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► **To cite this version:**

Laure Carassou, A.S. Al Kindi, S. Dobretsov. Preliminary assessment of the trophic structure of demersal fish community in the Sea of Oman. *Regional Studies in Marine Science*, 2017, 16, pp.145-151. <10.1016/j.rsma.2017.08.008>. <hal-01808811>

HAL Id: hal-01808811

<https://hal.science/hal-01808811v1>

Submitted on 6 Jun 2018

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3 Preliminary assessment of the trophic structure of demersal fish community in the Sea of
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62 ABSTRACT
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64 Detailed knowledge on the trophic ecology of marine species is an essential asset for the
65 development of appropriate ecosystem-based management of marine fisheries. In the Sea of
66 Oman, no studies to date have addressed the diet of demersal fish inhabiting soft-bottom
67 habitats, despite the importance of these habitats for local fisheries. This study provides a
68 preliminary investigation of feeding strategies displayed by demersal fish communities at two
69 seasons in the Sea of Oman, Muscat waters, based on stomach content and dorsal muscle
70 $\delta^{15}\text{N}$, $\delta^{13}\text{C}$ and $\delta^{34}\text{S}$ analyses. A total of 46 fishes from 15 species, 14 families and 7 orders
71 were collected in December 2013 and March 2014. All species displayed a carnivorous diet,
72 with variable contributions of invertebrate and fish prey. While stomach content data
73 suggested that *Fistularia petimba* (Fistulariidae), *Saurida tumbil* (Synodontidae) and *Ulua*
74 *mentalis* (Carangidae) were mostly piscivorous, their $\delta^{15}\text{N}$ values strongly overlapped with
75 other species found to feed mostly on invertebrates, suggesting a mixed fish-invertebrate
76 feeding on a longer time scale. No significant variations were found between months in terms
77 of mean isotopic values, but larger range values and variances were observed for $\delta^{13}\text{C}$ and
78 $\delta^{34}\text{S}$ in December, possibly indicating the consumption of food resources from more diverse
79 mixture and origin during that month. Only $\delta^{15}\text{N}$ was weakly but significantly related to fish
80 size at the community level, suggesting a poor size-related structuration of the demersal fish
81 community at the spatial and temporal scale examined, consistent with other studies in the
82 study area. However, the low number of samples analyzed limited the scope of our
83 conclusions, and further investigations based on stable isotope methodology are needed to
84 obtain essential biological knowledge for ecosystem-based management of fisheries in the Sea
85 of Oman.
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100 *Keywords:*

101 Sea of Oman; fish diet; stomach contents; stable isotopes; ecosystem-based management
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1. Introduction

The importance of ecosystem-based approaches to fisheries research and management is now increasingly recognized on a global scale (Pauly et al., 2002; Gorospe et al., 2016). Such approaches indeed allow the incorporation of biological traits characterizing species targeted by fisheries, as well as their interactions with non-commercial species, including their prey and predators, and their environment (Starr et al., 2010; Fogarty, 2013). In particular, understanding the trophic strategies of fishes (who eats what, where and when) remains a vast working challenge for biologists. For example, when consulting the latest available inventories from Fishbase (Froese and Pauly, 2017), among the total 33,600 species recorded in the database (as for July 25th 2017), information on ‘diet’ only encompass 2,281 localized records, and information on ‘food items’ 8,320 records. This means a lot still needs to be done by biologists in order to fully comprehend the complexity of fish trophic strategies, essential information for management policy guidance considering the basal feeding requirements of targeted fish species within their ecosystem of interest. Information on fish diet is particularly scarce in the Arabian Gulf and Sea of Oman, despite the peculiarity of this region in terms of diversity of marine habitats, oceanographic conditions and marine biodiversity (Rastgoo and Navarro, 2017).

Among the techniques used to study fish trophic strategies, stomach contents have been traditionally employed for decades (Hyslop, 1980; Cortés, 1997). Although relatively simple to implement, stomach content analyses however present the disadvantage of providing only very recent dietary information, i.e., only prey ingested just prior fish capture can be identified in fish stomachs (Hyslop, 1980; Cortés, 1997). Moreover, some prey can be ingested without being assimilated by a consumer, resulting in biased estimations of prey contributions (Cortés, 1997). Prey with soft bodies is also likely to be more quickly digested than prey with hard structures, such as shells or carapaces, resulting in over- or under-estimation of prey importance in fish diet. Finally, diet quantification from stomach content analyses requires a large number of samples to be analyzed due to the high variability characterizing stomach fullness and content in most fish species (Cortés, 1997).

Stable isotopes have more recently emerged as a promising complementary methodology to address fish dietary ecology (e.g., Carassou et al., 2008; Gning et al., 2010; França et al., 2011; Davis et al., 2012; Carassou et al., 2016). Stable isotopes can be used as natural tracers of the sources of food assimilated by a consumer, relying on the principle that the isotopic composition of the food is reflected in the consumer tissues after some period of time ranging from weeks to months depending on species, environmental conditions and

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180 consumer growth patterns (Bosley et al., 2002; Buchheister and Latour, 2010). In this context,
181 stable isotopes of carbon ($^{13}\text{C}/^{12}\text{C}$, or $\delta^{13}\text{C}$) and nitrogen ($^{15}\text{N}/^{14}\text{N}$, or $\delta^{15}\text{N}$) are the most often
182 measured in food web studies (Hobson, 1999; Post, 2002). The combination of stomach
183 content with $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ analyses is now recognized as a pertinent methodology in order to
184 quantify fish diet and address its spatial and temporal variability in a given ecosystem
185 (Hamidan et al., 2016; Keller et al., 2016; Malek et al., 2016; Olson et al., 2016; Weidner et
186 al., 2017). In addition to carbon and nitrogen isotopic ratios, sulfur isotopes are also useful to
187 trace the origin of the prey consumed by consumers in aquatic ecosystems (Peterson, 1999;
188 Post, 2002; Fry and Chumchal, 2011). The relative composition of $^{34}\text{S}/^{33}\text{S}$ ($\delta^{34}\text{S}$) in fish
189 muscles, in particular, provides additional information to carbon and nitrogen isotopic ratios
190 to unravel the identity and origin of basal resources used by mobile consumers, in particular
191 prey origin, i.e., benthic or pelagic, as well as the diversity of potential resources constitutive
192 of a consumer's diet (Peterson, 1999; Connolly et al., 2004; Jardine et al., 2012; Colborne et
193 al., 2016; Morkūnė et al., 2016).

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203 Only few published studies used stable isotopes to investigate wild fish diets in coastal
204 waters of the Sultanate of Oman (Al-Reasi et al., 2007; Al-Habsi et al., 2008; Mill, 2007; Mill
205 et al., 2007). For example, Al-Habsi et al. (2008) used carbon and nitrogen isotopic ratios to
206 investigate a potential size-structuration of demersal food webs in the coastal area of the
207 Arabian Sea (located on the south of the country). The same stable isotopes were used to
208 analyze the trophodynamics of coral reef communities from the Arabian Sea and the Sea of
209 Oman (located on the northwest of the country), the two sites being characterized by
210 contrasted influences of regional upwelling (Mill, 2007). The later study (Mill, 2007) focused
211 on fish species associated with reef habitats, using many $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ observations and
212 additional $\delta^{34}\text{S}$ on a restricted number of species, in an attempt to understand reef fishes'
213 reliance on a variety of basal food resources on the reefs, and the influence of upwelling
214 events on their trophic structure. The trophic structure of demersal fish communities in non-
215 reef habitats from the Sea of Oman has never been studied using stable isotope analyses. In
216 the present study, we therefore provide a preliminary analysis of stomach content, $\delta^{13}\text{C}$, $\delta^{15}\text{N}$
217 and $\delta^{34}\text{S}$ data to investigate the trophic structure of demersal fish assemblages collected by
218 trawling in soft-bottom Muscat coastal waters.
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228 229 **2. Material and Methods**

230 *2.1. Sampling site and methods*

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239 The Sea of Oman is located south of the Arabian Gulf, down the narrow Strait of
240 Hormuz, and is open to the Arabian Sea to the south. It is relatively deep, with 3/4th of its
241 waters being more than 1,000 m depth (Rastgoo and Navarro, 2017). Oceanographic
242 conditions characterizing the Sea of Oman are described in detail in Banse and Piontkovski
243 (2006), Al-Hashmi et al. (2010), Piontkovski et al. (2011) and Piontkovski and Chiffings
244 (2014). In short, Oman coastal waters are characterized by one of the most intensive coastal
245 upwelling phenomena in the world (Reynolds, 1993; Al-Hashmi et al., 2010). A monsoonal
246 regime drives a wind-driven circulation of the mixed layer, with recurrent formation of
247 cyclonic and anti-cyclonic eddies affecting the vertical transport of nutrient rich and low
248 oxygen sub-surface waters. In the Sea of Oman in particular, these vertical water movements
249 generate a strong variability in water temperature, with stronger temperature variations
250 observed between March and October, and relatively cooler and less variable temperature
251 between November and February (Al-Hashmi et al., 2010). Water temperature at the sub-
252 surface (8 m depth) varies between 23°C in February and 33 °C in June on average (Al-
253 Hashmi et al., 2010).
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263 Fish samples were collected over the course of teaching field trips on board of the
264 research vessel ‘Al-Jamiah’ during two periods: March and December 2014, and at a coastal
265 location near the city of Muscat (fishing position starting 23°41’803N 058°16’248E, ending
266 23°40’949N 058°19’126E; Fig.1). As fish samples were collected opportunistically in an
267 educational context, potential food resources consumed by fish could not be sampled. Our
268 analysis was therefore restricted to a preliminary description of the overall trophic structure of
269 fish consumers, with no analysis of their relationship with primary producers or any other
270 group of fauna. Each trip consisted in one-day fishing event, with all trips undertaken at
271 similar location. The fishing gear was a bottom trawl characterized by a 30 m² opening, with a
272 12 cm mesh size in the wings and 6 cm mesh size in the bag. A total of 2 to 3 tows were
273 performed at each sampling period. The trawl was towed at day-time during 30 minutes at a
274 speed of about 2 knots. After each tow, fish species were sorted out on the boat and one to six
275 specimens (depending on their availability) of different size for each species were placed on
276 ice and immediately transported back to the laboratory.
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287 2.2. *Laboratory work*

288 In the laboratory, all fish samples were measured as standard length (cm), except for
289 *Aetomylaeus nichofii* (banded eagle-ray) for which maximum wing width was measured.
290 Stomachs of all fishes were removed and preserved in 5 % formaldehyde (Sigma, USA) for
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298 48 hours, before being transferred to 70 % ethanol (Sigma, USA). Stomachs were later cut
299 open and poured in a Petri dish (Bio-rad, USA). Fullness of stomachs were visually estimated
300 (in %) during dissection. Prey were identified to coarse taxonomic categories under a
301 dissecting microscope. The relative abundance of prey categories was quantified by visually
302 estimating the proportion (in %) of different prey items relative to the total space occupied by
303 the total stomach content in the Petri dish.
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308 Samples for stable isotope analyses were prepared for one to three fish per species
309 (replication depending on samples availability; Table 1). For each fish, one piece of dorsal
310 muscle was dissected out, placed in an individual aluminum folder and frozen at -80 °C for
311 further storage. Then, fish muscle samples were defrosted and dried in an oven at 50 °C for 48
312 hours, before grinding with an ethanol-cleaned mortar and pestle. Samples of dried
313 homogenized muscle powder were finally placed in tin capsules for stable isotope analysis
314 performed at UC Davis Stable Isotope Facility laboratory
315 (<http://stableisotopefacility.ucdavis.edu/>). One mg of the fish dry sample was used for $\delta^{13}\text{C}$
316 and $\delta^{15}\text{N}$, while 3 mg of the sample was used for $\delta^{34}\text{S}$ analyses. Lipids were not removed from
317 our samples prior to analysis to avoid any protocol discrepancy among species and reduce
318 $\delta^{13}\text{C}$, $\delta^{15}\text{C}$ and $\delta^{34}\text{S}$ dispersion (Post et al., 2007).
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325 Measurement of dual $^{13}\text{C}:^{12}\text{C}$ and $^{15}\text{N}:^{14}\text{N}$ ratios in the samples was performed using a
326 PDZ Europa ANCA-GSL elemental analyzer interfaced to a PDZ Europa 20-20 isotope ratio
327 mass spectrometer ([IRMS] Sercon Ltd., Cheshire UK). Measurements of $^{34}\text{S}:^{33}\text{S}$ were
328 performed using an Elementar vario ISOTOPE cube interfaced to a SerCon 20-22 IRMS
329 (Sercon Ltd., Cheshire UK). $\delta^{13}\text{C}$, $\delta^{15}\text{N}$ and $\delta^{34}\text{S}$ values were expressed relative to the
330 international standards of Vienna PeeDee Belemnite, atmospheric N_2 and Vienna-Canyon
331 Diablo Troilite, respectively. Multipoint calibrations were done based on commercial
332 standards IAEA-N1, N2 and N3 and USGS 40 and 41 for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$, and IAEA-S1, S2
333 and S3 for $\delta^{34}\text{S}$. The experimental precision was calculated as the mean of standard deviations
334 for within-run internal standards replicates for each analysis: ± 0.09 for $\delta^{13}\text{C}$, ± 0.08 for $\delta^{15}\text{N}$
335 and ± 0.22 for $\delta^{34}\text{S}$.
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345 2.3. *Data analysis*

346 The occurrence (in %) of different prey items into fishes' non-empty stomachs was
347 averaged across sampling periods for each species, allowing to characterize their general
348 feeding regime. Stable isotope data were plotted separately for each sampling season in two
349 dimensional-spaces, i.e., $\delta^{13}\text{C}$ vs. $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ vs. $\delta^{34}\text{S}$. One-way analysis of variance
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(ANOVA) was then used to test for significant differences ($P < 0.05$) between seasons in mean $\delta^{13}\text{C}$, $\delta^{15}\text{N}$ and $\delta^{34}\text{S}$ (all species combined, d.f. = 1). The overall $\delta^{13}\text{C}$ and $\delta^{34}\text{S}$ variation range (i.e., maximum – minimum value) and variance characterizing fish communities at different periods were used to illustrate the global trophic niche utilized by the demersal fish community over time, i.e., the overall diversity of food resources used by fishes and their relative origins (benthic vs. pelagic, coastal vs. oceanic). The overall $\delta^{15}\text{N}$ range values and variance were also calculated to infer the diversity of trophic levels potentially represented in the demersal fish community at the two sampling periods, assuming that different positions in the food web would result in a difference of at least 3.4 ‰ between two trophic levels (Post, 2002; Post et al., 2007). Additionally, the relationship between community-level fish size (all species combined) and $\delta^{13}\text{C}$, $\delta^{15}\text{N}$ and $\delta^{34}\text{S}$ were examined to test for a possible size structuration of trophic relationships within the demersal fish community, such as investigated in Al-Habsi et al. (2008). Those relationships were tested using linear regression models, and considered significant if $P < 0.05$. The banded eagle ray *Aetomylaeus nichofii* was excluded from size vs. isotope ratios analyses as its size measurement method differed from other fish species.

3. Results

A total of 46 fish specimens representing 15 different species and 7 orders were collected over the two sampling periods (Table 1). This included 26 fish samples from 9 species in March 2014, 20 fish samples from 12 species in December 2014, and 6 species collected during both periods. Overall size range of the fish community was 7.5 to 55.0 cm SL (excluding the banded eagle ray *Aetomylaeus nichofii*) (Table 1). Among the 46 fish dissected for stomach content analyses, 12 (26 %) had empty stomachs, including two species for which only one specimen was collected, resulting in no available data for diet analysis. A total of 29 individual fish could be analyzed for dual carbon and nitrogen isotopes, and 27 for sulfur isotopes (Table 1).

All 13 species for which prey could be observed in the stomachs were characterized by a clear carnivorous diet, with variable contributions of fish and invertebrate prey (Table 2). Only *Fistularia petimba* (species 15) had consumed exclusively fish prey, but fish prey were also observed in all stomachs of *Saurida tumbil* (species 1) and *Ulua mentalis* (species 4), and in one third (33 %) of the stomachs of *Nemipterus bipunctatus* (species 8) and *Pelates quadrilineatus* (species 11) (Table 2). Crabs (Brachyura, Crustacea) occurred in all stomachs of *Plectorhynchus pictus* (species 6), *Argyrops spinifer* (species 10) and *Arius thalassinus*

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416 (species 14). At least half of analyzed stomachs of *N. bipunctatus*, *Nemipterus japonicus*
417 (species 9), and *Pseudorhombus arsius* (species 12) contained crabs as well (Table 2).
418
419 Shrimps (Dendrobranchiata, Crustacea) were found in all stomachs of *U. mentalis*, *P. pictus*
420 and *N. japonicus* and in at least half of the stomachs analyzed for *Aetomylaeus nichofii*
421 (species 2), *Taeniamia fucata* (species 3), *N. bipunctatus*, *A. spinifer*, and *P. quadrilineatus*.
422
423 At least a quarter of analyzed stomachs for *S. tumbil* and *P. arsius* were also filled with
424 shrimps. Manta shrimps (Stomatopoda, Crustacea) were observed in the stomach of one
425 individual *N. bipunctatus*. Mollusks (Gastropoda) were also abundant prey items (Table 2).
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427 Gastropods occurred in *P. pictus* stomachs, and in one third of *N. japonicus* and *A. spinifer*
428 stomachs. Annelida (Polychaetes) were only observed in stomachs of *N. bipunctatus*. Other
429 prey items recorded included unidentified crustaceans and particulate organic matter (detritus)
430 (Table 2).
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436 Seasonal variations in mean $\delta^{15}\text{N}$ were not significant (Table 3). However, $\delta^{15}\text{N}$ levels
437 characterizing the demersal fish community varied from 14.19 to 16.89 ‰ in March and from
438 14.85 to 16.88 ‰ in December, resulting in an overall $\delta^{15}\text{N}$ variation range lower in
439 December than in March (2.03 and 2.7 ‰, respectively), consistently with a lower variance in
440 December (Table 3). A more contracted trophic structure with lower variations in trophic
441 positions among species was therefore observed in December compared to March (Fig. 2).
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443 Observed $\delta^{15}\text{N}$ variation ranges were also largely inferior to the threshold level of 3.4 ‰
444 characterizing a change in trophic position.
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449 Seasonal variations in mean $\delta^{13}\text{C}$ were not significant either (Table 3). However, $\delta^{13}\text{C}$
450 varied from -17.24 to -15.11 ‰ in March and from -17.48 to -13.58 in December,
451 corresponding to an overall $\delta^{13}\text{C}$ variation range of 2.13 and 3.9 ‰, respectively. Similarly,
452 $\delta^{13}\text{C}$ variance was lower in March than in December (Table 3) Accordingly, the fish
453 community trophic structure appeared more widely distributed along the $\delta^{13}\text{C}$ axis in
454 December (Figs. 2 and 3), implying a larger variability in the nature and origin of food
455 resources consumed by fishes during that month. This pattern was confirmed by observed
456 variability in $\delta^{34}\text{S}$ values, which varied from 13.56 ‰ to 10.23 ‰ in March and from
457 13.03 ‰ to 19.09 ‰ in December. The overall $\delta^{34}\text{S}$ variation range was therefore slightly
458 larger in December (6.06 ‰) than in March (5.67 ‰), consistently with variance values
459 (Table 3), although difference between months in mean $\delta^{34}\text{S}$ was not significant (Table 3).
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461 The fish community trophic structure therefore appeared slightly more widely distributed
462 along both the $\delta^{13}\text{C}$ and $\delta^{34}\text{S}$ axes in December compared to in March (Fig. 3), confirming the
463 consumption by fishes of food resources from more diverse mixture and origin in December.
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475 Species-specific $\delta^{13}\text{C}$, $\delta^{15}\text{N}$ and $\delta^{34}\text{S}$ values differed little between the two periods
476 (Figs. 2 and 3). Regarding fish size, only $\delta^{15}\text{N}$ values appeared to significantly ($P < 0.05$) vary
477 according to the size structure of the fish community, with larger species having higher
478 nitrogen isotope ratios (Fig. 4). However, this relationship was weak ($r^2 = 0.36$).
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483 Discussion

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485 Our study highlighted a clear carnivorous diet, with a heavy reliance on invertebrate
486 and fish prey, for all fish species examined in Muscat coastal waters. Fish prey was found in
487 relatively large proportions in stomachs of some species, such as redcornet fish (*Fistularia*
488 *petimba*), greater lizardfish (*Saurida tumbil*), long raker trevally (*Ulua mentalis*), Delagoa
489 threadfin bream (*Nemipterus bipunctatus*) and four lined terapon (*Pelates quadrilineatus*).
490 However, the $\delta^{15}\text{N}$ values of these species largely overlapped with those ones in stomachs of
491 which mostly invertebrate prey was found. Furthermore, the overall $\delta^{15}\text{N}$ values obtained at
492 the community level had relatively narrow range, lower than the 3.4 ‰ threshold value
493 usually characterizing the difference in nitrogen isotope composition between two
494 consecutive trophic levels (Post, 2002; Post et al., 2007). This suggests that all species
495 analyzed in our study had a similar trophic position in the food web. Therefore, our results
496 indicate a largely mixed fish-invertebrate diet for most of demersal fish species in the Sea of
497 Oman. Our results therefore highlight how essential insights from stable isotope analysis had
498 proven to complement stomach content data, in order to fully apprehend the variability in
499 feeding habits of consumers. Similar conclusions have been presented by recent studies
500 (Carassou et al., 2016 and 2017; Keller et al., 2016; Olson et al., 2016). Stomach contents
501 indeed only provide very short-term information on consumer's diet, while isotopic ratios in
502 the tissues reflect dietary habits over longer time scales (Cortés, 1997; Hobson, 1999; Post,
503 2002; Olson et al., 2016). In our study in particular, the low number of specimens collected
504 for each species, together with the occurrence of fish with empty stomachs, further limited the
505 efficiency of stomach content analysis for capturing the full range and variability in prey
506 diversity characterizing demersal fish feeding regimen.
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520 As our study is the first one to address diet of demersal fish from soft-bottom habitats
521 with stable isotopes in the Sea of Oman, comparisons with similar studies in the region is
522 difficult. The study of Mill (2007) was focused on coral-reef associated fish species and it did
523 not include any species common with our study. Only one fish species, *Argyrops spinifer*,
524 which was collected in our study, was also analyzed by Al-Habsi et al. (2008) in the Arabian
525 Sea. Comparison of the data suggested that *A. spinifer* from the Arabian Sea and the Sea of
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534 Oman has very close values of $\delta^{13}\text{C}$ (mean \pm standard deviation of -15.91 ± 0.10 and -15.99
535 ± 0.04 , respectively) and $\delta^{15}\text{N}$ (17.10 ± 0.32 and 15.18 ± 0.82 , respectively). This suggests
536 little variation in *A. spinifer* diet across different coastal regions in Oman waters, although no
537 stomach content records or isotope data on the fish potential food resources were available for
538 comparison in Al-Habsi et al. (2008). In a recent study, Rastgoo and Navarro (2017) reviewed
539 stomach content data available from 21 finfish species of the Sea of Oman to infer their
540 respective trophic levels. Only two species were common to our study: *Nemipterus japonicus*
541 and *Saurida tumbil*, with both being characterized by a trophic level \geq to 4, indicating a
542 carnivorous diet dominated by the consumption of fish prey or high-order invertebrate
543 consumers. Our study highlighted a similar result, although stable isotope data highlighted a
544 probable mixture of fish and invertebrate prey for both species.
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552 Al-Habsi et al. (2008) found an apparent size-related structuration in $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$
553 values at the demersal fish community level in the Arabian Sea, although such size structure
554 was not apparent at the level of species. In our study in the Sea of Oman, no significant
555 relationship between fish size and isotope ratios were evident at the demersal fish community
556 level, except for $\delta^{15}\text{N}$ which increased with fish size but with a low regression coefficient ($r^2 <$
557 0.4). Rastgoo and Navarro (2017) also reported a positive correlation between trophic levels
558 estimated from stomach content data in the literature, and fish size in the Sea of Oman. Based
559 on a restricted number of samples, those relationships could however not be tested at the
560 species level in our study. This aspect should therefore be the focus of more future studies in
561 the Sea of Oman, in order to explicit the size-related variability in demersal fish diet in this
562 particular region. Issues of size-related structuration in ecological traits characterizing fish
563 communities indeed have crucial implications in terms of fisheries management locally, since,
564 as emphasized in Al-Habsi et al. (2008), size-based metrics are increasingly promoted to
565 assess fishing impacts on natural communities at an ecosystem scale.
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574 Analysis of stable isotope data conducted herein also suggest a possible seasonal
575 change in the range of diversity and origin of prey consumed by demersal fish in the studied
576 area, reflected by a larger range and variance of $\delta^{13}\text{C}$ (and $\delta^{34}\text{S}$ to a lesser degree) values in
577 December compared to March. Indeed, carbon and sulfur isotopic ratios depends not only on
578 the nature of prey contributing to consumers' diet, but also on their origin such as benthic vs.
579 pelagic or coastal vs. marine (Hobson, 1999; Layman et al., 2012). Accordingly, along the
580 $\delta^{13}\text{C}$ and $\delta^{34}\text{S}$ gradients, the trophic structure of demersal fish community appeared relatively
581 'relaxed' in December, and more 'contracted' in March (although variations in mean values
582 between seasons were not significant for any isotope). . This apparent change in the trophic
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593 structure may logically reflect seasonal changes in oceanographic conditions in our study
594 area, in particular variations in water temperature, water column mixing and primary
595 productivity related to the seasonal monsoon (Piontkovski et al., 2011). Stronger winds
596 occurring during the monsoon season, extending from March/April to September/October,
597 result in a stronger mixing of the water column, as highlighted by highly variable patterns of
600 water temperature during this period (Al-Hashmi et al., 2010). Stable isotope composition in
601 fish muscles reflects food assimilation along periods ranging from weeks to months,
602 depending on species and life stages (Buchheister and Latour, 2010). Therefore, it is likely
603 that fish collected at the end of the monsoon period, i.e., in December, have been feeding in a
604 marine environment with increased re-suspension of material from the bottom (e.g.,
605 sediments) to the middle and surface layers of the water column, and enhanced exchanges
606 between coastal and offshore water masses. Such resuspension and mixing processes
607 potentially resulted into a larger set of prey origin available for fish in December (mixture of
608 surface, bottom and/or coastal, marine fueled prey), as compared to fish collected at the
609 beginning of the monsoon, i.e., in March, which have likely been feeding upon prey relying
610 on basal resources from a more restricted range of environmental conditions. This hypothesis
611 should be tested in future studies, as the low number of analyzed samples in our study
612 precludes any clear conclusion to be drawn in this regards.
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622 Although limited in sampling effort and lack of spatial replication, this study
623 highlights the utility of detailed dietary studies to improve our understanding on demersal fish
624 community structure in a data poor region. Even based on a small data set, this study
625 emphasized some clear and interesting features characterizing the trophic structure of
626 demersal fish communities, demonstrating the utility of the approach to inform fishery
627 management in the Sea of Oman. The use of stable isotopes to address fish dietary
628 requirements and relationships also remains novel for the entire country, as highlighted by the
629 scarcity of studies addressing this issue in our region. We therefore strongly advocate for
630 complementary investigations to be implemented based on this methodology, in order to not
631 only improve knowledge on the trophic ecology of the highly diverse fish assemblages
632 characterizing the coastal environment of Oman (Al-Jufaily et al., 2010), but also to
633 contribute to the development of ecosystem-based approaches to the management of local
634 fisheries, which have a crucial economic and cultural importance in the region (Sideek et al.,
635 1999; Valinassab et al., 2006). Such future studies should rely on an appropriately designed
636 and intensive sampling of both fish and their potential prey at contrasted seasons and
637 locations, so as to: 1) provide necessary data for the calculation of consumer trophic positions
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652 based on precise stable isotope data, as mean trophic level of commercial species are an
653 important parameter from a fisheries management perspective (see for example Abd El-
654 Rahman, 2014 for a case study in Oman), and 2) incorporation of stable isotope data into
655 mixing models for estimating food resource contribution in supporting demersal fish
656 community diet across time and space.
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660 661 **Acknowledgements**

662 This study was supported by the funds from College of Agricultural and Marine Sciences,
663 Sultan Qaboos University - Dean's discretionary funds (IG/AGR/Dean/14/01). We thank all
664 students from cohorts Fall 2014, Spring 2015 and Fall 2015 of the Introduction to Marine
665 Science and Fisheries course (MASF2003) for participation in field sampling. We are also
666 grateful to Mr. Khamis Al-Riyami, Mr. Farid Al-Abdali, captain Mr. Saleh Al-Maashari, and
667 boat engineer Mr. Manolito Barate. From the UC Davis Stable Isotope facility, we thank Dr
668 Joy Matthews and Dr Chris Yarnes for carbon/nitrogen and sulfur analyses, respectively, and
669 Ms. Emily Schick for administrative and accounting support.
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947 **Figure captions**
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950 Fig. 1: Location of the sampling site (red star) in the coastal area of Muscat, Sea of Oman.
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953 Fig. 2: Mean (circles) and standard deviation (error bars) of $\delta^{13}\text{C}$ (x-axis) and $\delta^{15}\text{N}$ (y-axis)
954 values measured in dorsal muscle of demersal fishes collected by trawling in Muscat coastal
955 area. Numbers within circles indicate species codes, which are depicted in Table 1.
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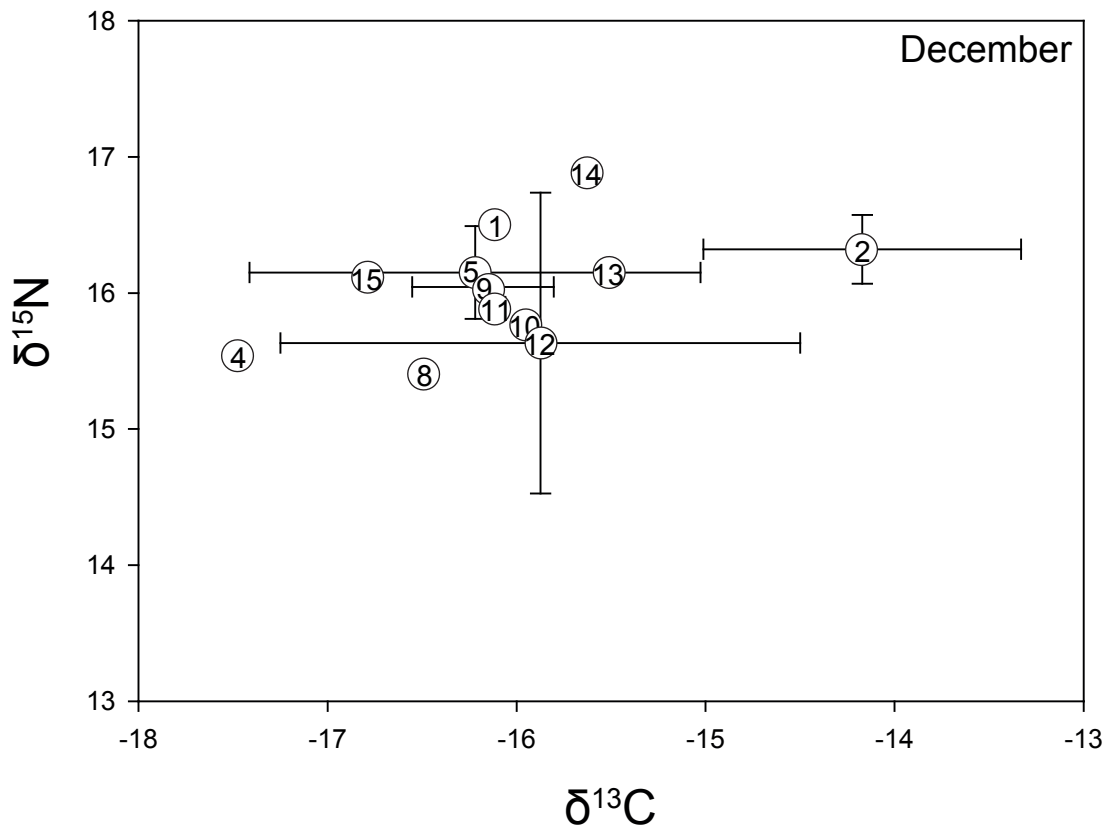
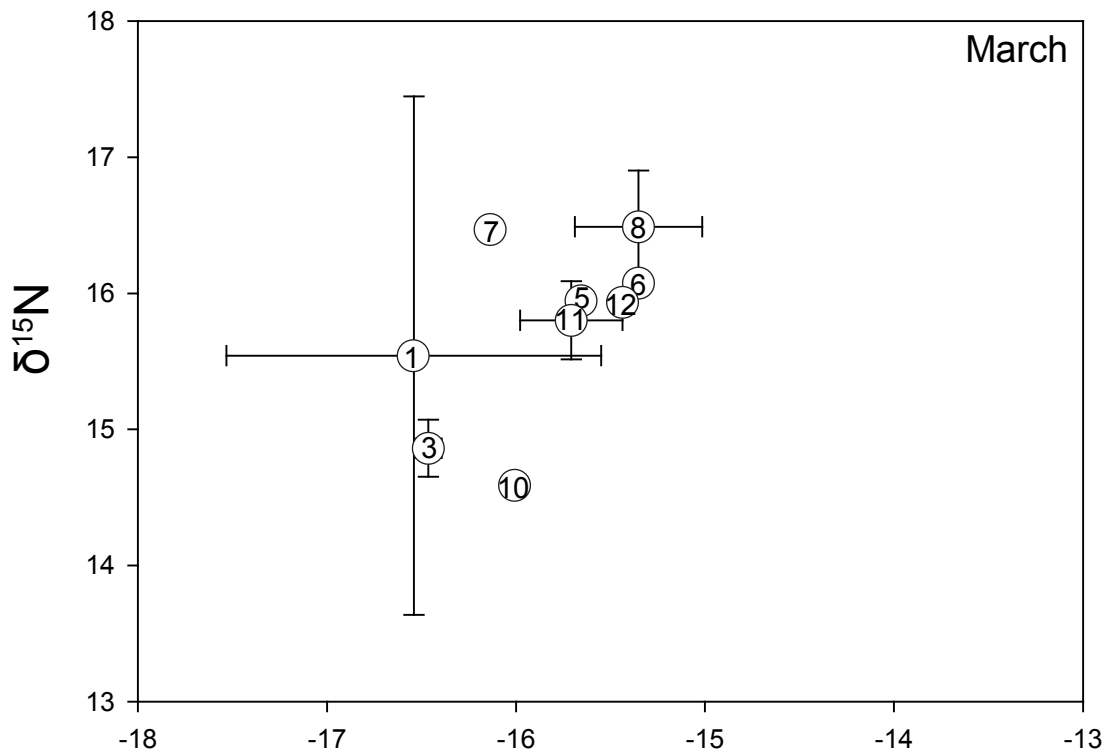
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959 Fig. 3: Mean (circles) and standard deviation (error bars) of $\delta^{13}\text{C}$ (x-axis) and $\delta^{34}\text{S}$ (y-axis)
960 values measured in dorsal muscle of demersal fishes collected by trawling in Muscat coastal
961 area. Numbers within circles indicate species codes, which are depicted in Table 1.
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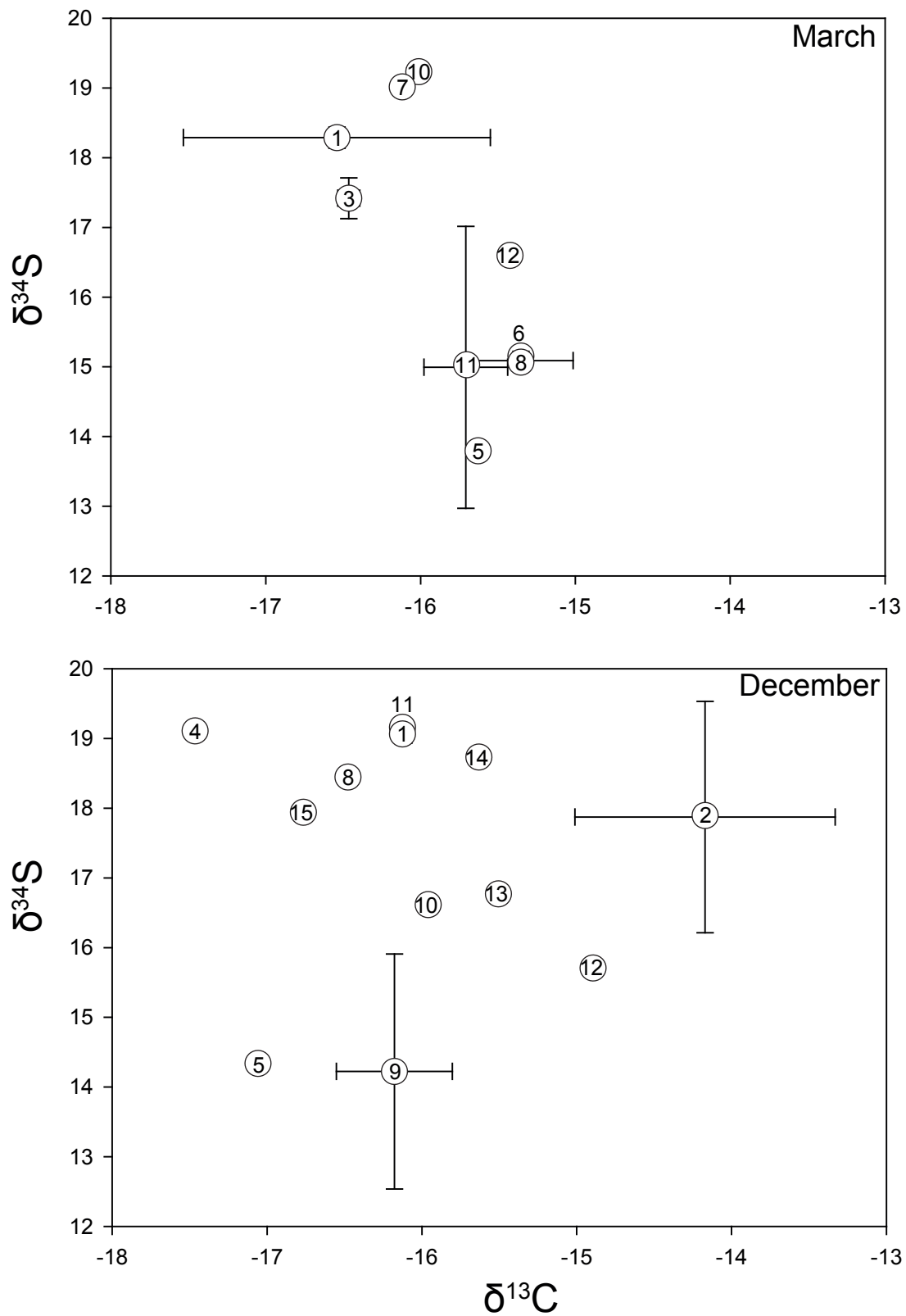
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966 Fig. 4: Relationships between fish size (x-axis) and a) $\delta^{13}\text{C}$, b) $\delta^{15}\text{N}$ and c) $\delta^{34}\text{S}$ values
967 characterizing demersal fish community sampled in Muscat coastal area. Regression line and
968 coefficient are only shown if the tested relationship is significant ($P < 0.05$).
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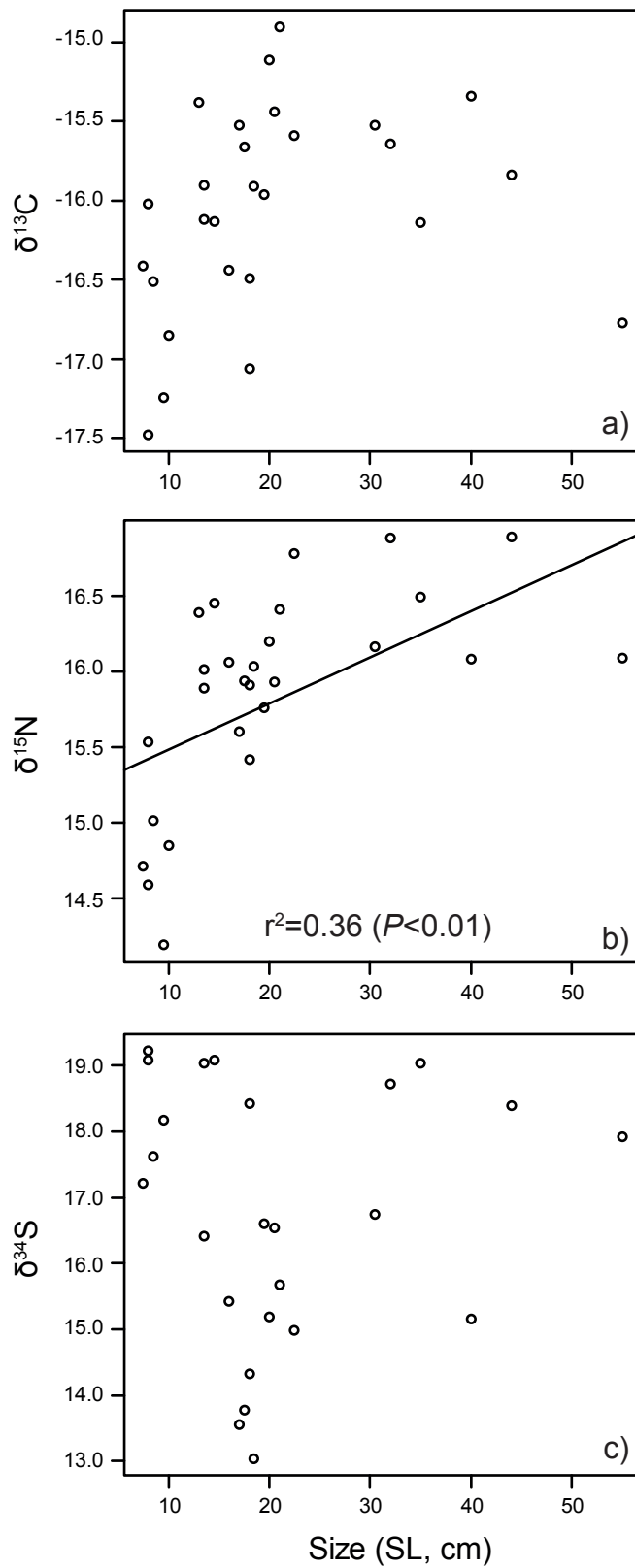


Table 1: Number and size range (min-max as SL in cm, except for banded eagle ray *Aetomylaeus nichoffi* for which size is given as maximum wing width in cm) of fishes collected off Muscat coastal area in March (Mar) and December (Dec) 2014 for diet studies, with corresponding species codes and number of replicates analyzed for stomach content and stable isotope ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$, $\delta^{34}\text{S}$) analyses. Numbers in brackets in the stomach contents' column indicate the number of fish for which stomachs were empty and therefore data not used for prey occurrence calculation.

Order	Family	Genus	Species	Common name	Code	Number of individuals collected			Size range	Number of replicates analyzed			
						Mar	Dec	Total		Stomach contents	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{34}\text{S}$
Aulopiformes	Synodontidae	<i>Saurida</i>	<i>tumbil</i>	Greater lizardfish	1	6	1	7	9,5-44,0	7 (3)	3	3	3
Myliobatiformes	Myliobatidae	<i>Aetomylaeus</i>	<i>nichoffi</i>	Banded eagle ray	2	0	2	2	28,0-50,0	2 (0)	2	2	2
Perciformes	Apogonidae	<i>Taeniamia</i>	<i>fucata</i>	Orangeline cardinalfish	3	4	0	4	7,5-8,5	4 (2)	2	2	2
Perciformes	Carangidae	<i>Ulua</i>	<i>mentalis</i>	Longcracked trevally	4	0	1	1	8,0	1 (0)	1	1	1
Perciformes	Gerreidae	<i>Gerres</i>	<i>filamentosus</i>	Whipfin silver-biddy	5	1	3	4	13,0-18,0	4 (1)	3	3	2
Perciformes	Haemulidae	<i>Plectorhynchus</i>	<i>pictus</i>	Trout sweetlips	6	1	0	1	40,0	1 (0)	1	1	1
Perciformes	Lutjanidae	<i>Lutjanus</i>	<i>lutjanus</i>	Bigeye snapper	7	1	0	1	14,5	1 (1)	1	1	1
Perciformes	Nemipteridae	<i>Nemipterus</i>	<i>bipunctatus</i>	Delagoa threadfin bream	8	5	1	6	18,0-22,5	6 (0)	3	3	3
Perciformes	Nemipteridae	<i>Nemipterus</i>	<i>japonicus</i>	Japanese threadfin bream	9	0	3	3	16,0-18,5	3 (0)	2	2	2
Perciformes	Sparidae	<i>Argyrops</i>	<i>spinifer</i>	King solder bream	10	1	2	3	8,0-19,5	3 (0)	2	2	2
Perciformes	Terapontidae	<i>Pelates</i>	<i>quadrilineatus</i>	Fourlined terapon	11	6	1	7	13,5-17,0	7 (4)	3	3	3
Pleuronectiformes	Paralichthyidae	<i>Pseudorhombus</i>	<i>arsius</i>	Largetooth flounder	12	1	3	4	10,0-21,0	4 (0)	3	3	2
Scorpaeniformes	Platycephalidae	<i>Grammoplites</i>	<i>suppositus</i>	Spotfin flathead	13	0	1	1	30,5	1 (1)	1	1	1
Siluriformes	Ariidae	<i>Netuma</i>	<i>thalassina</i>	Giant catfish	14	0	1	1	32,0	1 (0)	1	1	1
Syngnathiformes	Fistulariidae	<i>Fistularia</i>	<i>petimba</i>	Redcornet fish	15	0	1	1	55,0	1 (0)	1	1	1
Total for all species						26	20	46	-	46 (12)	29	29	27

Table 2: Average stomach fullness (%) and occurrence of various prey items (% of fish with non-empty stomachs) in stomachs of fishes collected off Muscat coastal area in December 2013 and March 2014. Refer to number of individuals and fish size ranges. With NA: not available due to empty stomach (refer to Table 1 and text).

Fish species (code)	Stomach fullness	CRUSTACEANS					MOLLUSCS Gastropods	ANNELIDS Polychaetes	TELEOSTEI (bony fish remains)	Particulate Organic Matter
		Unidentified	Decapods			Stomatopoda				
			Unidentified	Brachyura	Dendrobranchiata					
<i>Saurida tumbil</i> (1)	95,0	0,0	0,0	0,0	25,0	0,0	0,0	0,0	100,0	0,0
<i>Aetomylaeus nichofii</i> (2)	45,0	50,0	0,0	0,0	50,0	0,0	0,0	0,0	0,0	50,0
<i>Taeniamia fucata</i> (3)	35,0	0,0	50,0	0,0	50,0	0,0	0,0	0,0	0,0	0,0
<i>Ulua mentalis</i> (4)	30,0	0,0	0,0	0,0	100,0	0,0	0,0	0,0	100,0	0,0
<i>Gerres filamentosus</i> (5)	13,3	33,3	33,3	0,0	0,0	0,0	0,0	0,0	0,0	66,7
<i>Plectorhynchus pictus</i> (6)	30,0	0,0	0,0	100,0	100,0	0,0	100,0	0,0	0,0	100,0
<i>Lutjanus lutjanus</i> (7)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
<i>Nemipterus bipunctatus</i> (8)	53,3	0,0	33,3	50,0	50,0	16,7	16,7	33,3	33,3	0,0
<i>Nemipterus japonicas</i> (9)	46,7	0,0	0,0	66,7	100,0	0,0	33,3	0,0	0,0	33,3
<i>Argyrops spinifer</i> (10)	26,7	0,0	0,0	100,0	66,7	0,0	33,3	0,0	0,0	0,0
<i>Pelates quadrilineatus</i> (11)	38,4	0,0	0,0	0,0	66,7	0,0	0,0	0,0	33,3	33,3
<i>Pseudorhombus arsius</i> (12)	26,3	0,0	25,0	50,0	25,0	0,0	0,0	0,0	0,0	0,0
<i>Grammoplites suppositus</i> (13)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
<i>Arius thalassinus</i> (14)	5,0	0,0	0,0	100,0	0,0	0,0	0,0	0,0	0,0	0,0
<i>Fistularia petimba</i> (15)	50,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	100,0	0,0

Table 3: Mean and variance (var.) of $\delta^{13}\text{C}$, $\delta^{15}\text{N}$ and $\delta^{34}\text{S}$ measured in fish muscle tissues in December 2013 and March 2014 in the Sea of Oman, all species combined. No significant differences were found between months for any isotopic ratio ($P>0.05$ for all analyses).

Month	$\delta^{13}\text{C}$		$\delta^{15}\text{N}$		$\delta^{34}\text{S}$	
	Mean	Var.	Mean	Var.	Mean	Var.
December	-15.94	0.96	16.03	0.24	17.13	3.84
March	-15.90	0.33	15.72	0.72	16.57	3.68