)	88.09	44.55	10	1.47	0.74	0.20	0.1
sectors (S)	14.38	43.42	2	7.19	21.71	1.29	4.3*
depth-strata (D-S)	262.93	179.00	2	131.46	89.50	30.34*	20.6*
interactions							
Y × D-S	20.76	7.16	12	2.07	0.72	0.45	0.33
Y × S	18.50	8.59	12	1.85	0.86	1.70	1.09
S × D-S	17.67	8.48	4	8.84	4.24	21.3*	6.4*

effect of density for each sector

	mean density at S1			mean density at S2			mean density at S3		
	C	D	E	C	D	E	C	D	E
(C)									
depth strata	2.16	2.36	0.48	2.15	3.70	1.29	1.25	4.54	0.72
mean	$^{e-c}$1.69*	$^{d-e}$1.89*		$^{e-c}$0.86	$^{d-e}$2.41*		$^{e-c}$0.52	$^{d-e}$3.82*	
difference	$^{d-c}$0.20			$^{d-c}$1.55*			$^{d-c}$3.29*		

effect of density for each depth stratum

	mean density at stratum C			mean density at stratum D			mean density at stratum E		
	1	2	3	1	2	3	1	2	3
sector	2.16	2.15	1.25	2.37	3.70	4.54	0.48	1.29	0.72
mean	$^{3-1}$0.92	$^{3-2}$0.90		$^{3-1}$2.17*	$^{3-2}$0.84		$^{3-1}$0.25	$^{3-2}$0.56	
difference	$^{2-1}$0.02			$^{2-1}$1.33*			$^{2-1}$0.81		

effect of biomass for each sector

	mean biomass at S1			mean biomass at S2			mean biomass at S3		
	C	D	E	C	D	E	C	D	E
(D)									
depth strata	0.29	1.05	0.18	0.24	3.66	0.89	0.21	2.46	0.35
mean	$^{e-c}$0.11	$^{d-e}$0.86		$^{e-c}$0.65	$^{d-e}$2.77*		$^{e-c}$0.14	$^{d-e}$2.11*	
difference	$^{d-c}$0.75			$^{d-c}$3.42*			$^{d-c}$2.25*		

effect of biomass for each depth stratum

	mean density at stratum C			mean density at stratum D			mean density at stratum E		
	1	2	3	1	2	3	1	2	3
sector	0.29	0.24	0.21	1.05	3.66	2.46	0.18	0.89	0.35
mean	$^{3-1}$0.08	$^{3-2}$0.03		$^{3-1}$1.41*	$^{3-2}$1.19		$^{3-1}$0.16	$^{3-2}$0.54	
difference	$^{2-1}$0.06			$^{2-1}$2.61*			$^{2-1}$0.70		

*Denotes a statistically significant difference at the 95%confidence level.

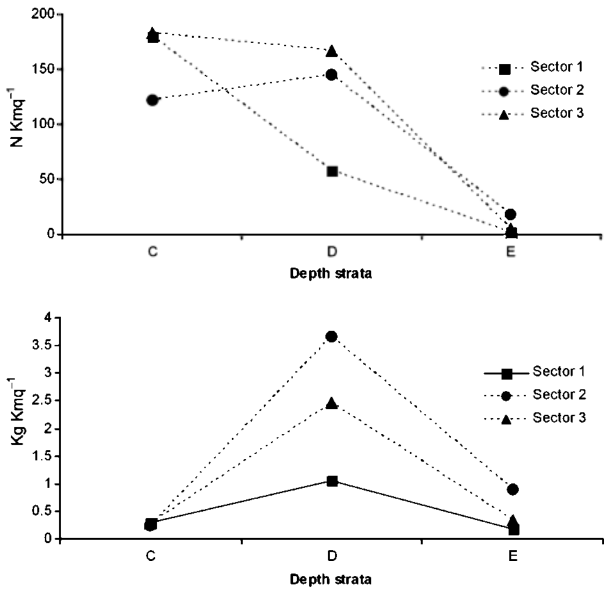

Fig. 2. Density and Biomass overall total mean, calculated from all the years mean, of *H. dactylopterus* by sectors and depth-strata.

hot spots of both DI and BI indices were mainly observed in the Gulf of St Eufemia (sector 3, Calabria) and in the Gulf of Patti (sector 2, Sicily).

Population structure and growth

The size of the specimens ranged from 2.5 to 24.5 cm of TL (Fig. 5). The median length showed a great variability between years (Fig. 6), although no significant temporal trend was observed (Spearman test).

Only specimens bigger than 9.5 cm TL could be sexed, although indeterminate individuals of up to 16.5 cm TL were still present. In particular, the length classes ranged from 10 to 24.5 cm TL for males and from 11 to 21.5 cm TL for females. Males predominated in length-classes between 13 and 24 cm TL ($\chi^2 = 23.91$; $P < 0.05$) (Fig. 7).

The length-frequency distributions of *H. dactylopterus* did not show significant differences among years (Kruskal–Wallis test). A first group characterized by small individuals (<7 cm) is well defined in almost all surveys (Fig. 5).

The dendrogram of similarities obtained from age composition allowed the identification of two main groups (Fig. 8). The first cluster includes all the hauls of the 100–200 m depth stratum and two samples of the 200–500 m stratum of the surveys carried out in 2004 and 2005. These samples were composed of fish 0–4 years of age, although more than 97% of specimens correspond to age class 0 and about 2% to age class 1. The second cluster includes samples of the 200–500 m depth stratum and one haul of the 500–800 m depth stratum in 1995. These samples were composed of fish 0–7 years of age; almost 50% of specimens correspond to age class 0, about 20% to age class 1, 12% to age class 2 and about 8% to age class 3 and 4.

The age structure of samples was significantly different between depth strata (ANOSIM, global test, R = 0.558, significance level 0.01). There were no significant differences between samples by year (ANOSIM, global test, R = 0.152, significance level >0.1) or sector (ANOSIM, global test, R = 0.177, significance level >0.1).

The growth parameters, deriving from the Von Bertalanffy model, for the whole population were: L_∞: 30 cm; K: 0.16 year^{-1}; t_0: −0.02 (Table 5).

Recruitment pattern

Recruits were collected in all surveys and showed a wide bathymetric distribution (100–610 m), although higher values are often recorded (Table 6) in the 100–200 m depth stratum. In particular, in this stratum very high values were observed in 2004 (552 N·km^{-2}) and in 2005 (444 N·km^{-2}). A significant positive direct correlation (Spearman's test) between youngest-of-the-year mean values and years was observed only for the 100–200 m depth stratum ($r_0 = 0.731$; $\alpha = 0.05$).

The distribution pattern of the recruits did not show significant variation over the 11 years and between sectors (Table 7). On the other hand, the number of recruits showed significant differences between the bathymetric strata analysed (F = 7.49 P = 0.05) and between depth strata and sectors (F = 7.04, P = 0.05). In particular, in sector 1 the recruits occur at shallower depths (100–200 m) than in sector 3 (200–500 m) (Table 7).

Although a wide spatial distribution of the recruits was observed in the surveyed area, three zones characterized by the highest concentration of recruits (normalized number of recruits per km^2) were observed (Fig. 9).

Discussion

In the studied area there are two areas that have been banned to trawling since 1990: the Gulf of Castellammare and the Gulf of Patti (Sicily). Therefore only 65% (4716.4 km^2) of the total studied area can be effectively trawled by commercial vessels.

The bottom of this area is characterized by a narrow continental shelf, sometimes entirely missing, and by a steep slope, with consequent spatial contiguity of the bathymetrics (Greco *et al.* 1998). The results reported in this paper show that the spatial distribution pattern of *Helicolenus dactylopterus dactylopterus* in this area is very similar over the time. No latitudinal gradient was observed. The density and biomass values showed differences between strata and sectors of the studied area, but not between years.

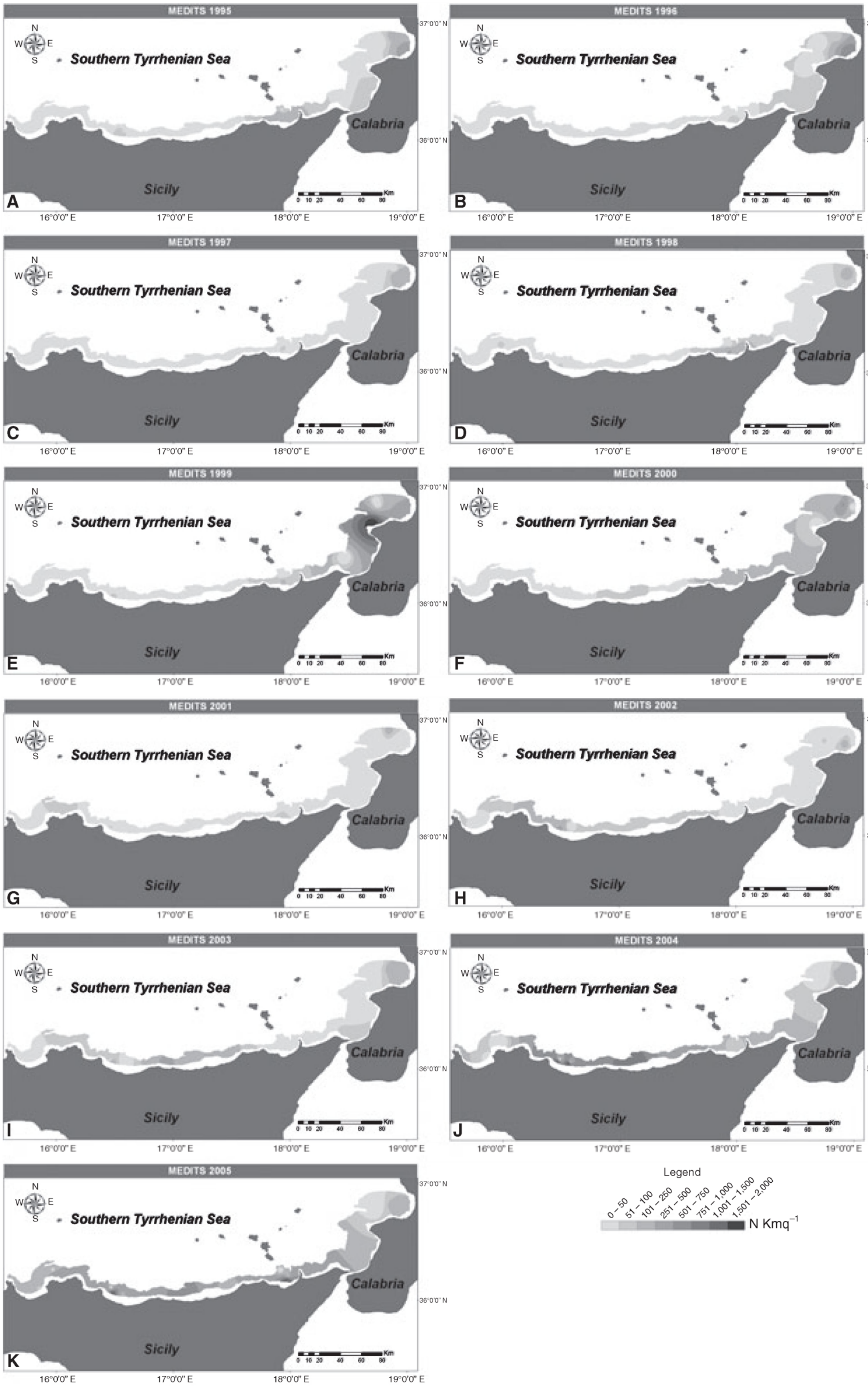

Fig. 3. Spatial distribution of *H. dactylopterus* in terms of density (N/km^2), from 1995 to 2005 (a–k).

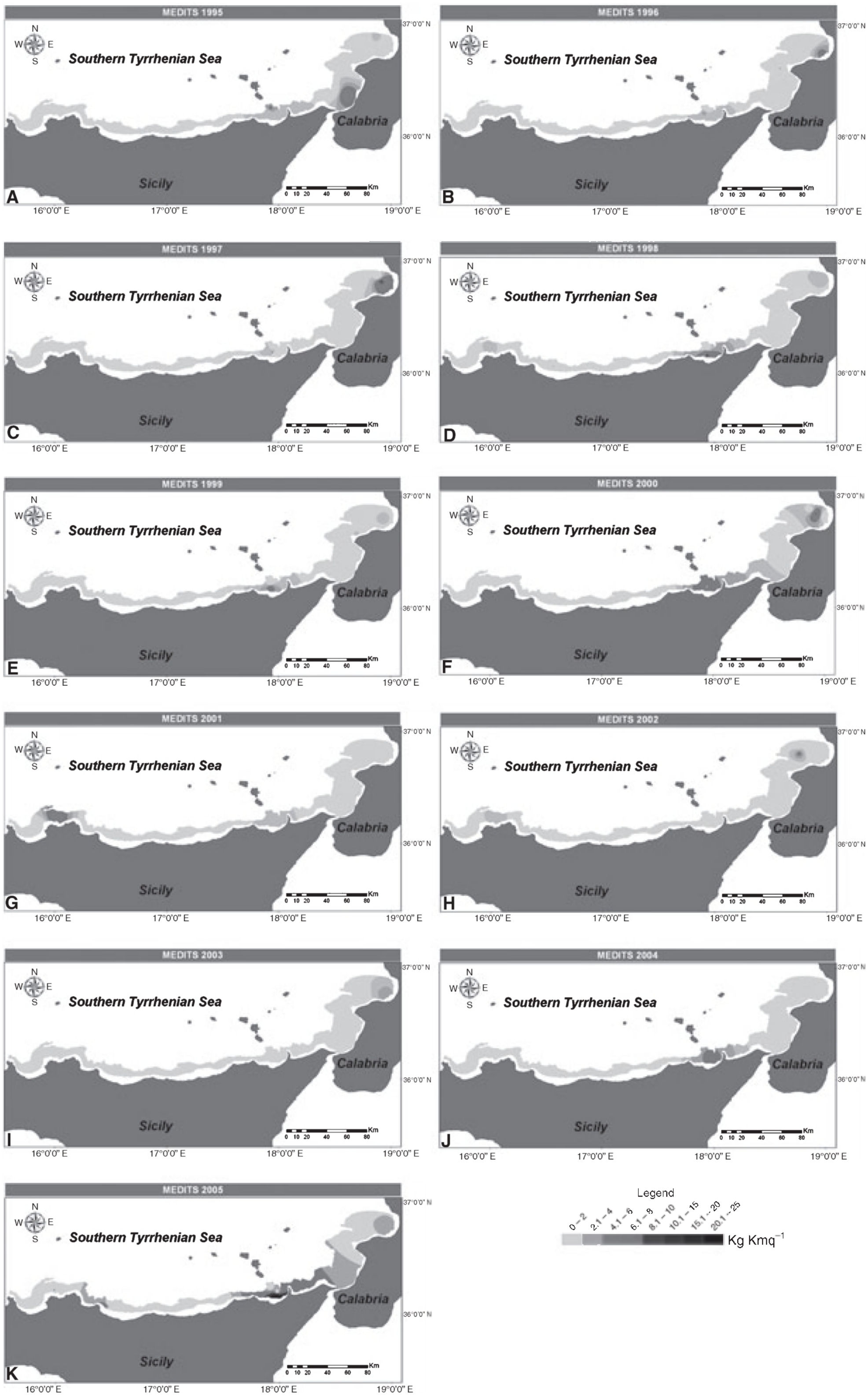

Fig. 4. Spatial distribution of *H. dactylopterus* in terms of biomass (kg/km^2), from 1995 to 2005 (a–k).

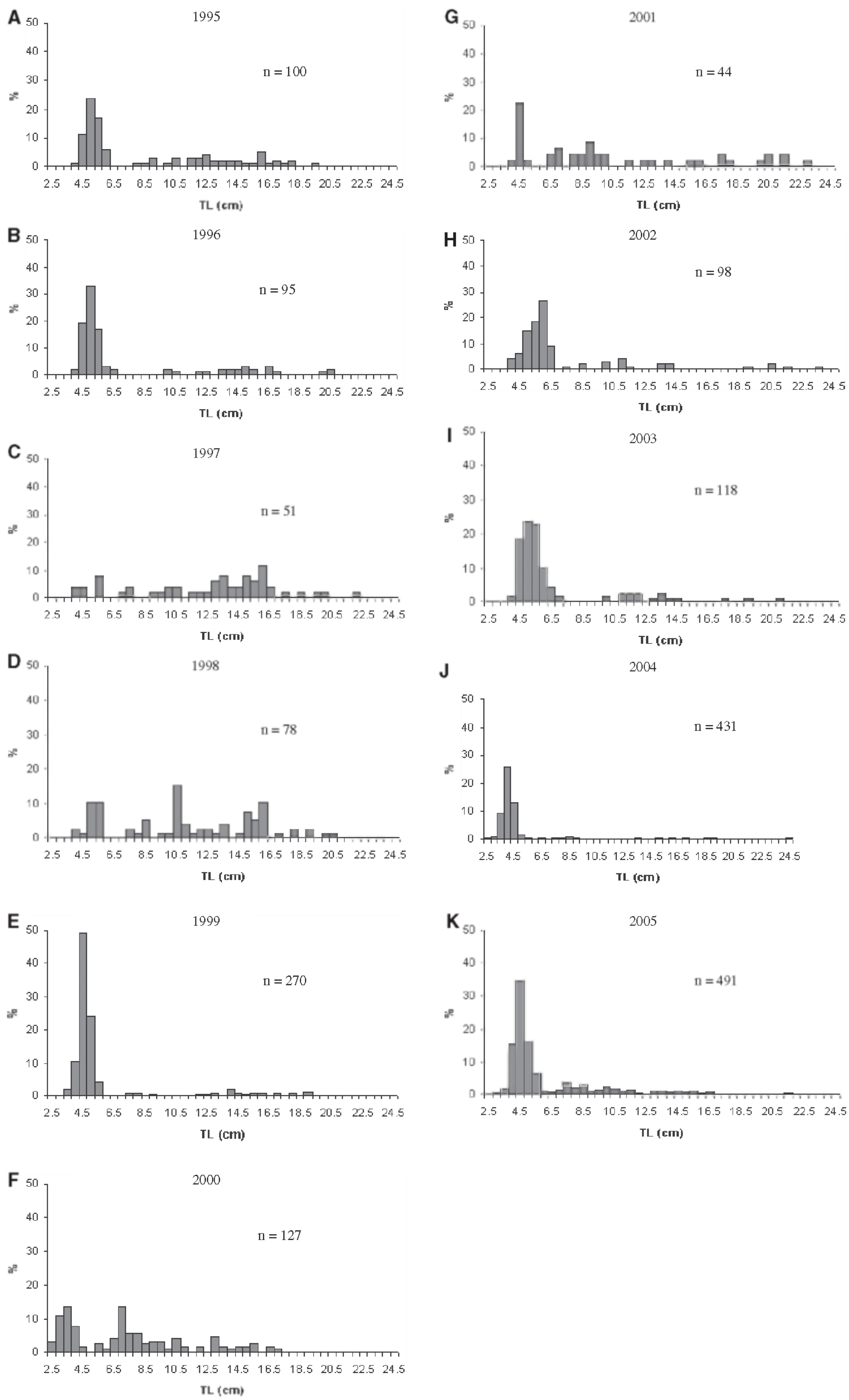

Fig. 5. Length frequency distributions of *H. dactylopterus* by survey.

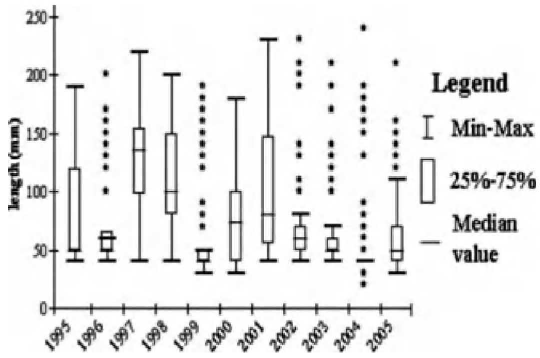

Fig. 6. Box plot representation of *H. dactylopterus* mean length by years. (* indicates outliers values).

Table 5. Growth parameters for *Helicolenus dactylopterus*, reported by several authors in different areas of the Mediterranean. (L_∞ = asymptotic length; K = growth coefficient; Φ′= growth performance index).

L_∞ (cm)	K (year^{-1})	Φ′	area	author
70.7	0.045	2.343	Ligurian Sea	Peirano and Tunesi (1986)
39.2	0.127	2.29	Sicilian Channel	Ragonese & Reale (1995)
30.7	0.156	2.167	Ionian Sea	D'Onghia *et al*. (1996)
29.9	0.19	2.23	Adriatic Sea	Ungaro & Marano (1995)
25.5	0.25	2.21	Iberian coast	Massutì *et al.* (2000a)
30	0.16	2.158	Southern Tyrrhenian Sea	Present study

The maximum catch of the species at 201–500 m is related to the major availability of the food (middle-sized decapod crustaceans), as reported for this species by other authors (Massutì *et al.* 2001; Cartes *et al.* 1994; Macpherson 1979).

The sampled population is composed mainly of the youngest-of-the-year fraction. Recruits (age 0+) and juveniles (age up 4 years) are limited to waters shallower than 500 m, whereas adults are present below this depth. The occurrence of aged individuals in deeper waters has fre-

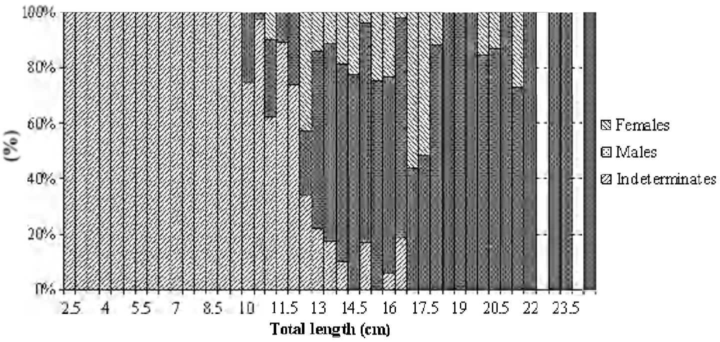

Fig. 7. Proportion of females, males and indeterminates in different length-classes of *H. dactylopterus*.

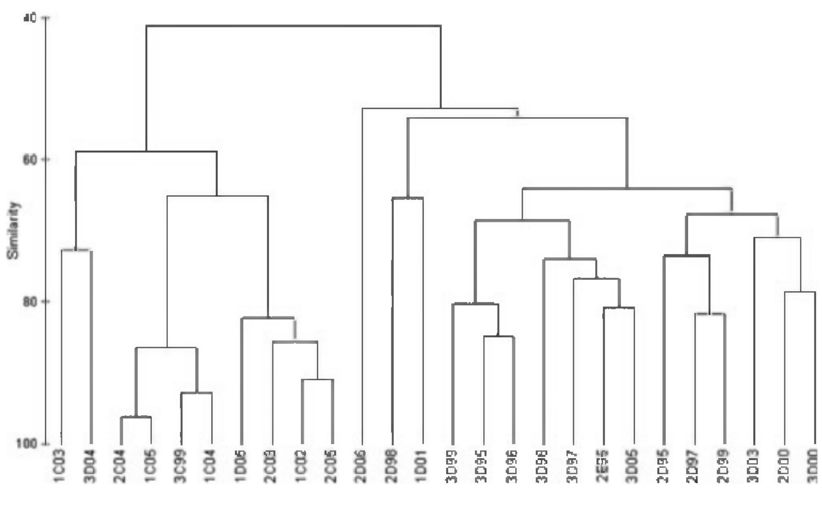

Fig. 8. Dendrogram of similarity between age composition samples of *H. dactylopterus* obtained by year (from 1995 to 2005), sector (1, 2, 3) and depth stratum (C, 101–200 m; D, 201–500; E, 501–800).

Table 6. Recruits (N/km^2), standard deviation (sd) and coefficient of variation (CV) of *H. dactylopterus* by stratum and by overall bathymetric range of each survey.

	year										
recruits (N·km^{-2})	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
C 100–200 m											
mean	10	0	0	10	213	10	3	127	121	552	444
SD	5	0	0	5	108	3	2	47	17	73	110
CV%	45	0	0	49	51	32	49	37	14	13	25
D 200–500 m											
mean	38	72	27	15	48	42	35	29	23	28	175
SD	23	53	6	10	23	18	10	9	10	11	66
CV%	60	74	21	65	49	44	29	32	43	38	38
E 500–800 m											
mean	8	0	0	0	2	0	0	0	0	2	0
SD	4	0	0	0	1	0	0	0	0	1	0
CV%	54	0	0	0	65	0	0	0	0	73	0
overall 100–800 m											
mean	15	20	7	6	49	13	10	29	27	101	122
SD	6	14	2	3	19	5	3	8	4	13	26
CV%	43	74	21	47	39	38	27	28	15	13	21

quently been observed for many demersal fish species (Macpherson & Duarte 1991) and for *H. dactylopterus* in the Mediterranean Sea (Ribas *et al.* 2006; Massutì *et al.* 2001; Ragonese & Reale 1995; D'Onghia *et al.* 1992; Peirano & Tunesi 1986). The different population structure observed along the bathymetric gradient persists over the years analysed.

The length structure of the whole population as well as the distribution pattern of recruits were quite homogeneous in the studied area. The recruits seem to be concentrated in the proximity of promontories and in particular in their eastern part. This phenomenon could be correlated to the western–eastern water flows in the Southern Tyrrhenian Sea and to the steep slope of the sea bottom (Della Croce 2000). In particular, the northern coasts of Sicily (sector 1 and 2) are influenced over the continental shelf by Modified Atlantic Water (MAW), characterized by temperatures of 14–15 °C, and in the slope by the Levantine Intermediate Water (LIW), marked by lower temperatures and higher salinity (Millot 1999). The Calabrian coasts (sector 3), where the recruits have a wider bathymetrical distribution, are probably influenced by local down-welling events, caused by wind forcing (Azzaro *et al.* 2006), which causes a major availability of trophic resources in deeper strata.

The growth parameters obtained in this study showed some differences compared with those reported from other Mediterranean areas; however, the Φ' values obtained are similar (Peirano & Tunesi 1986; Ragonese & Reale 1995; D'Onghia *et al.* 1996; Ungaro & Marano 1995 and Massutì *et al.* 2000a). This could be due to differences in the range of sizes sampled, the methodology applied and the different characteristics of the study areas. In fact, the estimation of growth parameters is strongly affected by sampling gear as well as by bias of age estimation (Massutì *et al.* 2000b).

Helicolenus dactylopterus dactylopterus is a long-lived species that can attain more than 30 years of age. Data related to the life span of this rockfish are influenced by estimation methods such as sliced or whole otolith readings (Abecais *et al.* 2006) and length-frequency distribution analysis. The differences of maximum age estimates are very important for management because the exploitation of the species is correlated to its life history (Jennings *et al.* 1998; Russ & Alcala 1998; Denney *et al.* 2002). Deep-water species like the blue-mouth rockfish are particularly vulnerable to overfishing because of their biological characteristics (long life, large size, late maturity, slow growth and low mortality rate) and are strongly exploited by trawling fishing (e.g. red shrimps fishery).

The length-frequency distribution analysed in this research suggests that the population is made up almost exclusively of recruits/juveniles individuals (0–4 years). The larger animals (up to 20 cm TL) can reach up to 8 years of age.

Finally, the results obtained by this study confirm, in agreement with the available Mediterranean and Atlantic literature, that the population sampled by trawl nets is mainly composed of recruits and juveniles. Probably, the older population prefers rocky bottoms not accessible to trawl fishery. Therefore, to correctly evaluate the true exploitation of the species, data coming from trawl surveys should be integrated with those coming from studies using different sampling gear.

Table 7. Summary of the statistic analysis to test the difference in recruits density between years (from 1995 to 2005), sectors (S1, S2 and S3) and strata (C, 100–200 m; D, 200–500 m and E, 500–800 m). A) Test for homogeneity of variance Levene's test. B) Multifactor analysis of variance (ANOVA). C) Multiple range Student-Newman-Keuls test for sectors and depth-strata.

(A)				
		density		F = 0.91 (P = 0.05)
	SS		MS	F-ratio
	Y·km^{-2}	df	Y·km^{-2}	Y·km^{-2}
(B)				
main effects				
years (Y)	2790.5	10	46.5	0.4
sectors (S)	54.57	2	27.3	0.3
depth strata (D-S)	1363.8	2	681.9	7.49*
interactions				
Y × D-S	543.2	12	54.3	1.3
Y × S	414.4	12	41.4	2.1
S × D-S	56.8	4	28.4	7.04*

	effect of density for each sector								
	mean density at S1			mean density at S2			mean density at S3		
	C	D	E	C	D	E	C	D	E
(C)									
depth strata	7.41	3	0	5.14	1.91	0.31	5.82	8.04	0.06
mean	$^{e-c}$7.41*	$^{d-e}$3		$^{e-c}$4.82	$^{d-e}$1.60		$^{e-c}$5.76	$^{d-e}$7.98*	
difference	$^{d-c}$4.41			$^{d-c}$3.23			$^{d-c}$2.22		

	effect of density for each depth-strata								
	mean density at stratum C			mean density at stratum D			mean density at stratum E		
	1	2	3	1	2	3	1	2	3
(D)									
sector	7.41	5.14	5.82	3	1.91	8.04	0	0.31	0.06
mean	$^{3-1}$1.60	3-20.68		$^{3-1}$5.04	$^{3-2}$6.13		$^{3-1}$0.06	$^{3-2}$0.25	
difference	$^{2-1}$2.28			$^{2-1}$1.09			$^{2-1}$0.31		

*Denotes a statistically significant difference at the 95%confidence level.

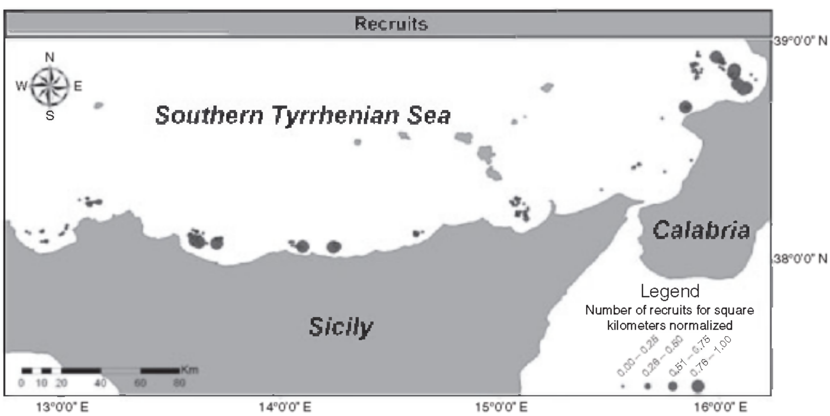

Fig. 9. Bubbles maps of normalized mean recruits index (R/km^2) in the studied area

References

Abecais D., Costa A.R., Pereira J.G., Pinho M.R. (2006) Age and growth of bluemouth, *Helicolenus dactylopterus* (Delaroche, 1809) from the Azores. *Fisheries Research*, **79**, 148–154.

Anonymous (2007) International bottom trawl survey in the Mediterranean (MEDITS). MEDITS survey, *Instruction manual, version 5. IFREMER, Nantes cedex France, April 2007*, 62 pp.

Azzaro F., Raffa F., Marini A., Rinelli P. (2006) Caratteristiche idrobiologiche del Golfo di S. Eufemia (Tirreno sud orientale): estate 2005. *Biologia Marina Mediterranea*, **13**(2), 228–229.

Bertrand J., Gil De Sola L., Papacostantinou C., Relini G., Souplet A. (2002) The general specifications of the MEDITS surveys. *Scientia Marina*, **66**, II (suppl. 2), 9–17.

Cartes J.E., Sorbe J.C., Sardà F. (1994) Spatial distribution of deep-sea decapods and euphausiids near the bottom in the northwestern Mediterranean. *Journal of Experimental Marine Biology and Ecology*, **179**, 131–144.

Clarke K.R., Green R.H. (1988) Statistical design and analysis for a biological effects study. *Marine Ecology Progress Series*, **46**, 213–226.

Clarke K.R., Warwick R.M. (2001) *Changes in Marine Communities: an Approach to Statistical Analysis and Interpretation* (2nd edition), PRIMER-E, Plymouth.

D'Onghia G., Matarrese A., Tursi A. (1992) Biologia di *Helicolenus dactylopterus* (Delaroche, 1809): Distribuzione e accrescimento sui fondali batiali del mar Ionio. *Oebalia*, **17**(Suppl.), 129–131.

D'Onghia G., Mastrototaro F., Panza M. (1996) On the growth and mortality of rockfish, *Helicolenus dactylopterus* (Delaroche 1809), from the Ionian Sea. *FAO Fisheries Report*, n. 533, 143–152.

Della Croce N. (2000) Il Mar Tirreno. *Atti Associazione Italiana Oceanologia e Limnologia*, **13**(2), 363–378.

Denney N.H., Jennings S., Reynolds J.D. (2002) Life-history correlates of maximum population growth rates in marine fishes. *Proceedings of the Royal Society of London: Biological Sciences*, **269**, 2229–2237.

Fischer W., Bauchot M.L., Schneider M. (1987) *Fiches FAO d'Identification des Especes pour les Besoins de la Peche. Méditerranée et Mer Noire. Zone de Peche 37. 2.* FAO, Rome. Vertébrés: 761–1530 pp.

Froglia C. (1976) Observations on the feeding of *Helicolenus dactylopterus* (Delaroche) (Pisces, Scorpaenidae) in the Mediterranean Sea. *Rapports et Process-Verbaux des Reunions du la Commission Internationale Pour l'Exploration Scientique de la Mer Méditerranée*, **23**(8), 47–48.

Gayanilo F.C. Jr, Sparre P., Pauly D. (2005) *The FAO-ICLARM stock assessment tools II (FiSAT) user's guide*. FAO, Rome: 168.

Greco S., Rinelli P., Giordano D., Perdichizzi F. (1998) Valutazione delle risorse demersali da Capo Suvero a San Vito lo Capo (Tirreno meridionale). *Biologia Marina Mediterranea*, **5**(3), 74–84.

Gunderson D.R. (1993) *Surveys of fisheries resources*. John Wiley & Sons, New York: 248 pp.

Hureau J.C., Litvinenko N.I. (1986) Scorpaenidae In: Whitehead P.J.P., Bauchot M.L., Hureau J.C., Nielsen J., Tortonese E. (Eds), *Fishes of the North-eastern Atlantic and the Mediterranean*. UNESCO, Paris, **3**, 1211–1229.

IREPA (2008). *Osservatorio economico sulle strutture produttive della pesca marittima in Italia*. 2006 IREPA. Franco Angeli, Milan: 288 pp.

Jennings S., Reynolds J.D., Mills S.C. (1998) Life history correlates of responses to fisheries exploitation. *Proceedings of the Royal Society of London: Biological Sciences*, **265**, 333–339.

Macpherson E. (1979) Estudio sobre el régimen alimentario de algunos peces en el Mediterráneo occidental. *The Zoological Miscellany*, **5**, 93–107.

Macpherson E., Duarte C.M. (1991) Bathymetric trends in demersal fish size: is there a general relationship? *Marine Ecology Progress Series*, **71**, 103–112.

Massutì E., Morales Nin B., Moranta J., Prats L. (2000a) Bathymetric distribution and biological parameters of the blue-mouth *Helicolenus dactylopterus* (Pisces: Scorpaenidae), on the trawling bottoms off the Iberian Mediterranean coast. *Resources halieutiques de la Méditerraneé*, **7**, 141–150.

Massutì E., Morales Nin B., Moranta J. (2000b) Age and growth of blue-mouth, *Helicolenus dactylopterus* (Osteichthyes: Scorpaenidae), in the western Mediterranean. *Fisheries Research*, **46**, 165–176.

Massutì E., Moranta J., Gil De Sola L., Morales Nin B., Prats L. (2001) Distribution and population structure of the rockfish *Helicolenus dactylopterus* (Pisces: Scorpaenidae), in the western Mediterranean. *Journal of the Marine Biological Association of the United Kingdom*, **81**, 129–141.

Millot C. (1999) Circulation in the Western Mediterranean Sea. *Journal of Marine Systems*, **20**, 423–442.

Muñoz M., Casadevall M., Bonet S. (1999) Annual reproductive cycle of *Heliconeus dactylopterus dactylopterus* (Teleostei: Scorpaeniformes) with special reference to the ovaries sperm storage. *Journal of the Marine Biological Association of the United Kingdom*, **79**, 3.

Muñoz M., Casadevall M., Bonet S., Quagio-Grassiotto I. (2000) Sperm storage structures in the ovary of *Helicolenus dactylopterus dactylopterus* (Teleostei: Scorpaenidae): an ultrastructural study. *Environmental Biology of Fishes*, **58**, 53–59.

Muñoz M., Casadevall M., Bonet S. (2002a) Gametogenesis of *Helicolenus dactylopterus dactylopterus* (Teleostei: Scorpaeniformes). *Sarsia*, **87**(2), 119–127.

Muñoz M., Koya Y., Casadevall M. (2002b) Histochemical analysis of sperm storage in *Helicolenus dactylopterus dactylopterus* (Teleostei: Scorpaenidae). *Journal of Experimental Zoology. Part A: Comparative Experimental Biology*, **292**(2), 156–164.

Munro J.L., Pauly D. (1983) A simple method for comparing the growth of fishes and invertebrates. *Fishbyte*, **1**, 5–6.

Peirano A., Tunesi L. (1986) Preliminary notes on the biology of *Helicolenus dactylopterus* (Delaroche, 1809) in the

Ligurian Sea. *Rapport de la Commission Internationale pour l'exploration scientifique de la Mer Méditerranée*, **30**, 233.

Ragonese S. (1989) L'applicazione dell'equazione di Von Bertalanffy generale: il caso di *Helicolenus dactylopterus* (Delaroche) (Pisces: Scorpaenidae) del Tirreno settentrionale. *Oebalia*, **15**, 753–762.

Ragonese S., Reale B. (1992) Estimation of mortality rates and critical age of *Helicolenus dactylopterus* (Pisces: Scorpaeniformes) in the Sicilian Channel (Central Mediterranean Sea). *Rapport de la Commission Internationale pour l'exploration scientifique de la Mer Méditerranée*, **33**, 307.

Ragonese S., Reale B. (1995) Distribuzione e crescita dello scorfano di fondale, *Helicolenus dactylopterus* (Delaroche, 1809), nello Stretto di Sicilia (Mar Mediterraneo). *Biologia Marina Mediterranea*, **2**(2), 269–273.

Relini G., Bertrand J., Zamboni A. (1999) Synthesis of the knowledge on bottom fishery resources in Central Mediterranean, Italy and Corsica. *Biologia Marina Mediterranea*, **6**(suppl.1), 868.

Ribas D., Munoz M., Casadevall M., Gil De Sola L. (2006) How does the northern Mediterranean population of *Helicolenus dactylopterus dactylopterus* resist fishing pressure? *Fisheries research*, **79**, 285–293.

Romanelli M., Palladino S., Tarulli E., Ferretti M. (1997) Stima dell'accrescimento di *Helicolenus dactylopterus dactylopterus* (Delaroche, 1809), nello Stretto di Sicilia (Mar Mediterraneo). *Biologia Marina Mediterranea*, **2**, 269–273.

Russ G.R., Alcala A.C. (1998) Natural fishing experiments in marine reserves. *Coral Reefs*, **17**, 399–416.

Smith A. (2003) A simple multivariate technique to improve the design of a sampling strategy for age-based fishery monitoring. *Fisheries Research*, **64**, 79–85.

Ungaro N., Marano G. (1995) Analytical models for Mediterranean species: an application on the *Helicolenus dactylopterus* (Delaroche) resource in the lower Adriatic. *Rapport de la Commission Internationale pour l'exploration scientifique de la Mer Méditerranée.*, **34**, 260.