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RECORDS OF SOME RARE DEEP-SEA FISHES CAUGHT IN THE LION, SUSAN, AND UNICORN SEAMOUNTS, OFF THE ARCHIPELAGO OF MADEIRA (EAST-CENTRAL ATLANTIC)

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Abstract. Fish communities off the seamounts inside the Madeira exclusive economic zone are scarcely known, hence the need to improve this knowledge. A bottom trawl fishing survey targeting orange roughy, *Hoplostethus atlanticus* Collett, 1889, was carried out on the Lion, Susan, and Unicorn seamounts in the autumn of 2001. The aim of this paper is to give an account of the catches of that survey, during which 9 tows were conducted and 21 deep-sea fish species caught, including species rarely caught. The following fish species were collected: *Chlamydoselachus anguineus* Garman, 1884; *Scymnodon ringens* Barbosa du Bocage et de Brito Capello, 1864; *Dalatias licha* (Bonnaterre, 1788); *Centrophorus squamosus* (Bonnaterre, 1788); *Deania profundorum* (Smith et Radcliffe, 1912); *Deania hystricosa* (Garman, 1906); *Serrivomer beanii* Gill et Ryder, 1883; *Rouleina maderensis* Maul, 1948; *Argyropelecus gigas* Norman, 1930; *Chauliodus sloani* Bloch et Schneider, 1801; *Macroparalepis nigra* (Maul, 1965); *Neoscopelus microchir* Matsubara, 1943; *Gadomus arcuatus* (Goode et Bean, 1886); *Mora moro* (Risso, 1810); *Melanonus zugmayeri* Norman, 1930; *Chaunax suttkusi* Caruso, 1989; *Diretmoides pauciradiatus* (Woods, 1973); *Hoplostethus mediterraneus* Cuvier, 1829; *Beryx splendens* Lowe, 1834; *Epigonus telescopus* (Risso, 1810); *Aphanopus carbo* Lowe, 1839. The presence of *Diretmoides pauciradiatus* was confirmed in the area and *Gadomus arcuatus* was recorded for the first time from Madeira. Aspects of the life history traits of some of the species caught are presented. This includes a first approach to the estimation of the length–weight relations of 11 deep-water, data-deficient species for which prior information, estimated from data collected, did not exist in FishBase and some new insights about the biology of *Hoplostethus mediterraneus*.

Keywords: deep-water fishes, species composition, relative growth, life history

A growing interest emerged, in the last decades of the 20th century, in the development of the exploitation of deep-sea species (Merret and Haedrich 1997). During this period, commercial fishing has greatly increased the fishing effort directed to seamount-aggregated species like the orange roughy, *Hoplostethus atlanticus* Collett, 1889, oreos (Oreosomatidae), and alfonsinos (*Beryx* spp.) (see Koslow et al. 2000, Morato and Clark 2007). Although the seamount-related fisheries represent nowadays a high stake of the world deep-water fish catches, seamount research has mostly followed fisheries exploitation. Seamounts are still poorly understood habitats, among other issues concerning the living communities they support (Brewin et al. 2007).

There is also a lack of knowledge about the life history of seamount fishes, with the majority of studies focusing on the main commercial species. Contributions on these issues are particularly important considering that seamount species, and particularly seamount-aggregating species, are more vulnerable to overfishing than other deep-sea species (Morato and Clark 2007).

Before the establishment of Exclusive Economic Zones (EEZ) in 1977, some 10 seamounts around the archipelagos of Madeira and Canaries were exploited by fishermen. The fishing gear used were mostly pelagic trawl, less frequently bottom trawl and seine. These fisheries continued intermittently after that date in the seamounts

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in international waters (Clark et al. 2007). Nowadays, the seamounts inside the Madeira EEZ are subject only to small scale fisheries using bottom or drifting long-lines to catch demersal fishes, mostly the bathypelagic—black scabbardfish, *Aphanopus carbo*, and intermediate scabbardfish, *Aphanopus intermedius* Parin, 1983 (see Biscoito et al. 2011, Delgado et al. 2013).

In October 2001, a fishing survey was done using a commercial trawler in order to assess potential fishing opportunities for orange roughy in the seamounts inside the Madeira EEZ. The survey failed in encountering the target species, but allowed to obtain information about some rare or poorly known deep-sea fishes and provided an opportunity to gather biological data of the most commonly caught species.

The main purpose of this paper is to give an account on the species recorded in the catches of the trawling survey, including some species that are seldom caught or the presence of which in the area was doubtful until now. It also provides a contribution to the knowledge about some aspects of the life history traits of the most commonly caught species during the tows, namely its length composition and relative growth.

Fish specimens were collected during a trawl survey at depths of about 1500 m using a commercial trawler (F/V *Pakura*) within 26–31 October 2001. Nine tows taking in average 55 min were made at Unicorn, Lion, and Susan seamounts within the Portuguese EEZ near Madeira (eastern-central Atlantic) (Table 1).

The species composition of each catch was assessed before processing the specimens and the list of species is arranged taxonomically according to Nelson (2006). Whenever possible, specimens of species that are seldom caught were retained and frozen for further identification. Voucher specimens were deposited in the collection of the Funchal Natural History Museum (MMF).

For each specimen, the total length (TL) was recorded to the nearest centimetre and total weight (W) and gonad weight (GW) to the nearest gram. Whenever possible, sex and gonad development stages were determined macroscopically. Gonad development was classified according to a six-point maturity scale adapted from Holden and Raitt (1974): 0 = immature; I = recovering spent; II = early maturing, development; III = late maturing, ripening; IV = ripe; V = spawned, spent.

Due to insufficient number of specimens collected for the majority of species, length–weight relation (LWR) was estimated following a method suggested in Froese (2006), setting the slope to 3 ($b = 3$)

$$a = W \times \left(L^3 \right)^{-1})$$

and taking the geometric mean of "a" for species where several specimens were available. For *Hoplostethus mediterraneus*, the sole species with a sufficient number of collected specimens, length–weight relation was estimated by least-square linear regression analysis of log transformed length and weight data (Bagenal and Tesch 1978)

$$\log W = \log a + b \times \log L$$

In this species the gonadosomatic index was obtained following the formula (King 2007)

$$\mathrm{GSI} = 100 \times \mathrm{GW} \times W^{-1}$$

Whenever parametric tests were used to compare means, the samples were tested for normality and homogeneity of variances (respectively Kolmogorov–Smirnov and Levene's tests; $\alpha = 0.05$).

A total of 197 specimens of 21 fish species, belonging to 19 families, were caught during the survey tows (Table 2). The following fish species were collected: *Chlamydoselachus anguineus* Garman, 1884; *Scymnodon ringens* Barbosa du Bocage et de Brito Capello, 1864; *Dalatias licha* (Bonnaterre, 1788); *Centrophorus squamosus* (Bonnaterre, 1788); *Deania profundorum* (Smith et Radcliffe, 1912); *Deania hystricosa* (Garman, 1906); *Serrivomer beanii* Gill et Ryder, 1883; *Rouleina maderensis* Maul, 1948; *Argyropelecus gigas* Norman, 1930; *Chauliodus sloani* Bloch et Schneider, 1801; *Macroparalepis nigra* (Maul, 1965); *Neoscopelus*

Table 1

Characteristics of the fisheries survey carried out at the Lion, Susan, and Unicorn seamounts, off the archipelago of Madeira

Location	Beginning of tows			Mean depth [m]
	Date	Hour	Coordinates	
Pelagic trawl	26 Oct 2001	09:01	34º10′N, 14º20′W	—
Lion seamount	27 Oct 2001	13:50	35º14′N, 15º26′W	939
Lion seamount	27 Oct 2001	21:16	35º16′N, 15º29′W	1045
Lion seamount	28 Oct 2001	09:47	35º20′N, 15º36′W	1277
Unicorn seamount	28 Oct 2001	23:20	34º47′N, 14º30′W	1211
Unicorn seamount	29 Oct 2001	15:40	34º49′N, 14º35′W	1412
Susan seamount	30 Oct 2001	20:50	32º45′N, 13º13′W	695
Susan seamount	31 Oct 2001	09:36	32º45′N, 13º12′W	1091
Susan seamount	31 Oct 2001	16:15	32º45′N, 13º12′W	1098

Mean depth obtained from depths recorded at the beginning and end of each set.

microchir Matsubara, 1943; *Gadomus arcuatus* (Goode et Bean, 1886); *Mora moro* (Risso, 1810); *Melanonus zugmayeri* Norman, 1930; *Chaunax suttkusi* Caruso, 1989; *Diretmoides pauciradiatus* (Woods, 1973); *Hoplostethus mediterraneus* Cuvier, 1829; *Beryx splendens* Lowe, 1834; *Epigonus telescopus* (Risso, 1810); *Aphanopus carbo* Lowe, 1839. The highest number of fishes caught (86%) occurred in the Susan seamount, but the catch mainly (82%) constituted of specimens of the Mediterranean slimehead, *H. mediterraneus*.

Three of the species recorded (*Serrivomer beanii*, *Chauliodus sloani*, and *Macroparalepis nigra*) are bathypelagic fish caught during a trial pelagic trawl.

Descriptive statistics of the size of the specimens are indicated for all the species caught and provided the values obtained for the parameter *a* of the LWR of 20 species (Table 3).

The samples of the Mediterranean slimehead, the most abundant species, were taken from the catches obtained on the bathyal bottom in the Susan seamount, in 3 bottom trawling tows. The mean tow depths were 695, 1091, and 1098 m. The length composition of all the individuals of *H. mediterraneus* caught is showed in Fig. 1. The size of the specimens ranged from 16 to 29 cm TL. The mean size (TL) of males (24.36 cm) and females (24.14 cm) caught was equal (*t*-test, $P > 0.05$), however, fish caught at deeper tows (1091 m and 1098 m: 24.60 cm) had a higher mean size than fish caught at a lower depth (695 m: 23.53 cm) (*t*-test, $P < 0.05$).

A relation between FL and TL (both in cm), was obtained from 75 specimens: TL = 1.0518 FL + 3.4014; $r^2 = 0.8785$; $n = 75$; the relation between TL [cm] and W [g] in the pooled specimens was: $W = 0.0088\ TL^{3.1533}$; $r^2 = 0.9258$; $n = 141$; both relations were significant (ANOVA; $P < 0.05$).

The analysed gonads ($n = 28$) showed a 1 ÷ 1 sex ratio in an early stage of maturation (II). The respective mean GW and GSI were: 3.01 ± 0.97 (females), 0.76 ± 0.25 (males) and 1.43 ± 0.29 (females), 0.37 ± 0.11 (males).

Among the catches the presence of one specimen of *Diretmoides pauciradiatus* is a rare occurrence and confirms the presence of this species in the FNAM area (Whitehead et al. 1986), which was considered as doubtful by Post (1986). In the case of *Gadomus arcuatus*, although its occurrence was known from off the Canaries, Morocco, Azores, and Portugal (Geistdoerfer 1986, 1990, Froese and Pauly 2016) this is, to our knowledge, the first record of this species from the Madeiran waters.

Table 2

List and abundance of species caught in the fisheries survey carried out at the Lion, Susan, and Unicorn seamounts, off the archipelago of Madeira

Family	Species	Seamounts with mean depth of tows [m]									Voucher specimens
		Lion			Susan			Unicorn		PEL	
		939	1045	1277	695	1091	1098	1211	1412	—	
CHLA	*Chlamydoselachus anguineus*	—	—	—	—	—	—	1	—	—	MMF33890
SOMN	*Scymnodon ringens*	—	—	1	—	—	—	—	—	—	
DALA	*Dalatias licha*	—	1	—	—	—	—	—	—	—	
CENT	*Centrophorus squamosus*	—	—	1	—	—	—	—	—	—	
	Deania profundorum	—	1	—	1	—	1	—	—	—	MMF33892
	Deania hystricosa	—	1	—	—	—	—	—	—	—	MMF33891
SERR	*Serrivomer beanii*	—	—	—	—	—	—	—	—	1	
ALEP	*Rouleina maderensis*	—	—	6	—	—	—	—	—	—	
STER	*Argyropelecus gigas*	—	—	—	—	—	—	1	—	—	MMF36285
STOM	*Chauliodus sloani*	—	—	—	—	—	—	—	—	1	
PARA	*Macroparalepis nigra*	—	—	—	—	—	—	—	—	1	
NEOS	*Neoscopelus microchir*	—	—	—	3	—	—	—	—	—	MMF33893
MACR	*Gadomus arcuatus*	—	—	—	—	—	—	1	—	—	MMF38664
MORI	*Mora moro*	—	1	—	—	1	—	—	—	—	
MALA	*Melanonus zugmayeri*	—	—	1	—	—	—	—	—	—	
CHAU	*Chaunax suttkusi*	—	1	—	—	—	—	—	—	—	MMF36284
DITR	*Diretmoides pauciradiatus*	—	1	—	—	—	—	—	—	—	
TRAC	*Hoplostethus mediterraneus*	—	—	—	68	90	3	—	—	—	MMF33806
BERC	*Beryx splendens*	—	—	—	3	—	—	—	—	—	
EPIG	*Epigonus telescopus*	1	—	—	—	—	—	—	1	—	
TRICH	*Aphanopus carbo*	—	—	2	—	—	—	2	—	—	
Total		1	6	11	75	91	4	5	1	3	

PEL = pelagic trawl; CHLA = Chlamydoselachidae, SOMN = Somniosidae, DALA = Dalatiidae, CENT = Centrophoridae, SERR = Serrivomeridae, ALEP = Alepocephalidae, STER = Sternoptychidae, STOM = Stomiidae, PARA = Paralepididae, NEOS= Neoscopelidae, MACR = Macrouridae, MORI = Moridae, MALA = Melanonidae, CHAU = Chaunacidae,DITR = Diretmidae,TRAC = Trachichthyidae, BERC = Berycidae, EPIG = Epigonidae, TRICH = Trichiuridae.

Table 3

Length and weight descriptive statistics of the species caught in the fisheries survey carried out at the Lion, Susan, and Unicorn seamounts, off the archipelago of Madeira

Species	*n*	Total length [cm]			Weight [g]			*a*	*b*
		TL	SD	Range	*W*	SD	Range		
Chlamydoselachus anguineus	1	151	—	—	6300	—	—	0.00183	3
Scymnodon ringens	1	73	—	—	2480	—	—	0.00638	3
Dalatias licha	1	132	—	—	12700	—	—	0.00552	3
Centrophorus squamosus	1	114	—	—	6350	—	—	0.00429	3
Deania profundorum	3	60	19.97	37–73	926	686.53	139–1400	0.00329	3
Deania hystricosa	1	84	—	—	2100	—	—	0.00354	3
Serrivomer beanii	1	48	—	—	30	20.97	51–97	0.00027	3
Rouleina maderensis	6	25	1.97	23–28	72	—	—	0.00432	3
Argyropelecus gigas	1	14	—	—	38	—	—	0.01384	3
Chauliodus sloani	1	27	—	—	37	—	—	0.00188	3
Macroparalepis nigra	1	44	—	—	42	—	—	0.00049	3
Neoscopelus microchir	3	33	1.73	32–35	357	44.52	325–407	0.00099	3
Gadomus arcuatus	1	41	—	—	310	—	—	0.00449	3
Mora moro	2	42	2.12	42–43	675	137.39	578–772	0.00937	3
Melanonus zugmayeri	1	25	—	—	79	—	—	0.00506	3
Chaunax suttkusi	1	26	—	—	410	—	—	0.02333	3
Diretmoides pauciradiatus	1	31	—	—	577	—	—	0.01937	3
Hoplostethus mediterraneus	141	24	2.24	16–29	207	57.24	50–390	0.00880	3.153
Beryx splendens	3	41	2	39–43	923	222.34	790–1180	0.01319	3
Epigonus telescopus	2	—	—	—	2000	1414.21	1000–3000	—	—
Aphanopus carbo	4	115	5.56	109–122	2105	166.03	1880–2280	0.00138	3

TL and *W* represent mean values when $n > 1$, SD = standard deviation; the parameter *a* from the WLR was estimated setting $b = 3$; Bold font denotes the fish species with no prior LWR parameters in FishBase.

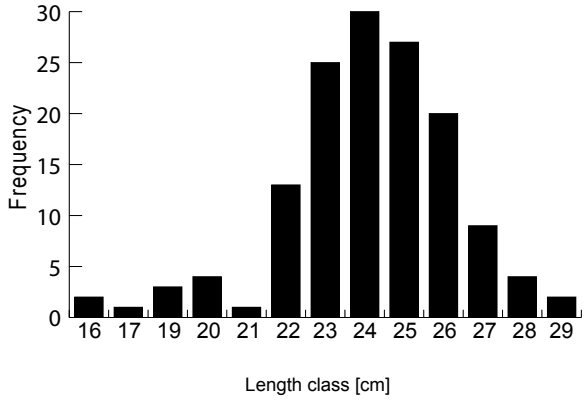

Fig. 1. Length composition of *Hoplostethus mediterraneus* (n = 141; mean TL = 24.09 cm) caught at Susan seamount, off the archipelago of Madeira

This study added information to the knowledge on the relative growth of deep water fishes considering that for 11 of the species caught (in bold in Table 3) no prior information estimated from data collection existed for LWR parameters in FishBase (Froese and Pauly 2016). In three species (*S. beanii*, *M. nigra*, and *N. microchir*) the value of *a* obtained in this study is outside the range indicated by the Bayesian estimates available in FishBase following the model developed by Froese at al. (2013).

This study provides an addition to the growth data studied in demersal fish species from this area of the Atlantic Ocean (Ferreira et al. 2007) representing a useful contribution to improve further species-specific parameter estimates in data deficient deep-sea fishes.

Concerning the Mediterranean slimehead, this species was only present in the catches made along the Susan seamount and, according to the growth performance of this species reported by D'Onghia (1998), the size composition of catches suggests all specimens caught were adult. Although young specimens were reported in catches of an experimental survey off the Greek and Italian Ionian Sea (Mytilineou et al. 2001) and from commercial trawling off South Portugal (Pais 2001), they were totally absent in this survey. The results obtained also showed an increase of the mean size of fish with depth, reflecting probable vertical segregation (the youngest up, the oldest down). This pattern was also reported by several other authors who have studied this species (D'Onghia et al. 1995, 1998, Figueiredo et al. 1995, Pais 2001, Vitale et al. 2006) and probably the cause for the absence of small sized individuals in this study, was the survey covering only depths deeper than 600 m.

The maturity stages found (late autumn) by this study suggest a later spawning season than found by Figueiredo et al. (1995) (winter), for this species off Portugal mainland. Based on the occurrence of spent fish from autumn to spring at the same latitudes, Pais (2001) suggested a more extended spawning season, which is more in line with the data obtained in this study.

Overall, this survey, with a few fishing hauls performed, resulted in new knowledge about the fish communities on seamounts, only confirming the need for further investigation about these ecosystems and strict conservation and management approaches to deal with activities, such as fisheries, in these peculiar and vulnerable sites that, appropriately, Pitcher et al. (2007) called: "the depths of ignorance".

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