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Biological and Ecological Aspects of the Blackmouth Catshark (*Galeus melastomus* Rafinesque, 1810) in the Southern Tyrrhenian Sea

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Abstract: Data on the biology and ecology of *Galeus melastomus* are old/absent for the Southern Tyrrhenian Sea, despite there being numerous studies in the wider area. A total of 127 specimens of *G. melastomus* from the southern Tyrrhenian Sea, collected in 2018–2019 using trawling nets, were analyzed to investigate size at sexual maturity, sex ratio, length–weight relationships, and feeding habits. To our best knowledge, this is the first time in which all these features were investigated in the Southern Tyrrhenian Sea for *G. melastomus.* The stomach content analysis showed that *G. melastomus* had intermediate feeding habits, preying on a great variety of species, especially Cephalopoda, Osteichthyes, and Crustacea. The Levin's index value (Bi) was 0.53. Sex ratio was 0.92:1, with females slightly more abundant and bigger than males. The results also showed a decrease (33.7 cm for females, 31.1 cm for males) in length at 50% maturity (L_{50}). This could be a result of anthropogenic stressors, such as overfishing and/or and environmental changes, which can induce physiological responses in several species. Our results highlighted the differences related to sexual maturity, growth, and feeding habits of the blackmouth catshark in the studied area, providing reference data to allow comparison with future studies on this species adaptations to this and other deep-sea areas in the Mediterranean Sea.

Keywords: sexual maturity; sharks diet; length–weight relationship; feeding habits; blackmouth catshark

1. Introduction

Elasmobranchs are a key group for the smooth functioning of marine ecosystems, as they regulate prey populations and the ecological dynamics among the different habitats they move between [1–4]. Sharks, skates, and rays are both top predators and meso-predators in most marine environments, but despite their importance, elasmobranchs are seriously threatened by fishing activities worldwide. Their vulnerability to fishing activities, both directly for human consumption (meat and fins) and as by-catch in several fisheries, is related to their reproductive cycle, characterized by low fecundity and delayed age at maturity [5,6]. More than half of the Mediterranean elasmobranchs are regarded as threatened (included in the IUCN red list) [7], including "deep-water species" (below

200 m). The demersal deep-sea animals are particularly vulnerable to trawl fisheries, which is one of the most important fishery activities, operating at a bathymetric range of 50 to 800 m and exploiting a wide variety of species [8].

However, among demersal elasmobranchs, Scyliorhinidae—as *Galeus melastomus*, Rafinesque, 1810; *Scyliorhinus canicula* Linnaeus, 1758, and *Scyliorhinus stellaris* Linnaeus, 1758—are better able to resist high fishing pressure [9–11]. These include early maturation [12], short generation time, faster population dynamics [13], morpho-functional adaptation of gastroenteric and sensorial systems [14,15], and, for *G. melastomus* and *S. canicula*, a continuous reproductive cycle. These biological features helped them adapt to the most exploited environments. Thanks to early maturation, short generation time, faster population, and a continuous reproductive cycle, they can maintain their population, concluding their reproductive cycle before being caught (unlike most elasmobranchs), despite a high fishing effort. Moreover, their gastroenteric and sensorial system helped them adapt to scavenger feeding habits and mesopelagic hunting, both essential in deeper habitats, often overexploited by trawling. Despite smaller specimens of *G. melastomus* and *S. canicula* being commonly caught by deep-sea trawl fishing, their populations seem to be maintained in many overexploited areas in the Mediterranean Sea and Atlantic Ocean [9,11,16–19]. By monitoring their diet and feeding habits, especially for *G. melastomus*, which is commonly caught by trawl fisheries, it is possible to obtain new information about deep benthopelagic environments by studying the changes in abundance and population dynamics of *G. melastomus* [8,20–22].

The blackmouth catshark (*G. melastomus*) is an oviparous demersal elasmobranch belonging to the Carcharhiniformes order that lives in the benthic environments of the outer continental shelf breaks and upper slopes [21,22]. It is ubiquitous in the Mediterranean basin, and it is also distributed in the eastern Atlantic [23,24]. It occupies a generalist niche, with a low trophic level, and it is an opportunistic generalist predator, feeding mainly on mesopelagic species. It can adapt its diet to the available prey in different marine environments and with seasonal fluctuations, and sometimes shows scavenger behavior [8].

The reported depth range for *G. melastomus* is from 55 to 1873 m, but it is commonly found between 300 and 800 m deep. In the southern Tyrrhenian Sea, according to previous studies [22,25], this species prefers depths between 500 and 800 m, while in the western basin, it is common between 400 and 1400 m. Larger individuals often prefer the trawled muddy bottoms between 200 and 550 m, as shown by the high occurrence of this species in the by-catch of trawl fisheries [26]. This can be correlated with the scavenging habits of the species, which increase with growth [27,28]. The blackmouth catshark has shown allometric growth in the southern Tyrrhenian Sea and Ionian Sea, with a continuous reproductive period in the Tyrrhenian Sea, Adriatic Sea, Alboran Sea, and off Southern France [9,13,25,29].

The aim of this paper was to investigate several aspects of the biology and ecology of the species. The aspects on which we focused were growth parameters, feeding habits, and size at sexual maturity in specimens of *G. melastomus* from the southern Tyrrhenian Sea. In the Mediterranean Sea, data about this species are generally dated and fragmented, and to the best of our knowledge, the present research represents the first study in the southern Tyrrhenian Sea focused on *G. melastomus* biology.

2. Materials and Methods

A total of 127 specimens of *G. melastomus* ranging from 14.5 to 52 cm in total length (TL) were collected in the southern part of the Tyrrhenian Sea (geographical subarea (GSA)—10), from the coastal area of Campania (41°14′38.7″ N 13°37′04.2″ E) to San Vito lo Capo (38°11′41.0″ N 12°44′29.8″ E) (white arrows in Figure 1b), including the entire Sicilian Tyrrhenian coast. Blackmouth catsharks were sampled in 2018 and 2019 using trawl nets during MEDITS (international bottom trawl survey in the Mediterranean) [30] and from commercial landings of the fishing fleet CAMPBIOL (PLNRDA 2017–2019-CAMPBIOL) survey [31].
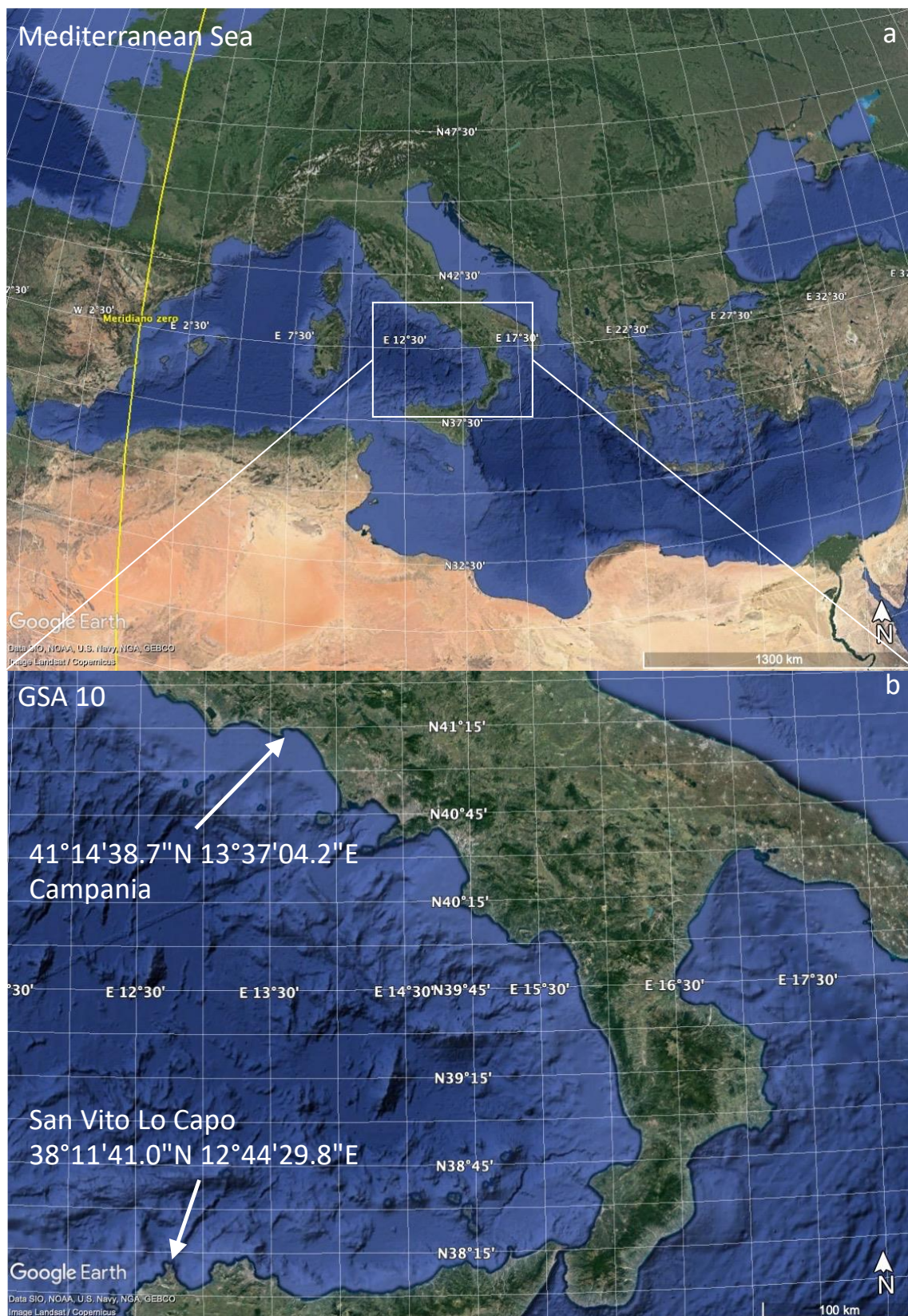
Figure 1. Maps of the Mediterranean Sea (**a**) and the subarea studied (GSA 10) (**b**). In (**b**), the white arrows indicate northern and southern GSA geographical border points with their relative coordinates.

Samples collected during spring, summer, and autumn were frozen on board to prevent the digestion of the stomach content and were immediately transferred to the laboratory after landing. In the laboratory, each specimen was measured (TL in cm) and weighed (W in g), and the sex was determined.

Weight and total length measurements of 127 specimens were used for the total length–weight relationships (LWR) following the formula: $W = aTL^b$, where W is the weight in grams (g), TL is the total length in centimeters (cm), a is the intercept, and b is the slope of the logarithmic regression curve (Bayes method) [32–34]. A *t*-test was used to verify the null hypothesis of the isometric growth (H0: b = 3): when b = 3, the increase in weight was isometric; when b > 3, the weight increase was positive allometric (the fish grew faster in weight than in length); if b < 3, the weight increase was negative allometric (the fish grew faster in length than in weight) [35]. Total length frequency distributions were constructed for both sexes. A chi-square test [36] was used to verify if there was a significant difference ($\alpha = 0.05$) between the observed and the expected sex ratio (M:F, 1:1). To test if the regressions of the weight (W) on total length (TL) were significantly different ($\alpha = 0.05$) for the sexes, an analysis of covariance (ANCOVA) was performed. A *t*-test was used to verify females' length compared to males.

Size at sexual maturity of both females and males was estimated using "sizeMat", an open-source software package that runs on the R platform. Specimens were first divided into two pools according to sex. Following the proposed protocol [37], two data frames were prepared, containing three variables: TL (cm), sex, and gonadal stages. Sex and gonadal stages were estimated visually at the macroscopical level according to the codes of sexual maturity for fish [38], considering immature ("I") the specimens with a maturation state of "Immature/Virgin" (Stage 1 of the code of sexual maturity for fish), while considering mature ("II, III, IV") all the others (Stages 2, "Maturing"; 3a, "Mature"; 3b, "Mature/Extruding"; and 4b, "Regenerating", of the code of sexual maturity for fish [38]). The function used to estimate gonadal stages was "gonad_mature" set on the GLM (generalized linear model, frequentist) regression method. The maturity ogive estimation obtained was subsequently plotted using the "plot" function to extrapolate the graphs.

During the stomach content analyses, each prey item was identified to the lowest taxonomic level possible, counted, and weighed. In the category "digested", all prey not identified because they were too digested or were identified as discards of fishing activities were included. The vacuity index (VC) was calculated to evaluate the percentage of empty stomachs, using the formula: VC = (Ne/N) × 100, where Ne is the number of empty stomachs and N is the number of total stomachs analyzed [39]. No everted stomachs were found in the analyzed specimens. The contribution of each prey item was calculated using the percentage of abundance composition (%N), the percentage of biomass composition (%W), and the frequency of occurrence (%F) [40]. Through these indices, the index of relative importance, IRI = %F(%N + %W) was calculated [41,42]. According the %N values, prey were classified as dominant (N > 50%), secondary (10% < N < 50%), or accidental (N < 10%) [43]. The breadth of the diet was evaluated using the standardized Levin's index (B_i) [44]:

$$B = \frac{1}{\sum p_j^2}$$

$$B_i = \frac{B - 1}{B_{max} - 1}$$

where p_j is the relative specimen's frequency of the jth prey item and B_{max} is the total number of prey item categories found. B_i was calculated only for prey categories identified at the generic or specific level, while main categories such as phylum or order were excluded from analysis in order not to alter the results due to the aggregation of several species under a single category. The same categories were also considered for the three levels of "dominance" of %N. If the trophic niche of the studied species is narrow, B_i values are near 0, but if the trophic niche is wide, B_i values are closer to 1. According to B_i value,

the species are classified as specialist feeder ($B_i < 0.40$), intermediate feeder ($0.40 < B_i < 0.60$) or generalist feeder ($B_i > 0.60$) [45].

Using R studio and the "vegan" package, a cumulative prey curve was estimated to assess the representativity of analyzed stomachs, to obtain sufficient data to define the diet of the species in the studied area. The cumulative number of analyzed specimens was plotted against the estimated number of prey groups with the associated standard deviation (SD). Prey items recorded only once in the stomachs were excluded from analysis because they were considered as "accidental" preys.

3. Results

Out of the total of 127 specimens studied, 61 were males and 66 were females, with a sex ratio of 0.92:1, not significantly different from 1:1 (*p*-value = 0.657). Females showed, on average, larger sizes than males (Figure 2, Table 1), ranging from 21.5 to 52 cm (SD = 8.4; *p*-value = 0.034) in total length and from 25 to 538 g (SD = 129.8; *p*-value = 0.029) in weight.
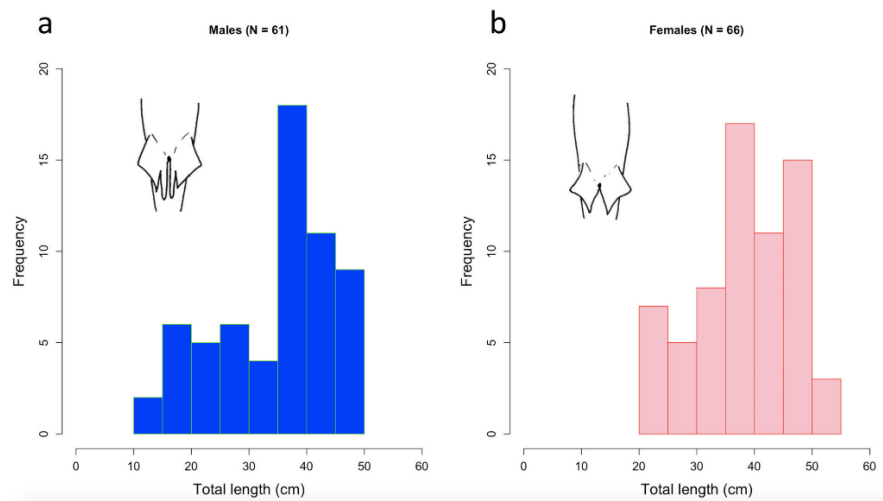

Figure 2. Sex composition by size classes of *G. melastomus*: (**a**) male; (**b**) female.

Table 1. Total length–weight relationship parameters of *G. melastomus* in the Tyrrhenian Sea (western Mediterranean Sea); "a" represents the values of the intercept, and "b" is the slope of the logarithmic regression curve. C.I. = 95% confidence interval.

			Length–Weight Relationship Parameters			
	a	C.I. a	b	C.I. b	R^2	*p*-Value
Females	0.001	0.001–0.002	3.201	3.058–3.343	0.969	0.027
Males	0.003	0.002–0.004	2.953	2.883–3.023	0.992	0.047
Combined	0.002	0.001–0.003	3.049	2.976–3.121	0.982	0.079

The analysis of sexual maturity and size showed the presence of both adults and juveniles. Male specimens showed a total length ranging from 14.5 to 50 cm (SD = 10.1) and a weight ranging from 9.5 to 386 g (SD = 99.8). For the entire sample (both sexes, N = 127), the total length ranged from 14.5 to 52 cm (SD = 9.4), and the weight from 9.5 to 538 g (SD = 119.8). Results obtained with the ANCOVA test showed that females were heavier than males (*p*-value = 0.0047). The total length–weight relationships for both sexes and combined are reported in Table 1 and graphically represented in Figure 3. A positive allometry was found for females (b = 3.201), while males showed a negative allometry (b = 2.953), and an isometric growth was obtained for both sexes combined (b = 3.049) (Figure 3b, Table 1).
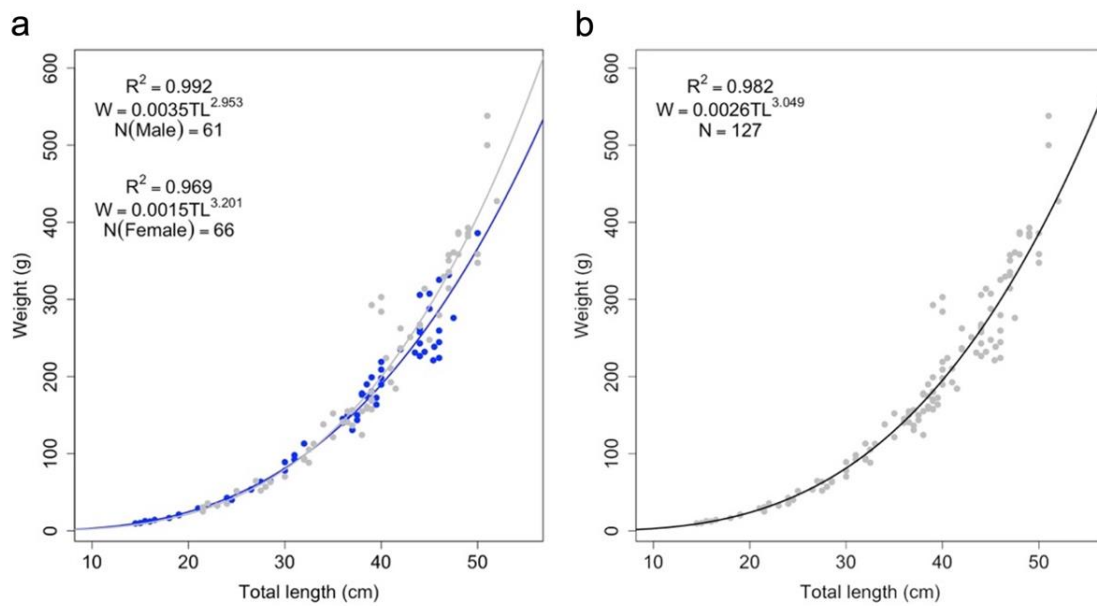
Figure 3. Total length–weight relationships of *G. melastomus* for both sexes: (**a**) females (gray, N = 66) and males (blue, N = 61) and (**b**) combined.

The size at first (50%) maturity (L_{50}) was 33.7 cm for females and 31.1 cm for males, indicating that females mature at larger sizes than males (Figure 4).
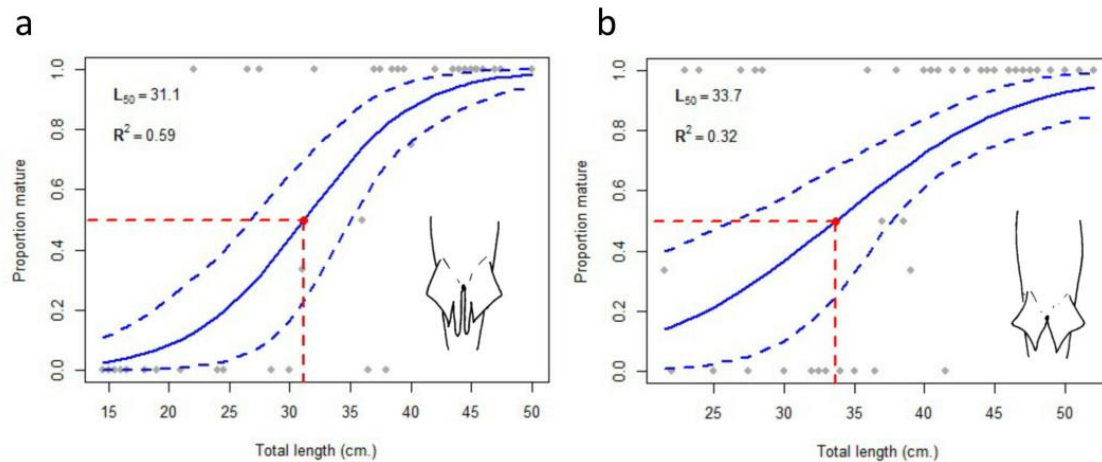

Figure 4. Plotting the maturity ogives of *G. melastomus* male (**a**) and female (**b**) specimens: values of size at gonad maturity (L_{50}) and R-squared (R^2) are reported. Grey dots refer to the specimens analyzed. Red dots indicate the L_{50} in the curve. Dashed blue curves indicate confidence intervals.

As shown by the cumulative prey group (Figure 5), the number of analysed stomachs was sufficient to describe the *G. melastomus* diet. The vacuity index was 11.8%, with 15 empty stomachs out of the total number of stomachs analysed (N = 127).

The B_i value obtained was 0.53, indicating quite generalist feeding habits and an intermediate, between wide and narrow, trophic niche for *G. melastomus*. The values obtained for %N indicated there were no dominant prey, with Crustacea (mainly Decapoda and Euphausiacea), Mollusca (mainly Cephalopoda), and Osteichthyes classified as secondary prey (10% < N < 50%) (Table 2). The values obtained for %W indicated the importance of Osteichthyes (40.67%) and Mollusca (44.05%), especially Cephalopoda (43.87%) (Figure 6, Table 2) in the diet of this species. Among Cephalopoda, the highest %W values were obtained for *Eledone* sp. (11.22%); *Todarodes sagittatus*, Lamarck, 1798 (9.66%); and *Histioteuthis* sp. (6.96%). Among Osteichthyes, the highest %W values were obtained for Osteichthyes

not identified (n.i.) (20.22%); *Sardinella aurita,* Valenciennes, 1847 (5.74%); *Sardina pilchardus,* Walbaum, 1792 (3.77%); *Ceratoscopelus maderensis,* Lowe, 1839 (3.57%); and *Electrona risso,* Cocco, 1892 (3.16%) (Table 2). Concerning the %IRI, Osteichthyes showed the highest value (48.56%) (Table 2).
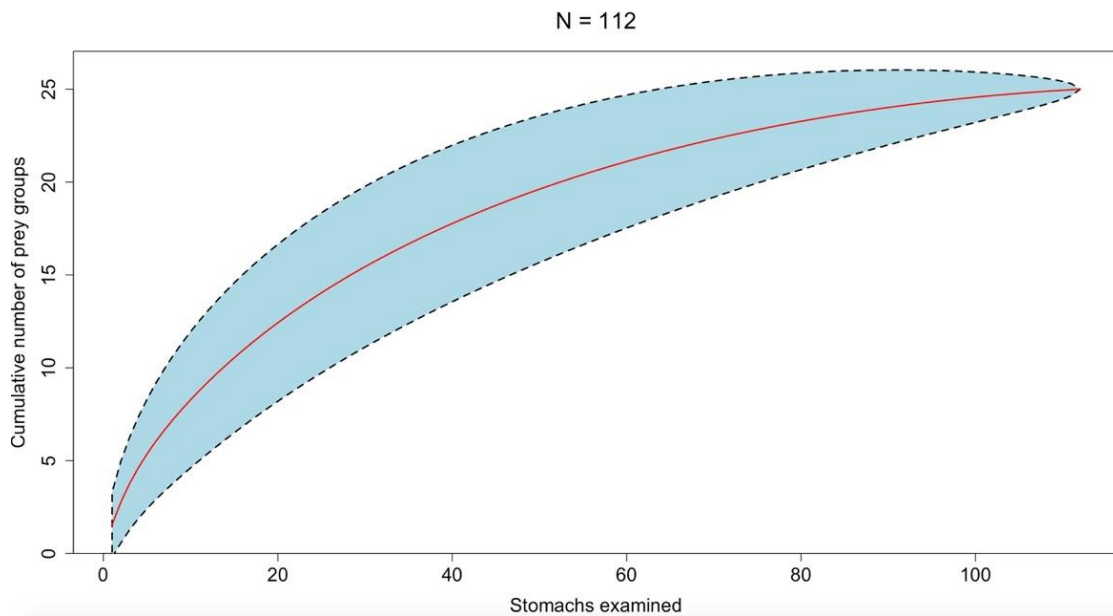
Figure 5. Cumulative prey curve (in red) as a function of sample size for all stomachs of *G. melastomus* analysed. The standard deviation (SD) is represented with dashed lines.
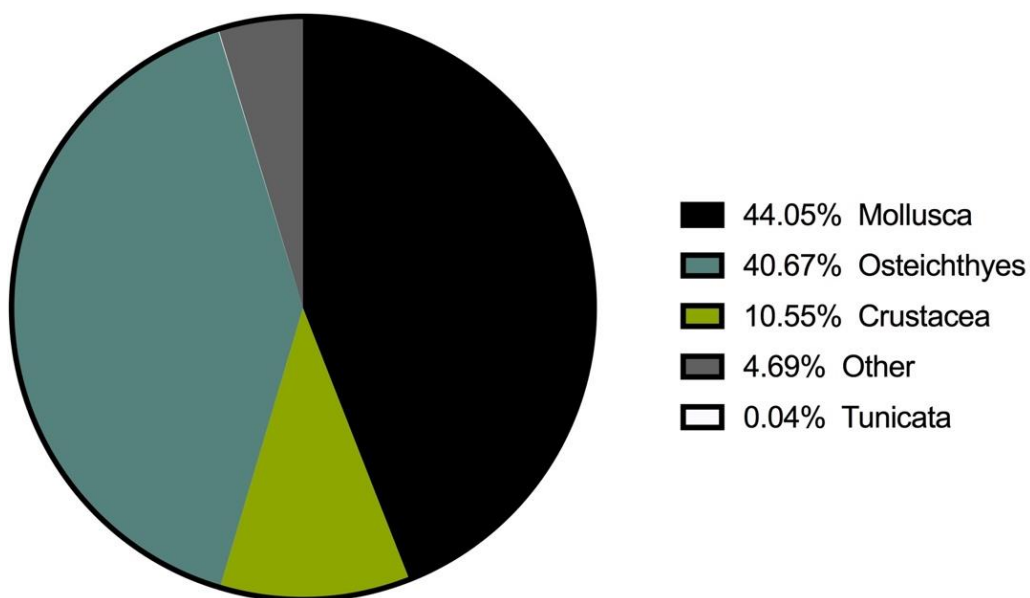
Figure 6. Diet composition by weight (%W) of *G. melastomus*. The percentage of biomass composition of main prey categories is summarized on the right of the figure. "Other" indicates unidentified prey and sea bird remains.

Table 2. Diet composition of *G. melastomus* from the southern Tyrrhenian Sea (western Mediterranean Sea). %F = percentage frequency of occurrence; %N = percentage in number; %W = percentage in biomass; IRI = index of relative importance of prey items and its percentage (%IRI). Numbers in bold are sums of indices for main categories.

	%N	%W	%F	%IRI
MOLLUSCA	**29.00**	**44.05**	**56.94**	**35.57**
Gasteropoda	**0.28**	**0.18**	**0.76**	**0.01**
Gasteropoda n.i.	0.28	0.18	0.76	0.01
Cephalopoda	**28.72**	**43.87**	**56.18**	**35.56**
Abraliopsis morisii	0.28	0.50	0.76	0.02
Alloteuthis media	0.56	0.54	1.52	0.06
Eledone cirrhosa	0.28	0.85	0.76	0.03
Eledone sp.	0.56	11.22	1.52	0.68
Heteroteuthis dispar	1.41	0.61	2.27	0.18
Histioteuthis reversa	0.85	0.86	2.27	0.15
Histioteuthis sp.	0.28	6.96	0.76	0.21
Loligo sp.	0.56	0.35	1.52	0.05
Scaeurgus unicirrhus	0.28	0.85	0.86	0.03
Sepia orbignyana	5.07	1.00	5.30	1.23
Sepietta oweniana	0.28	0.13	0.76	0.01
Sepiola intermedia	0.56	0.09	0.76	0.02
Todarodes sagittatus	3.10	9.66	5.30	2.59
Cephalopoda n.i.	**14.65**	**10.25**	**31.82**	**30.30**
CRUSTACEA	**38.86**	**10.55**	**39.44**	**11.63**
Amphipoda	0.28	0.04	0.76	0.01
Amphipoda n.i.	**0.28**	**0.04**	**0.76**	**0.01**
Decapoda	10.97	9.13	25.79	5.01
Eusergestes arcticus	0.28	0.09	0.76	0.01
Parapenaeus longirostris	0.28	0.26	0.76	0.02
Pasiphaea multidentata	0.56	2.00	0.76	0.07
Pasiphea sivado	1.41	0.78	3.79	0.32
Pasiphea sp.	0.56	0.46	1.52	0.06
Plesionika giglioli	0.28	1.07	0.76	0.04
Robustosergia robusta	0.28	0.45	0.76	0.02
Solenocera membranacea	0.28	0.56	0.76	0.02
Brachyura n.i.	0.28	0.13	0.76	0.01
Decapoda n.i.	0.56	0.26	1.52	0.05
Dendrobranchiata n.i.	5.92	2.98	12.88	4.38
Sergestidae n.i.	0.28	0.09	0.76	0.01
Euphausiacea	**27.05**	**1.27**	**11.37**	**6.57**
Meganyctiphanes norvegica	3.10	0.35	3.03	0.40
Nematoscelis atlantica	1.41	0.16	1.52	0.09
Euphausiacea n.i.	22.54	0.76	6.82	6.08
Isopoda	**0.56**	**0.11**	**1.52**	**0.04**
Isopoda n.i.	0.56	0.11	1.52	0.04
OSTEICHTHYES	**27.02**	**40.67**	**56.11**	**48.56**
Ceratoscopelus maderensis	2.82	3.57	5.30	1.30
Chauliodus sloani	0.28	0.04	0.76	0.01
Diaphus holti	0.28	0.89	0.76	0.03
Diaphus sp.	0.85	0.18	1.52	0.06
Electrona risso	1.41	3.16	2.27	0.40
Gadiculus argenteus	0.28	0.11	0.76	0.01
Hygophum benoiti	0.28	0.13	0.76	0.01
Hygophum hygomii	0.28	0.32	0.76	0.02
Hygophum sp.	0.28	0.04	0.76	0.01

	%N	%W	%F	%IRI
Macroramphosus scolopax	0.28	0.15	0.76	0.01
Myctophum punctatum	0.28	0.29	0.76	0.02
Ophidion rochei	0.28	0.37	0.76	0.02
Peristedion cataphractum	0.28	0.09	0.76	0.01
Sardina pilchardus	0.56	3.77	1.52	0.25
Sardinella aurita	0.56	5.74	1.52	0.37
Stomias boa	0.28	0.06	0.76	0.01
Synchiropus phaeton	0.28	0.39	0.76	0.02
Congridae n.i.	0.28	0.08	0.76	0.01
Myctophidae n.i.	0.56	1.07	1.52	0.09
Osteichthyes n.i.	16.62	20.22	32.58	45.90
TUNICATA	**0.28**	**0.04**	**0.76**	**0.01**
Ascidiacea n.i.	0.28	0.04	0.76	0.01
OTHER	**4.79**	**4.69**	**12.88**	**4.22**
Digested	4.51	4.57	12.12	4.21
Feathers (*Mergus merganser*)	0.28	0.12	0.76	0.01

Our results also showed the presence of fish heads and sea bird remains (Figure 7) in stomachs contents, confirming the scavenger habits of *G. melastomus*.
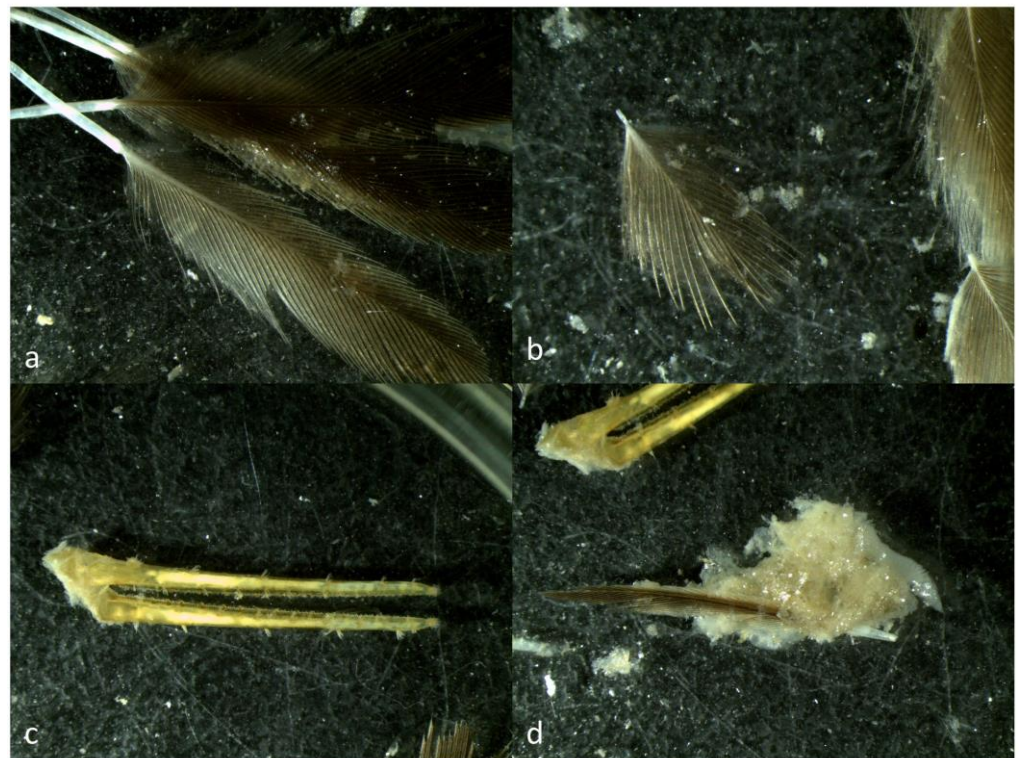

Figure 7. Evidence of the presence in stomachs of sea birds (*Mergus merganser* Linnaeus, 1758): plumage remains (**a**,**b**), beak (**c**), and tissue remains (**d**).

4. Discussion

The sex ratio analysis showed that across all sites, the number of male specimens did not significantly differ from that of females, while the analysis of sexual maturity and size showed that both adults and juveniles were present in the area, as shown by other authors in the Strait of Sicily, and Tyrrhenian and Alboran Seas [13,25,46]. However, in other areas of the Mediterranean Sea, such as the Ionian and NW Aegean Seas, immature specimens in the catches were abundant [10,17,29,47,48]. These differences could be correlated with

different fishing depths, geographic areas, and size/maturation stages of the species. In some areas, *G. melastomus* in fact showed seasonal and bathymetric variations related to recruitment and reproductive period ([47] and references therein).

Female specimens matured at larger sizes than males and were larger than males. They showed positive allometric growth, unlike the males, which instead showed a negative allometric growth. These findings were different from those obtained in the Strait of Sicily [46], where the species showed an isometric growth for both sexes, while it was coherent with a previous study from the southern Tyrrhenian Sea [25]. *G. melastomus* growth patterns from the studied area also differed from those of *S. canicula.* In this species, the males were often bigger than females in most areas of Mediterranean Sea ([9,47,49–51] and literature therein), while female specimens matured at a larger size than males, as in blackmouth catsharks. This difference may be related to metabolic and ecological variations between the two Scyliorhinidae species, which show different feeding habits, distribution patterns, and diet.

Comparing our results with the few data present from the southern Tyrrhenian Sea, our findings showed an increase of large specimens in trawling catches, with the highest frequency of occurrence for individuals with a TL of 35–40 cm for males, and 35–40 cm and 45–50 cm for females (Figure 3). The previous study of the southern Tyrrhenian Sea [25] showed the dominance of immature small individuals (<30 cm), with a small fraction of mature large individuals in the total catch obtained through trawling in a depth range between 500 and 880 m. Similar abundances in total trawling catch of small specimens also were shown in other areas in the Mediterranean Sea, such as the Alboran Sea (Western Mediterranean [13]), the Ionian Sea [10], and the Southern Adriatic Sea [29]. The highest frequency of occurrence for larger specimens (35–50 cm) shown by our results could indicate the need for larger individuals, which are usually distributed in deeper environments not exploited by trawling, to move to shallow water, increasing the risk of being caught by trawling. The reason behind this movement is not clear, considering which variations on bathymetrical distribution could be influenced by many factors. However, according to previous literature on other areas in the Mediterranean Sea [10,52], this high frequency of occurrence for larger specimens showed by the results could be correlated with mating. In fact, this species carried out periodical migration from deeper waters, using shallow environments for mating and perhaps nursery grounds [48–50]. The collection of new data from landings and studies on the population dynamics of *G. melastomus* could help to improve knowledge regarding reproductive areas of this species in the southern Tyrrhenian Sea. Identifying and protecting these areas is essential for the conservation of blackmouth catsharks.

L_{50} decreased from 42.5 cm for females and 37 cm for males, as shown by a previous study from the southern Tyrrhenian Sea [53], to 33.7 cm for females and 31.1 cm for males. The variation of this biological parameter compared with the literature on this area may be related to differences in methodology, statistical analysis, stock variability, and stability of the species [54]. Another aspect that could influence this variation may be the differences in sample size between the present and previous studies [55,56]. For this reason, further analysis of population dynamics and biology of this species with a larger sample are necessary to confirm this result. It is essential to highlight that changes in maturation size of the species could be correlated with environmental changes, such as increase in water temperature and acidification, or anthropogenetic stressors, such as overfishing and/or environmental pollution [57–64]. In general, size-selective fishing pressure or overfishing can lead to a decreased size at first maturity, as it is a way for the species to adapt and be able to reproduce before being caught. High catches of juveniles in the trawl fishery could have led to this adaptation [65–68]. Moreover, the presence of pollutants can induce physiological adaptations, leading to early gonadal maturation stages and size reduction [69–71]. Other studies concerning the effects of pollutants on this and other species [57,63,64,72,73] are necessary to better understand these processes. It is also essential to consider and study pollutants with unknown effects on marine organisms,

such as plastics, now ubiquitous in marine environments [58–62,74]. In the last 150 years temperatures increased globally by ~0.76 °C (a further increase of 1–3 °C is expected by 2100) [75], in combination with a pH decrease by 0.0044 units and a further expected decrease of 0.3–0.4 units by 2100 [67,68]. Ocean warming and acidification are known to be factors that induce physiological responses in elasmobranchs [76–78]. These include increases in embryonic development, growth rate, and food consumption, as well as changes in hunting behavior [79–84]. These biological and ecological variations may also have negative, cascading effects on predator–prey relationships, altering the food web, and consequently entire ecosystems [85–88]. Concerning the deep-sea environment of the Mediterranean Sea, climate change and anthropogenetic stressors are progressively impacting the deep biocenosis ([89] and references therein) by changing the physic-chemical conditions ([90] and references therein). These variations inevitably have an impact on the physiology and ecology of deep biocenosis, especially on benthic ecosystems, and consequently on benthic and benthopelagic fauna, including sharks [91–94]. Further analyses of population dynamics and biology are needed to understand the reproductive biology and ecological variations of *G. melastomus* populations. Increased knowledge will improve the efficacy of deep marine biocenosis conservation and management.

Diet indices obtained in the present study clearly showed how this species mainly feeds on cephalopods, crustaceans, and bony fishes; however, except for a few species (*Sepia orbignyana*, Férussac (in d'Orbigny), 1826; *T. sagittatus*; *Pasiphea* sp.; *Meganyctiphanes norvegica*, M. Sars, 1857; *C. maderensis*), no clear preference was detected for particular species within these groups. The high occurrence of Euphasiacea—*M. norvegica* and *Nematoscelis atlantica*, Hansen, 1916—and small cephalopods and bioluminescent mesopelagic fishes of the family Myctophidae Gill, 1893—*Diaphus* sp., *E. risso*—should be correlated with feeding habits of small specimens, as shown by previous studies of other areas in the Mediterranean Sea [95,96]; while the high occurrence of larger cephalopods, such as *T. sagittatus*; *Eledone* sp.; *Scaeurgus unicirrhus*, Delle Chiaje (in Férussac and d'Orbigny), 1841; Dendrobranchiata (such as *Pasiphaea* sp.); and Osteichthyes species, could be correlated with adult feeding [97–100].

The most represented prey in terms of abundance belonged to Crustacea, followed by Mollusca and Osteichthyes. Considering the % IRI, the main prey of importance among Crustacea were Euphausiacea and *Pasiphaea* sp. Among Mollusca, the most relevant taxa were Cephalopoda, with *T. sagittatus*, *Eledone* sp., and *S. orbignyana* as the most important prey species. Among Osteichthyes, the most relevant prey was *C. maderensis*. Overall, bioluminescent mesopelagic fishes, such as those of the family Myctophidae, were commonly detected, and also easily identified thanks to their peculiar saccular otolith shape [101,102]. Moreover, Clupeidae, Cuvier, 1816 species derived from the discard of fisheries—remains of *S. pilchardus* and *S. aurita*—were also often identified. These latter species, once thrown back into the sea, become a fundamental source of food in the deep environment. The scavenging habit of *G. melastomus* has been highlighted by the presence in some stomachs of animal remains, like fish heads (deriving from fishery discards) and sea bird remains (Figure 7). This ecological feature could explain the resilience of this species, which often lives in an environment highly exploited by fisheries in many geographical areas that provide them the possibility to exploit fishery discards and offal [95,103].

The value obtained for B_i showed that *G. melastomus* in the southern Tyrrhenian Sea was an intermediate feeder, with quite generalist and opportunistic feeding habits and an intermediate trophic niche. This species preys on a few main taxa (e.g., Crustacea, Osteichthyes, Mollusca), but with no specific preference for any particular prey species within these main groups. In other words, while the diet of *G. melastomus* was not dominated by specific prey, species belonging to the groups of Crustacea, Osteichthyes, and Mollusca were clearly the most abundant in its diet. These results were similar to those found in other areas, such as the western Mediterranean Sea and the central Aegean Sea [104–106], where this species mainly fed on Crustaceans; whereas in the Gulf of Lion, the species preyed mainly on Cephalopoda and Decapoda [106,107]. The diet of this species here

and in different areas in the Mediterranean Sea may be related to the different availability of prey, which shifts in different environments with seasonality, confirming its ability to adapt, survive in different habitats, and exploit the food availability of the area. This is a fundamental condition to survive in different deep oligotrophic environments, where it is essential to adapt the diet according to the food availability, a typical condition for opportunistic species such as *G. melastomus*.

A common feature in diet composition across different areas, also shown by our results, was the high occurrence of bioluminescent mesopelagic prey—*Abraliopsis morisii*, Verany, 1839; *Heteroteuthis* sp.; *M. norvegica; Diaphus* sp.; *C. maderensis; E. risso; and Hygophum* sp. [104,107–111]. This was due to the adaptation of the large eyes and retina of the blackmouth catshark to a dark, deep environment. Its retina, with long rods, provides a better sense of sight, and is adapted to distinguish the photophores' light spectral emission of the main bioluminescent mesopelagic preys [108], reducing their counterstaining camouflage effectiveness.

The habit of blackmouth catsharks to prey mainly on benthopelagic species in all the areas in the Mediterranean and Atlantic Ocean has been confirmed by several studies [104,106,107,109–114]. In most environments, such as the Cantabrian Sea, this is a strategic way to achieve trophic partitioning with other syntopic shark species, such as *S. canicula* and *S. stellaris*, which mainly prey on strictly benthic species by using their developed olfactory sense [95]. On the other hand, to confirm the presence of a similar situation in the Tyrrhenian Sea, further analysis about the diet of other Scyliorhinidae species is necessary.

The trophic features of this species in most marine environments are essential for the proper functioning of the deep marine biocenosis. *G. melastomus*, in fact, plays a key role in the energy transfer across the different depth strata. Therefore, the study and monitoring of its diet, feeding habits, and ecological interactions with other sympatric and syntopic predators in areas where the data are scarce or absent (as in the case of the southern Tyrrhenian Sea) could help in understanding the ecological dynamic of the trophic network in the deep environments.

5. Conclusions

Although further studies are needed to better understand the biology and ecology of this species in the Mediterranean Sea, our study provided new data on several biological and ecological aspects of *G. melastomus* in the southern Tyrrhenian Sea and contributed to filling some of the gaps in the literature. Sharks represent key species in several marine habitats, and the study of their biology and ecology remains fundamentally important for management and conservation purposes. Our study highlighted the sexual maturity, size distribution, and feeding habits of the blackmouth catshark in the southern Tyrrhenian Sea, essential for understanding its ecological role, importance, and adaptation strategies in a deep environment.

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