



## Age, growth and feeding habits of the bluemouth rockfish, *Helicolenus dactylopterus dactylopterus* (Delaroche 1809) in the central Mediterranean (southern Tyrrhenian Sea)

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### Summary

This paper provides data on age, growth and diet of the bluemouth rockfish, *Helicolenus dactylopterus dactylopterus* (Scorpaenidae), central Mediterranean Sea. Estimated by otolith readings, ages ranged from 0 to 21 years. Parameters of the von Bertalanffy growth curves were  $L_{inf} = 26.1$  cm,  $k = 0.14$  year<sup>-1</sup>,  $t_0 = -1.92$  years and the growth performance index was  $\Phi = 1.98$ . The weight-length relationship,  $W = 0.016 TL^{2.99}$ ;  $R^2 = 0.99$ , described an isometric growth of the species. This species is a carnivore focusing mainly on the crustaceans *Goneplax rhomboides* and *Lophogaster typicus*. Statistical analysis showed an ontogenetic shift between small (4.0–6.3 cm) and larger fishes. Significant differences were also found in relation to the sampling depth.

### Introduction

The bluemouth, *Helicolenus dactylopterus dactylopterus* (Delaroche 1809) (Pisces : Scorpaenidae), is a deep-sea scorpionfish living on the coarse and mud-sandy bottoms of the continental shelf and slope from 20 to 1000 m (Fischer et al., 1987). It is widely distributed in the eastern Atlantic, from Norway to the south-west coasts of Africa (Hureau and Litvinenko, 1986), in the western Atlantic from Venezuela to Nova Scotia, and in the entire Mediterranean.

This teleost is a commercial species with an important economic value targeted by long-lines and gillnets and which also appears regularly in the by-catch of bottom trawl and pots set for deep-water crustaceans (Fischer et al., 1987; Relini et al., 1999).

In the Mediterranean, several authors investigated age and growth of *H. d. dactylopterus* by means of modal progression analysis and otolith readings. These studies were carried out in the Alboran and Balearic seas (Massutí et al., 2000), Ligurian Sea (Peirano and Tunesi, 1986; Ragonese, 1989), Sicily Channel (Ragonese and Reale, 1992), Ionian Sea (D'Onghia et al., 1992, 1996) and Adriatic Sea (Ungaro and Marano, 1995; Romanelli et al., 1997), but no age data are available from the southern Tyrrhenian Sea. In spite of the differences in maximum age and growth parameters, all authors seem to agree that bluemouth is a slow-growing and long-lived species. Sizes of this species are larger in the Atlantic Ocean, above 40 cm (Isidro, 1987; Morales-Nin, 1989), than in the Mediterranean Sea where it reaches a maximum total length of 36 cm (Massutí et al., 2000).

*H. d. dactylopterus* is a typical sit-and-wait ambush predator with a highly cryptic colouration, attacking prey as they swim

by (Uiblein et al., 2003). It is considered selectively carnivorous, feeding mainly on benthic crustaceans (decapods), fishes, gelatinous plankton (pyrosomes) and incidental cephalopods and polychaetes (Nouar and Maurin, 2000).

Notwithstanding the several studies on diet and feeding behaviour in various Mediterranean areas (Frogliia, 1976; Wurtz, 1977; Macpherson, 1981; Sartor et al., 1993; Madurell and Labropoulou, 2000), very little is known of its trophic spectrum at a specific level and none of these authors used a statistical approach.

In light of these considerations, the aim of this paper was to investigate some aspects of *H. d. dactylopterus* biology in the southern Tyrrhenian Sea giving more detailed information on age, growth, diet composition, niche breadth and also evaluating how size and depth affect the observed feeding pattern.

### Materials and methods

Specimens of *H. d. dactylopterus* were occasionally collected from January 2002 to December 2004, during several scientific bottom trawl and longline surveys carried out in the southern Tyrrhenian Sea (Fig. 1). Samplings were not specifically designed for the capture of this species, but were aimed at estimating the abundance of demersal resources in the study area on sea bottoms ranging from 100 to 600 m. Fishing surveys were uniformly performed on five depth ranges (100–200; 201–300; 301–400; 401–500; 501–600 m).

Each specimen (total length–TL) was measured by calliper to the nearest 0.01 cm and weighed to the nearest 0.1 g. Stomachs were then removed and preserved in 70% ethanol.

### Age

*Sagittae* were removed from the vestibular apparatus, cleaned, dried and stored with a code number. Before observation, they were immersed in a solution of glycerine, ethanol and water for 1 day and read the following day. Readings were carried out with a stereomicroscope under reflected light; whole otoliths were observed in the above-mentioned mixture on a dark background, to better distinguish opaque and translucent zones (Massutí et al., 2000). A growth increment including one opaque zone together with the adjacent translucent zone was considered equivalent to 1 year of life (Beckman and Wilson, 1995), as suggested by several studies on this species in the Mediterranean Sea (Ragonese and Reale, 1992, 1995; Romanelli et al., 1997; Massutí et al., 2000) and the Atlantic Ocean (Isidro, 1987; Esteves et al., 1997; Abecasis et al., 2006).

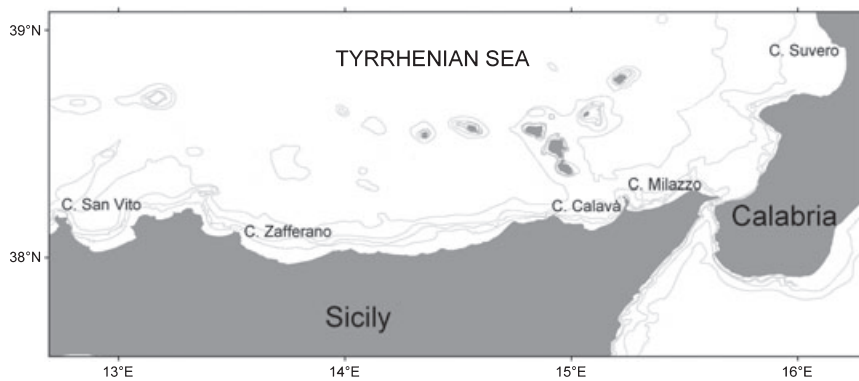


Fig. 1. Map of the southern Tyrrhenian Sea

The count of *annuli* was performed on the concave side of the *sagitta*, usually on the postrostral area, checking their continuity all around the otolith to avoid adding any possible fakes (Beckman and Wilson, 1995; Campana, 2001; Panfili and Morales-Nin, 2002).

When otoliths were thick and not clearly readable, they were made thinner using semi-automatic polishing equipment (LS2 machine, Offshore srl, Bologna, Italy) on sandpaper (grid 1200–2000). Once the sagittal plan was close to the core, otoliths were polished with alumina  $0.2 \mu\text{m}$  and the opaque zones then counted.

Each *sagitta* was read by two observers; only coincident interpretations were accepted. If readings had differing results, both readers discussed the age differences detected; the otolith was then read once more. When agreement was not possible, the otolith was considered unreadable and thus discarded.

### Growth

To describe *H. d. dactylopterus* growth, the weight-length relationship was calculated using the exponential equation:

$$W = aL^b$$

where  $W$  is the total weight (g),  $L$  is the total length (mm),  $a$  is the intercept of the regression line and represents a coefficient related to the body shape of the species,  $b$  is the regression coefficient and indicates the isometric growth when equal to 3 (Wootton, 1990; Anderson and Neumann, 1996). Estimation of parameters  $a$  and  $b$  was carried out by transforming (ln) the equation by linear regression. To check the theoretical isometric ( $b = 3$ ) or allometric growth ( $b \neq 3$ ) the Student's  $t$ -test (Snedecor and Cochran, 1967) was employed.

Moreover, growth parameters ( $L_{\text{inf}}$ ,  $k$ ,  $t_0$ ) were estimated by fitting age and related length data into the theoretical growth model of von Bertalanffy (1938):

$$L_t = L_{\text{inf}} \left( 1 - e^{-k(t-t_0)} \right)$$

where  $L_t$  is the total length at age  $t$  (years),  $L_{\text{inf}}$  is the predicted asymptotic length,  $k$  is the instantaneous growth coefficient, describing how rapidly this length is achieved,  $t_0$  is the theoretical age at zero length (years).

The growth performance index ( $\Phi = 2 \log L_{\text{inf}} + \log k$ ) (Munro and Pauly, 1983) was also calculated in order to compare the values of the growth parameters obtained in the present paper with those reported by other authors for the same species in the Mediterranean Sea (Peirano and Tunesi, 1986; D'Onghia et al., 1992, 1996; Ragonese and Reale, 1992; Ungaro and Marano, 1995; Massutì et al., 2000) and Atlantic Ocean (Isidro, 1987; Morales-Nin, 1989; Esteves et al., 1997;

Krug et al., 1998; White et al., 1998; Kelly et al., 1999; Allain and Lorange, 2000; Abecasis et al., 2006).

### Feeding habits

Gastric contents analysis was carried out under a binocular microscope and prey items identified to the lowest possible taxonomic level, counted and weighed to the nearest 0.1 mg, after removing excess water with blotting paper.

To count the remains of digested prey, the criteria suggested by Quiniou (1978) and Cherabi (1987) were used: (i) fragments of crustaceans and polychetes were considered as prey units; (ii) unidentified individuals or fragments of individuals of the same taxonomic group were counted and weighed; (iii) remains of individuals of the same species were counted and weighed together.

In order to measure sample size sufficiency, the cumulative number of new prey types was plotted against the cumulative number of non-empty stomachs analysed (Ferry and Caillet, 1996). The PRIMER statistical package v.6 (Clarke and Gorley, 2006 licensed to Pierpaolo Consoli) was utilized to compute a prey species accumulation plot as an average of 999 curves based on different random orders of the stomachs.

The logistic and the linear regressions were calculated and the goodness of fit coefficient ( $R^2$ ) compared: the sample size is considered sufficient when  $R^2$  for the logistic curve results is higher than  $R^2$  for the linear relation.

The contribution of each prey in the diet of *H. d. dactylopterus* was estimated by calculating abundance ( $\%N = \text{number of prey } i / \text{total number of prey} * 100$ ), weight ( $\%W = \text{weight of prey } i / \text{total weight of all prey} * 100$ ) and frequency of occurrence ( $\%F = \text{number of stomachs containing prey } i / \text{total number of stomachs containing prey} * 100$ ). These values were used to calculate the index of relative importance (IRI) for each taxonomic category, using mass instead of volume (Pinkas et al., 1971; Hyslop, 1980; Hacunda, 1981):  $\text{IRI} = (\%N + \%W)(\%F)$ .

The  $\%IRI$  was also calculated as:  $\%IRI = (\text{IRI} / \sum \text{IRI}) * 100$ .

To evaluate the rate of feeding activity, the vacuity coefficient ( $\%V = \text{percent of empty stomachs}$ ) was estimated.

Diet breadth was calculated by Levin's standardized index (Hulbert, 1978; Krebs, 1989) for prey biomass:

$$B_i = \frac{1}{n-1} \left( \frac{1}{\sum_j p_{ij}^2} - 1 \right)$$

$B_i$  = Levin's standardized index for predator  $i$ ;  $p_{ij}$  = proportion of diet of predator  $i$  that is made up of prey  $j$ ;  $n$  = number of prey categories.

The index ranges from 0 to 1; low values indicate diets dominated by few prey items (specialist predator), high values indicate generalist diets (Krebs, 1989).

To assess the feeding behaviour of *H. d. dactylopterus*, a modified Costello graphical method (Costello, 1990; Amundsen et al., 1996) was applied to the data set of prey taxa identified at species level. In the new graphical method, the prey-specific abundance ( $P_i$ ) is plotted against the frequency of occurrence ( $F_i$ ), providing a two-dimensional graph (Amundsen et al., 1996). In mathematical terms  $F_i$  and  $P_i$  can be described by the equations:

$$F_i = (N_i/N) \text{ and } P_i = \left( \frac{\sum S_i / \sum S_{ii}}{100} \right)$$

Where  $N_i$  is the number of predators with prey  $i$  in their stomach,  $N$  is the total number of predators with empty stomachs,  $S_i$  is the stomach content (as a number) comprised of prey  $i$ , and  $S_{ii}$  the total stomach content in only those fishes with prey  $i$  in their stomachs.

To verify the existence of differences in the diet of bluemouth in relation to the predator length and depth of capture a two-way 'Analysis of Similarities' (ANOSIM; Clarke, 1993) was performed. Although size is a continuous variable which changes continuously throughout ontogeny, size-related diet variations were investigated by dividing the collected sample into four size-classes: Class I, 40–63 cm (~ age 0); Class II, 64–90 cm (~ age 1); Class III, 91–137 cm (~ age 2–3); Class IV, > 137 cm (age > 4). With respect to the factor 'depth', four levels were considered: depth 1 (100–200 m), depth 2 (201–300 m), depth 3 (301–400 m) and depth 4 (> 401 m). To reach a sufficient number of samples for the statistical analyses the last depth level was obtained by combining the specimens caught in the two bathymetric ranges: 401–500 and 501–600 m.

Prior to the analysis, prey items were clustered into taxonomic categories at the order level. A binomial test, on the frequency of occurrence values of each one, was applied to select prevailing orders in the diet of bluemouth: a *taxon* was considered as rare when its frequency of occurrence was significantly < 5%, for  $P < 0.05$ ; the rare orders and unidentified taxa were pooled into broad taxonomic groups. The prey categories considered were: Euphausiacea, Decapoda reptantia, Decapoda natantia, Amphipoda, Isopoda, Mysidacea, Other Crustaceans, Cephalopoda, Polychaeta, Osteichthyes, Thaliacea, and Others. The data matrix based on the weight of these 12 prey categories was then standardized to the total weight sample, transformed to square root and analysed on the basis of Gower distance.

## Results

Overall, 524 specimens of bluemouth ranging from 3.3 to 27.0 cm total length (mean  $11.1 \pm 5.8$  cm) and from 0.58 to 288.6 g total weight (mean  $40.8 \pm 57.8$  g) were examined. Figure 2 shows the length (2 cm classes) frequency distribution of the bluemouth specimens; 38.9% of samples belong to the 6 cm TL class (5.0–6.9 cm).

## Age

Sagittal otoliths of *H. d. dactylopterus* appear elliptic, longer than wide, with a rostrum moderately elongated. On a total of 524 sagittae only 5% (equally distributed in all size classes) were unreadable, since they were broken or difficult to

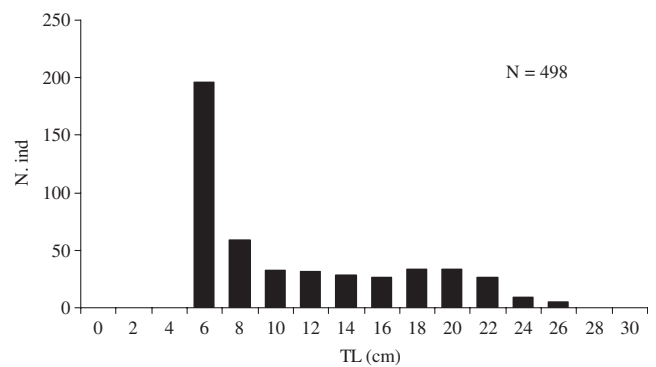


Fig. 2. Length frequency distribution (2 cm TL classes) of bluemouth *Helicolenus d. dactylopterus* specimens caught in the study area, 2002–2004. N = 498

interpret. Otoliths showed the characteristic pattern of teleosts, with hyaline and opaque rings laid down around an opaque nucleus due to slow and fast growth phases. As reported by Massuti et al. (2000) the first 4–6 pairs of rings were wider than the following rings, which were laid down with decreasing thickness, while in adult fish the outer rings decreased in width, becoming irregular and equally wide.

Analysis of 498 otoliths permitted an estimate of a maximum age of 21 years, but specimens aged more than 14 years were uncommon in this study area. The majority of samples belonged to the first age classes; in particular, 237 specimens (47.6%) were included in age class 0 (average TL =  $6.3 \pm 0.7$  cm), 57 were aged as 1 year old (average TL =  $9.0 \pm 1.2$  cm) and age class 2 was represented by 38 *H. d. dactylopterus* (average TL =  $11.6 \pm 1.1$  cm).

## Growth

The relationship between weight and length estimated for *H. d. dactylopterus* in the study area is expressed by the equation:  $W = 0.016 TL^{2.99}$ ,  $R^2 = 0.99$  (Fig. 3).

Weight increased isometrically with size, since the value of  $b = 2.99$  did not have a significant difference from the value 3.0, as confirmed by the Student's  $t$ -test ( $t_{496} = -0.1324$ ;  $P < 0.05$ ).

The parameters of the von Bertalanffy growth curve fitted to total lengths at age were estimated as  $L_{inf} = 26.1$  cm,  $k = 0.14 \text{ year}^{-1}$ ,  $t_0 = -1.92$  years (Fig. 4). The theoretical

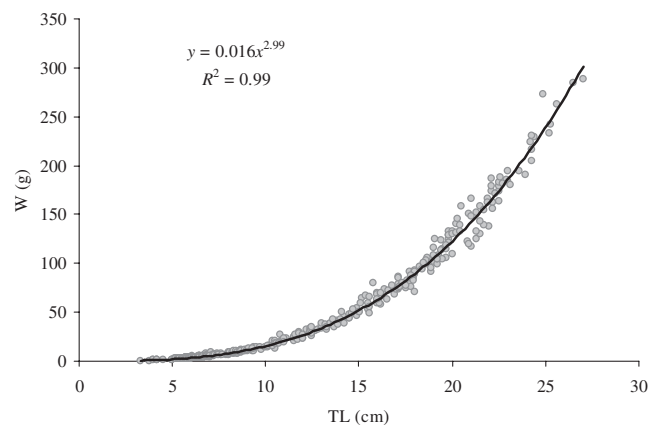


Fig. 3. *Helicolenus d. dactylopterus* weight-length relationship observed in the southern Tyrrhenian Sea. N = 498



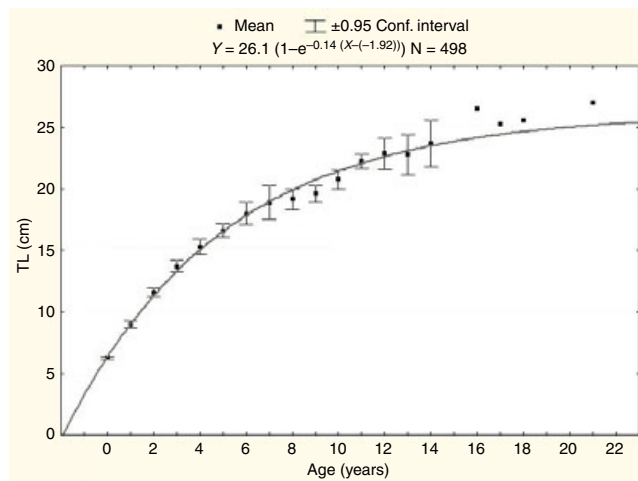


Fig. 4. Average observed length ( $\pm 0.95$  confidence interval) by age-class and von Bertalanffy growth curves determined from *annuli* interpretation in otoliths of *Helicolenus d. dactylopterus*, southern Tyrrhenian Sea

asymptotic total length ( $L_{\text{inf}} = 26.1$  cm) gave results lower than the largest specimen (TL = 27.0 cm) caught in this study. The value of the growth performance index obtained for all individuals was  $\Phi = 1.98$ .

#### Feeding habits

The gastric contents analysis was performed on a total of 455 individuals; the remaining samples were utilized for other purposes. Of the 455 stomachs analysed, 219 were empty ( $\%V = 52$ ) whereas 236 had at least one food item ( $\%V = 48$ ). Specimens ranged from 3.3 to 24.9 cm TL (mean  $8.4 \pm 3.9$  cm).

The cumulative prey type curve for the entire data set was a better fit with a logistic curve ( $R^2 = 0.953$ ,  $F_{(1,234)} = 4795.8$ ,  $P < 0.001$ ) than with a linear relation ( $R^2 = 0.826$ ,  $F_{(1,234)} = 1114.1$ ,  $P < 0.001$ ); therefore, the sample size was considered sufficient to describe bluemouth feeding habits in this area.

Stomach contents analysis led to the identification of 512 prey for a total weight of 43.52 g (mean prey weight in each stomach =  $0.64 \pm 2.68$  g) belonging to 67 taxa, 45 of which were represented by benthic or epibenthic crustaceans (Table 1).

In fact, crustaceans were the most important taxon in terms of  $\%W$  (80.3),  $\%N$  (83.8),  $\%F$  (86.0) and  $\%IRI$  (92.8). Among them, decapods were largely dominant by weight ( $\%W = 68.7$ ) and the most representative species was the brachiura *Goneplax rhomboides* ( $\%IRI = 56.8$ ). Mysids were the best-represented taxon in terms of abundance ( $\%N = 27.4$ ), followed by isopods ( $\%N = 20.2$ ) and decapods ( $\%N = 16.8$ ).

Molluscs, Anellids, Fishes, Tunicates and Others represented only a small fraction of the *H. d. dactylopterus* diet; their contributions in terms of the relative importance index were  $< 6\%$ .

Levin's standardized index, calculated for the evaluation of diet breadth, was 0.41 for the biomass of 67 prey items.

The dietary pattern of *H. d. dactylopterus* is graphically represented in Fig. 5a where the prey-specific abundance ( $P_i$ ) is plotted against the frequency of occurrence ( $\%F$ ). As food categories, the lowest taxonomic level of the different food items was considered. Information on prey importance and

Table 1

Diet composition of *Helicolenus d. dactylopterus* with relative food indexes: weight % ( $\%W$ ), number % ( $\%N$ ), frequency % ( $\%F$ ) and Index of Relative Abundance % ( $\%IRI$ ). Unid. = unidentified

Prey types	$\%W$	$\%N$	$\%F$	$\%IRI$
<b>Crustacea</b>				
Stomatopoda				
Pseudosquillae	0.17	0.20	0.42	0.01
Euphausiacea				
<i>Euphausia krohni</i>	0.01	0.20	0.42	0.00
Unid. Euphausiacea	0.17	0.98	1.27	0.07
Decapoda				
<i>Brachynotus</i> sp.	0.01	0.20	0.42	0.00
<i>Goneplax rhomboides</i>	50.37	9.98	19.49	56.77
<i>Monodaeus couchii</i>	2.10	0.20	0.42	0.05
Unid. Brachiura	1.58	1.37	2.97	0.42
Unid. Reptantia	0.11	0.20	0.42	0.01
<i>Alpheus glaber</i>	0.18	0.20	0.42	0.01
<i>Philocheras echinulatus</i>	1.25	0.59	1.27	0.11
<i>Philocheras bispinosus</i>	0.03	0.20	0.42	0.00
<i>Pontocaris lacazei</i>	0.91	0.20	0.42	0.02
Unid. Crangonidae	1.19	0.59	0.85	0.07
<i>Pasiphaea</i> sp.	0.27	0.20	0.42	0.01
<i>Chlorotocus crassicornis</i>	3.75	0.39	0.85	0.17
<i>Pandalina</i> sp.	0.23	0.20	0.42	0.01
<i>Processa</i> sp.	3.71	0.78	1.69	0.37
Unid. Natantia	2.57	1.17	2.12	0.38
Unid. Decapoda	0.41	0.39	0.85	0.03
Total Decapoda	68.67	16.83	32.20	58.44
Amphipoda				
Gammaridea				
<i>Arrhis mediterraneus</i>	0.00	0.20	0.42	0.00
<i>Cheirocratus assimilis</i>	0.00	0.20	0.42	0.00
<i>Hippomedon bidentatus</i>	0.01	0.39	0.85	0.02
<i>Rhachotropis caeca</i>	0.00	0.20	0.42	0.00
<i>Rhachotropis grimaldii</i>	0.04	0.98	2.12	0.10
<i>Stegocephaloides</i>	0.01	0.20	0.42	0.00
<i>christianiensis</i>				
Unid. Gammaridea	0.14	1.96	3.39	0.34
Hyperiidea				
<i>Scina</i> sp.	0.00	0.20	0.42	0.00
<i>Vibilia</i> sp.	0.00	0.20	0.42	0.00
Unid. Hyperiidea	0.02	2.54	1.27	0.16
Total Amphipoda	0.23	7.05	8.47	0.65
Cumacea				
<i>Diastylis cornuta</i>	0.03	0.20	0.42	0.00
Unid. Cumacea	0.00	0.59	0.85	0.02
Isopoda				
Flabellifera				
Cirolanidae	1.31	3.91	5.93	1.50
Unid. Flabellifera	0.96	3.72	5.93	1.34
Asellota				
Joeropsidae	0.07	0.98	0.85	0.04
Gnathiidea				
Gnathiidae	0.38	6.65	2.12	0.72
Unid. Gnathiidea	0.07	0.98	0.85	0.04
Unid. Isopoda	0.15	3.13	2.97	0.47
Total Isopoda	2.97	20.16	17.80	4.11
Mysidacea				
<i>Paramysis</i> sp.	0.02	0.20	0.42	0.00
Unid. Mysinae	0.01	0.20	0.42	0.00
<i>Siriella</i> sp.	0.25	2.35	4.24	0.53
<i>Lophogaster typicus</i>	3.06	8.41	12.71	7.04
Unid. Mysida	0.09	3.13	4.24	0.66
Unid. Mysidacea	0.48	13.11	12.71	8.34
Total Mysidacea	3.90	27.40	33.90	16.58
Copepoda				
Copepoda	0.00	1.17	1.27	0.07
Unid. Crustacea	4.15	9.78	19.07	12.83
Total Crustacea	80.28	83.76	86.02	92.78
Mollusca				
Gasteropoda				
Opisthobranchia	1.55	0.59	1.27	0.13
Cephalopoda				
Sepioliidae	0.11	0.20	0.42	0.01

Table 1  
(Continued)

Prey types	%W	%N	%F	%IRI
Teuthoidea	0.11	0.20	0.42	0.01
Unid. Cephalopoda	0.27	0.98	2.12	0.13
Total Mollusca	2.04	1.96	3.81	0.27
Anellida				
Polychaeta				
Alciopidae	0.69	0.20	0.42	0.02
Fabriciinae	0.05	0.20	0.42	0.01
Nephtyidae	0.29	0.39	0.85	0.03
Polynoidae	0.08	0.59	1.27	0.04
<i>Chloeia venusta</i>	0.07	0.20	0.42	0.01
Unid. Polychaeta	0.03	0.20	0.42	0.00
Total Anellida	1.20	1.76	3.81	0.10
Teleostea				
Stomiiformes				
<i>Argyropelecus hemigymmus</i>	0.51	0.39	0.85	0.04
Perciformes				
<i>Deltentosteus quadrimaculatus</i>	0.46	0.20	0.42	0.01
Gadiformes				
Macrouridae	0.54	0.20	0.42	0.02
Gadidae larvae	0.69	0.20	0.42	0.02
Myctophiformes				
<i>Myctophum punctatum</i>	0.94	0.39	0.85	0.05
<i>Hygophum benoiti</i>	0.35	0.39	0.85	0.03
Lampriformes				
Trachipteridae	0.70	0.20	0.42	0.02
Unid. Teleostea	7.17	4.50	9.32	5.25
Total Teleostea	11.37	6.46	13.14	5.44
Tunicata				
Pyrosomida				
<i>Pyrosoma atlanticum</i>	0.34	0.20	0.42	0.01
Salpida				
Salpida	4.35	4.89	2.97	1.32
Total Tunicata	4.69	5.09	2.97	1.33
Others				
Siphonophora				
Calyctophorae	0.04	0.39	0.85	0.02
Echinodermata				
Ophiuroidea	0.37	0.59	1.27	0.06

feeding strategy of the predator can be obtained by examination of the point distributions along the diagonals and axes of the diagram (Fig. 5b). The percent abundance, increasing along the diagonal from the lower left to the upper right corner, provides a measure of prey importance, with dominant prey at the upper, and rare or unimportant prey at the lower end. The vertical axis represents the feeding strategy of the predator in terms of specialization or generalization.

Feeding strategy indicates a specialization of individual fish (high between-phenotype contribution) on food items of high specific abundance and low occurrence; most of the species or food categories are located on the left side of the diagram, close to the vertical axis in a region of low importance. Conversely, *G. rhomboides* located near the central area of the graph, can be considered the most important prey at population level, mainly due to the highest value of frequency of occurrence (%F = 19.5).

#### Diet variations with predator size and sampling depth

Twelve prey categories were selected by means of the binomial test: Euphausiacea, Decapoda reptantia, Decapoda natantia, Amphipoda, Isopoda, Mysidacea, Other Crustaceans, Cephalopoda, Polychaeta, Osteichthyes, Thaliacea, and Others.

Two-way crossed ANOSIM (based on the data matrix of these 12 prey categories) allowed us to test the significance of

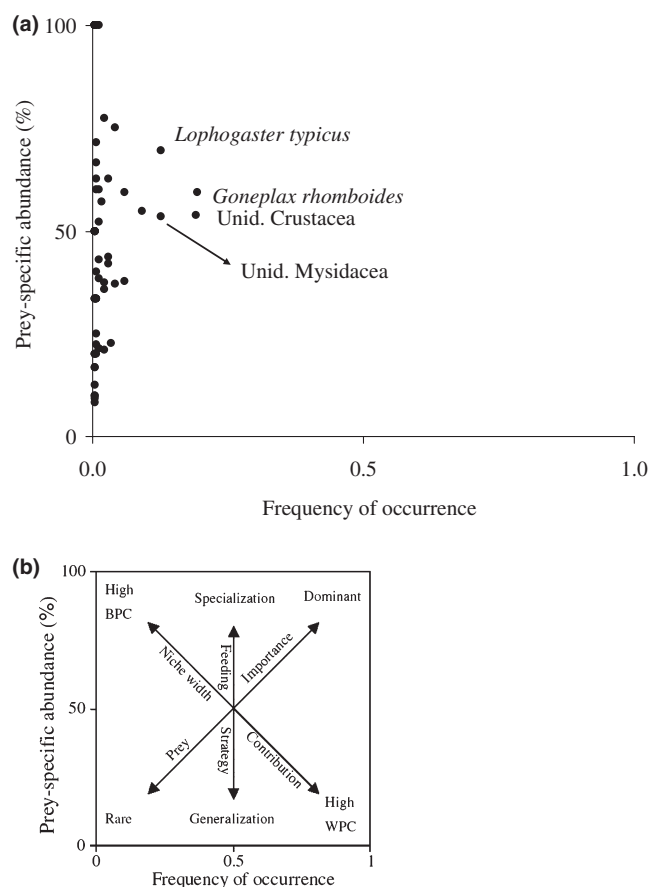


Fig. 5. Graphic representation of diet composition in *Helicolenus d. dactylopterus*. (a) Diagram representing prey taxa. Only most important species specified. (b) Explanatory diagram for interpretation of feeding strategy, prey importance and niche width contribution (adapted from Amundsen et al., 1996)

differences in diet observed between fish groups pooled in relation to depth and size (Table 2). These differences were both statistically significant, attaining an  $R$  value of 0.11 ( $P < 0.01$ ) and 0.22 ( $P < 0.01$ ), respectively, thus allowing rejection of the null hypothesis (Table 3).

Pairwise comparisons showed that the dietary compositions were significantly different among depth groups except between depth 3 and 4 (Table 3). On the other hand, pairwise tests confirmed significant differences in diet only between size groups 1 vs 3 and 1 vs 4.

Applying the SIMPER routine, we obtained the relative contribution of each prey category to the dissimilarities

Table 2  
Number of samples for both variables (depth and size) considered in statistical analyses of bluemouth diet

	Size 1 4.0–6.3 cm	Size 2 6.4–9.0 cm	Size 3 9.1–13.7 cm	Size 4 > 13.7 cm	Total
Depth 1 100–200 m	33	16	4	3	56
Depth 2 201–300 m	10	19	10	6	45
Depth 3 301–400 m	25	52	16	8	101
Depth 4 > 401 m	6	12	3	13	34
Total	74	99	33	30	236

Table 3

Two-way crossed ANOSIM testing for differences in bluemouth diet among depths and sizes. Depth 1 (100–200 m), depth 2 (201–300 m), depth 3 (301–400 m) and depth 4 (> 401 m); Size 1: 4.0–6.3 cm (~age 0), Size 2: 6.4–9.0 cm (~age 1), Size 3 9.1–13.7 cm (~age 2–3), Size 4 > 13.7 cm (age > 4). \*P < 0.05; \*\*P < 0.01; ns, not significant

	R-value	P		R-value	P
Among depths	0.112	**	Among sizes	0.221	*
Pairwise tests	R-value	P	Pairwise tests	R-value	P
Depth 1 vs depth 2	0.243	**	Size 1 vs size 2	0.051	ns
Depth 1 vs depth 3	0.220	**	Size 1 vs size 3	0.109	**
Depth 1 vs depth 4	0.183	**	Size 1 vs size 4	0.194	**
Depth 2 vs depth 3	0.194	**	Size 2 vs size 3	0.031	ns
Depth 2 vs depth 4	0.352	**	Size 2 vs size 4	0.039	ns
Depth 3 vs depth 4	0.066	ns	Size 3 vs size 4	0.084	ns

among sizes and among depths at capture (Table 4). Mysids, isopods, walking decapods and other crustaceans were main contributors to the dissimilarity between size groups. In particular, small fishes (size 1) fed mainly on mysids, whereas walking decapods became an important food item for larger fishes (size 4). Isopods were consumed mainly by size 3 specimens. Regarding diet changes in relation to the bathymetry, mysids represented the food item contributing most to the dissimilarity among depth 1 and the others, except between depths 1 and 2; in particular they were more abundant on specimens caught on the bottom at 100–200 m. Walking decapods were the dominant prey of bluemouth specimens belonging to depth 2 (201–300 m) and contributed the most to the diet dissimilarity between this bathymetric range and the others.

## Discussion

The present study provides new information on biology and ecology of *H. d. dactylopterus* from the southern Tyrrhenian

Sea. Results showed that the maximum total length of *H. d. dactylopterus* in the study area was 27 cm, corresponding to an estimated age by otolith readings of 21 years, even if only a few samples were over 14 years old. Our maximum TL recorded is, in most cases, lower than those reported for other Mediterranean areas (Table 5); in particular, specimens of 36 cm were found in the Alboran Sea by Massutí et al. (2000).

Observed differences in bluemouth length, as shown in Table 5, could be due to the different fishing pressure in the study areas, to the maximum sampling depth, and also to the fishing gear employed. In fact, according to Massutí et al. (2001), smaller sized individuals are concentrated at shallow depths while larger ones prefer deeper areas, showing a clear preference for rocky bottoms, which are not very accessible to trawling, and thus they can escape or avoid the net.

Although we used two types of fishing gear (trawling and bottom longlines to catch *H. d. dactylopterus* specimens, it is possible that undersampling with bottom longlines introduced a bias towards small fishes whereby the size-frequency distribution obtained could not reflect that of the population. In fact, a high percentage of the sample studied (~59%) consisted of fish between 4 and 12 cm TL classes, corresponding to juveniles from 0 to 1 years of age.

It is clear that comparisons of the estimated bluemouth ages with other authors may be done only when considering similar size ranges. Nevertheless, maximum age obtained in our study seems higher than that reported in other Mediterranean areas (Ligurian Sea, Ionian Sea, lower Adriatic), as shown in Table 5.

On the other hand, other authors (White et al., 1998; Kelly et al., 1999; Allain and Lorange, 2000; Abecasis et al., 2006) estimated a higher *H. d. dactylopterus* longevity in the Atlantic Ocean. These differences could be due to the different age reading methodologies as those authors used thin-sectioning whereas we used whole otoliths. According to Allain and Lorange (2000) and Abecasis et al. (2006), when comparing the two methods the sliced otoliths readings appear to be more

Table 4

Results of SIMPER analysis showing average abundances (Av Ab) of fish taxa most contributing to diet dissimilarities (Diss %), according to the factor size and depth. Values given only for groups with significant differences in accordance with ANOSIM results. Size 1: 4.0–6.3 cm, Size 2 6.4–9.0 cm, Size 3 9.1–13.7 cm, Size 4 > 13.7 cm, depth 1 (100–200 m), depth 2 (201–300 m), depth 3 (301–400 m) and depth 4 (> 401 m)

Taxa	Av Ab	Av Ab	Diss (%)	Taxa	Av Ab	Av Ab	Diss (%)	Taxa	Av Ab	Av Ab	Diss (%)
	Size 1	Size 3			Size 1	Size 4			Depth 1	Depth 2	
Mysidacea	3.31	1.48	18.26	Other Crustaceans	2.23	1.53	18.77	Decapoda reptantia	1.22	5.34	35.75
Isopoda	0.6	3.01	14.84	Decapoda reptantia	1.87	3.75	17.82	Mysidacea	5.21	0.68	31.25
Other Crustaceans	2.23	1.11	14.64	Mysidacea	3.31	0.48	14.87	Other Crustaceans	2.01	0.51	13.23
	Depth 1	Depth 3			Depth 1	Depth 4			Depth 2	Depth 3	
Mysidacea	5.21	3.04	31.75	Mysidacea	5.21	0.31	29.73	Decapoda reptantia	5.34	1.65	32.21
Other Crustaceans	2.01	1.91	20.07	Other Crustaceans	2.01	2.3	21.68	Mysidacea	0.68	3.04	18.91
Decapoda reptantia	1.22	1.65	12.19	Isopoda	0.06	2.65	20.89	Other Crustaceans	0.51	1.91	11.38
	Depth 2	Depth 4									
Decapoda reptantia	5.34	2.06	34.42								
Isopoda	0.88	2.65	22.85								
Other Crustaceans	0.51	2.3	18.5								

Table 5

Age-classes, von Bertalanffy growth parameters ( $L_{inf}$  = asymptotic length, cm;  $k$  = growth coefficient, year<sup>-1</sup>;  $t_0$  = theoretical age at zero length, years) and growth performance indexes ( $\Phi$ ) for *Helicolenus d. dactylopterus*, reported in different areas of Mediterranean Sea. W = whole population, F = females, M = males, N = number of specimens

Source	Area	Depth range (m)	Methods	Sex	N	TL range (cm)	Age classes	$L_{inf}$	$k$	$t_0$	$\Phi$
Peirano and Tunesi (1986)	Ligurian Sea	0–700	Whole otoliths	W	300	4–28	0–9	70.7	0.05	–0.41	2.35
Ragonese and Reale (1992)	Sicilian Channel	100–750	Whole otoliths	W	585	–	–	39.2	0.13	–1.46	2.29
D'Onghia et al. (1992)	NE Ionian Sea	160–550	Length-frequency analysis	W	1370	4–29	–	30.0	0.20	–1.41	2.24
D'Onghia et al. (1996)	NE Ionian Sea	–	Whole otoliths	W	410	3–24	1–7	30.7	0.16	–0.90	2.17
Ungaro and Marano (1995)	S Adriatic	–	Whole otoliths	W	–	–	–	29.9	0.19	–0.85	2.23
Romanelli et al. (1997)	S Adriatic	–	Whole otoliths	W	434	5–34	1–10	–	–	–	–
Massutí et al. (2000)	Alboran Sea	64–786	Whole otoliths	W	1455	3–36	0–30	30.0	0.10	–2.86	1.95
Massutí et al. (2000)	Alboran Sea	64–786	Whole otoliths	F	561	8–32	1–26	27.1	0.12	–2.65	1.95
Massutí et al. (2000)	Alboran Sea	64–786	Whole otoliths	M	575	8–36	1–30	32.3	0.09	–3.31	1.97
Massutí et al. (2000)	Balearic Sea	25–1713	Whole otoliths	W	938	2–30	0–22	29.9	0.13	–1.75	2.06
Massutí et al. (2000)	Balearic Sea	25–1713	Whole otoliths	F	178	7–28	1–22	27.0	0.16	–1.62	2.07
Massutí et al. (2000)	Balearic Sea	25–1713	Whole otoliths	M	198	8–30	1–21	32.5	0.10	–2.62	2.02
Present study	S Tyrrhenian Sea	100–600	Whole otoliths	W	498	3–27	0–21	26.1	0.14	–1.92	1.98

realistic and more accurate for ageing older fish while also being more time consuming and costly. Whole otolith readings are cheaper and less time consuming, but should not be used for older fish since they significantly underestimate age because the otoliths are more opaque and the rings closer together in older fish. Nevertheless, as suggested by Beamish (1979) and Bennett et al. (1982), divergence of ages in other scorpionfishes, estimated by whole or sliced otoliths, usually occurs after 20–25 years of age. As our estimated maximum age for *H. d. dactylopterus* is 21 years, the possibility for error may be considered as negligible.

Analysis of growth rates indicates that this species is a slow-growing fish with  $k = 0.14$  year<sup>-1</sup>, as confirmed in the Mediterranean Sea by other authors (Table 5). The theoretical asymptotic total length ( $L_{inf} = 26.1$  cm) was lower than the observed maximum (27 cm). This could depend on the sampling effort, which was perhaps too small for larger individuals. In fact, in our sample only two individuals outnumbered the  $L_{inf}$  value and only exceptional samples reached ages beyond 15 years. The growth performance index ( $\Phi$ ) from our study was somewhat lower than those obtained in other areas (Table 5). However, it is clear that there could be some differences between growth characteristics from one area to another for reasons of food availability, hydrographical and climatic conditions, and fishing mortality rates.

The length-weight relationship describes an isometric growth for *H. d. dactylopterus* in the study area, confirming the results reported for the Balearic Sea by Massutí et al. (2000).

The feeding study provides an accurate description of the diet composition with an identification of a higher number of prey taxa (67), an improvement on previous studies (Frogliia, 1976; Wurtz, 1977; Sartor et al., 1993; Madurell and Labropoulou, 2000).

Results put in evidence the habits of the bluemouth rockfish as a benthic feeder. Preferential prey categories are crustaceans, as also reported in studies carried out along the Moroccan coasts, western Mediterranean, and the Ligurian, Ionian and Tyrrhenian seas (Collignon and Alonclè, 1960; Frogliia, 1976; Wurtz, 1977; Macpherson, 1981; Sartor et al., 1993; Madurell and Labropoulou, 2000).

The value of Levin's index indicates a moderate trophic niche width with a diet dominated by a limited number of taxa. The two dominant prey species (*G. rhomboides* and *Lophog-*

*aster typicus*) show quite high frequencies of occurrence that, combined with their high prey-specific abundances and %W, suggest a slight population specialization towards these two species (which again lead to a quite narrow population niche width). The role of *G. rhomboides* as a preferential food in the bluemouth diet was also reported by Frogliia (1976) in the same area (southern Tyrrhenian Sea) where this burrowing crab is abundant (Castriota et al., 2004).

In contrast with other studies (Collignon and Alonclè, 1960; Madurell and Labropoulou, 2000), fishes were only occasionally found in the bluemouth gastric contents. However, the occurrence of myctophid fishes in the diet, together with other pelagic prey performing vertical migrations, indicates that *H. d. dactylopterus* could play a role in the energy transfer from pelagic to benthic domains.

Statistical analysis showed a shift between feeding habits of fishes belonging to size 1 (4.0–6.3 cm TL) and larger fishes. In particular, as reported also by other authors (Madurell and Labropoulou, 2000; Sartor et al., 2003), small fishes feed mainly on mysids with a preference for *L. typicus* whereas adults are feeders of reptantian decapods (mostly *G. rhomboides*). This ontogenetic shift toward bigger prey could be related to a size increase in the mouth gape of adult fishes. Moreover, the contribution of prey types appeared to be depth related, maybe because of the different composition of the macrobenthonic communities along the bathymetric gradient.

This study provides new information on the biology and ecology of the bluemouth, contributing to the knowledge required by resource management. Nevertheless, more research effort should be finalized to standardize age reading methods in order to better compare results from different study areas.

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