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NOTE

Stomach contents analysis of *Tursiops aduncus* and *Sousa plumbea* stranded along the United Arab Emirates coastline

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The Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) and the Indian Ocean humpback dolphin (*Sousa plumbea*), previously reported as *Sousa chinensis* (Mendez et al., 2013) are among the resident small cetacean species inhabiting the United Arab Emirates (UAE) and broadly the Arabian/Persian Gulf coastal waters (hereafter referred to as "the Gulf") (Baldwin et al., 2004; Natoli et al., 2022; Preen, 2004). Although both species are listed as threatened in the IUCN Red List, knowledge on their population status, distribution and ecology is patchy in this region (Notarbartolo di Sciara et al., 2021). Aerial surveys performed in 1989, and repeated in 1999, in UAE waters (Abu Dhabi) estimated a marked difference in small cetacean occurrence, indicating a 71% decline in dolphin sightings across the 13-year period (Preen, 2004). Transect surveys conducted along the coast and offshore islands of Abu Dhabi over two consecutive years (2014–2015), estimated an Indian Ocean humpback dolphin population of 701 individuals, 95% CI [476, 845], (López et al., 2018) and an Indo-Pacific population of 782 individuals, 95% CI [496, 1,294] (Díaz López et al., 2021). However, the lack of comparable historical data prevents estimation of population trends to accurately assess the status of the population in the area. Further to this, ecological niche modeling using UAE based citizen science sightings data, gathered between 2012 and 2019, indicate regular presence of the above-mentioned species in the Gulf waters, and a subtle niche partitioning among them, likely driven by different diets and energy requirements (Natoli et al., 2022).

The Indian Ocean humpback dolphin is known to occur in nearshore, shallow waters of the Indian Ocean from South Africa to the southern tip of India and northern Sri Lanka (Braulik et al., 2015; Jefferson & Rosebanum, 2014). In the Gulf and Oman, this species occurs less than 3 km from shore and no deeper than 20 m, in various inshore habitats such as mangroves, rocky reefs, coastal lagoons and shallow protected bays (Braulik et al., 2015; Natoli et al., 2022; Owfi et al., 2016). Comparatively, Indo-Pacific bottlenose dolphins have a wider geographic distribution occurring from eastern South Africa, throughout the northern Indian Ocean (including the Red Sea, the Gulf, and around offshore islands), and extending eastward throughout Southeast Asia, North to Southern Japan, and southward to Australia (Braulik et al., 2019; Natoli et al., 2022; Reeves & Brownell, 2009). Indo-Pacific bottlenose dolphins generally inhabit shallow coastal waters and offshore reef banks no deeper than 200 m, however, in some cases they are found in deeper waters (Wang & Yang, 2009).

These cetaceans face major threats due to their proximity to the extensive anthropogenic activity occurring along the coastline, including coastal developments, seismic activities, vessel traffic fisheries, and climate change (Baldwin et al., 2002, 2004; Bouwmeester et al., 2020; Braulik et al., 2015, 2019). These threats are further exacerbated by the lack of general awareness of the presence of these species in coastal waters combined with the paucity of scientific information on their regional status.

Being top marine predators, small cetaceans are considered "sentinel" species that play a vital role in shaping the structure and function of marine ecosystems and are often used as indicators of marine ecosystem health and productivity (Bowen, 1997; Katona & Whitehead, 1988; Moore, 2008). Dietary studies can provide valuable insight on cetacean foraging behavior, habitat utilization, and interaction with commercial fisheries (Pierce & Boyle, 1991), which collectively feed into understanding their overall ecological role within a particular ecosystem (Pauly et al., 1998). Stomach content analysis is a common method used to gather dietary information on cetaceans and identifies recently consumed prey species through various techniques, including the use and characterization of prey hard parts (i.e., fish otoliths, bones, and cephalopod beaks) found in their digestive tracts (Fitch & Brownell, 1968; Granadeiro &

Silva, 2000; Pierce & Boyle, 1991).

There is a significant gap in knowledge about the feeding ecology of small cetaceans resident in the Gulf. To date, there are no published dietary studies on cetaceans occurring in its waters and only few studies have been conducted in neighboring regions, including Oman and India (Krishnan et al., 2008; Ponnampalam et al., 2012). However, the Gulf marine environment varies considerably from that of the Indian Ocean, in both oceanographic and biological parameters, characterized by shallow often turbid waters, sandy bottom habitats, and extreme shifts in both salinity and temperature across seasons. This difference may influence the feeding habits of species such as the Indian Ocean humpback dolphin and the Indo-Pacific bottlenose dolphin, which commonly occur in both waters.

This study investigates the stomach contents of two Indian Ocean humpback dolphins, and six Indo-Pacific bottlenose dolphins, stranded along the UAE coastline and aims to provide a preliminary insight on their feeding habits.

Eight stomach samples were collected from stranded small cetaceans, opportunistically found on the shores of Abu Dhabi and Dubai Emirates (Figure 1) as part of full necropsy investigations following standard guidelines outlined in Jefferson et al. (1994) and IJsseldijk et al. (2019). Details of the stranding events analyzed are presented in Table 1.

Sagittal otoliths found in the stomach samples were cleaned and stored dry, while cephalopod beaks were stored in 70% ethanol. Otoliths extracted from heads of intact fish were kept as pairs, while those found in the loose otoliths were paired, where possible, based on shape, size, thickness, and degree of degradation. Skeletal remains such as jaws, teeth, and vertebrae were gathered and archived dry for further identification purposes. All otoliths were photographed using an Olympus microscope SZX-ILLK200 equipped with a 14MP USB 3.0 C-mount digital camera (model MU1403-MK; AmScope, Irvine, CA), calibrated to the millimeter scale (Figure 2). Sagittal otoliths were characterized and identified to the lowest possible taxonomic level following Smale et al. (1995). Other otolith atlases were also utilized (Rivaton & Bourret,1999; Sadighzadeh & Tuset, 2012). Skeletal remains were used for secondary confirmation using private comparative reference collections (Beech, 2004; Yeomans & Beech, 2021a,b). The minimum number of prey items was estimated as the highest number of right or left otoliths plus the highest number of upper or lower cephalopod beaks found in an individual stomach (Pate & McFee, 2012; Santos et al., 2001). The occurrence of prey items found in the stomachs of individuals of the same species were quantified using percentage by number (%N) and percentage frequency of occurrence (%FO). The relative importance of prey items (at the family level) was ranked through the calculation of a modified version of Pinkas et al. (1971) Index of Relative Importance (IRI = %N × %FO), as implemented by Amir et al. (2005), and Ponnampalam et al. (2012).

All examined stomachs contained identifiable prey items, except for one from a humpback dolphin (sample 79strand) that only contained remains of seagrass and was therefore excluded from further analysis. No macroscopic plastic or other artificial debris were detected in any of the stomachs. Of the six bottlenose dolphin stomachs examined, two contained only teleosts, one contained only cephalopods, and the remaining three contained both teleosts and cephalopods.

Across all stomachs of the two species analyzed, a total of 186 prey items comprising 159 teleost fish individuals and 27 cephalopods were found, based on the otoliths, bones, and cephalopod beaks isolated. Of the prey items detected, 19 were confirmed at the species level, 124 at the closest species, 19 at the genus level and 8 at the family level, leaving a total of 16 prey items unidentified at any classification level due either lack of comparable reference material or difficulty in identification owing to the highly degraded state of the otoliths. The stomach containing the highest number of prey items was the one of an adult male bottlenose dolphin with a total of 70 teleost individuals detected (sample 23strand). Conversely, the stomach of a female humpback dolphin contained the lowest number of prey items with only two teleost individuals present (sample 32strand).

Across the six bottlenose dolphin stomachs analyzed, a total of 184 prey (157 teleosts [85%] and 27 cephalopods [15%]) were detected (Table 2). Those successfully identified represented 15 genera across 11 families, whereas a total of 16 teleost preys were unidentifiable, as mentioned above. All cephalopod beaks recovered had identical morphological features and appeared to belong to the same species, most likely *Sepia pharaonis*. A detailed breakdown of prey items identified per stomach is represented in Figure 3.

The highest number of prey items belong to the family Gerreidae with 48 individuals of the genus *Gerres* spp., recorded in only a single stomach (sample 23strand) accounting for 26.1% of total prey count from the six stomachs analyzed. The second highest number of prey items belongs to the family Carangidae, with a total of 30 individuals representing 16.3% of the total prey count. Prey items from the Carangidae family were identified in three stomachs (samples: 23strand, 30strand, and

80strand). Sepiidae were the third highest prey family identified with 27 individuals of *S. pharaonis* (14.7 %), recorded in four stomachs (samples: 29strand, 70strand, 71strand, and 80strand). These cuttlefish are the most common species in the Gulf, occur down to 130 m and are economically important (Tehranifard & Daston, 2011). The modified IRI, showed Sepiidae having the highest value (IRI = 978.26), followed by Carangidae (IRI = 815.22) and Gerreidae (IRI = 434.78), despite Gerreidae being detected in only one stomach (Table 2). Such high score is due to the relatively large number (48 individuals) of *Gerres* spp. identified in the stomach of sample 23strand. This was closely followed by Sparidae (IRI = 380.43) and Mullidae (IRI = 271.74).

At the species level, the highest modified IRI recorded was *Sepia pharaonis* (IRI = 978.26). The second highest modified IRI *was Carangoides bajad* (IRI = 461.96) which was detected in 50% of the stomachs. In contrast to the modified IRI values calculated at the family level, the third highest modified IRI at the species level was recorded for *Rhabdosargus haffara* (IRI = 380.42) (Sparidae) that was also detected in 50% of the stomachs. This is followed by *Upeneus sulphureus* (Mullidae) (IRI = 271.74), four unidentified species (IRI = 199.28), *Gerres longirostris* (IRI = 144.93), *Gerres filamentosus* (IRI = 144.93), *Gerres* sp. (IRI = 117.75), and *Lutjanus* sp. (IRI = 108.70). Those with lower modified IRI values are shown in Table 2.

The stomach content of two humpback dolphins were analyzed, but one did not contain any prey items (only seagrass), and the other contained only bone remains of two teleost prey items, both identified as *Scomberoides commersonnianus* through comparison with teleost bone reference collections (Beech, 2004), mainly by examining dentaries and vertebrae.

The bottlenose dolphins analyzed in this study fed on a wide variety of fish species belonging to at least 15 genera across 11 families. The relatively high diversity of prey species aligns with the common observation of bottlenose dolphins feeding on a wide variety of fish and cephalopod species (Amir et al., 2005; Cockcroft & Ross, 1990; Kaiser, 2012). All prey families identified in this study were reported in the diet of this species across its range (Amir et al., 2005; Cockcroft & Ross, 1990; Kaiser, 2012; Ponnampalam et al., 2012; Sekiguchi et al., 1992; Smith & Sprogis 2016; Wang & Yang, 2009). Stomach content analysis of 11 bottlenose dolphins (*Tursiops* sp.), stranded along the Omani coastlines, identified 14 teleost and two cephalopod families (Ponnampalam et al., 2012). Seven of the identified teleost families in Ponnampalam et al. (2012) overlap with those reported in this study, including Carangidae, Engraulidae, Gerreidae, Mullidae, Scombridae, Sparidae, and Sphyraenidae.

Eight prey families namely Carangidae, Lutjanidae, Leiognathidae, Mullidae, Lethrinidae, Sphyranidae, Sparidae, and Sepiidae occurred in more than one stomach (Figure 3). However, the abundance of some of these prey families varied considerably across the stomach samples. For instance, the individual 30strand contained 53% Carangidae and 27% Mullidae while 23strand contained only 4% Carangidae and 3% Mullidae. Similarly, 29strand contained 40% Sparidae, while 23strand contained only 1% of the same family. On the other hand, the variance in prey abundance for Lutjanidae, Leiognathidae, Sphyranidae, and Lethrinidae was minimal across the stomachs where these families were identified.

Prey items found in the current study generally inhabit waters with an approximate depth range of 1–200 m suggesting potential utilization of shallow, coastal waters for feeding. The majority of the prey items identified are reef-dwelling species, however, some species belonging to Gerreidae, Mullidae and Leiognathidae families are known to be demersal species that are commonly found over sandy bottom habitats. This suggests that in the Gulf, Indo-Pacific bottlenose dolphins preferentially utilize reef and sandy-bottom habitats for foraging.

The overall proportion of teleost fish (85%) in the diet of the recovered bottlenose dolphins is markedly higher than cephalopods (15%). Similar observations have been recorded in other study areas across the species' distribution. The diet of bottlenose dolphins (*Tursiops* spp.) found stranded along coastlines of Oman comprised 71% teleost fish and 29% cephalopods (mainly Sepiidae) by prey number (Ponnampalam et al., 2012). Stomach contents of Indo-Pacific bottlenose dolphins caught in shark nets off the KwaZulu-Natal coast of South Africa show that percentage prey type to be 75% teleost fish and 25% cephalopods by mass (Cockcroft & Ross, 1990). A similar study conducted off the coast of Zanzibar presented the diet of bottlenose dolphins to be 84% teleost fish and 16% cephalopods by prey number (Amir et. al, 2005).

In terms of relative importance (IRI), this study suggests the most important prey family for the diet of Indo-Pacific bottlenose dolphin in the Gulf to be Sepiidae because it has been identified in high number and recorded in the majority of the stomachs analyzed. This, however, needs to be considered with caution given the small sample size. The Sepiidae family is followed by the families, in order of importance, Carangidae, Gerreidae, Sparidae, and Mullidae respectively. In other regions, the relative importance of prey for Indo-Pacific bottlenose dolphins varies drastically. Off the coast of Zanzibar (Tanzania) the most important prey family for the diet of Indo-Pacific bottlenose dolphins is reported to be Congridae followed by Synaphobranchidae, Apogonidae, and Lethrinidae (Amir et al. 2005), whereas in KwaZulu-Natal (South Africa) it is the family Haemulidae (Cockcroft & Ross, 1990). Along the Omani coastline in contrast, reports the most important prey families in the diet of bottlenose dolphin species (*Tursiops* spp.) are Apogonidae, Scombridae, Sciaenidae, and Carangidae respectively (Ponnampalam et al., 2012). The notable differences in relative importance of prey species for bottlenose dolphins (*Tursiops* spp.) across different geographical locations may suggest a potential response to local prey availability (i.e., opportunistic feeding behavior), whereby selection of prey species relates the most abundant and readily available prey items at the time of feeding (Amir at al., 2005; Cockcroft & Ross, 1990).

Only the remains of two fish identified both as *Scomberoides commersonnianus* were found in one humpback dolphin. This prey species belongs to the family Carangidae and generally frequents inshore coastal waters up to depths of 50 m. In the second humpback dolphin, only few seagrass filaments were found, suggesting that it was likely starving for some time. The presence of nodules in both lungs suggested that this individual may have been affected by a disease. Given the small number of samples examined and the small number of prey items observed, interpretation of the results is limited. It is worth noting that the same prey species was also identified in bottlenose dolphins reported in this study, suggesting a possible dietary overlap between the two species and potential utilization of similar habitats for feeding. However, this needs further investigation to be confirmed. As our sample size is small, we cannot ensure that is representative of the two species' diet, although the variety of prey observed in the bottlenose dolphin's samples analyzed is ample.

All prey families identified in this study, except for Mullidae, include species that are considered commercially important in the UAE, of which five prey genera (Carangoides, Scomberoides, Lutjanus, Lethrinus, and Rhabdosargus) are amongst those reported as over-exploited in Abu Dhabi waters (Al-Blooshi et al., 2017). At the species level, *Carangoides bajad, Sepia pharaonis*, *Gerres longirostris*, *Gerres filamentosus*, *Rhabdosargus haffara*, *Scomberoides commersonnianus, Lethrinus nebulosus*, and *Deveximentum insidiator* are also reported as commercially important species in the UAE (Al-Blooshi et al., 2017; Grandcourt et al., 2007). Among those the first five species are those that showed the highest IRI and therefore considered as important prey items in the diet of Indo-Pacific bottlenose dolphins analyzed. The over-exploited *Scomberoides commersonnianus* was recorded in the diets of both bottlenose dolphins and humpback dolphin. This suggest that the diets of these two dolphin species have the potential to overlap significantly with key fisheries species targeted in the Gulf. This may further elevate their risk of incidental capture by fisheries activities as well as reduction of prey availability and raises a concern on their regional conservation status.

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Conflict of Interest

The authors declare no conflict of interest.

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Table 1 Details of the stranding events analyzed in this study.

Stranding ID	Date of recovery	Stranding location	Species	Sex	TBL (cm)	Decomposition stage and necropsy information	Stomach content weight (g)
23strand	November 13, 2013	Saadiyat Island, Abu Dhabi	*T. aduncus*	M	225	DS 3: Found floating close to shore. No evident external sign of emaciation, entanglement, or boat strike. Stomach containing intact fish ingested.	1,987
29strand	February 3, 2017	Saadiyat Island, Abu Dhabi	*T. aduncus*	F	250[a]	DS 4: Found on the beach. Dorsal fin and tail completely missing. Injuries on posterior area. Stomach content partially digested.	2,505
30strand	November 13, 2017	Saadiyat Island, Abu Dhabi	*T. aduncus*	M	205[a]	DS 4: Found onshore. Right pectoral fin missing. Dorsal fin and tail shredded. Stomach content possible multiple meals.	1,053
32strand	July 11, 2018	Daria Island, Dubai	*S. plumbea*	F	242	DS 3: Found onshore. No evident external sign of emaciation, entanglement, or boat strike. Stomach content digested (only fish bones).	569
70strand	October 28, 2019	Mamzar, Dubai	*T. aduncus*	F	234	DS 3-4: Brought into shore whit intestine extruding from the side. Fishing line+ hook entangled in the tail. Left flipper show old damaged with missing phalanges. Stomach content digested (fish bones and cephalopod beaks).	980
71strand	February 2, 2020	Palm Jumeirah, Dubai	*T. aduncus*	F	233	DS 4: Found floating close to shore. Dorsal fin and tail missing. Short rope attached to the pedunculus. Not evident external sign of emaciation. Stomach content digested (cephalopod beaks)	0[b]

79strand	August 18, 2021	Saadiyat Island, Abu Dhabi	*S. plumbea*	F	216	DS 3: Found onshore. Body emaciated with visible vertebrae. Left flipper shows old damage with missing phalanges. Nodules found in the lungs.	Empty
80strand	August 24, 2021	Qirqishan island, Abu Dhabi	*T. aduncus*	F	213	DS 4: Found onshore. Skin dried and intact all over the body. Not evident external sign of emaciation, entanglement, or boat strike. Stomach content digested (fish bones).	6

Note: Stranding ID refers to the univocal code of the UAE stranding database. TBL = total body length. Decomposition stage (DS): 3 = moderate but clear signs of decomposition, e.g., skin peeling, changes in color and consistency of skin and organs; 4 = carcass collapsing; sloughing of skin; strong odor, blubber soft, possibly with pockets of gas or oil; muscle liquefying or easily torn, possibly falling off bones; blood thin and black; organs identifiable but very friable, easily torn and difficult to detect; gut gas-filled.

[a] Body length measured without tail in cases where tail fluke has been severed.

[b] stomach content weight could not be precisely estimated due to the light weight of prey items which the scale did not detect.

TABLE 2 Composition of prey found in stomachs of Indo-pacific bottlenose dolphins (*n* = 6) represented in percentage number (%N) and percent frequency of occurrence (%F), and modified Index of Relative Importance (IRI).

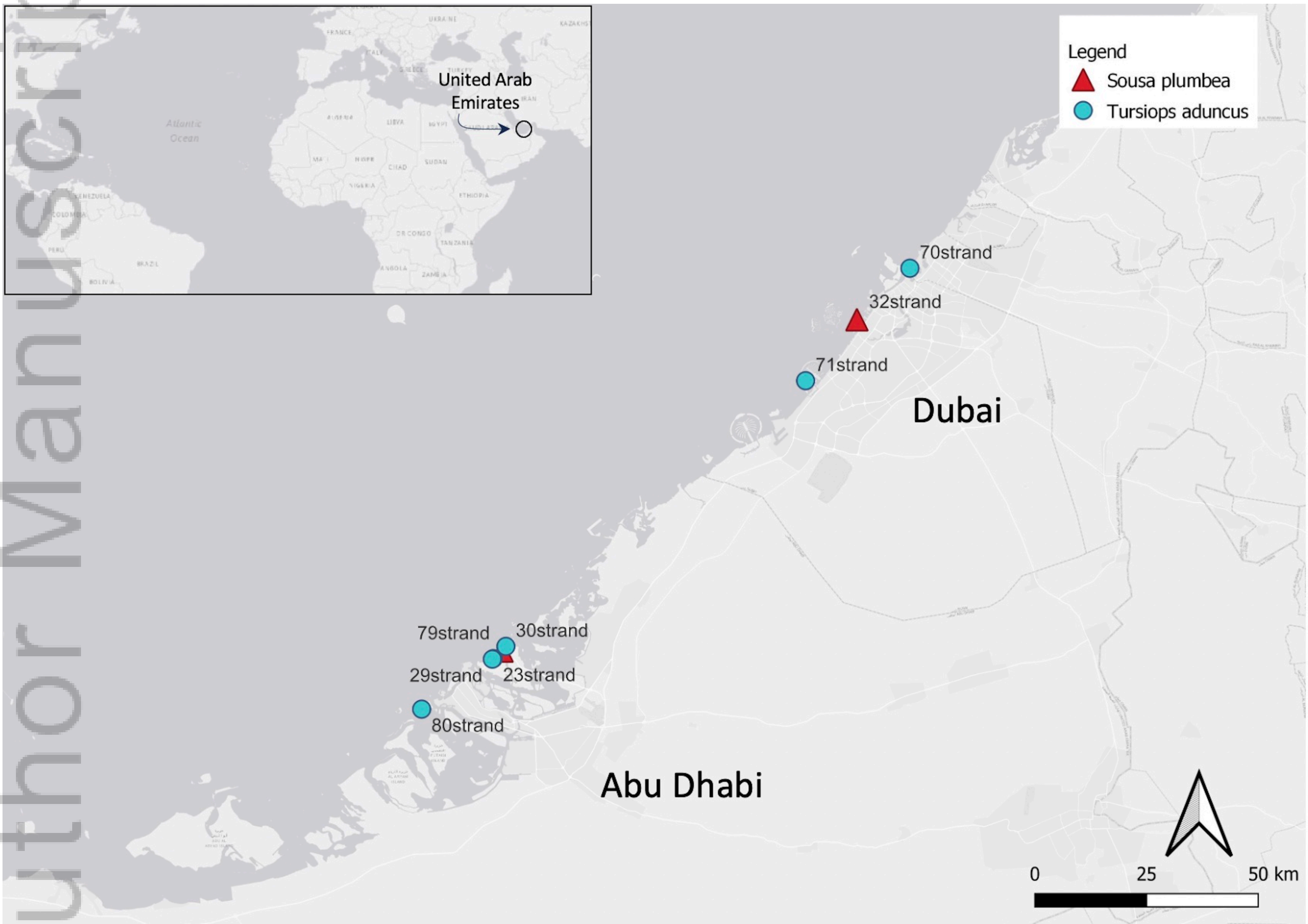
Prey species	***n***	**%N**	**F**	**%F**	**Modified IRI**
Carangidae	30	16.30	3	50.00	815.22
Carangoides bajad	17	9.24	3	50.00	461.96
Decapterus russelli	2	1.09	1	16.67	18.12
Scomberoides commersonnianus	2	1.09	1	16.67	18.12
Scomberoides tol	1	0.54	1	16.67	9.06
unidentified sp. a	1	0.54	1	16.67	9.06
unidentified sp. b	1	0.54	1	16.67	9.06
unidentified sp. c	1	0.54	1	16.67	9.06
unidentified sp. d	1	0.54	1	16.67	9.06
unidentified sp. e	1	0.54	1	16.67	9.06
unidentified sp. f	1	0.54	1	16.67	9.06
unidentified sp. g	1	0.54	1	16.67	9.06
unidentified sp. h	1	0.54	1	16.67	9.06
Clupidae	8	4.35	1	16.67	72.46
Herklotsichthys quadrimaculatus	8	4.35	1	16.67	72.46
Engraulidae	6	3.26	1	16.67	54.35
Stolephorus indicus	6	3.26	1	16.67	54.35
Gerreidae	48	26.09	1	16.67	434.78
Gerres filamentosus	16	8.70	1	16.67	144.93
Gerres longirostris	19	10.33	1	16.67	172.10
Gerres sp.	13	7.07	1	16.67	117.75
Leiognathidae	3	1.63	2	33.33	54.35

Deveximentum insidiator	2	1.09	1	16.67	18.12
Gazza minuta	1	0.54	1	16.67	9.06
Lethrinidae	3	1.63	2	33.33	54.35
Lethrinus nebulosus	3	1.63	2	33.33	54.35
Lutjanidae	4	2.17	3	50.00	108.70
Lutjanus sp.	4	2.17	3	50.00	108.70
Mullidae	15	8.15	2	33.33	271.74
Upeneus sulphureus	15	8.15	2	33.33	271.74
Scombridae	1	0.54	1	16.67	9.06
Rastrelliger kanagurta	1	0.54	1	16.67	9.06
Sepiidae	27	14.67	4	66.67	978.26
Sepia pharaonis	27	14.67	4	66.67	978.26
Sparidae	14	7.61	3	50.00	380.43
Rhabdosargus haffara	14	7.61	3	50.00	380.43
Sphyraenidae	9	4.89	2	33.33	163.04
Sphyraena obtusata	3	1.63	1	16.67	27.17
Sphyraena putnamae	4	2.17	1	16.67	36.23
Sphyraena sp.	2	1.09	2	33.33	36.23
Unidentified	16	8.70	2	33.33	289.86
unidentified 1 sp.	1	0.54	1	16.67	9.06
unidentified 2 sp.	**1**	0.54	1	16.67	9.06
unidentified 3 sp.	2	1.09	1	16.67	18.12
unidentified 4 sp.	11	5.98	2	33.33	199.28
unidentified 5 sp.	1	0.54	1	16.67	9.06

FIGURE 1 Locations of Indo-Pacific bottlenose and Indian Ocean humpback dolphins stranded across Dubai and Abu Dhabi coastline analyzed in this study.

FIGURE 2 Sagittal otoliths, recovered from the stomachs of Indo-Pacific bottlenose dolphins, of the two most represented families: (a) Carangidae (species: *Carangoides bajad*); (b) Gerreidae (species: *Gerres longirostris*). The red scale in both pictures corresponds to 2 mm.

FIGURE 3 Proportion of prey families in the stomachs of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*). Different colors represent different prey families as reported in the legend on the right.



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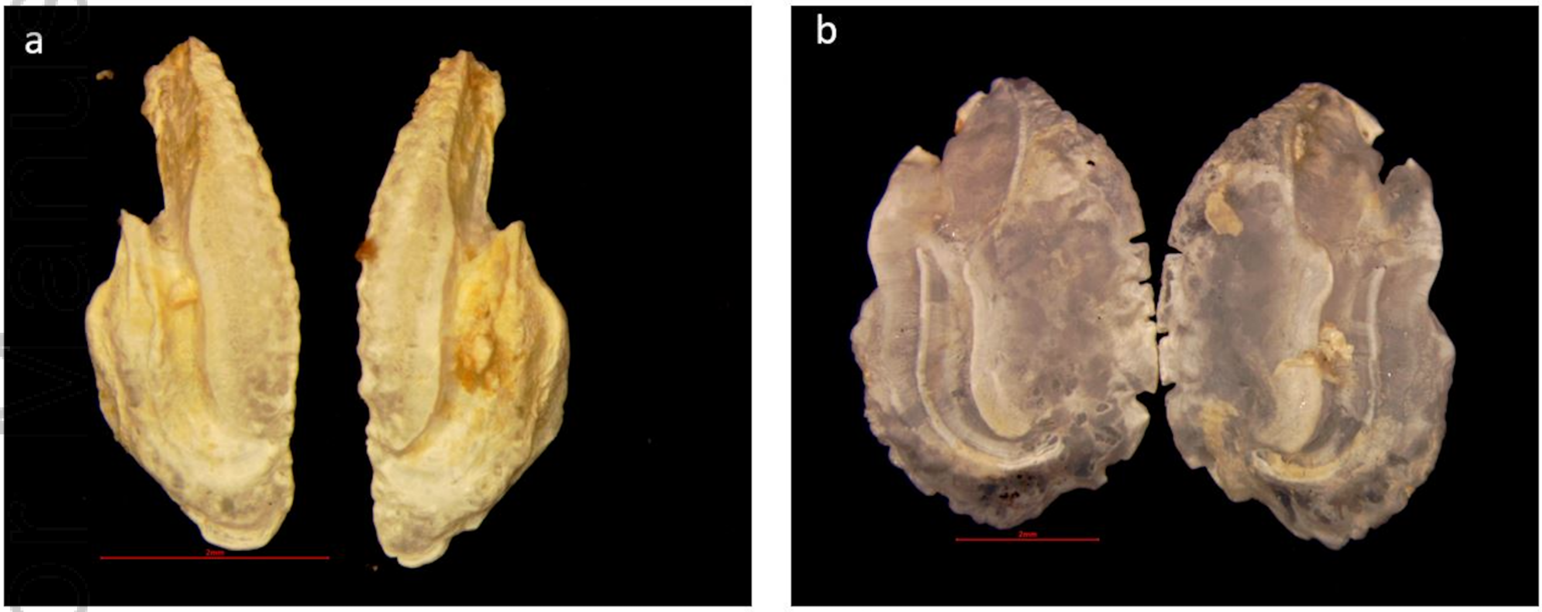

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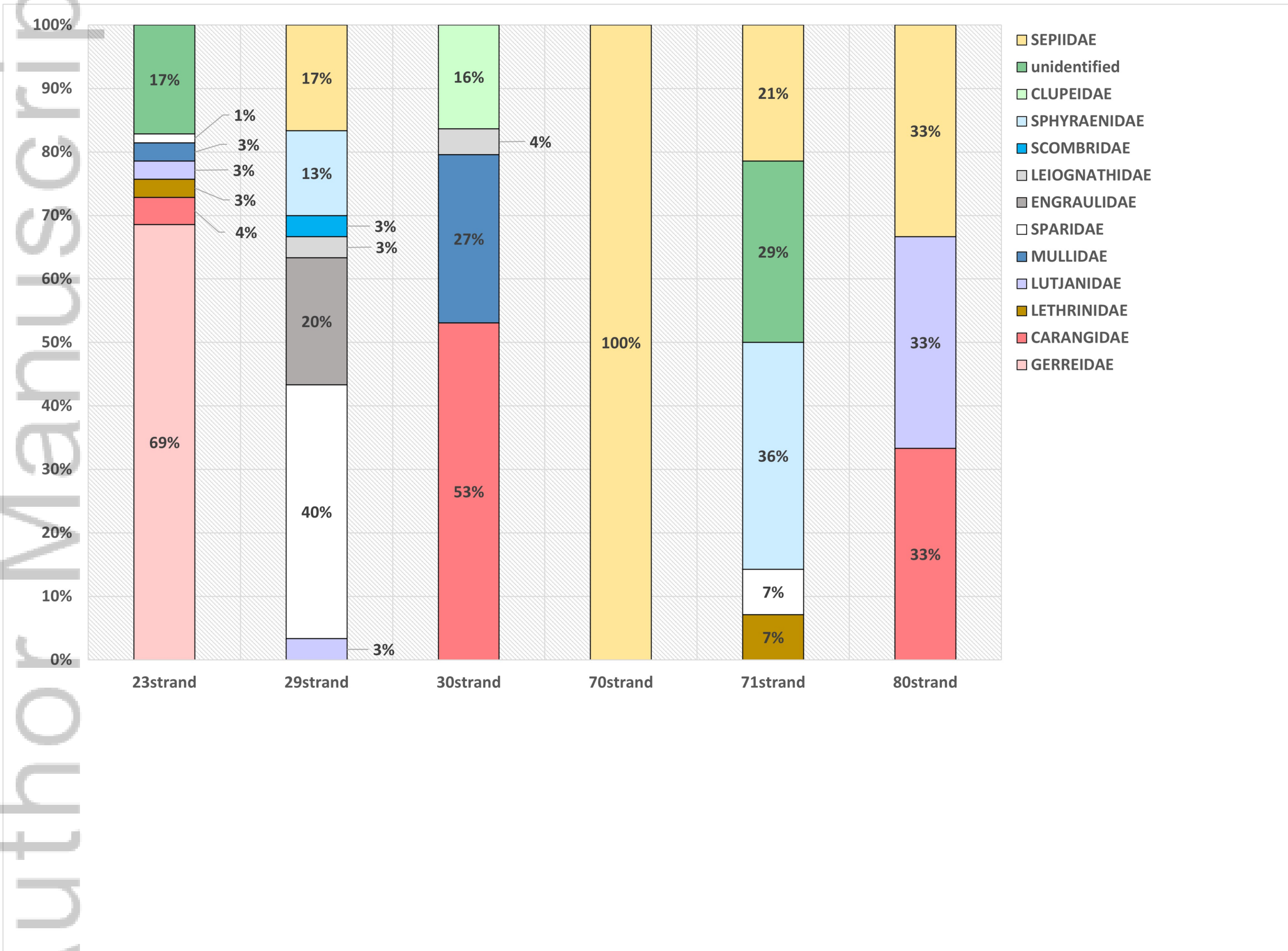

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