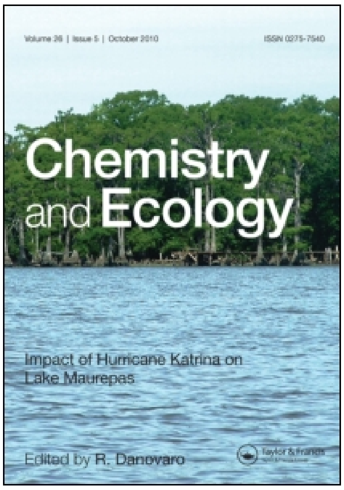

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SHORT NOTE

Biochemical composition of a meso-bathyal lobster (*Polycheles typhlops*, Heller 1862 Decapoda, Palinura, Polychelidae)

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To characterise some traits of the life strategies of *Polycheles typhlops*, a deep-sea small lobster usually encountered as by-catch within deep trawls in the Southern Tyrrhenian Sea (Mediterranean Sea), we analysed the biochemical composition of the caudal muscles of 49 specimens collected in March and April 2007. Differences in the biochemical composition between females and males were weak, but relevant differences in protein (>90% of the organic C) and lipid (4–6%) contents were observed between developmental stages both in females and males. These differences are likely to be related to different food items and/or to the metabolic shifts associated with their reproduction. We argue that this deep-sea lobster could cover a relevant role in the meso-pelagic food webs and attract future commercial interest.

Keywords: *Polycheles typhlops*; biochemical composition; deep sea

Life in the deep sea depends entirely upon the rain of material deriving from the productive superficial layers of the water column, and the quantity and composition of this material affects the trophic strategies of consumers, as well as their biochemical composition [1].

Many deep-sea organisms display specific adaptations to the low levels of available energy in their food-limited environment: adaptations in ponderal growth (gigantism vs. dwarfism) and in reproductive biology are, indeed, very common in the deep sea [2]. Despite the fact that the knowledge of the deep-sea has increased considerably in the last few decades, information on the biology and ecology of marine organisms living in the largest biome on Earth (i.e. deep oceans at > 1000 m depth) are still scarce, being limited in space and fragmentary in time [3].

Knowledge of the structure and function of communities supporting fishing stocks exploited by humans is considered a basic aim of fisheries research, in particular for the ecological sustainability of bottom trawling. The low selectivity of bottom trawling leads to many bentho-nektonic species, most of which have no commercial interest (by-catch), being caught and almost entirely discharged [4]. Most studies dealing with deep-sea fisheries conducted in the Mediterranean Sea have been dedicated to the commercial species, while species which are usually discharged as scrap fishing

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have been almost entirely neglected, despite some of those species have a strong role in the benthic ecosystem [5].

In the Mediterranean Sea, decapod crustaceans are one of the dominant groups of the megabenthos in the continental shelf, and are an important component of the demersal community [8,9]. In particular, in the Western Mediterranean Sea decapod crustaceans may represent up to 40% of the megafaunal biomass along the open slope [6]. Decapod crustaceans play an important ecological role in the deep Mediterranean communities, as they represent the linkage between the benthic macro-megafauna and the higher trophic levels, i.e. predator fishes [6].

The small lobster *Polycheles typhlops* (Polychelidae, Decapoda, Crustacea) is present in all oceans worldwide down to 5000 m water depth between 50°N and 55°S of latitude [7]. This species is particularly abundant in the Mediterranean Sea in epi- and meso-bathyal waters, between 450 and 2000 m water depth, and represents one of the most numerically conspicuous fractions of the deep trawling by-catch along the southern coasts of the Tyrrhenian Sea [13].

P. typhlops is almost entirely a scavenger, but there is evidence that this species also feeds on Euphasiacea and Mysidacea [12]. Recently, it has been suggested that the lack of structured eyes makes this species a 'non-visual feeder', confirming its preferential 'scavenging' feeding behaviour [12].

To provide the first insights on the potential trophic significance of *P. typhlops* in the meso-bathyal trophic webs of the Western Mediterranean Sea, we analysed the biochemical composition (protein, carbohydrate and lipid) of caudal muscle tissues of 49 specimens of *P. typhlops* in different developmental stages from males and females. The aim of this study was to provide the first characterisation of some traits of the life strategies of this deep-sea small lobster on the basis of its biochemical composition, and in response to some biological factors (sex and developmental stage).

Specimens of *P. typhlops* were caught using a bottom otter trawl with a 20 mm stretched mesh size cod end, on board of the fishing boat Gisella, during two fishing campaigns (March and April 2007) carried out along the south-western coast of Sardinia, Italy (Western Mediterranean sea) between 500 and 600 m water depths. Of the 49 specimens, 26 were females (F) and 23 were males (M). For each specimen, sex, developmental stage, carapace length, and the wet weight were immediately determined on board (Table 1). All specimens were assigned to one of four

Table 1. Sampling period, sex, developmental stage, number of specimens, carapace length (mm), wet weight (g) and biochemical composition of *Polycheles typhlops* specimens collected in the Southern Mediterranean Sea. Carapace length and wet weight are reported as average ± standard deviation.

Sampling period	Sex	Developmental stage	Number of specimens	Carapace length (mm)	Wet weight (g)	Protein (%)	Carbohydrate (%)	Lipid (%)
March 2007	F	Immature	7	24.3 ± 2.8	3.3 ± 1.2	87 ± 2	4 ± 1	9 ± 1
		Pre-mature	10	29.0 ± 4.2	5.6 ± 2.5	93 ± 0	2 ± 1	5 ± 1
		Mature	4	30.6 ± 1.9	6.9 ± 1.4	93 ± 3	3 ± 1	4 ± 2
		Post-spawning adult	2	30.0 ± 7.7	7.6 ± 5.6	88 ± 1	3 ± 1	10 ± 2
	M	Immature	0	–	–	–	–	–
		Pre-mature	7	38.6 ± 1.5	11.6 + 2.8	93 ± 1	2 ± 0	5 ± 1
		Mature	4	23.9 ± 2.1	3.7 ± 1.0	94 ± 1	2 ± 1	4 ± 0
		Post-spawning adult	8	24.6 ± 1.9	3.9 ± 1.0	89 ± 3	3 ± 1	8 ± 3
April 2007	F	Immature	0	–	–	–	–	–
		Pre-mature	0	–	–	–	–	–
		Mature	0	–	–	–	–	–
		Post-spawning adult	3	23.7 ± 1.9	3.1 ± 0.6	92 ± 9	2 ± 0	6 ± 1
	M	Immature	0	–	–	–	–	–
		Pre-mature	1	19.5 ± 0.0	1.9 ± 0.0	92 ± 6	1 ± 0	7 ± 1
		Mature	1	18.8 ± 0.0	1.8 ± 0.0	92 ± 6	2 ± 0	6 ± 1
		Post-spawning adult	2	39.3 ± 1.3	10.2 ± 1.8	85 ± 5	3 ± 0	12 ± 1

developmental stages according to the animals' sexual maturity: immature, maturing, mature and post-spawning adults [7]. The total body weight (W) and length (L) from all male and female specimens were log-log transformed and used to fit the allometric regression model [14,15]. All specimens were then preserved at −20° C until the biochemical analyses were carried out in the laboratory (within two weeks of sampling).

Once in the laboratory, the tissues of each specimen were homogenised by means of an ultra-turrax and three aliquots of the homogenates were analysed for protein, carbohydrate and lipid content using spectrophotometric assays [14]. Protein, carbohydrate and lipid contents were converted into carbon equivalents using the conversion factors of 0.40, 0.49 and 0.75 $mg\,C \cdot mg^{-1}$ and normalised to the wet weight [17].

Differences in the biochemical composition of different developmental stages were assessed using one-way analysis of variance (ANOVA) separately for females and males, followed by a Student–Newman–Keuls (SNK) post-hoc comparison test (at $\alpha = 0.05$). One-way ANOVA was also carried out to ascertain differences in content of all of the measured variables between the two sampling periods (i.e. March and April), separately for females and males.

The biochemical composition of tissues in marine organisms depends upon different factors, such as food availability, diet, sex, habitat, temperature, and season, but also upon the developmental stage. Since the accumulation of biopolymers such as proteins and lipids is the most widespread energetic strategy of marine heterotrophs [16], the analysis of the tissutal contents of protein, carbohydrates and lipids appears to be a useful tool for investigating their trophodynamics.

Previous studies pinpointed that seasonal fluctuations in the food availability can have considerable effects on the biochemical composition of different marine benthic invertebrates that were coupled with different bio-energetic strategies [18]. In comparison with the available literature on epi- and meso-pelagic species, however, fewer studies have addressed the relationships between biochemistry and the metabolism of deep-sea species. This lack of information is likely to be because the randomness of the food input to the deep sea makes investigations dealing with the

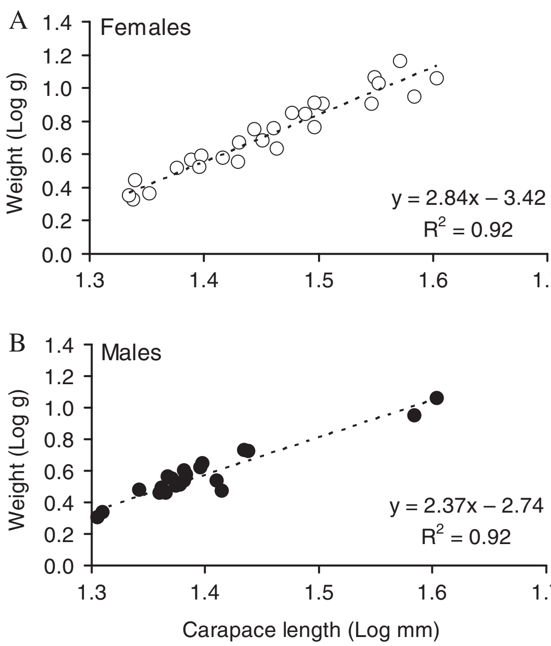

Figure 1. Allometric relationships in (A) females and (B) males of *Polycheles typhlops* in the Southern Tyrrhenian Sea.

bio-energy of organisms spending their entire life in these remote habitats more difficult. It is, however, worth noting that although benthic and bentho-pelagic life is defined by morphological, taxonomical, trophic and metabolic features, only a few studies have considered the biochemistry of benthic crustaceans [20].

The biometrical analyses of *P. typhlos* revealed the presence of a positive allometric relationship for the two sexes, with females exhibiting a ponderal growth per length unit slightly higher than the one of males (Figure 1). The sex-ratio (as females/[females + males]) of the analysed samples ranged from 0.50 to 0.69, and falls within the range of previous investigations [21] and for other deep-sea species (e.g. *Munida intermedia*) [22].

At both sampling times (i.e. March and April) the ANOVA revealed no significant differences in the biochemical composition between adult females and males (Table 2), suggesting that, at least during the sampling periods, both sexes could share similar feeding behaviour. In both sexes, a strong dominance of proteins (more than 90%) was observed, followed by lipids (4–6%) and carbohydrates (2–3%), as also reported for other marine crustaceans including Mysidacea, Harpacticoida and Euphasiacea [23,24]. In this regard, it is noticeable that lipid contents of *P. typhlops*

Table 2. Results of the ANOVA and post-hoc analyses carried out to test differences in the biometric attributes and biochemical composition: (a) between adult males and females in the two sampling periods; (b) between developmental stages in females and males; and (c) between the two sampling periods in males and females.

Sampling period	Variable	Mean square	F	*p*-level	Post-hoc
(a) Differences between males and females					
March	Weight	32.38	9.19	**	Females > Males
	Length	127.62	16.39	***	Females > Males
	Protein	2401.88	3.54	ns	na
	Carbohydrate	0.18	0.74	ns	na
	Lipid	0.18	0.81	ns	na
April	Weight	25.85	1.88	ns	na
	Length	23.59	0.43	ns	na
	Protein	171.07	0.28	ns	na
	Carbohydrate	1.06	5.18	ns	na
	Lipid	0.50	3.38	ns	na
(b) Differences between developmental stages					
Females	Weight	10.69	2.54	ns	na
	Length	24.83	2.96	ns	na
	Protein	1725.68	8.92	**	[2, 3] > [1, 4]
	Carbohydrate	0.44	2.14	ns	na
	Lipid	0.28	1.04	ns	na
Males	Weight	0.11	0.60	ns	na
	Length	0.10	0.10	ns	na
	Protein	2193.07	7.41	**	[2, 3] > [1, 4]
	Carbohydrate	0.38	3.06	ns	na
	Lipid	0.24	2.11	ns	na
(c) Differences between sampling periods					
Females	Weight	23.90	2.65	ns	na
	Length	113.10	7.44	ns	na
	Protein	2333.90	4.14	ns	na
	Carbohydrate	0.15	0.71	ns	na
	Lipid	0.16	0.55	ns	na
Males	Weight	74.38	87.14	***	April > March
	Length	366.21	571.61	***	April > March
	Protein	686.09	3.14	ns	na
	Carbohydrate	0.23	1.13	ns	na
	Lipid	0.01	0.24	ns	na

Notes: ** $p < 0.01$; *** $p < 0.001$; ns, not significant; na, not applicable.

are much lower than those reported for other deposit-feeding crustaceans of the northern Baltic Sea (15–45%) and of southern ocean deep waters (>40%) [14]. Since temperature and food availability have been invoked as the main determinants in controlling lipid content in marine crustaceans [25], the very low lipid contents of *P. typhlops* are likely to be related to the general oligotrophic conditions and higher temperatures typically encountered in the deep Mediterranean Sea [1].

In both males and females, significant differences in protein content were observed among the different developmental stages. Protein content increased from the immature to the mature stage then decreased in the post-spawning adult stage, whereas carbohydrate and lipid content displayed patterns opposite to the one of proteins (Figure 2). Changes in the biochemical composition of both males and females of *P. typhlops* are likely to be related with changes in feeding habits with ageing, but, at present, we cannot exclude that these differences could also be related to the depth at which the different size classes are typically encountered, with juveniles typically found at the highest depths [7]. Previous studies, in fact, identified water depth as a major factor controlling the biochemical composition of different marine crustaceans, depending upon the composition of the available food items [26]. Unfortunately, in the present study, we did not have the opportunity to collect samples from different water depths, so that the tendency of an accumulation of proteins in the mature stage cannot be unquestionably associated with changes in the trophic habits of specimens living at different depths.

Another possible explanation for the relevant changes in the biochemical composition of *P. typhlops* in the transition from the mature to the post-spawning adult stage could be the large metabolic shift that is typically associated with reproduction [27].

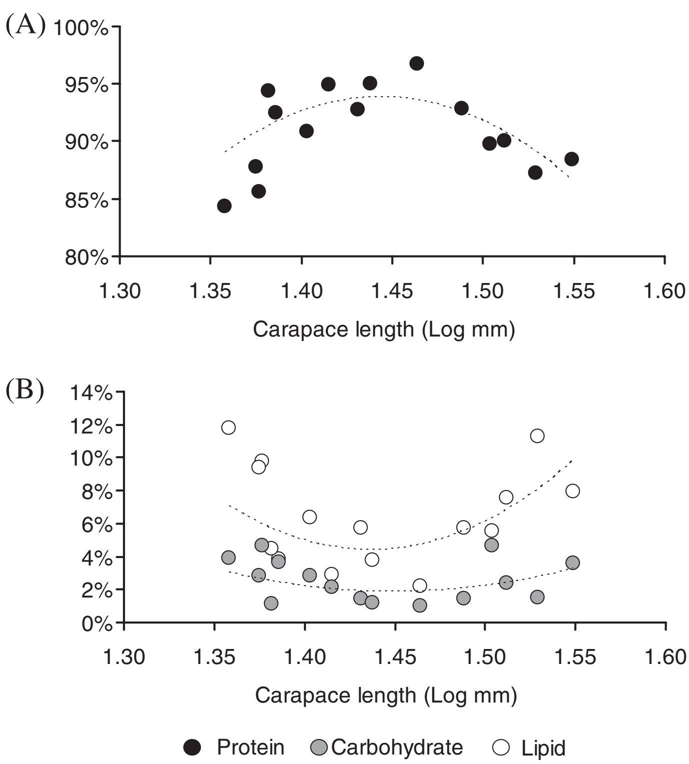

Figure 2. Changes in the biochemical composition of *Polycheles typhlops* in different developmental stages. Reported are: (A) protein and (B) carbohydrate and lipid concentrations. Data are relative to samples collected in March 2007.

The results of the present study suggest that *P. typhlos* is characterised by even short-term changes in the biochemical composition, and that these variations, apparently similar for females and males, could be associated with different trophodynamic strategies and, possibly, with different reproductive stages.

These results pinpoint also that this deep-sea lobster, being extremely rich in high-energy molecules (i.e. proteins and lipids), could, on the one hand, cover a relevant role in the meso-pelagic food webs and, on the other, attract future commercial interest. Before this species could enter the market for human consumption, further studies are therefore necessary to better assess: (i) its actual stocks; (ii) its biology and temporal (seasonal and interannual) dynamics; and (iii) the relationships between its biochemical composition and the bathymetric distribution and of its main food items.

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