Trophic ecology of the deep-sea skate *Dipturus oxyrinchus* (Linnaeus, 1758) in the bathyal food web of the central Mediterranean Sea

Martina Arcioni[1], Isabella D'Ambra[2], Salvatrice Vizzini[3,4], Danilo Scannella[5,7*], Monica Calabrò[5], Fabio Falsone[5], Michele Luca Geraci[5], Marco Oliverio[6], Sergio Vitale[5], Germana Garofalo[5], Gioacchino Bono[5], Francesco Colloca[1]

[1]Department of Integrative Marine Ecology, Stazione Zoologica Anton Dohrn, Via Po 25, 00198, Roma, Italy.

[2]Department of Integrative Marine Ecology, Stazione Zoologica Anton Dohrn, Villa Comunale, 80121, Naples, Italy

[3]Department of Earth and Marine Sciences, University of Palermo, Via Archirafi, 18, 90123 Palermo, Italy

[4]National Inter-University Consortium for Marine Sciences, CoNISMa, Piazzale Flaminio, 9, 00196 Roma, Italy

[5]Institute for Marine Biological Resources and Biotechnology (IRBIM), National Research Council–CNR, Via Luigi Vaccara, 61, 91026 Mazara del Vallo, TP, Italy

[6]Department of Biology and Biotechnologies "Charles Darwin", Sapienza University of Rome, Viale dell'Università 32, 00185 Roma, Italy

[7]Italian Institute for Environmental Protection and Research (ISPRA), Department for the Monitoring and Protection of the Environment and for the Conservation of Biodiversity, Lungomare C. Colombo 4521–Addaura, 90149 Palermo, Italy

[*]Corresponding author: danilo.scannella@isprambiente.it

Abstract

The Mediterranean Sea is a biodiversity hotspot where most elasmobranchs are severely threatened, with poor knowledge about life history traits and trophic ecology. In this context, our study focused on the trophic ecology of the deep-sea longnose skate (*Dipturus oxyrinchus*) in the Strait of Sicily (central Mediterranean), designated as an Important Shark and Ray Area. The objectives of the present study were to investigate the main changes in the feeding habits of the species according to ontogeny and bathymetric distribution. We collected 152 specimens from the continental slope (200-750 m) from 2016 to 2019. The combination of stomach content and stable isotope analyses identified the longnose skate as a generalist feeder, with a diet dominated by crustaceans, with smaller contributions from bony fish and cephalopods. Among crustaceans the most consumed were decapods (including *Parapenaeus longirostris, Iridonida speciosa*, *Chlorotocus crassicornis*) and mysids (*Lophogaster typicus*). Generalized additive models indicated that predator body size and depth had a significant effect on the consumption pattern of certain prey groups. Significant ontogenetic changes were observed, with smaller individuals primarily preying upon benthic organisms and larger individuals adopting a more benthopelagic diet, reflected by a slight increase in trophic position.

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

This study highlights the role of the longnose skate within the bathyal food web of the Strait of Sicily, providing useful information for ecosystem modelling and effective conservation strategies.

Keywords: Trophic niche; dietary composition; stomach contents; elasmobranchs; stable isotopes; ontogenetic shifts

1. Introduction

Elasmobranchs play a key ecological role in marine ecosystems as apex or meso-predators and thus regulate the dynamics of trophic webs through a top-down control (Heupel et al., 2014). As observed in several marine regions, the loss or decline of their populations may have cascading effects, altering the trophic structure of marine communities (Baum and Worm, 2009; Ferretti et al., 2010). One of the main threats to elasmobranchs is overfishing (Dulvy et al., 2024, 2021; Falsone et al., 2022). Indeed, a decline in elasmobranch populations has been observed in correlation with increasing fishing intensity in many exploited areas due to their large body size, slow growth, late maturity and low fecundity (Bearzi et al., 2006; Dulvy et al., 2008; Fiorentino et al., 2024b; Lucifora et al., 2011; Pacoureau et al., 2021). Specifically, batoids have shown a decreasing abundance trend in the last decades (Aldebert, 1997; Jukic-Peladic et al., 2001; Lotze et al., 2011; Walls and Dulvy, 2021) with 16 species in the Mediterranean Sea currently classified as Threatened (Serena et al., 2020).

Several studies conducted in the Mediterranean Sea have shown that batoids are mesopredators, feeding mainly on crustaceans, molluscs, bony fish, and polychaetes (Barría et al., 2015; Fanelli et al., 2023; Mulas et al., 2019; Yemışken et al., 2018). They occupy medium to upper trophic levels, playing a key role in trophic webs (Flowers et al., 2021); however, knowledge of their life history traits is limited, especially for deep-sea species (Geraci et al., 2021b). Among these, the genus *Dipturus* includes three species of large skates (*D. batis*, *D. nidarosiensis*, and *D. oxyrinchus*) characterized by a long, pointed snout (Serena et al., 2010). Recent studies have shed some light on their taxonomy (Carugati et al., 2022; Iglésias et al., 2010) and distribution (Carbonara et al., 2019; Follesa et al., 2019; Geraci et al., 2021b, 2019). The most common of the three species is *D. oxyrinchus* (Linnaeus, 1758), generally known as longnose skate for its remarkably long rostrum. Typically ranging from 60 to 120 cm in length, it inhabits soft-bottom habitats at depths between 90 and 900 m (Ebert and Stehmann, 2013). Within the Mediterranean Sea, the longnose skate is most abundant around Corsica, Sardinia, and in the Strait of Sicily (Follesa et al., 2019). In the Strait of Sicily (herein SoS), the species has a low commercial value and is generally discarded at sea by fishing vessels exploiting deep-sea rose shrimps on the continental slope (Geraci et al., 2017; Milisenda et al., 2017). Its numerical decrease in recent years in European seas led the International Union for Conservation of Nature (IUCN) to assess the longnose skate as Near Threatened (NT) (Ellis et al., 2015).

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

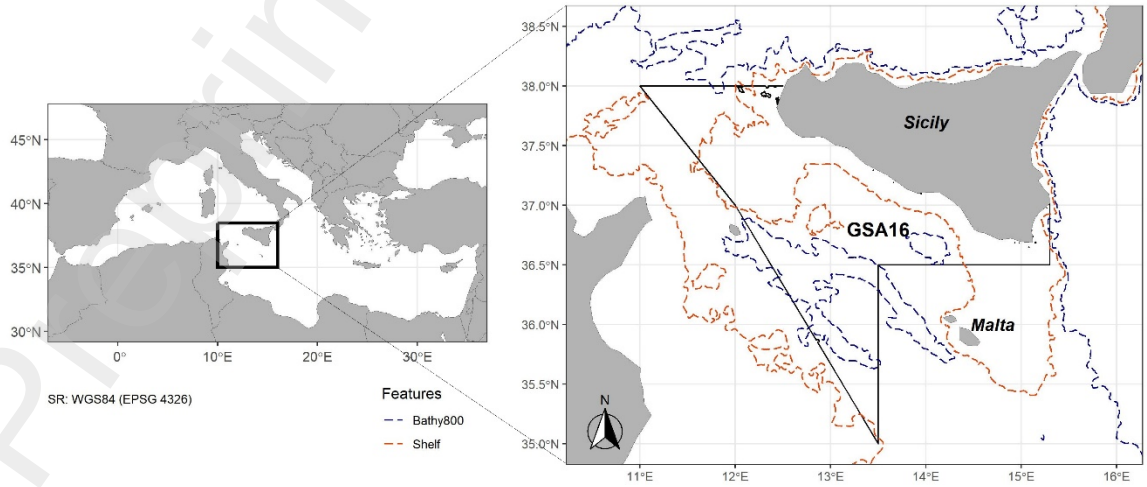
Many important aspects of the life cycle of the longnose skate, including natural mortality, reproductive areas, movement patterns, and the exploitation status of populations, still remain poorly understood. In the Mediterranean Sea, studies focusing on the species biology have shown a slow growth rate and late maturity (Alkusairy and Saad, 2017; Bellodi et al., 2017; Geraci et al., 2021b; Kadri et al., 2015; Yiğin and Ismen, 2010). Regarding the feeding habits of the species, in the Gulf of Gabès (Tunisia) the diet included benthopelagic organisms, primarily bony fish and secondarily crustaceans (Kadri et al., 2010), while in Sardinian waters (Mulas et al., 2015) and in the northern Aegean Sea (Cabbar and Yiğin, 2023; Yiğin and Ismen, 2010) the diet was mainly composed of crustaceans.

This study aimed to elucidate the feeding habits and trophic role of the longnose skate within the bathyal food web of the SoS, one of the few Mediterranean regions where the species still remains abundant (Follesa et al., 2019; Geraci et al., 2021b, 2017). This region is widely recognized as a biodiversity hot-spot for elasmobranchs in the Mediterranean Sea (Colloca et al., 2020; Follesa et al., 2019; Ragonese et al., 2013; Scannella et al., 2020; Serena et al., 2020; Zava et al., 2022) and as such it has been acknowledged as an Important Shark and Ray Area (ISRA) in 2023 (https://sharkrayareas.org/e-atlas/). To provide a comprehensive, time-integrated analysis of the trophic resources assimilated by the longnose skate, we combined the analyses of stomach contents, and carbon and nitrogen stable isotopes. The study investigated dietary composition, trophic position, and ecological niche across ontogenetic stages and bathymetric ranges, highlighting their relevance for conservation strategies.

2. Materials and Methods

2.1 Study Area

The study area is the northern sector of the SoS and covers approximately 34,000 km^2 between the southern coasts of Sicily and North Africa, corresponding to the Geographic Subarea 16 (GSA16) according to the General Fisheries Commission for the Mediterranean classification (GFCM, 2007) (Fig. 1).



This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

Fig. 1 Map of the study area showing the Geographical Sub-Area 16 (Southern Sicily). The orange and blue dashed lines represent the 200 m and 800 m isobaths, respectively.

The SoS is a complex ecosystem characterized by wide shallow detritic bottoms and rocky banks on the continental shelf that host large biodiverse communities. The peculiar circulation pattern enhances primary productivity, also promoting both species diversity and abundance (Coll et al., 2010; Consoli et al., 2016; Di Lorenzo et al., 2018). Offshore banks play a crucial role for fish and shellfish communities, contributing significantly to species richness and their abundance (Garofalo et al., 2007; Gristina et al., 2006; Ragonese et al., 2013). Trawl surveys have revealed the presence of 15 species of demersal sharks and 21 of batoids (Fiorentino et al., 2024b; Geraci et al., 2017; Ragonese et al., 2013), making the SoS one of the areas with the highest richness of demersal elasmobranchs in the Mediterranean Sea (Coll et al., 2010; Follesa et al., 2019; Gaertner et al., 2007). Given the critical significance of the SoS for biodiversity, the entire area has been recognized as an 'Ecologically or Biologically Significant Area' (EBSA), as defined by the Contracting Parties of the Convention on Biological Diversity (COP12, October 2014, Pyeongchang, Republic of Korea) (Bax et al., 2016), and several sites have been identified for inclusion in a broader Mediterranean network of marine protected areas (De Juan et al., 2012). Despite its ecological importance, the SoS has been subjected to extensive fishing exploitation for decades, carried out by the fleets of multiple countries (Italy, Tunisia, Malta, Libya) (Colloca et al., 2017). Notably, the harbour in Mazara del Vallo hosts one of the largest and most active trawl fleets in the Mediterranean Sea (Di Maio et al., 2022; Russo et al., 2014), which targets a wide range of demersal species (Jarboui et al., 2022).

2.2 Sample collection and laboratory processing

A total of 152 longnose skate specimens were sampled in the northern sector of the SoS (FAO-GFCM GSA 16) between 2016 and 2019. The samples were collected from June to December both from the commercial catches of the Mazara del Vallo trawl fleet (51 specimens) and the MEDITS bottom trawl survey (MEDiterranean International Bottom Trawl-Survey, for details about the survey methodology refer to Bertrand et al. (2002)) (101 specimens). Specimens were frozen and maintained at -20°C until processing. In the laboratory, each individual was thawed and its total length (TL, cm), total weight (W, g), sex, and maturity stage were recorded. The maturity stage was macroscopically assigned based on the gonad maturity scale described in the MEDITS Handbook (Anonymous, 2017). After measurements, stomachs were dissected, and their contents were preserved in a 70% ethanol solution. Prey items were identified to the lowest possible taxonomic level using a stereomicroscope. They were then dried on blotting paper, counted, and weighed (Precisa analytical balance 80A-200M, ± 0.001 g). Hard parts (otoliths and corneous mandibles) were rinsed with ultrapure water and used to identify bony fish (Tuset et al., 2008) and cephalopods (Pedà et

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

al., 2022). In order to define the dietary composition of longnose skates using stable isotope analysis, a sample of dorsal muscle was removed from each specimen, while samples of 24 fish species and benthic invertebrates were collected from the discards of commercial fisheries carried out in the bathyal fishing grounds of the study area to determine the stable isotopic composition of potential prey. The selection of prey species was based on the stomach contents reported in literature (Kadri et al., 2010; Mulas et al., 2015; Yiğin and Ismen, 2010). A total of 152 dorsal muscle samples of longnose skate and 62 muscle samples from the 24 potential prey species were dried in an oven at 60°C for 24−48 hours, homogenized and powdered with a grinder. A dry mass of 0.6 ± 0.2 mg of each powdered sample was packed into tin capsules. Stable isotope ratios of carbon and nitrogen were determined using an elemental analyser (Thermo Flash EA 1.112) coupled with a continuous-flow isotope ratio mass spectrometer (Thermo IRMS Delta Plus XP). The ratio of stable isotopes was expressed in relation to international standards [Vienna Pee Dee Belemnite (VPDB) for $\delta^{13}C$, and atmospheric nitrogen (N_2) for $\delta^{15}N$] as $\delta^{13}C$ or $\delta^{15}N = [(Rsample/ Rstandard) - 1] \times 10^3$ where Rsample and Rstandard are the ratios of the heavy-to-light isotopes ($^{13}C/^{12}C$ and $^{15}N/^{14}N$) in the sample and the standard, respectively. The analytical precision based on the standard deviations of the internal standards (International Atomic Energy Agency IAEA-CH-6; IAEA-NO-3; IAEA-N-2) was 0.1 ‰ for $\delta^{13}C$ and 0.2‰ for $\delta^{15}N$. The C:N ratio was used as a proxy of lipid content and the $\delta^{13}C$ of samples with C:N > 3.5 was corrected using the equation by Post et al. (2007): $\delta^{13}C_{corrected} = \delta^{13}C_{bulk} - 3.32 + 0.99$ x C:N.

2.3 Stomach content analysis

To provide an overview of the overall dietary composition, trophic indices were calculated for each taxonomic category of prey found in the stomachs of longnose skate: relative numerical abundance ($\%N$ = number of a prey category/ total number of prey × 100), relative gravimetric composition ($\%W$ = mass of a prey category/ total mass of all prey × 100) and relative frequency of occurrence ($\%F$ = number of stomachs containing a prey/ total number of filled stomachs × 100). The vacuity index (I_v) was computed, according to Hyslop (1980), as number of empty stomachs/ total number of stomachs × 100.

In addition, we categorized prey into seven distinct groups: Natantia, Anomura, Brachyura, Lophogastrida, other Crustaceans, Cephalopoda, and Teleostei. These categories were chosen for their representativeness of dietary diversity; they included prey types with a frequency ($\%F$) greater than 5%, ensuring a robust assessment of dietary patterns. For each prey category, we constructed Generalized Additive Models (GAMs) with the number of prey consumed as the response variable, and different combinations of predator size (TL) in cm, water depth in m, and sex as the independent variables. Smooth terms were applied to the continuous predictors (TL and depth) to capture potential non-linear relationships, while the categorical variable (sex) was included as a parametric term. To effectively manage the overdispersion inherent in our count data we applied a negative binomial error distribution (Wood et al., 2016). For

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

each competing model, we examined the residuals, percentage of deviance explained, and calculated the Akaike Information Criterion (AIC), selecting the model with the lowest AIC as the best model. The best-fitting GAMs yielded the following model for all categories:

$$y_i = \beta_0 + f_1(x_{1i}) + f_2(x_{2i}) + \varepsilon_i$$

Where β_0 is the model intercept, f_1 and f_2 are the smooth terms for the explanatory variables TL and depth, and ε_i it's the error term for the *i*-th observation.

All models were fitted using the mgcv package in R (version 4.2.1).

2.4 Stable isotope analysis

In order to determine possible ontogenetic changes in the diet linked to the achievement of sexual maturity, the size at first sexual maturity estimated from all specimens collected in this study (55 cm), was used as a threshold to classify specimens as juveniles (TL < 55 cm) and adults (TL ≥ 55 cm).

Additionally, sex was considered in the analyses to assess its influence on dietary patterns. Similarly, to determine possible changes linked to depth distribution of the species, skates were divided in individuals collected in three different depth strata (200−400 m, 401−550 m, 551−750 m).

The ontogenetic variation of carbon and nitrogen stable isotopes was analysed using linear regressions between $\delta^{13}C$ and $\delta^{15}N$ against longnose skate size (TL). Differences in $\delta^{13}C$ and $\delta^{15}N$ between juveniles and adults, and between males and females, were tested using a Mann-Whitney test, while a Kruskal-Wallis test was performed to compare $\delta^{13}C$ and $\delta^{15}N$ across the different depth strata. The Stable Isotope Bayesian Ellipses in R (SIBER) package (Jackson et al., 2011) was used to determine trophic niches of juveniles and adults, and of individuals grouped according to their bathymetric distribution, separately. Moreover, we calculated the Standard Ellipse Area (SEAb) based on 4,000 posterior iterations, the Standard Ellipse Area corrected for small sample size (SEAc), and the niches overlap between juveniles and adults, and between depth strata. The trophic position of juvenile and adult longnose skates (TP_{SIA}) was calculated on the basis of $\delta^{15}N$ according to Post (2002):

$$TP_{SIA} = [(\delta^{15}N - \delta^{15}N_b)/\Delta] + \lambda$$

where $\delta^{15}N$ and $\delta^{15}N_b$ are the nitrogen isotopic values of each specimen and of the baseline, respectively; Δ is the diet tissue discrimination factor (DTDF); and λ is the trophic position of the baseline. The mean $\delta^{15}N$ of *Pagurus alatus* (8.2 ± 0.1 ‰) collected within the same study area at the same time as the predator was used as the baseline. As *P. alatus* is a secondary consumer λ was set at 3, while Δ was set at 1.5 ‰ following Galván et al. (2016), since this value was determined for the taxonomically closest species [the smallnose fanskate, *Sympterygia bonapartii* (Müller & Henle, 1841)] available in literature. All tests and packages were performed in R version 4.2.1.

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

3. Results

The specimens analysed (68 males, 84 females) ranged in size between 14.0 and 119.5 cm TL. Out of them, 73 were classified as juveniles (TL < 55cm) and the remaining 79 as adults (TL ≥ 55 cm). Both juveniles and adults were most abundant between 200 and 400 m depth, with their number decreasing at greater depths (Table 1).

3.1 Stomach content analysis

Of the 152 stomachs analysed in this study, 38 were empty, with an I_v of 25%. Within the stomach contents, a total of 49 different prey were identified and belonged to three main taxonomic groups: Crustacea, Cephalopoda, and Teleostei (Table 2). Highly digested remains were found with a frequency of 11.40%. Crustaceans dominated the dietary composition, with decapods and mysids being the most abundant groups. At the species level, the most abundant prey were the squat lobster *Iridonida speciosa* and the deep-water rose shrimp *Parapenaeus longirostris*, followed by the mysid *Lophogaster typicus* and the green shrimp *Chlorotocus crassicornis*. The deep-water rose shrimp accounted for c. 28% of the total mass of stomach contents, whereas bony fishes overall made up to 15.8% of the mass. The small crustacean *L. typicus* was present with a low percentage in weight, counterbalanced by a high numerical proportion. Regarding the variations in dietary composition sex was not significant for all prey categories. The deviance explained by models varied among prey categories, ranging from 12.5−69.4% (Table 3).

Predator size and depth had a significant effect on the consumption patterns of certain prey groups (Table 3). In particular, Anomura consumption was significantly affected by both depth (estimated degrees of freedom (edf) = 1.00, $p < 0.001$) and TL (edf = 3.19, $p = 0.014$). Consumption decreased with increasing depth, while TL showed a strong nonlinear relationship, with peak consumption observed at intermediate predator sizes, even if with high uncertainty (Fig. 2A, B). Lophogastrida abundance was strongly influenced by both depth (edf = 1.00, $p = 0.002$) and TL (edf = 1.00, $p < 0.001$) (Fig. 2C, D), while Brachyura abundance did not show significant associations with either predictor. Other crustaceans were consumed increasingly with depth (edf = 2.44, $p = 0.028$) reaching a plateau of abundance in the diet from c. 400 meters depth onwards (Fig. 2F). For Natantia, Cephalopoda and Teleostei there was a significant positive relationship with TL (edf = 1.00, $p < 0.001$; edf = 1.34, $p = 0.019$; edf = 1.00, $p = 0.009$), while depth showed no significant effect (Fig. 2E, G, H).

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

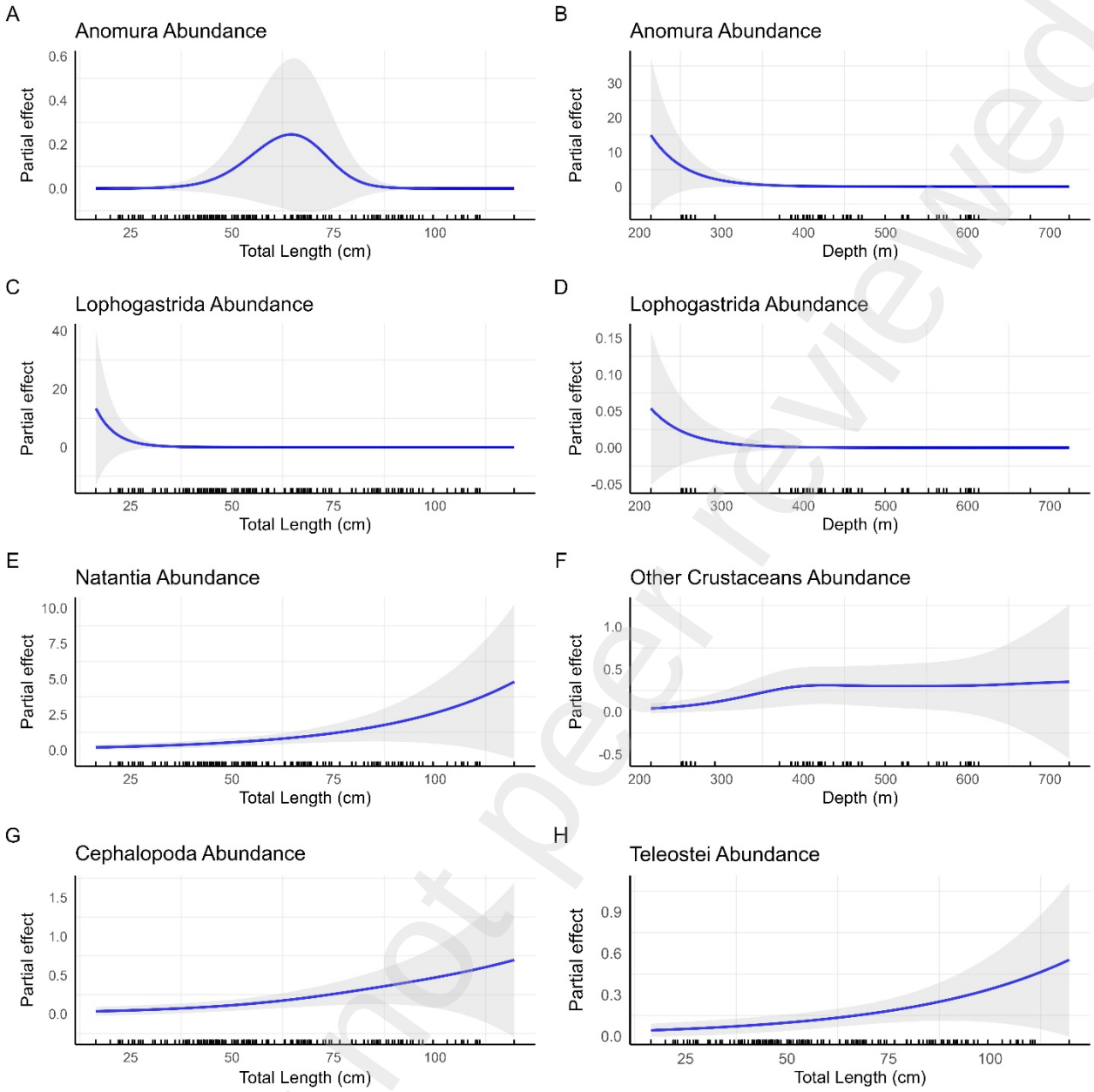


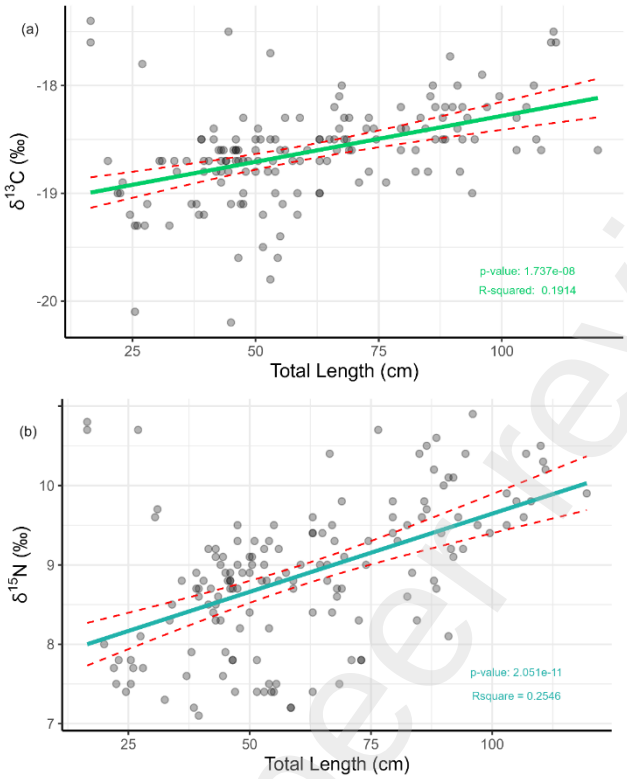
Fig. 2 Predicted effects of total length and depth on the abundances of Anomura (A, B), Lophogastrida (C, D), Natantia (E), Other Crustaceans (F), Cephalopoda (G) and Teleostei (H) in the stomach contents of *Dipturus oxyrinchus*. Shaded areas represent 95% confidence intervals. Only significant terms are shown

3.2 Stable isotope analysis

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

208 Stable isotope values of the 152 dorsal muscles of the longnose skate were positively correlated with size ($r^2 = 0.191$, P

209 $= 1.737^{-08}$ for $\delta^{13}C$ and $r^2 = 0.255$, P $= 2.051^{-11}$ for $\delta^{15}N$) (Fig. 3).



210

211 **Fig. 3** Correlation between total length (TL, cm) and **(a)** $\delta^{13}C$ (‰), and **(b)** $\delta^{15}N$ (‰) of *Dipturus oxyrinchus* collected in the Strait of

212 Sicily (central Mediterranean Sea) between 2016 and 2019. The solid line represents the linear regression, dashed lines indicate the

213 95% confidence intervals. The parameters of the regressions (r^2 and P-values) are shown at the bottom

214 Carbon and nitrogen stable isotopes were significantly different between juveniles and adults (Mann-Whitney test, P =

215 2.241^{-08} for $\delta^{13}C$; P $= 7.438^{-07}$ for $\delta^{15}N$), although differences fell within the range of variation expected for a single

216 trophic level (1.3‰ for $\delta^{13}C$ and 1.5 ‰ for $\delta^{15}N$ according to Galván et al. (2016)). Adults showed a wider range of

217 $\delta^{15}N$ compared to juveniles, while the opposite pattern was observed for $\delta^{13}C$ (Table 4). Carbon and nitrogen stable

218 isotopes were not significantly different between males and females. Isotopic values were significantly different among

219 the three depth ranges (Kruskal-Wallis test, P = 0.02776 for $\delta^{13}C$; P $= 8.122^{-08}$ for $\delta^{15}N$). The individuals in the upper

220 slope stratum showed a wider range of both $\delta^{13}C$ and $\delta^{15}N$ than those in the other depth ranges (Table 4).

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

The Stable Isotope Bayesian Ellipse Area (SEAb) and the Standard Ellipse Area corrected for small sample size (SEAc) of adults were wider than those of juveniles (Fig. 4; Table 5), but overall the degree of overlap between them was high (>50%; Table 6). When longnose skates were grouped according to the depth of collection, individuals in the deeper depth range (551−750 m) had the broadest isotopic niche, with an overlap with other depths of 46−49%.

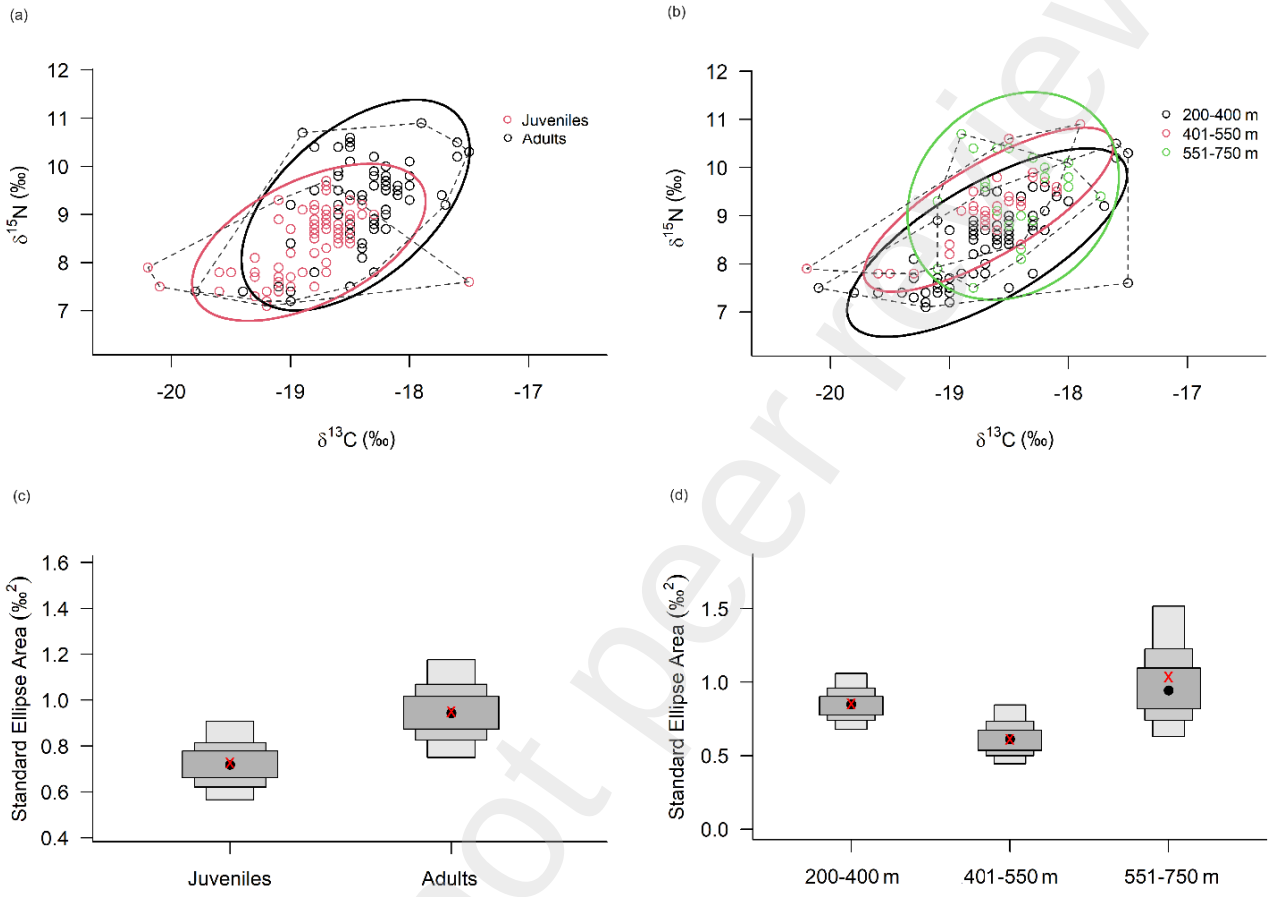


Fig. 4 Isotopic niches represented by polygons encompassing isotopic values and standard ellipse areas (SEAc) of *Dipturus oxyrinchus* collected in the Strait of Sicily (central Mediterranean Sea) between 2016 and 2019 grouped according to **(a)** size: juveniles (TL<55 cm) and adults (TL≥55 cm); and **(b)** depth of collection (200−400m; 401−550m; 551−750m). **(c)** and **(d)** represent comparison of estimated Bayesian Standard Ellipse Area (SEAb) for juveniles and adults and for the individuals in the three bathymetric layers. Boxes from dark to light grey represent the 50%, 75% and 95% of credibility intervals respectively, black points represent the mode and red crosses the estimated Standard Ellipse Area corrected for small sample size (SEAc)

The mean $\delta^{13}C$ and $\delta^{15}N$ of the longnose skate were -18.6 ± 0.5 ‰ and 8.9 ± 0.9‰, respectively (Fig. 5). Potential prey encompassed a wide range of $\delta^{13}C$ and $\delta^{15}N$ (Table 7, Fig. 5, additional data are available in the supplementary materials). Crustaceans exhibited the broadest range of variability, followed by Teleostei. The range of variation of both isotopes in cephalopods was remarkably narrower than that of the other two taxa (Fig. 5). The mean trophic position

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

estimated for *D. oxyrinchus* within the bathyal trophic web of the SoS using $\delta^{15}N$ (TP_{SIA}) was 3.4 ± 0.6, with a significant increase from juveniles (3.1 ± 0.4) to adults (3.7 ± 0.6) (Mann-Whitney test, P = 3.009^{-08}).

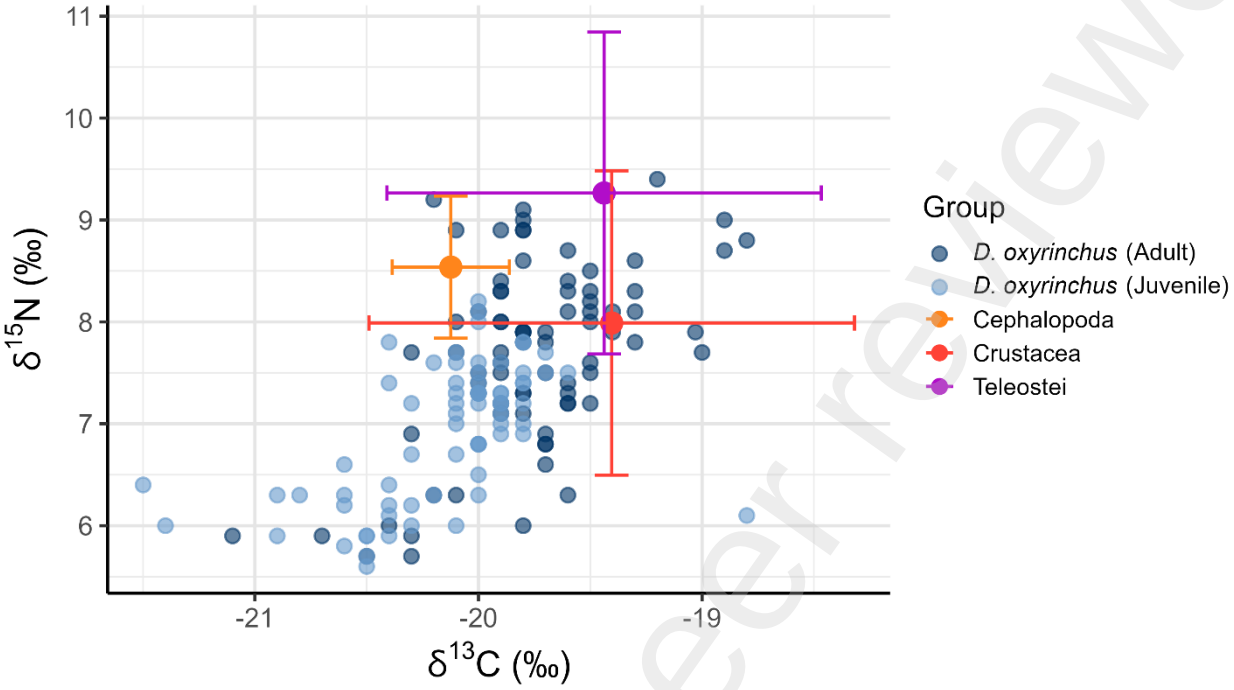


Fig. 5 Biplot of the mean (± standard deviation) $\delta^{13}C$ and $\delta^{15}N$ (‰) of potential prey of *Dipturus oxyrinchus* (Cephalopoda, Crustacea, and Teleostei), along with juveniles and adults *Dipturus oxyrinchus* isotopic values. The isotopic values of juvenile and adult skates are corrected for the diet-tissue discrimination factor by Galván et al. (2016). Data were collected in the Strait of Sicily (central Mediterranean Sea) between 2016 and 2019

4. Discussion

Knowledge of the ecology of batoids remains limited for most species, especially in the Mediterranean Sea (Barría et al., 2015; Rigolet et al., 2014). Among these species, the longnose skate and its trophic ecology were still poorly understood in the SoS, one of the areas in the Mediterranean Sea where this species is still relatively abundant (Fiorentino et al., 2024b; Follesa et al., 2019). Stomach content and stable isotope analyses indicate that the longnose skate is a mesopredator, feeding in both benthic and demersal environments. A large variety of prey was found in its diet, but only a few crustacean species were consumed regularly. This discrimination could be influenced by factors such as prey availability, prey size, and the predator's hunting strategy, among others. The significant presence of crustaceans in the diet of many batoids has been consistently observed by several authors (Bizzarro et al., 2009; Ebert and Bizzarro, 2007). Our analysis further supports this observation through the high frequency of occurrence in the diet of deep-water rose shrimps (*P. longirostris*), squat lobsters (*I. speciosa*), green shrimps (*C. crassicornis*), and mysids

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

(*L. typicus*). Indeed, bony fish and cephalopods contribute only to a lesser extent to the diet. However, the higher digestibility of the latter two groups compared to crustaceans may have led to their underrepresentation in stomach content analyses, partially explaining their perceived lower importance in the diet. These results partly align with the limited existing literature on the longnose skate, indicating that skates consume benthic prey, facilitated by their flat body shape and ventral mouth position. However, our findings differ from other studies conducted in the Mediterranean region regarding the proportional contribution of certain prey categories. In the Ligurian Sea, a diet based on equal quantities of cephalopods and crustaceans was described (Vannucci et al., 2006). In the Gulf of Gabès (Tunisia), the trophic spectrum of the longnose skate primarily consisted of benthic-pelagic teleosts, followed by crustaceans (Kadri et al., 2010). In the northern Aegean Sea and in Sardinian waters crustaceans contributed to the diet more than other prey, but while the deep-water rose shrimp was the most consumed prey in the Aegean Sea, it was notably absent in Sardinia. Instead, in the latter area, skates predominantly fed on mysids (Cabbar and Yiğin, 2023; Mulas et al., 2015; Yiğin and Ismen, 2010). These variations in the proportion of resource consumption can be attributed to several factors, including differences in habitat types, bathymetric distribution, size composition of the analysed samples, and prey availability across distinct Mediterranean regions. Indeed, consumption of certain prey by the Sicilian longnose skate could also be influenced by the higher abundance of some species in its environment, such as the deep-water rose shrimp, a commonly exploited resource by trawlers in the bathyal bottoms of the SoS, where it is particularly abundant (Fiorentino et al., 2024a; Geraci et al., 2021a; Vitale et al., 2006).

Studies have shown ontogenetic changes in feeding habits of batoids (Braccini et al., 2005; Brickle et al., 2003; Espinoza et al., 2012; Treloar et al., 2009). In skates, a decrease in the consumption of crustaceans and an increase in the consumption of cephalopods and teleosts has been observed during growth in different regions (Belleggia et al., 2016; Brown-Vuillemin et al., 2020; Koen Alonso et al., 2001; Packer et al., 2003; Schmitt et al., 2015; Treloar et al., 2009; Vargas-Caro et al., 2015). Such trends for the longnose skate were observed in Sardinian waters, with mature individuals decreasing the consumption of mysids while increasing that of decapods, cephalopods, and bony fish (Mulas et al., 2015). In the Aegean Sea instead, Yiğin and Ismen (2010) reported a higher occurrence of cephalopods in the stomach of small skates (16−50 cm total length) and an increase of bony fish in larger size classes (70−98 cm total length). The results of the present study align with these general trends yet provide new and refined insights into the feeding dynamics of longnose skates in the SoS. By capturing non-linear relationships between explanatory and response variables, GAMs offer a flexible and robust framework for modelling complex interactions. This approach allowed us to finely represent dietary changes and identify prey-specific trends that might otherwise remain obscured using traditional trophic indices. While crustaceans were consistently dominant in the diet, our analysis revealed an ontogenetic change in crustacean type consumption. Juvenile skates primarily consumed hyperbenthic mysids, which

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

declined logarithmically with growth, underscoring their critical role for smaller individuals. As skates grew, they transitioned to anomuran decapods as an intermediate forage resource, with a dome shaped feeding pattern indicating peak consumption at intermediate sizes. Subsequently, an increase in the intake of swimming decapods was observed for the largest predators, highlighting a shift towards larger, more mobile prey with growth. This progression reflects both morphological and ecological adaptations throughout skate's ontogeny and underscores their increasing ability to exploit higher-energy resources, in accordance with our isotopic results. Adults also seem to have a wider niche, preying on 35 taxa compared to the 26 taxa consumed by juveniles. This difference may be attributed to the narrow mouth size of juveniles, which could limit their predatory ability compared to adults.

The variations in the feeding habits of the longnose skate in the SoS were also influenced by the bathymetric distribution of the individuals. Limited information on such variations is available in the literature. Indeed, the longnose skates analysed in the northern Aegean Sea seem to occupy a restricted depth range (samples were captured between 215 and 444 m) (Yiğin and Ismen, 2010). Mulas et al. (2015) instead provided some insight into changes in feeding habits by depth. They observed longnose skates between 100 and 200 m feeding mainly on teleosts, cephalopods, and crustaceans; while individuals in deeper waters (200 to 800 m) preyed mostly on crustaceans, especially decapods, mysids, and euphausiids. In this study, we found that depth particularly affected the consumption of anomuran decapods and mysids, which both decreased with increasing depth. Additionally, skates found at depths greater than 400 m consistently included other crustaceans in their diet. Changes in depth could lead to variations in the composition of available prey and thus reflect on the trophic spectrum. It is then plausible that both resource availability and the distributional pattern of preys and predators influenced the results obtained. The relationships between body size and depth may reflect ontogenetic changes in predatory capabilities such as swimming speed, time devoted to prey searching, etc. Smaller and younger individuals may be more opportunistic and target easily obtainable prey, such as small invertebrates, while larger and more experienced animals may actively pursue a wider range of prey, including bony fish. In the absence of a clear bathymetric separation between juveniles and adults, differences in dietary composition between them reduce intraspecific competition, thus easing coexistence on the same seafloors (Gouraguine et al., 2011; Rodríguez-Cabello et al., 2007; Valls et al., 2011). Conversely, the absence of significant differences in the diets between sexes, as highlighted by both GAM and isotopic analyses, suggests that males and females exploit similar trophic resources.

The integration of stomach content and stable isotope analyses has proven to be a powerful tool to gain a comprehensive view of a predator's trophic ecology (Barría et al., 2015; Ebert and Bizzarro, 2007; Mulas et al., 2015; Treloar et al., 2009). We explored the isotopic composition of the longnose skate across individuals of different size classes and inhabiting various depths. Overall stable isotope results were consistent stomach contents data, providing

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

316 complementary insights into the species' feeding habits. Notably, the isotopic niche of adults was broader than the niche
317 of juveniles, although they were partially overlapping. This result may be driven by the higher diversity of prey
318 consumed, as indicated by stomach contents, the use of diverse habitats with different isotopic baselines, or a
319 combination of these factors. Carbon and nitrogen stable isotope values of the predator and its potential prey suggested
320 that crustaceans may provide the highest contribution to the diet of both juveniles and adults.
321 Despite these insights, the isotopic data collected did not allow a quantitative definition of the dietary composition of
322 skates. After applying corrections for lipid content and DTDF, the isotopic polygon of potential prey did not fully
323 encompass the predator's isotopic values, especially for the y-axis (i.e., $\delta^{15}N$) (Fig. 5). This pattern suggests that one or
324 more prey were missing within our stable isotope determinations. The comparison of the list of taxa found in the
325 stomach contents with the prey items for which isotopic values were determined revealed the absence of the isotopic
326 data for the mysid *L. typicus*, a significant resource in the diet of the longnose skate according to stomach content
327 analysis. In fact, *L. typicus* is expected to have low $\delta^{15}N$ values, as reported in literature for other Mediterranean regions
328 (Madurell et al., 2008). Although the stable isotope data collected in this study did not allow to proceed further with
329 dietary composition, the positive correlation between both carbon and nitrogen isotopic values and the size of the
330 predator supports the integration of higher trophic level prey into the diet of adult skates, also in agreement with GAM
331 models results. In particular, the isotope values observed in adults may be a consequence of an increased consumption
332 of fish, which have higher nitrogen stable isotope values than crustaceans and cephalopods.
333 The longnose skate was found to belong to a trophic position between 3 and 4 (TL = 3.4 ± 0.6) in the SoS, confirming
334 its role as a mesopredator within the bathyal ecosystem. The trophic position increases with growth, consistently with
335 the observations of the diet. However, values estimated in this study are slightly lower than those reported for this
336 species and its congeners in other Mediterranean areas and beyond (Barría et al., 2015; Ebert and Bizzarro, 2007; Mulas
337 et al., 2015; Treloar et al., 2009). Comparing the trophic niche of the longnose skate with those of other sympatric
338 batoids of the Mediterranean Sea, we observed that this skate showed similar values to those of other species with a
339 crustacean-based diet such as *Leucoraja naevus*, *Raja polystigma*, *R. asterias*, *R. clavata*, and *R. montagui* (Barría et al.,
340 2015; Coll-Calvo et al., 2020; Fanelli et al., 2023).
341 In conclusion, this study provides new insights into the trophic ecology of the longnose skate in the SoS, which can be
342 valuable for informing fisheries management in the region. For example, the longnose skate population could
343 significantly contribute to regulate the populations of the deep-water rose shrimp (*P. longirostris*) and other
344 commercially important species by predation-induced mortality, and therefore the quantification of this impact could be
345 valuable for effective fisheries management.

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

More broadly, the obtained data can support existing ecosystem models for the study area, such as Ecopath with Ecosim (EwE) (Agnetta et al., 2019), and ATLANTIS (Sinerchia et al., 2025), enabling the quantification of the specie's role in the trophic web of the SoS.

5. Declarations

5.1 Compliance with ethical standards

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

5.2 Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

5.3 Data availability statement

The data used are located in the databases of the CNR-IRBIM institute in Mazara del Vallo. All data used in this study are open and available to any qualified researcher, and comply with the FAIR principle (findable, accessible, interoperable, and reusable).

5.4 Author contributions

Conceptualization and design of the study: Martina Arcioni, Isabella D'Ambra, Salvatrice Vizzini and Francesco Colloca; Methodology: Isabella D'Ambra, Salvatrice Vizzini and Marco Oliverio; Formal analysis and investigation: Martina Arcioni, Isabella D'Ambra, Salvatrice Vizzini, Monica Calabrò, Fabio Falsone, Michele Luca Geraci, Danilo Scannella and Marco Oliverio; Writing - original draft preparation: Martina Arcioni; Resources: Sergio Vitale, Gioacchino Bono, Germana Garofalo; Writing - review and editing: Francesco Colloca, Isabella D'Ambra, Salvatrice Vizzini, Monica Calabrò, Fabio Falsone, Michele Luca Geraci, Danilo Scannella, Sergio Vitale, Gioacchino Bono, Germana Garofalo and Marco Oliverio; Supervision: Francesco Colloca and Salvatrice Vizzini.

6. Acknowledgements

Data used in this work were collected within the European Data Collection Framework (DCF)-Medits survey module-funded by the European Union and the Italian Ministry for Agricultural, Food and Forestry Policies. We are grateful to all staff of CNR-IRBIM of Mazara del Vallo, who collected and processed samples.

7. References

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

Agnetta, D., Badalamenti, F., Colloca, F., D'Anna, G., Di Lorenzo, M., Fiorentino, F., Garofalo, G., Gristina, M., Labanchi, L., Patti, B., 2019. Benthic-pelagic coupling mediates interactions in Mediterranean mixed fisheries: An ecosystem modeling approach. PLoS One 14, e0210659. https://doi.org/10.1371/journal.pone.0210659

Aldebert, Y., 1997. Demersal resources of the Gulf of Lions (NW Mediterranean). Impact of exploitation on fish diversity. Vie MilieuLife Environ. 47, 275–284.

Alkusairy, H.H., Saad, A.A., 2017. Some morphological and biological aspects of longnosed skate, *Dipturus oxyrinchus* (Elasmobranchii: Rajiformes: Rajidae), in Syrian marine waters (eastern Mediterranean). Acta Ichthyol. Piscat. 47, 371–383. https://doi.org/10.3750/AIEP/02283

Anonymous, 2017. International bottom trawl survey in the Mediterranean instruction manual. Version 9 (MEDITS-Handbook). MEDITS Working Group.

Barría, C., Coll, M., Navarro, J., 2015. Unravelling the ecological role and trophic relationships of uncommon and threatened elasmobranchs in the western Mediterranean Sea. Mar. Ecol. Prog. Ser. 539, 225–240. https://doi.org/10.3354/meps11494

Baum, J.K., Worm, B., 2009. Cascading top-down effects of changing oceanic predator abundances. J. Anim. Ecol. 78, 699–714. https://doi.org/10.1111/j.1365-2656.2009.01531.x

Bax, N.J., Cleary, J., Donnelly, B., Dunn, D.C., Dunstan, P.K., Fuller, M., Halpin, P.N., 2016. Results of efforts by the Convention on Biological Diversity to describe ecologically or biologically significant marine areas. Conserv. Biol. 30, 571–581. https://doi.org/10.1111/cobi.12649

Bearzi, G., Politi, E., Agazzi, S., Azzellino, A., 2006. Prey depletion caused by overfishing and the decline of marine megafauna in eastern Ionian Sea coastal waters (central Mediterranean). Biol. Conserv. 127, 373–382. https://doi.org/10.1016/j.biocon.2005.08.017

Belleggia, M., Andrada, N., Paglieri, S., Cortés, F., Massa, A.M., Figueroa, D.E., Bremec, C., 2016. Trophic ecology of yellownose skate *Zearaja chilensis*, a top predator in the south-western Atlantic Ocean. J. Fish Biol. 88, 1070–1087. https://doi.org/10.1111/jfb.12878

Bellodi, A., Porcu, C., Cannas, R., Cau, Al., Marongiu, M.F., Mulas, A., Vittori, S., Follesa, M.C., 2017. Life-history traits of the long-nosed skate *Dipturus oxyrinchus*. J. Fish Biol. 90, 867–888. https://doi.org/10.1111/jfb.13205

Bertrand, J.A., Sola, L.G. de, Papaconstantinou, C., Relini, G., Souplet, A., 2002. The general specifications of the MEDITS surveys. Sci. Mar. 66, 9–17. https://doi.org/10.3989/scimar.2002.66s29

Bizzarro, J.J., Robinson, H.J., Rinewalt, C.S., Ebert, D.A., 2009. Comparative feeding ecology of four sympatric skate species off central California, USA. Biol. Skates 91–114.

Braccini, J.M., Perez, J.E., Braccini, J.M., Perez, J.E., 2005. Feeding habits of the sandskate *Psammobatis extenta* (Garman, 1913): sources of variation in dietary composition. Mar. Freshw. Res. 56, 395–403. https://doi.org/10.1071/MF04205

Brickle, P., Laptikhovsky, V., Pompert, J., Bishop, A., 2003. Ontogenetic changes in the feeding habits and dietary overlap between three abundant rajid species on the Falkland Islands' shelf. J. Mar. Biol. Assoc. U. K. 83, 1119–1125. https://doi.org/10.1017/S0025315403008373h

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

Brown-Vuillemin, S., Barreau, T., Caraguel, J.-M., Iglésias, S.P., 2020. Trophic ecology and ontogenetic diet shift of the blue skate (*Dipturus* cf. *flossada*). J. Fish Biol. 97, 515–526. https://doi.org/10.1111/jfb.14407

Cabbar, K., Yiğin, C.Ç., 2023. Feeding habits of two skate species, *Raja miraletus* Linnaeus, 1758 and *Dipturus oxyrinchus* (Linnaeus, 1758)(Chondrichthyes, Rajidae), around the Gökçeada Island (Northern Aegean Sea). Egypt. J. Fish. Aquat. Sci. 40, 110–117. https://doi.org/10.12714/egejfas.40.2.04

Carbonara, P., Cannas, R., Donnaloia, M., Melis, R., Porcu, C., Spedicato, M.T., Zupa, W., Follesa, M.C., 2019. On the presence of *Dipturus nidarosiensis* (Storm, 1881) in the Central Mediterranean area. PeerJ 7, e7009. https://doi.org/10.7717/peerj.7009

Carugati, L., Melis, R., Cariani, A., Cau, A., Crobe, V., Ferrari, A., Follesa, M.C., Geraci, M.L., Iglésias, S.P., Pesci, P., Tinti, F., Cannas, R., 2022. Combined COI barcode-based methods to avoid mislabelling of threatened species of deep-sea skates. Anim. Conserv. 25, 38–52. https://doi.org/10.1111/acv.12716

Coll, M., Piroddi, C., Steenbeek, J., Kaschner, K., Ben Rais Lasram, F., Aguzzi, J., Ballesteros, E., Bianchi, C.N., Corbera, J., Dailianis, T., 2010. The biodiversity of the Mediterranean Sea: estimates, patterns, and threats. PloS One 5, e11842. https://doi.org/10.1371/journal.pone.0011842

Coll-Calvo, E., Barría, C., Recasens, L., Navarro, J., 2020. Feeding ecology of a Mediterranean endemic mesopredator living in highly exploited ecosystems. Mar. Environ. Res. 157, 104932. https://doi.org/10.1016/j.marenvres.2020.104932

Colloca, F., Carrozzi, V., Simonetti, A., Di Lorenzo, M., 2020. Using local ecological knowledge of fishers to reconstruct abundance trends of elasmobranch populations in the Strait of Sicily. Front. Mar. Sci. 7, 508. https://doi.org/10.3389/fmars.2020.00508

Colloca, F., Scarcella, G., Libralato, S., 2017. Recent trends and impacts of fisheries exploitation on Mediterranean stocks and ecosystems. Front. Mar. Sci. 4, 244. https://doi.org/10.3389/fmars.2017.00244

Consoli, P., Esposito, V., Battaglia, P., Altobelli, C., Perzia, P., Romeo, T., Canese, S., Andaloro, F., 2016. Fish distribution and habitat complexity on banks of the Strait of Sicily (Central Mediterranean Sea) from remotely-operated vehicle (ROV) explorations. PLOS ONE 11, 1–21. https://doi.org/10.1371/journal.pone.0167809

De Juan, S., Moranta, J., Hinz, H., Barberá, C., Ojeda-Martinez, C., Oro, D., Ordines, F., Ólafsson, E., Demestre, M., Massutí, E., 2012. A regional network of sustainable managed areas as the way forward for the implementation of an Ecosystem-Based Fisheries Management in the Mediterranean. Ocean Coast. Manag. 65, 51–58. https://doi.org/10.1016/j.ocecoaman.2012.04.024

Di Lorenzo, M., Sinerchia, M., Colloca, F., 2018. The North sector of the Strait of Sicily: a priority area for conservation in the Mediterranean Sea. Hydrobiologia 821, 235–253. https://doi.org/10.1007/s10750-017-3389-7

Di Maio, F., Geraci, M.L., Scannella, D., Russo, T., Fiorentino, F., 2022. Evaluation of the economic performance of coastal trawling off the southern coast of Sicily (Central Mediterranean Sea). Sustainability 14, 4743. https://doi.org/10.3390/su14084743

Dulvy, N.K., Baum, J.K., Clarke, S., Compagno, L.J.V., Cortés, E., Domingo, A., Fordham, S., Fowler, S., Francis, M.P., Gibson, C., Martínez, J., Musick, J.A., Soldo, A., Stevens, J.D., Valenti, S., 2008. You can swim but you can't hide: the global status

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

443 and conservation of oceanic pelagic sharks and rays. Aquat. Conserv. Mar. Freshw. Ecosyst. 18, 459–482.
444 https://doi.org/10.1002/aqc.975
445 Dulvy, N.K., Pacoureau, N., Matsushiba, J.H., Yan, H.F., VanderWright, W.J., Rigby, C.L., Finucci, B., Sherman, C.S., Jabado,
446 R.W., Carlson, J.K., Pollom, R.A., Charvet, P., Pollock, C.M., Hilton-Taylor, C., Simpfendorfer, C.A., 2024. Ecological
447 erosion and expanding extinction risk of sharks and rays. Science 386, eadn1477. https://doi.org/10.1126/science.adn1477
448 Dulvy, N.K., Pacoureau, N., Rigby, C.L., Pollom, R.A., Jabado, R.W., Ebert, D.A., Finucci, B., Pollock, C.M., Cheok, J., Derrick,
449 D.H., Herman, K.B., Sherman, C.S., VanderWright, W.J., Lawson, J.M., Walls, R.H.L., Carlson, J.K., Charvet, P.,
450 Bineesh, K.K., Fernando, D., Ralph, G.M., Matsushiba, J.H., Hilton-Taylor, C., Fordham, S.V., Simpfendorfer, C.A., 2021.
451 Overfishing drives over one-third of all sharks and rays toward a global extinction crisis. Curr. Biol. 31, 4773-4787.e8.
452 https://doi.org/10.1016/j.cub.2021.08.062
453 Ebert, D., Bizzarro, J., 2007. Standardized diet compositions and trophic levels of skates (Chondrichthyes: Rajiformes: Rajoidei).
454 Environ. Biol. Fishes 80, 221–237. https://doi.org/10.1007/s10641-007-9227-4
455 Ebert, D., Stehmann, M., 2013. Sharks, batoids, and chimaeras of the North Atlantic. FAO Species Catalogue for Fishery Purposes.
456 No. 7. Rome, FAO. 523 p.
457 Ellis, J., Abella, A., Serena, F., Stehmann, M.F.W., Walls, R., 2015. *Dipturus oxyrinchus* [WWW Document]. IUCN Red List
458 Threat. Species. URL https://dx.doi.org/10.2305/IUCN.UK.2015-1.RLTS.T63100A48908629.en (accessed 9.6.23).
459 Espinoza, M., Clarke, T.M., Villalobos-Rojas, F., Wehrtmann, I.S., 2012. Ontogenetic dietary shifts and feeding ecology of the
460 rasptail skate *Raja velezi* and the brown smoothhound shark *Mustelus henlei* along the Pacific coast of Costa Rica, Central
461 America. J. Fish Biol. 81, 1578–1595. https://doi.org/10.1111/j.1095-8649.2012.03410.x
462 Falsone, F., Gancitano, V., Geraci, M.L., Sardo, G., Scannella, D., Serena, F., Vitale, S., Fiorentino, F., 2022. Assessing the stock
463 dynamics of Elasmobranchii off the southern coast of Sicily by using trawl survey data. Fishes 7, 136.
464 https://doi.org/10.3390/fishes7030136
465 Fanelli, E., Da Ros, Z., Martino, I., Azzurro, E., Bargione, G., Donato, F., Lucchetti, A., 2023. Crowding in the middle of marine
466 food webs: A focus on *Raja asterias* and other mediterranean batoids. Mar. Environ. Res. 183, 105830.
467 https://doi.org/10.1016/j.marenvres.2022.105830
468 Ferretti, F., Worm, B., Britten, G.L., Heithaus, M.R., Lotze, H.K., 2010. Patterns and ecosystem consequences of shark declines in
469 the ocean. Ecol. Lett. 13, 1055–1071. https://doi.org/10.1111/j.1461-0248.2010.01489.x
470 Fiorentino, F., Garofalo, G., Bono, G., Vitale, S., 2024a. Learning from the history of red shrimp fisheries in the Mediterranean to
471 improve sustainability of deep-water bottom trawling. ICES J. Mar. Sci. 81, 652–664.
472 https://doi.org/10.1093/icesjms/fsae031
473 Fiorentino, F., Zava, B., Quattrocchi, F., Serena, F., 2024b. Integrating historical and recent information to understand
474 chondrichthyan dynamics in the central Mediterranean. Mar. Environ. Res. 197, 106468.
475 https://doi.org/10.1016/j.marenvres.2024.106468

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

Flowers, K.I., Heithaus, M.R., Papastamatiou, Y.P., 2021. Buried in the sand: uncovering the ecological roles and importance of rays. Fish Fish. 22, 105–127. https://doi.org/10.1111/faf.12508

Follesa, M.C., Marongiu, M.F., Zupa, W., Bellodi, A., Cau, Alessandro, Cannas, R., Colloca, F., Djurovic, M., Isajlovic, I., Jadaud, A., Manfredi, C., Mulas, A., Peristeraki, P., Porcu, C., Ramirez-Amaro, S., Jiménez, F.S., Serena, F., Sion, L., Thasitis, I., Cau, Angelo, Carbonara, P., 2019. Spatial variability of Chondrichthyes in the northern Mediterranean. Sci. Mar. 83, 81–100. https://doi.org/10.3989/scimar.04998.23A

Gaertner, J.-C., Bertrand, J.A., Relini, G., Papaconstantinou, C., Mazouni, N., Sola, L.G. de, Durbec, J.-P., Jukic-Peladic, S., Souplet, A., 2007. Spatial pattern in species richness of demersal fish assemblages on the continental shelf of the northern Mediterranean Sea: a multiscale analysis. Mar. Ecol. Prog. Ser. 341, 191–203. https://doi.org/10.3354/meps341191

Galván, D.E., Jañez, J., Irigoyen, A.J., 2016. Estimating tissue-specific discrimination factors and turnover rates of stable isotopes of nitrogen and carbon in the smallnose fanskate *Sympterygia bonapartii* (Rajidae). J. Fish Biol. 89, 1258–1270. https://doi.org/10.1111/jfb.13024

Garofalo, G., Fiorentino, F., Gristina, M., Cusumano, S., Sinacori, G., 2007. Stability of spatial pattern of fish species diversity in the Strait of Sicily (central Mediterranean), in: Relini, G., Ryland, J. (Eds.), Biodiversity in Enclosed Seas and Artificial Marine Habitats, Developments in Hydrobiology. Springer Netherlands, Dordrecht, pp. 117–124. https://doi.org/10.1007/978-1-4020-6156-1_10

Geraci, M.L., Colloca, F., Di Maio, F., Falsone, F., Fiorentino, F., Sardo, G., Scannella, D., Gancitano, V., Vitale, S., 2021a. How is artificial lighting affecting the catches in deep water rose shrimp trawl fishery of the Central Mediterranean Sea? Ocean Coast. Manag. 215, 105970. https://doi.org/10.1016/j.ocecoaman.2021.105970

Geraci, M.L., Lorenzo, M.D., Falsone, F., Scannella, D., Maio, F.D., Colloca, F., Vitale, S., Serena, F., 2019. The occurrence of Norwegian skate, *Dipturus nidarosiensis* (Elasmobranchii: Rajiformes: Rajidae), in the Strait of Sicily, central Mediterranean. Acta Ichthyol. Piscat. 49, 203–208. https://doi.org/10.3750/AIEP/02566

Geraci, M.L., Ragonese, S., Norrito, G., Scannella, D., Falsone, F., Vitale, S., 2017. A tale on the demersal and bottom dwelling Chondrichthyes in the south of Sicily through 20 years of scientific survey, in: Chondrichthyes - Multidisciplinary Approach. IntechOpen, pp. 13–37. https://doi.org/10.5772/intechopen.69333

Geraci, M.L., Ragonese, S., Scannella, D., Falsone, F., Gancitano, V., Mifsud, J., Gambin, M., Said, A., Vitale, S., 2021b. Batoid abundances, spatial distribution, and life history traits in the Strait of Sicily (Central Mediterranean Sea): bridging a knowledge gap through three decades of survey. Animals 11, 2189. https://doi.org/10.3390/ani11082189

Gouraguine, A., Hidalgo, M., Moranta, J., Bailey, D.M., Ordines, F., Guijarro, B., Valls, M., Barberá, C., De Mesa, A., 2011. Elasmobranch spatial segregation in the western Mediterranean. Sci. Mar. Barc. 75, 653–664. https://doi.org/10.3989/scimar.2011.75n4653

Gristina, M., Bahri, T., Fiorentino, F., Garofalo, G., 2006. Comparison of demersal fish assemblages in three areas of the Strait of Sicily under different trawling pressure. Fish. Res. 81, 60–71. https://doi.org/10.1016/j.fishres.2006.05.010

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

509 Heupel, M.R., Knip, D.M., Simpfendorfer, C.A., Dulvy, N.K., 2014. Sizing up the ecological role of sharks as predators. Mar. Ecol.
510 Prog. Ser. 495, 291–298. https://doi.org/10.3354/meps10597
511 Hyslop, E.J., 1980. Stomach contents analysis—a review of methods and their application. J. Fish Biol. 17, 411–429.
512 https://doi.org/10.1111/j.1095-8649.1980.tb02775.x
513 Iglésias, S.P., Toulhoat, L., Sellos, D.Y., 2010. Taxonomic confusion and market mislabelling of threatened skates: important
514 consequences for their conservation status. Aquat. Conserv. Mar. Freshw. Ecosyst. 20, 319–333.
515 https://doi.org/10.1002/aqc.1083
516 Jackson, A.L., Inger, R., Parnell, A.C., Bearhop, S., 2011. Comparing isotopic niche widths among and within communities: SIBER
517 – Stable Isotope Bayesian Ellipses in R. J. Anim. Ecol. 80, 595–602. https://doi.org/10.1111/j.1365-2656.2011.01806.x
518 Jarboui, O., Ceriola, L., Fiorentino, F., 2022. Current fisheries management in the Strait of Sicily and progress towards an ecosystem
519 approach. Transit. Ecosyst. Approach Fish. Mediterr. Sea—Lessons Learn. Sel. Case Stud. 681, 147–162.
520 Jukic-Peladic, S., Vrgoc, N., Krstulovic-Sifner, S., Piccinetti, C., Piccinetti-Manfrin, G., Marano, G., Ungaro, N., 2001. Long-term
521 changes in demersal resources of the Adriatic Sea: comparison between trawl surveys carried out in 1948 and 1998. Fish.
522 Res. 53, 95–104. https://doi.org/10.1016/S0165-7836(00)00232-0
523 Kadri, H., Marouani, S., Bradai, M.N., Bouaïn, A., Morize, E., 2015. Age, growth, longevity, mortality and reproductive biology of
524 *Dipturus oxyrinchus*, (Chondrichthyes: Rajidae) off the Gulf of Gabès (Southern Tunisia, central Mediterranean). J. Mar.
525 Biol. Assoc. U. K. 95, 569–577. https://doi.org/10.1017/S0025315414000551
526 Kadri, H., Marouani, S., Saidi, B., Bouain, A., Bradai, M., 2010. Régime alimentaire du pocheteau noir, *Dipturus oxyrinchus*, dans le
527 Golfe de Gabes (Tunisie). Rapp. Procès Verbaux Réun. Int. Pour L'Exploration Sci. Mer Méditerranée 39, 551.
528 Koen Alonso, M., Crespo, E.A., García, N.A., Pedraza, S.N., Mariotti, P.A., Vera, B.B., Mora, N.J., 2001. Food habits of *Dipturus*
529 *chilensis* (Pisces: Rajidae) off Patagonia, Argentina. ICES J. Mar. Sci. 58, 288–297.
530 https://doi.org/10.1006/jmsc.2000.1010
531 Lotze, H.K., Coll, M., Dunne, J.A., 2011. Historical changes in marine resources, food-web structure and ecosystem functioning in
532 the Adriatic Sea, Mediterranean. Ecosystems 14, 198–222. https://doi.org/10.1007/s10021-010-9404-8
533 Lucifora, L.O., García, V.B., Worm, B., 2011. Global diversity hotspots and conservation priorities for sharks. PLOS ONE 6,
534 e19356. https://doi.org/10.1371/journal.pone.0019356
535 Madurell, T., Fanelli, E., Cartes, J.E., 2008. Isotopic composition of carbon and nitrogen of suprabenthic fauna in the NW Balearic
536 Islands (western Mediterranean). J. Mar. Syst., The Wrapping Up of the IDEA Project: 71, 336–345.
537 https://doi.org/10.1016/j.jmarsys.2007.03.006
538 Milisenda, G., Vitale, S., Massi, D., Enea, M., Gancitano, V., Giusto, G.B., Badalucco, C., Gristina, M., Garofalo, G., Fiorentino, F.,
539 2017. Discard composition associated with the deep water rose shrimp fisheries (*Parapenaeus longirostris*, Lucas 1846) in
540 the south-central Mediterranean Sea. Mediterr. Mar. Sci. 18, 53–63. https://doi.org/10.12681/mms.1787

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

Mulas, A., Bellodi, A., Cannas, R., Carbonara, P., Cau, A., Marongiu, M.F., Pesci, P., Porcu, C., Follesa, M.C., 2019. Resource partitioning among sympatric elasmobranchs in the central-western Mediterranean continental shelf. Mar. Biol. 166, 153. https://doi.org/10.1007/s00227-019-3607-0

Mulas, A., Bellodi, A., Cannas, R., Cau, Al., Cuccu, D., Marongiu, M.F., Porcu, C., Follesa, M.C., 2015. Diet and feeding behaviour of longnosed skate *Dipturus oxyrinchus*. J. Fish Biol. 86, 121–138. https://doi.org/10.1111/jfb.12551

Packer, D.B., Zetlin, C.A., Vitaliano, J.J., 2003. Essential fish habitat source document. Barndoor skate, *Dipturus laevis*, life history and habitat characteristics.

Pacoureau, N., Rigby, C.L., Kyne, P.M., Sherley, R.B., Winker, H., Carlson, J.K., Fordham, S.V., Barreto, R., Fernando, D., Francis, M.P., Jabado, R.W., Herman, K.B., Liu, K.-M., Marshall, A.D., Pollom, R.A., Romanov, E.V., Simpfendorfer, C.A., Yin, J.S., Kindsvater, H.K., Dulvy, N.K., 2021. Half a century of global decline in oceanic sharks and rays. Nature 589, 567–571. https://doi.org/10.1038/s41586-020-03173-9

Pedà, C., Battaglia, P., Romeo, T., Stipa, M., Longo, F., Malara, D., Consoli, P., Andaloro, F., 2022. Photographic atlas of cephalopod beaks from the Mediterranean Sea.

Post, D.M., Layman, C.A., Arrington, D.A., Takimoto, G., Quattrochi, J., Montaña, C.G., 2007. Getting to the fat of the matter: models, methods and assumptions for dealing with lipids in stable isotope analyses. Oecologia 152, 179–189. https://doi.org/10.1007/s00442-006-0630-x

Ragonese, S., Vitale, S., Dimech, M., Mazzola, S., 2013. Abundances of demersal sharks and chimaera from 1994-2009 scientific surveys in the Central Mediterranean Sea. PLOS ONE 8, e74865. https://doi.org/10.1371/journal.pone.0074865

Rigolet, C., Thiébaut, E., Dubois, S.F., 2014. Food web structures of subtidal benthic muddy habitats: evidence of microphytobenthos contribution supported by an engineer species. Mar. Ecol. Prog. Ser. 500, 25–41. https://doi.org/10.3354/meps10685

Rodríguez-Cabello, C., Sánchez, F., Olaso, I., 2007. Distribution patterns and sexual segregations of *Scyliorhinus canicula* (L.) in the Cantabrian Sea. J. Fish Biol. 70, 1568–1586. https://doi.org/10.1111/j.1095-8649.2007.01444.x

Russo, T., Parisi, A., Garofalo, G., Gristina, M., Cataudella, S., Fiorentino, F., 2014. SMART: A spatially explicit bio-economic model for assessing and managing demersal fisheries, with an application to italian trawlers in the Strait of Sicily. PLOS ONE 9, e86222. https://doi.org/10.1371/journal.pone.0086222

Scannella, D., Geraci, M.L., Falsone, F., Colloca, F., Zava, B., Serena, F., Maio, F.D., Vitale, S., 2020. A new record of a great white shark, *Carcharodon carcharias* (Chondrichthyes: Lamnidae) in the Strait of Sicily, Central Mediterranean Sea. Acta Adriat. 61, 231–238. https://doi.org/10.32582/aa.61.2.13

Schmitt, J.D., Gedamke, T., DuPaul, W.D., Musick, J.A., 2015. Ontogenetic and sex-specific shifts in the feeding habits of the Barndoor skate. Mar. Coast. Fish. 7, 409–418. https://doi.org/10.1080/19425120.2015.1063553

Serena, F., Abella, A.J., Bargnesi, F., Barone, M., Colloca, F., Ferretti, F., Fiorentino, F., Jenrette, J., Moro, S., 2020. Species diversity, taxonomy and distribution of Chondrichthyes in the Mediterranean and Black Sea. Eur. Zool. J. 87, 497–536. https://doi.org/10.1080/24750263.2020.1805518

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

Serena, F., Mancusi, C., Barone, M., 2010. Field identification guide to the skates (Rajidae) of the Mediterranean Sea. Guidelines for data collection and analysis, 2nd ed. https://doi.org/10.13140/2.1.2414.9764

Sinerchia, M., Fiorentino, F., Colloca, F., Cucco, A., Garofalo, G., Perilli, A., Quattrocchi, G., Fulton, E.A., 2025. Atlantis end-to-end modeling to explore ecosystem dynamics in the Strait of Sicily, Central Mediterranean Sea. Environ. Model. Softw. 183, 106237. https://doi.org/10.1016/j.envsoft.2024.106237

Treloar, M.A., Laurenson, L.J.B., Stevens, J.D., 2009. Dietary comparisons of six skate species (Rajidae) in south-eastern Australian waters, in: Ebert, D.A., Sulikowski, J.A. (Eds.), Biology of Skates, Developments in Environmental Biology of Fishes 27. Springer Netherlands, Dordrecht, pp. 75–90. https://doi.org/10.1007/978-1-4020-9703-4_6

Tuset, V.M., Lombarte, A., Assis, C.A., 2008. Otolith atlas for the western Mediterranean, north and central eastern Atlantic. Sci. Mar. 72, 7–198. https://doi.org/10.3989/scimar.2008.72s17

Valls, M., Quetglas, A., Ordines, F., Moranta, J., 2011. Feeding ecology of demersal elasmobranchs from the shelf and slope off the Balearic Sea (western Mediterranean). Sci. Mar. 75, 633–639. https://doi.org/10.3989/scimar.2011.75n4633

Vannucci, S., Mancusi, C., Serena, F., Cuoco, C., Volani, A., 2006. Feeding ecology of rays in the southern Ligurian Sea. Biol. Mar. Mediterr. 13, 296–297.

Vargas-Caro, C., Bustamante, C., Lamilla, J., B. Bennett, M., 2015. A review of longnose skates *Zearaja chilensis* and *Dipturus trachyderma* (Rajiformes: Rajidae). Univ. Sci. 20, 321–359. https://doi.org/10.11144/Javeriana.SC20-3.arol

Vitale, S., Cannizzaro, L., Bono, G., Beltrano, A.M., Milazzo, A., Norrito, G., 2006. Catch composition of decapoda crustaceans from trawl fishery catches in the Central Mediterranean Sea. J Coast Res 39, 1798–1800.

Walls, R.H.L., Dulvy, N.K., 2021. Tracking the rising extinction risk of sharks and rays in the Northeast Atlantic Ocean and Mediterranean Sea. Sci. Rep. 11, 15397. https://doi.org/10.1038/s41598-021-94632-4

Wood, S.N., Pya, N., Säfken, B., 2016. Smoothing parameter and model selection for general smooth models. J. Am. Stat. Assoc. 111, 1548–1563. https://doi.org/10.1080/01621459.2016.1180986

Yemışken, E., Forero, M.G., Megalofonou, P., Eryilmaz, L., Navarro, J., 2018. Feeding habits of three Batoids in the Levantine Sea (north-eastern Mediterranean Sea) based on stomach content and isotopic data. J. Mar. Biol. Assoc. U. K. 98, 89–96. https://doi.org/10.1017/S002531541700073X

Yiğin, C., Ismen, A., 2010. Age, growth, reproduction and feed of longnosed skate, *Dipturus oxyrinchus* (Linnaeus, 1758) in Saros Bay, the north Aegean Sea. J. Appl. Ichthyol. 26, 913–919. https://doi.org/10.1111/j.1439-0426.2010.01510.x

Zava, B., Insacco, G., Deidun, A., Said, A., Souissi, J.B., Nour, O.M., Kondylatos, G., Scannella, D., Corsini-Foka, M., 2022. Records of the critically endangered *Squatina aculeata* and *Squatina oculata* (Elasmobranchii: Squatiniformes: Squatinidae) from the Mediterranean Sea. Acta Ichthyologica et Piscatoria 52, 285–297. https://doi.org/10.3897/aiep.52.94694

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

608 **Tables**

609 **Table 1** Number of *Dipturus oxyrinchus* collected in the Strait of Sicily (central Mediterranean Sea) from 2016 to 2019 classified
610 according to their size (juveniles, TL <55 cm; adults, TL ≥ 55 cm; where 55 cm is the size at first maturity observed in this study)
611 and depth strata

612

Depth strata	Juveniles	Adults	Total
200-400 m	51	28	79
401-550 m	14	24	38
551-750 m	6	18	24
NA	2	9	11
Total	73	79	**152**

613

614 **Table 2** Prey identified within stomach contents of *Dipturus oxyrinchus* collected in the Strait of Sicily (central Mediterranean Sea)
615 between 2016 and 2019. %W: percentage in mass of prey; %N: percentage in number; %F: Frequency of occurrence. Nd = not
616 determined

617

Prey	%W	%N	%F
Crustacea			
nd	1.79	1.88	16.67
Mysidacea			
nd	0.08	4.69	3.51
Lophogaster typicus	0.35	16.20	7.89
Amphipoda			
Phronima sedentaria	0.00	0.23	0.88
Euphasiacea			
nd	0.00	0.23	0.88
Decapoda			
Natantia			

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

nd	3.98	11.50	21.05
Aegaeon lacazei	0.09	0.23	0.88
Chlorotocus crassicornis	4.17	5.40	12.28
Parapenaeus longirostris	27.77	13.85	16.67
Plesionika edwarsii	4.22	1.41	1.75
Plesionika gigliolii	0.80	0.70	0.88
Plesionika spp.	2.26	0.70	1.75
Pontophilus spinosus	0.06	0.23	0.88
Solenocera membranacea	0.51	0.23	0.88
Macrura			
Alpheus spp.	0.08	0.23	0.88
Nephrops norvegicus	6.85	0.47	1.75
Polycheles typhlops	0.25	0.23	0.88
Scyllarus spp.	0.06	0.70	2.63
Anomura			
Iridonida speciosa	20.68	24.41	15.79
Munida spp.	0.33	0.23	0.88
Brachiura			
Goneplax rhomboides	2.17	2.35	5.26
Parthenope spp.	0.42	0.23	0.88
Stomatopoda			
nd	0.33	0.47	1.75
Rissoides desmaresti	1.05	0.47	1.75
Rissoides spp.	0.15	0.23	0.88
Cephalopoda			
nd	0.57	3.99	11.4
Abraliopsis morisii	0.01	0.23	0.88
Bathypolypus sponsalis	0.02	0.23	0.88
Eledone spp.	1.71	0.23	0.88
Heteroteuthis dispar	0.35	0.70	2.63

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

Illex coindetii	0.01	0.23	0.88
Loligo forbesii	0.01	0.23	0.88
Pteroctopus tetracirrhus	0.01	0.23	0.88
Sepietta oweniana	0.01	0.23	0.88
Teleostei			
nd	5.67	2.82	9.65
Anguilliformes	0.41	0.23	0.88
Callionymus spp.	0.15	0.23	0.88
Ceratoscopelus maderensis	0.07	0.23	0.88
Coelorinchus caelorhincus	4.50	0.70	2.63
Gaidropsarus biscayensis	0.05	0.23	0.88
Glossanodon leioglossus	0.14	0.23	0.88
Gnathophis mystax	0.64	0.23	0.88
Nemichthys scolopaceus	0.30	0.23	0.88
Notacanthus bonaparte	2.03	0.23	0.88
Ophisurus serpens	0.07	0.23	0.88
Phycis blennoides	1.72	0.23	0.88
Trachyrincus scabrus	0.02	0.23	0.88
Not identified material	3.10	0.00	11.40

Table 3 Summary of the outputs of the best model explaining the consumption in number of the main prey categories of *Dipturus oxyrinchus*, including their smooth terms for depth (s(Depth)) and total length (s(TL)), estimated degrees of freedom (edf), reference degrees of freedom (Ref.df), chi-square statistics (Chi.sq), p-values, and the percentage of deviance explained by each model.

Model	Term	edf	Ref.df	Chi.sq	p-value	Deviance Explained
gam_Anomura	s(Depth)	1.000	1.000	18.752	*0.000	62.169
	s(TL)	3.185	3.990	12.492	*0.014	62.169
gam_Brachyura	s(Depth)	2.079	2.522	2.630	0.478	18.359
	s(TL)	1.000	1.000	0.784	0.376	18.359
gam_Lophogastrida	s(Depth)	1.000	1.000	9.759	*0.002	69.399

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

Model	Term	edf	Ref.df	Chi.sq	p-value	Deviance Explained
	s(TL)	1.000	1.000	19.143	*0.000	69.399
gam_Natantia	s(Depth)	1.433	1.730	0.480	0.640	18.746
	s(TL)	1.000	1.000	11.808	*0.001	18.746
gam_OthCrustaceans	s(Depth)	2.436	3.001	9.115	*0.028	19.986
	s(TL)	3.483	4.316	6.053	0.197	19.986
gam_Cephalopoda	s(Depth)	1.000	1.000	0.003	0.959	12.492
	s(TL)	1.339	1.608	6.543	*0.019	12.492
gam_Teleostei	s(Depth)	1.000	1.000	2.229	0.135	15.587
	s(TL)	1.000	1.000	6.917	*0.009	15.587

Table 4 Mean (± SD) $\delta^{13}C$, $\delta^{15}N$, carbon range (CR), nitrogen range (NR) (all in ‰) and number (n) of *Dipturus oxyrinchus* collected in the Strait of Sicily (central Mediterranean Sea) between 2016 and 2019 and grouped according to size (juveniles, TL<55 cm; adults, TL ≥55 cm), and the collection depth (200-400 m; 401-550 m; 551-750 m)

Group	n	$\delta^{13}C$	$\delta^{15}N$	CR	NR
Size					
Juveniles	70	-18.9 ± 0.4	8.4 ± 0.7	2.7	2.6
Adults	79	-18.5 ± 0.4	9.2 ± 0.9	2.3	3.7
Depth range					
200-400 m	78	-18.7 ± 0.5	8.4 ± 0.8	2.6	3.4
401-550 m	38	-18.7 ± 0.4	9.1 ± 0.7	2.3	3.1
551-750 m	22	-18.5 ± 0.4	9.4 ± 0.9	1.4	3.2

Table 5 Stable Isotope Bayesian Ellipse Area (SEAb, mode and credible intervals) and mean Standard Ellipse Area corrected for small sample size (SEAc), all in $‰^2$, of *Dipturus oxyrinchus* collected in the Strait of Sicily (central Mediterranean Sea) between 2016 and 2019. Individuals were grouped based on their size (juveniles, TL<55cm; adults, TL ≥55cm), and the collection depth (200-400 m; 401-550 m; 551-750 m)

	SEAb

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574

Group	SEAc	Modes	Credible intervals		
			99%	95%	50%
Sizes					
Juveniles	0.73	0.71	0.51-0.99	0.56-0.90	0.65-0.77
Adults	0.95	0.94	0.69-1.26	0.75-1.17	0.87-1.02
Depth range					
200-400 m	0.85	0.84	0.63-1.14	0.67-1.07	0.78-0.91
401-550 m	0.61	0.61	0.40-0.94	0.44-0.85	0.54-0.67
551-750 m	1.04	0.96	0.53-1.73	0.62-1.48	0.83-1.11

631

632 **Table 6** Values and pairwise estimates of the proportion of overlap (%) between the Stable Isotope Ellipse Area corrected for small
633 sample size (SEAc) of *Dipturus oxyrinchus* collected in the Strait of Sicily (central Mediterranean Sea) between 2016 and 2019 and
634 grouped based on their size (juveniles, TL<55cm; adults, TL ≥55cm), and the collection depth (200-400 m; 401-550 m; 551-750 m)

Group 1 *vs* group 2	Area of group 1 (‰^{2})	Area of group 2 (‰^{2})	Area of overlap (‰^{2})	Proportion of 1 that overlaps with 2 (%)	Proportion of 2 that overlaps with 1 (%)	Overlap (%)
Adults *vs* Juveniles	5.70	4.35	3.46	60.7	79.5	52.5
200-400 m *vs* 401-550 m	5.10	3.67	2.87	56.3	78.3	48.7
551-750 m *vs* 200-400 m	6.20	5.10	3.71	59.7	72.6	48.8
551-750 m *vs* 401-550 m	6.20	3.67	3.12	50.4	85.1	46.3

635

636 **Table 7** Mean (± SE) of $\delta^{13}C$ and $\delta^{15}N$, carbon range (CR) nitrogen range (NR) (all in ‰) and number of samples (n) of the potential
637 prey taxa of *Dipturus oxyrinchus* collected in the Strait of Sicily (central Mediterranean Sea) between 2016 and 2019.

Group	n	$\delta^{13}C$	$\delta^{15}N$	CR	NR
Crustacea	37	-19.4 ± 1.1	8.0 ± 1.5	5.1	6.5
Teleostei	17	-19.4 ± 1.0	9.3 ± 1.6	4.3	5.8
Cephalopoda	8	-20.1 ± 0.3	8.5 ± 0.7	0.9	2.0

638

Preprint not peer reviewed

This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=5090574