Diet Composition of Indo-Pacific Sailfish (*Istiophorus platypterus*) By-Catch in the East Coast of Peninsular Malaysia

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ABSTRACT

The distribution of sailfish across Malaysian waters provides socioeconomic importance to the coastal community. However, there is a declining rate of catch in sport fishing event held in Pahang, Malaysia over the past four years from 2016 to 2019. The urgency to study local sailfish populations is also driven by the recent conservation status change of Indo-Pacific sailfish by the International Union for Conservation of Nature (IUCN) in 2022. Diet composition was determined throughout this study to perceive the feeding behavior of sailfish. The by-catch samples were collected at Kuantan, Pahang from March 2021 to December 2022. Only one species of sailfish, *Istiophorus platypterus* was observed during the period of sampling. The stomach contents of 170 samples were analyzed, and 566 prey items were identified to the lowest possible taxa. The index of relative importance percentage (%IRI) was calculated for the prey comparison. The top three dominant prey recorded from genus taxa were *Amblygaster* sp. (28.25%), *Uroteuthis* sp. (20.03%) and *Encrasicholina* sp. (18.22%). The least prey recorded was *Scolopsis* sp. (0.02%). Cluster analysis based on diversity and prey abundance between 2021 and 2022 was determined. The sailfish diet composed of high diversity of tropical pelagic fish which can be found in the Malaysian waters. This indicates sailfish as generalist predators in Pahang coastal waters that serve as nursing grounds for juveniles and early adults of the species.

Keywords: Billfish, By-catch, Conservation, Diet composition, *Istiophorus platypterus*

INTRODUCTION

Sailfish, which are known for their elongated bills are one of the top predators known in the pelagic ecosystem (Kitchell *et al*., 2006). They are widely distributed in tropical and temperate regions of waters worldwide (Nakamura, 1985). High socioeconomic value plays a major part in the presence of sailfish as they are primarily targeted for sport fishing events despite being by-catch species in fisheries resources (Ahmad *et al*., 2009). Their distribution in the East Coast of Peninsular Malaysia particularly Pahang waters have created a world-class sport fishing competition called Royal Pahang International Billfish Challenge (RPBIC). The abundance of sailfish is seasonal with a peak from July to August where the event mostly took place (Ahmad *et al*., 2009).

New updates have shown that Indo-Pacific sailfish (*Istiophorus platypterus* [Shaw, 1792]) has been classified as vulnerable in the Red List of Threatened Species by the International Union for Conservation of Nature (IUCN, 2022). This is

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supported by RPBIC which stated a 50% decline in number of billfish catch throughout the fishing competition in the last four years that mostly comprised of Indo-Pacific sailfish (RPBIC, 2019). Previous revenue generated almost 4 million US dollars from the event alone could be at stake especially to the boat operators, accommodation services and local stalls (Aziz, 2018). A reduction in the number of species and total catches pose threat that can lead to food insecurity (Vadziutsina and Riera, 2021). If the abundance of top predators such as sailfish continues to decrease, this could potentially affect not only the economy of coastal community but also to the local fishery as the food web dynamics in the marine ecosystem are altered (Paine, 1966; Hinke *et al*., 2004).

Recent reports on the diet of sailfish are lacking in the western Pacific even though they are an important economic source to local communities. Few documented stomach content analyses from Mexico, eastern Pacific and Taiwan (Rosas-Alayola *et al*., 2002; Arizmendi-Rodriguez *et al*., 2006; Tsai *et al*., 2015) were considered insufficient for comparable information in the Malaysian waters. Through diet composition analysis, the relationship between sailfish and availability of prey items can be studied. This could potentially become a strong foundation towards future studies and establishing conservation efforts towards sailfish in sustaining the fisheries economy.

MATERIALS AND METHODS

Study area and sampling schedule

Specimens of sailfish were bought from suppliers or fishermen from the fish landing complex of Kuantan, Pahang, Malaysia (3°47'8.21"N, and 103°18'57.37"E) (Figure 1). The period of sampling lasted from March 2021 to December

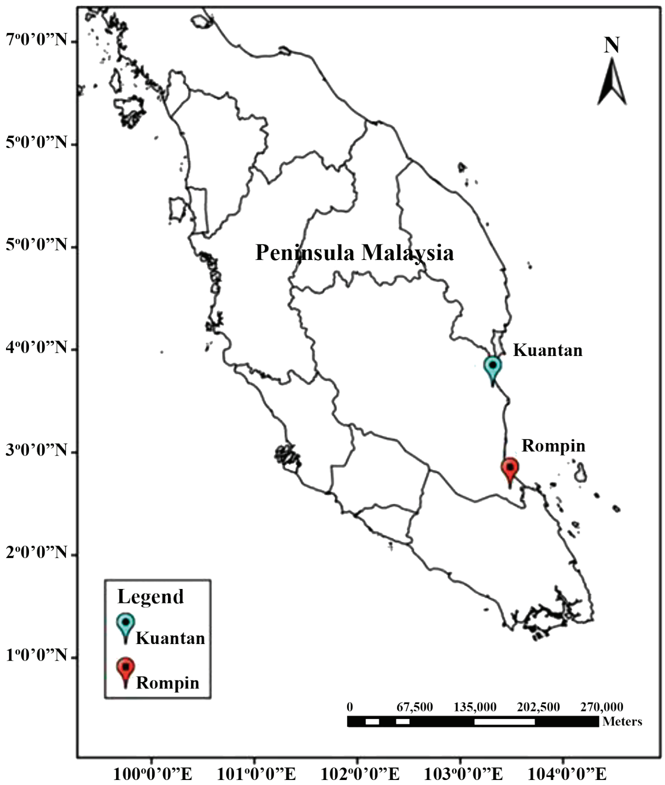

Figure 1. Map of the study area showing the sampling locations.

2022 where samples were obtained monthly as many as possible and immediately kept in ice box for laboratory analysis. Measurements such as weight and lower jaw-fork length (LJFL) (Figure 2) were taken to the nearest kg and cm respectively from the samples before further analysis of their stomach contents (Muhamad and Mohamad, 2012). The preferred type of measurement (i.e., LJFL) was chosen as most samples of by-catch landed with broken and damaged bill (IOTC, 2005). It must be noted that there were restrictions in sampling activity from June to October 2021 due to Restrict Movement Order (RMO) during Covid-19 outbreak.

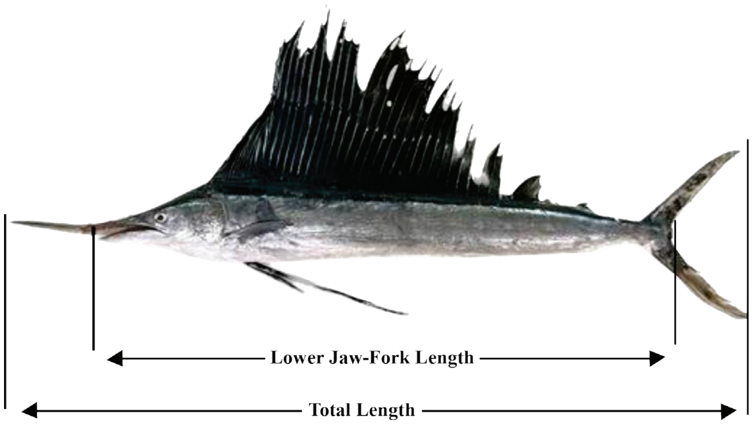

Figure 2. Length measurements used for sailfish.

Diet composition analysis

The stomach contents from sampled fish were removed and were identified to the lowest possible taxonomic group (Fischer and Bianchi, 1984; Lin, 1992; Torres-Rojas *et al*., 2014). Prey items were validated based on published guides set as references (Matsunuma *et al*., 2011; Loor-Andrade *et al*., 2017). The total number, wet weight (nearest 0.01 g) and frequency of occurrence were recorded (Ortega-Garcia *et al*., 2017).

The food items were analyzed from three diet indices that were calculated on percentage by number (%N), percentage by wet weight (%W) and percentage by frequency of occurrence (%FO) (Grudpan *et al*., 2016). Quantitative importance of each prey was determined by Index of Relative Importance (IRI) which the most important family of prey were represented from standardized %IRI (Pinkas *et al*., 1971; Hyslop, 1980):

$$IRI = (\%N+\%W) \times \%FO$$

Statistical analysis such as similarity index in cluster analysis was measured with Euclidean distance by using Paleontological statistics (PAST) software to analyze the abundance and diversity of prey items (Hammer *et al*., 2001). The degree of specialization was given by the diet breadth set for each month using Levin's standardized index, *Bi* (Hurlbert, 1978; Krebs, 1989):

$$Bi = \frac{1}{(n-1)} \left[\frac{1}{(\sum P^2 i)} - 1 \right]$$

where Pi is the proportion in numbers of prey species i and total number of items is represented by n. High values ($Bi>3$) is indication of generalist predators while lower values ($1<Bi<2$) shows predators as specialists (Rosas-Alayola *et al*., 2002; Thong-ngok *et al*., 2022). Diet breadth was evaluated by analysis of variance (ANOVA) and Kruskal-Wallis test based on monthly differences in the mean indices with consideration of $p<0.05$ significance level on all tests.

RESULTS

Based on the morphological observation of sailfish specimens gathered in this study were identified as Indo-Pacific sailfish (*Istiophorus platypterus* [Shaw, 1792]). The prominent identification features include elongated bills or prostrated rostra, the enormous sail-like dorsal fin that runs almost the entire length of body and is mainly taller in height compared to the body of sailfish (Velayutham *et al*., 2012). The coloration of sailfish can also be identified from the vertical bars on the backside, silver belly and numerous dark spots on the first dorsal fin (Nakamura, 1985). The weight and length (LJFL) of samples collected ranged from 0.95 to 37.5 kg and 60.4 to 212 cm respectively which were classified as juveniles and early adults (Arocha and Ortiz, 2010).

Out of the 170 total of examined stomachs, 566 prey items have been recognized which comprised of 20 genera from 14 families of teleost, one of each cephalopod and crustacean family (Table 1). The total abundance showed that teleosts have the highest percentage (79.7%), followed by cephalopods (14.8%), crustaceans (2.8%) and other prey items that are hardly identified due to being fully digested before analysis (2.7%) (Figure 3).

Table 1. List of prey found in the stomach of *Istiophorus platypterus* from East Coast of Peninsular Malaysia.

Groups / Family	Common Name	Scientific Name	2021	2022
Teleosts				
Caesionidae	Mottled fusilier	*Dipterygonotus* sp.	+	+
	Goldband fusilier	*Pterocaesio* sp.	-	+
Carangidae	Oxeye scad	*Selar* sp.	-	+
	Indian scad	*Decapterus* sp.	-	+
	Yellowstripe scad	*Selaroides* sp.	+	+
Dorosomatidae	Sardine	*Amblygaster* sp.	+	+
Engraulidae	Anchovy	*Encrasicholina* sp.	-	+
Gerreidae	Longfin silverbiddy	*Pentaprion* sp.	+	+
	Whipfin silverbiddy	*Gerres* sp.	-	+
Leiognathidae	Ponyfish	*Secutor* sp.	+	+
Lutjanidae	Snapper	*Lutjanus* sp.	-	+
Mullidae	Goatfish	*Upeneus* sp.	+	+
Nemipteridae	Threadfin bream	*Nemipterus* sp.	-	+
	Monocle bream	*Scolopsis* sp.	-	+
	Butterfly whiptail	*Pentapodus* sp.	-	+
Priacanthidae	Bigeyes	*Priacanthus* sp.	+	+
Synodontidae	Lizardfish	*Saurida* sp.	+	+
Tetraodontidae	Pufferfish	*Lagocephalus* sp.	-	+
Cephalopod				
Loliginidae	Squid	*Uroteuthis* sp.	+	+
Crustacean				
Penaeidae	Penaeid shrimp	*Penaeus* sp.	+	+

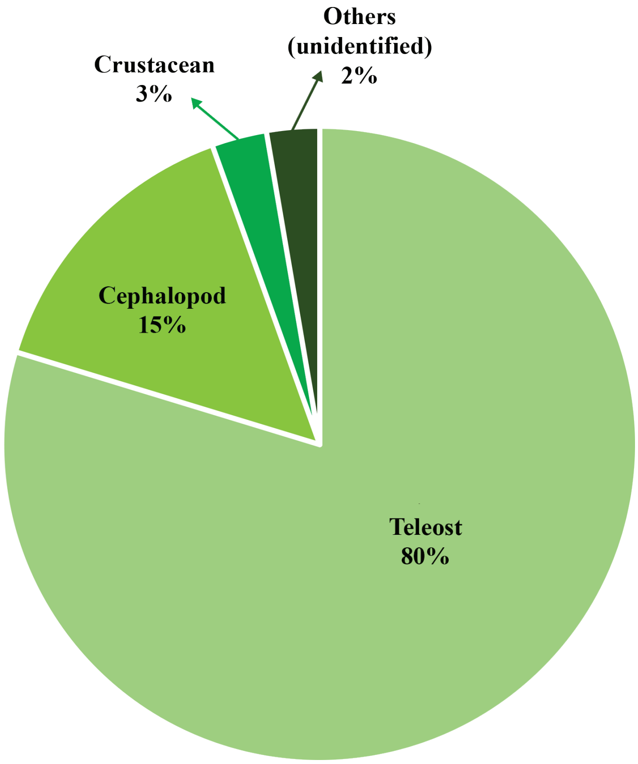

Figure 3. Pie charts showing the composition and abundance of diets observed in stomach content of *Istiophorus platypterus*.

The most representative prey in total numbers were *Encrasicholina* sp. (23.32%), *Amblygaster* sp. (15.72%), *Uroteuthis* sp. (14.84%), *Secutor* sp. (10.78%) and *Decapterus* sp. (7.95%) (Table 2). In terms of weight, the most important prey was *Amblygaster* sp. (28.25%), followed by *Selaroides* sp. (16.16%), *Selar* sp. (12.03%), *Uroteuthis* sp. (10.44%) and *Decapterus* sp. (6.13%). Besides that, the most frequent prey found in the stomachs were *Uroteuthis* sp. (12.77%), *Encrasicholina* sp. (10.64%), *Secutor* sp. (11.17%), *Amblygaster* sp. (9.57%) and *Decapterus* sp. (8.51%). Five items that make up more than 80% of the diet composition according to the Index of Relative Importance (%IRI), with the most important *Amblygaster* sp. (26.13%), *Uroteuthis* sp. (20.03%), *Encrasicholina* sp. (18.22%), *Secutor* sp. (9.31%) and *Decapterus* sp. (7.44%). Out of all the prey items from the stomachs, *Scolopsis* sp. was recorded to be the least important (0.02%).

High diversity and prey abundance separated two groups in 2021: April and (March, November and December). Meanwhile, in 2022 five clusters were separated which are: April, June, (May, September and July), August and (October, November and December) (Figure 4). All monthly samples when pooled together showed values of diet breadth in 2021 and 2022 were 5.26 and 7.2 respectively indicating wide range of food items (generalists). No significant difference was found among monthly diet breadth ($p = 0.23$) from the statistical analyses.

Table 2. Diet composition of *Istiophorus platypterus* in the East Coast of Peninsular Malaysia.

Prey item (Genus)	N	%N	FO	%FO	W	%W	IRI	%IRI	%IRI Rank
Teleosts									
Amblygaster sp.	89	15.72	18	9.57	2250.79	28.25	421.03	26.13	1st
Decapterus sp.	45	7.95	16	8.51	488.23	6.13	119.82	7.44	5th
Dipterygonotus sp.	20	3.53	10	5.32	81.43	1.02	24.23	1.50	8th
Encrasicholina sp.	132	23.32	20	10.64	340.72	4.28	293.60	18.22	3rd
Gerres sp.	1	0.18	1	0.53	50.9	0.64	0.43	0.026	20th
Lagocephalus sp.	2	0.35	2	1.06	7.55	0.09	0.48	0.029	19th
Lutjanus sp.	9	1.59	7	3.72	301.57	3.79	20.01	1.24	9th
Nemipterus sp.	12	2.12	7	3.72	196.66	2.47	17.08	1.06	11th
Pentapodus sp.	4	0.71	3	1.60	183.61	2.30	4.81	0.30	16th
Pentaprion sp.	9	1.59	9	4.79	74.72	0.94	12.10	0.75	14th
Priacanthus sp.	3	0.53	3	1.60	210.07	2.64	5.05	0.31	15th
Pterocaesio sp.	4	0.71	4	2.13	22.32	0.28	2.10	0.13	18th
Saurida sp.	3	0.53	3	1.60	126.32	1.59	3.38	0.21	17th
Scolopsis sp.	2	0.35	1	0.53	17.51	0.22	0.30	0.02	21st
Secutor sp.	61	10.78	21	11.17	211.75	2.66	150.07	9.31	4th
Selar sp.	11	1.94	7	3.72	958.72	12.03	52.04	3.23	7th
Selaroides sp.	35	6.18	10	5.32	1287.22	16.16	118.83	7.37	6th
Upeneus sp.	9	1.59	7	3.72	150.72	1.89	12.96	0.80	13th
Cephalopod									
Uroteuthis sp.	84	14.84	24	12.77	832.1	10.44	322.78	20.03	2nd
Crustacean									
Penaeus sp.	15	2.65	8	4.26	32.86	0.41	13.03	0.81	12th
Others									
(Unidentified)	16	2.83	7	3.72	141.65	1.78	17.15	1.064	10th
Total	**566**		**188**		**7967.42**		**1611.29**		

Note: N = number; FO = frequency of occurrence; W = wet weight; IRI = index of relative importance

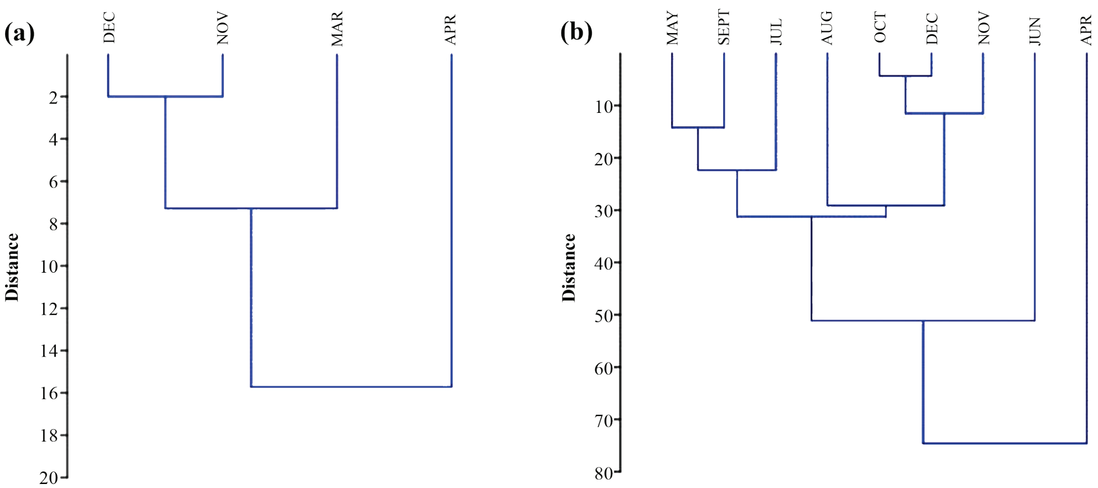

Figure 4. Cluster dendrogram of samples based on similarity in prey abundance and diversity in (a) 2021 and (b) 2022.

DISCUSSION

Sailfish mainly feed on high diversity of epipelagic species in coastal waters (diet breadth 2021 = 5.26 and 2022 = 7.2) which makes them generalist predators. This indicates that sailfish feed on a broad range of prey items such as teleosts, cephalopods and crustaceans that contributed to the diet thus gives a better understanding in fish trophic interactions within a community. This result agrees with sailfish as generalist predators (high diet breadth) from the southern Gulf of California, Mexico (Rosas-Alayola *et a*l., 2002). However, Hernandez-Aguilar *et al*. (2012) argued that sailfish in Acapulco (southern Mexican Pacific) are characterized as specialist predators as the diet prominently comprised of prey fish *Auxis thazards*. This is supported by the low diet breadth of sailfish in the area due to high frequency of a single prey item.

Fish and cephalopods were found to be the main diet of the Indo-Pacific sailfish caught from the East Coast of Peninsular Malaysia which suggested as generalist predators based on the various prey from pelagic, mesopelagic and demersal species found in the stomach contents. The results aligned with other documented studies where dominance of fish is prominent in the composition of prey items in Mexico and Taiwan waters (Rosas-Alayola *et al*., 2002; Tsai *et al*., 2015).

Cephalopods ranked 2nd in the Index of Relative Importance (%IRI). This comparison is similar to the previous results that showed cephalopods were found to be important (Arizmendi-Rodriguez *et al*., 2006). The *Uroteuthis* genus is classified as inshore squid, occupies all over continental shelves. Despite being epipelagic and oceanic species, Indo-Pacific sailfish shows a strong tendency to approach continental coast for food hunting (Mourato *et al*., 2010).

In addition, the size range of sailfish collected are mostly classified as juveniles and early adults based on the reported size ranged between 65–130 cm and 170–270 cm respectively (Arocha and Ortiz, 2010). Bachok *et al*. (2004) implied that prey items of marine fishes like sailfish from the east coast of Peninsular Malaysia mostly comprised of scads, squids and anchovies. This is due to abundant and diverse food sources of pelagic species such as sardines (*Amblygaster* sp.), anchovies (*Encrasicholina* sp.), squids (*Uroteuthis* sp.) and ponyfish (*Secutor* sp.). This suggests the east coast of Peninsular Malaysia (Pahang and Terengganu waters) as an ideal habitat for feeding ground for sailfish. However, new data showed a decline in the number of catches from marine species (-4.0%) which include sardines and anchovies (DOF, 2021). This shows that the amount of food for predators is becoming limited thus could potentially be the reason for the low occurrences of sailfish in the region in the past years.

Seasonal variations based on cluster analysis showed that the highest diversity and prey abundance was observed in the month of April in both the years 2021 and 2022 which coincide with the Inter Monsoon season (Figure 4). On the contrary, low diversity and prey abundance was observed during the North-East monsoon (November to March) which is the wet season. Variation of climate could affect the resources as some species will fluctuate in numbers depending on the environment (Nedtharnn, 2015). Besides, elevated sea surface temperature could be another factor affecting the overall sailfish population dynamics due to changes of prey availability. Saewong *et al*. (2021) concluded that surge in temperature will disrupt the distribution and composition of species that can cause imbalance in coastal ecosystems. This was proven as high sea surface temperature or more than 30 °C has shifted the bluefin tuna larvae to another suitable habitat (Dell'Apa *et al*., 2018). Thus, the distribution of fish species could be restricted from rise in sea temperature as the normal temperature normally falls (27.0–27.7 °C) (Shimose *et al*., 2010).

The Indo-Pacific sailfish can be commonly found within 20 m of the upper surface of ocean thus making them more vulnerable to trawlers and discarded as by-catch (Chiang *et al*., 2004). Therefore, uncontrolled catch could potentially remove the species as apex predators that can influence the trophic changes in the marine ecosystem and local fisheries industry in the long term.

CONCLUSION

In summary, the high diversity in diet composition of Indo-Pacific sailfish by-catch in the east coast of Peninsular Malaysia mainly comprised of fish and cephalopods. The variation in prey items is more likely to be related to abundance of species in the area which makes sailfish as generalist predators. Changes that were observed between months could relate to abundance of prey during monsoon seasons. As some sampling sessions were restricted due to covid-19, further studies are needed to avoid this limitation. Malaysian waters serve as nursery ground to sailfish (juveniles and early adults) as they feed on any available species.

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