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Diet composition and feeding habits of flat needlefish *Ablennes hians* (Valenciennes, 1846) (Beloniformes: Belonidae) in the Southeastern Arabian Sea

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The study describes the feeding habits, diet composition and prey diversity of *Ablennes hians* based on 396 specimens collected between October 2015 and September 2017 from Kerala, south-west coast of India. The Index of Relative Importance (IRI) showed that teleosts were the most preferred food items (%IRI = 65.43 %) followed by molluscs (%IRI = 32.91) and crustaceans (%IRI = 1.66). Prey biodiversity analyses indicated no significant variation in the prey items between the sexes and immature (juvenile) and mature (adult) specimens. Similarly, a non-significant difference in Vacuity Index (VI) and Fullness Index (FI) was observed between the sexes ($p > 0.05$), juveniles, and adults ($p > 0.05$). Mean number of prey items per stomach (Nm/ST) was found to be higher in females and juveniles than males and adults; whereas the mean weight of prey items per stomach (Wm/ST) was higher in females and adults. Analysis of similarities (ANOSIM) test also indicated that there was no significant difference in prey types and preferences between sexes (global $R = -0.25$, $P > 0.05$) and juveniles and adults (global R = 0.5, $P > 0.05$). Diet analysis revealed that the species is a carnivorous and active pelagic predator, predominately consuming teleost fishes and an opportunistic feeder and might perform vertical migrations in search of food. The present study provides a first reference on the detailed information on feeding biology of the flat needlefish, which can be used as a baseline information for future studies in the region.

[**Keywords**: *Ablennes hians*, Arabian Sea, Diet composition, Feeding habits, Flat needle fish]

Introduction

The dietary study of fish is the fundamental concept to understand the prey-predator and trophic relationships for monitoring marine resources with time[1]. Data on diet composition of a fish is useful for the identification of stable food preferences and to provide a preliminary estimate of trophic level[2]. Diet analysis is also necessary for exploring the trophic overlap within and between the species and determining the intensity of inter- and intraspecific interactions in marine fish communities[3]. Additionally, diet composition data is essential for developing trophic models to understand the complexity of coastal ecosystems in terms of trophic interactions[4,5]. The diet of a fish is influenced by several factors, such as prey availability, mobility, abundance, environmental factors, developmental stages and sex of the predator, and these are been identified as potential determinants of ecological importance of each species in the trophic web in which they participate[6,7].

The flat needlefish *Ablennes hians* (Valenciennes, 1846) is a pelagic species inhabiting both offshore and inshore (more frequently around islands) surface waters, having worldwide distribution in the tropical and warm temperate waters[8]. In Indian waters, this species is abundant and has been reported all along the coast, including Lakshadweep and Andaman and Nicobar Islands. The fish is mainly caught by long lines and gill nets year-round in the south-eastern Arabian Sea region and is considered one of the commercially important pelagic fish species locally. The unit price of this species is quite high (160 – 230 INR/ 2.2 – 3.2 USD per kg) in local fish markets compared with several other high-valued species (personal observation). Despite its commercial value and wide distribution, the basic biological information which is essential for its fishery management is scarce. Few studies focussing its fishery, length-weight relationships, growth, mortality and stock assessment has been conducted along the Indian waters[9-11]; but the diet composition and feeding habits of the species are not yet explored along the region. Studying food and feeding habits of flat needlefish is highly essential in order to understand their ecological significance in trophic webs in a given space and time. Therefore, the present study is aimed to provide preliminary information on feeding habits, diet composition and prey diversity of flat needlefish along the southeastern Arabian Sea and to describe its prey and dietary changes in relation to body size, sex and maturity in a comprehensive manner.

Materials and Methods

Sampling and laboratory handling

Altogether 396 specimens of flat needlefishes were collected between October 2015 to September 2017 from the Cochin Fishing Harbour (9°56'32.70" N, 76°14'22.17" E), Munambam Fishing Harbour (10°10'58.78" N, 76°10'13.51" E) and Kalamukku Fishing Harbour (9°58'52.95" N, 76°14'34.18" E) along the Kerala coast (India), southeastern Arabian Sea (Fig. 1). The fishes were captured mostly by long lines with serially arranged 150 – 200 hooks (hook no. IX-XIV) and drift gill nets (80 – 120 mm mesh size). Fishes were identified based on standard taxonomic key given by Collette (1984) and the specimens without any physical damage were brought to the laboratory in iced condition for further studies. For each specimen, Total Length (TL) was recorded to the nearest 0.1 cm using a fish measuring board and scale. Total body Weight (TW) for each specimen was also measured by an electronic weighing balance with 0.1 g accuracy.

Following measurements, stomachs were removed from each specimen and cut opened to remove its content. Food/prey items in the stomach content were sorted into taxonomic groups at species level, whenever possible. These food items were mostly identified based on the external morphology and in certain instances with the help of a stereo-zoom microscope (Nikon DS-Fi2, Japan) depending on the size and digestion stage of each food item. To ease analysis and interpretation, the food items were grouped into major taxonomic groups namely, teleosts, crustaceans, molluscs and plastics. The number of each food item was counted and weighed to the nearest 0.01 g after the removal of surface water by blotting on a tissue paper. The food items, beyond recognition due to excessive digestion were classified as unidentified food items such as fish, shrimp, crab and squid. The variation in feeding habits was accessed between sexes and maturity stages (immature and mature specimens). The sex and

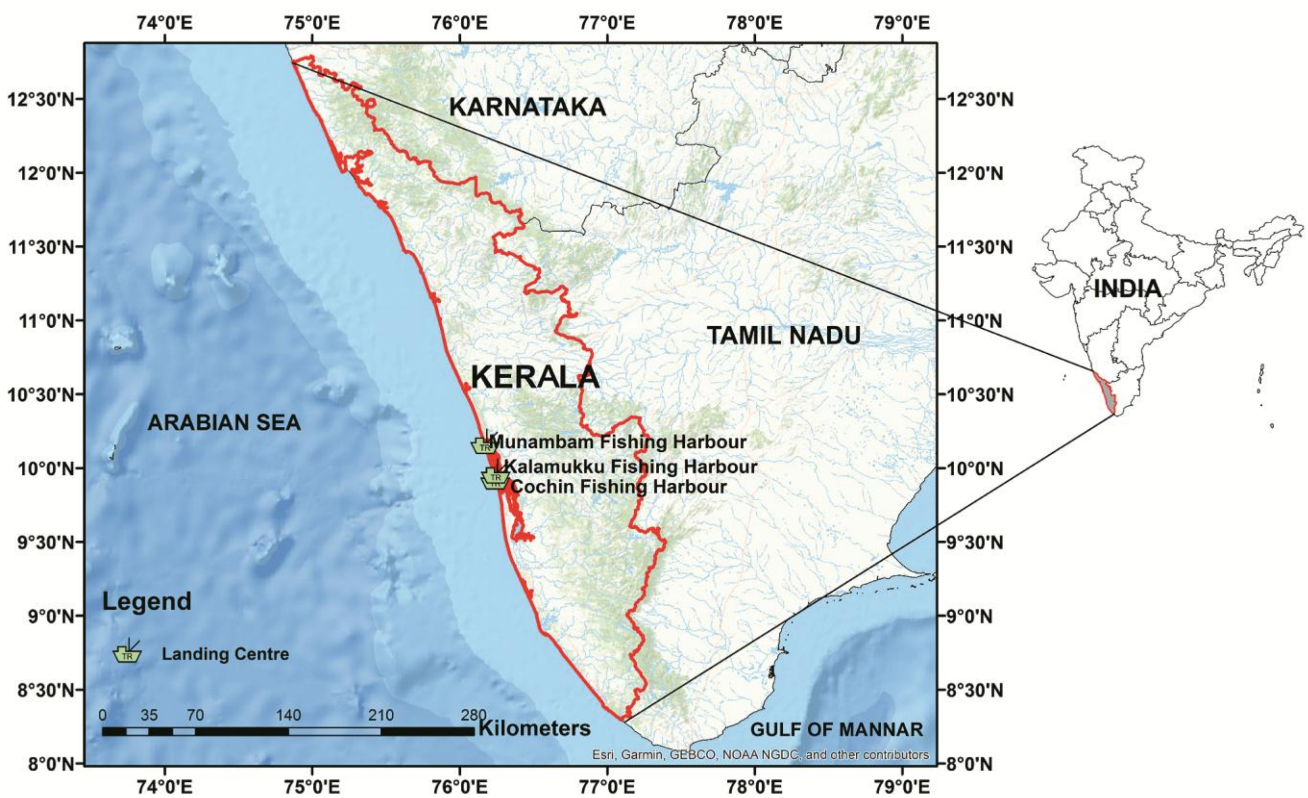

Fig. 1 — Map showing the sampling locations of *Ablennes hians* along Kerala coast in the southeastern Arabian Sea

maturity stages of flat needlefishes were identified based on both macroscopic and microscopic examination of gonads. The specimens were divided into two size classes such as immature (juveniles) and mature (adults) based on size at first maturity (Lm_{50}) which was estimated at 76 cm TL. The individuals measuring below 76 cm TL (length at 50 % maturity) were considered as juveniles and above 76 cm TL as adults.

Diet analysis

The main food/prey items in the diet were identified by a conventional index *i.e*. Index of Relative Importance (IRI) based on three sub-indices namely, (1) Percentage frequency of occurrence (%F) = [Number of stomachs in which a food/prey item was found/Total number of non-empty stomachs] × 100; (2) Percentage numerical composition (%N) = [Number of each prey item in all non-empty stomachs/Total number of food/prey items in all stomachs] × 100; and Percentage gravimetric composition (%W) = [Wet weight of each prey item/Total weight of stomach contents] × 100. Index of Relative Importance (IRI) of each food/prey item was calculated by combining above three indices[12] and analysed separately using the method given by Pinkas *et al*.[13]. The index gives the information on relative importance of one food item over another. *IRI = (%N + %W) × %F*. The IRI values thus obtained for each food/prey item were converted into a percentage (%IRI) using the following formula given by Cortes[14].

$$\% IRI_i = 100\, IRI_i \sum_{I=i}^{n} IRI$$

The %IRI values were used to classify the food items using the method described by Rosecchi & Nouaze[15]. The prey items constituting 50 % of the total sum of IRI and above are considered as preferential food items, next 25 to 49.99 % as secondary food items and the remaining *i.e*. < 25 % as accessory food items. The Vacuity Index (%VI)[16] and Fullness Index (FI)[12] were calculated in order to investigate the variations in feeding intensity between sexes and size groups.

$$\% VI = \frac{No.\ of\ \ empty\ stomach}{Total\ number\ of\ stomachs}\ x\ 100$$

$$FI = \frac{Stomach\ content\ weight\ (g)}{Fish\ weight\ (g)}\ x\ 100$$

Tropic diversity based on food items in the stomachs were assed and compared using the following indices. Diversity index (H′): The Shannon–Wiener diversity index was used to analyse the trophic diversity of food items in the stomach of flat needlefishes.

$$H' = \sum_{i=1}^{s} (p_i\ log\ \ p_i)$$

Where, S = total number of species, and P_i is the frequency of the i^{th} species. The index provides idea about richness as well as evenness of the prey species.

Species evenness (*J′*): describes how evenly the different species occur in the diet of needle fish and is calculated using the Pielou's index.

$$J' = \frac{H'}{\mathrm{Log}\ S}$$

Where, *H′* is the Shannon–Wiener index, and '*S*' is the number of species recorded in the diet. The value of *J′* varies between 0 to 1 and depends on the variation in prey species.

Species richness (d): describes how richly the diet of the needlefish is composed of with different prey items, and was calculated using the Margalef's index.

$$d = \frac{S - 1}{\mathrm{LogN}}$$

Where, '*N*' is the total number of individuals present in the diet and '*S*' is the number of species recorded in the diet.

Hill's Number is calculated using the following formula.

N1 = Exp(H'),

Where, *H'* is the Shannon–Wiener index. This is used as unified diversity concept by defining biodiversity as a reciprocal mean proportional abundance and differently weighing taxa based on their abundances.

The data on Fullness Index (FI) for different groups (sexes and maturity stages) were tested using Kolmogorov–Smirnov test and found to be deviating from normal distribution. Therefore, Mann–Whitney's test (M-W test) and Kruskal–Wallis test (K-W test) were performed for two groups and more than two groups, respectively to test the significant difference in FI values between sexes and maturity stages. The mean number of food item per stomach (Nm/ST) and mean weight of food item per stomach (Wm/ST) were calculated for each sex and maturity stage, separately.

Statistical analyses were performed using IBM SPSS 22 SOFTWARE package. Differences in dietary preferences between the sexes and maturity stages were examined by two statistical techniques such as CLUSTER analysis and non-metric Multi-Dimensional Scaling (MDS). Initially the data were standardized for sample total, and then transformed by square root and were tested for resemblance between the males, females, immature and mature specimens using Bray-Curtis similarity index. The analysis of similarity test (ANOSIM) was performed to find out the differences between the sexes and between the immature and mature specimens. CLUSTER analysis was performed with SIMPROF test to group samples through dendrogram plot using their resemblance in terms of prey preference. MDS analysis was carried out with overlaid cluster from dendrogram plot to depict the similarities and dissimilarities among males, females, immature and mature specimens. All the above analysis was performed using the PRIMER 6 (Ver.6.1.13, PRIMER-E Ltd.).

Results

Sample characteristics

A total of 396 flat needlefishes were examined, ranging from 45 – 122 cm TL and 90 – 2585 g TW. No differences in external morphology were observed between the sexes. Females (n = 190) ranged from 45 – 122 cm TL and 90 – 2585 g TW; whereas, males (n = 206) ranged from 53.5 – 114.5 cm TL and 155 – 2255 g TW. The mean total length of female needlefish, 87.0±0.9 cm was found to be significantly different from the males, 81.9±0.8 cm (independent t test, $p < 0.001$). Similarly, the mean total weight of female needlefishes, 910.1±32.8 g was found to be significantly different from the males, 794.6±26.4 g (independent t test, $p < 0.05$). The length frequency distribution of male and females was not significantly different (Kolmogorov-Smirnov test, $p > 0.05$) (Fig. 2). Females constituted 48 % and males 52 % in the population with an overall sex ratio of males to females was 1:0.92 and did not significantly differ from the expected 1:1 ratio (chi-square df = 1; $p > 0.05$). The summary of sample size of *Ablennes hians* collected over tqhe four seasons is given in Table 1.

Diet composition

The stomach contents of flat needlefishes were identified into 18 different food items belonging to three major groups such as teleosts, crustaceans, and molluscs (Table 2). Based on %IRI, teleosts were found to be the preferential food item *i.e.* most

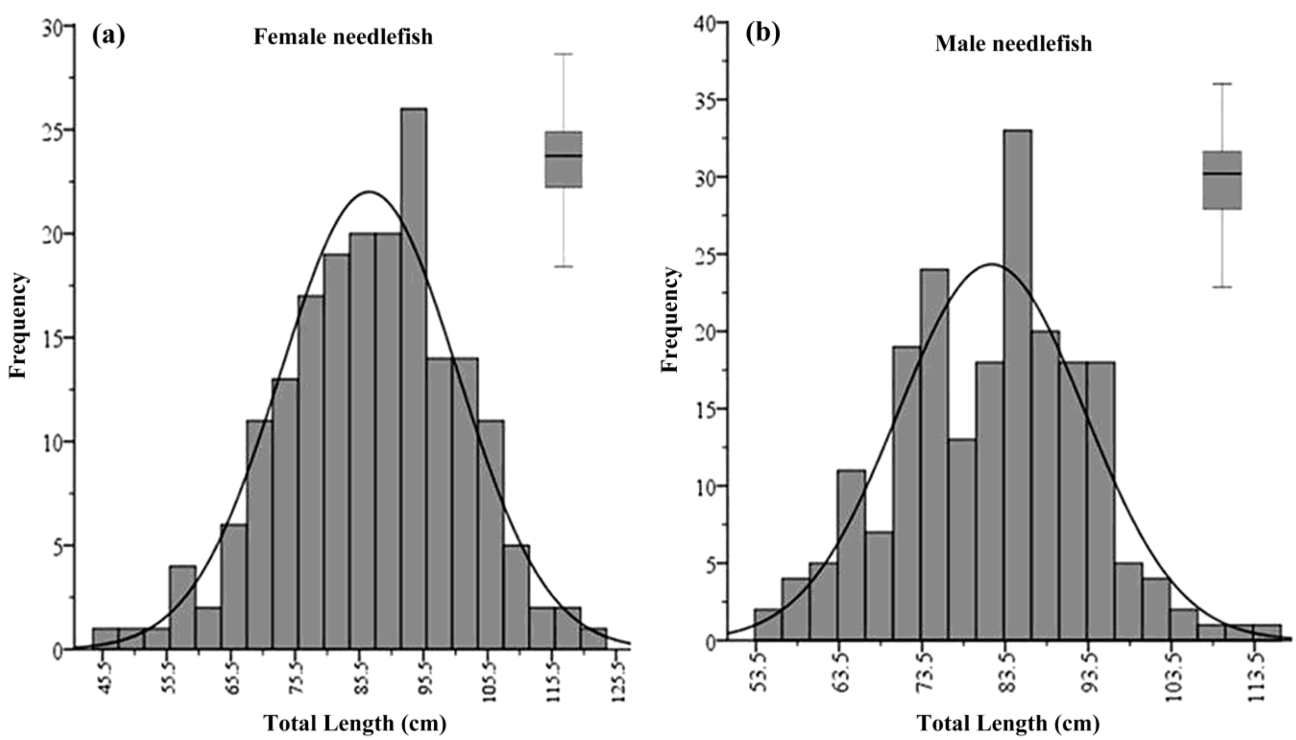

Fig. 2 — Length frequency distribution of female and male populations of *Ablennes hians* caught along Kerala coast in the southeastern Arabian Sea

important or preferred food with 65.43 % of the total IRI, followed by molluscs (%IRI = 32.91) which constituted as secondary food item, and crustaceans (%IRI = 1.66) and plastics (%IRI = < 0.1) as accessory or accidental food groups which is having less importance for the predator due to their negligible contribution (Table 3). Due to the advance stage of digestion, identification of certain food items to the species level was often impossible. The teleosts in the diet of needle fish were mainly constituted by scads, sardines, anchovies, codlets, threadfin breams, halfbeaks, puffers, etc.; whereas, crustaceans are represented by crabs, nonpenaeid and sergestid shrimps; and molluscs were constituted by cephalopods and pteropods. Few specimens with plastic debris in stomachs were also recorded (%IRI < 0.1). The most common identifiable food items in the diet were teleosts: *Decapterus russelli* (%IRI = 17.75), *Sardinella longiceps* (%IRI = 0.51), *Bregmaceros mcclellandi* (%IRI = 0.14) and *Nemipterus japonicas* (% IRI = 0.05); followed by crustaceans: *Trachysalambria curvirostris* (%IRI =

Table 1 — Summary of sample size of *Ablennes hians* collected over four seasons between October 2015 to September 2017

Season	*n*	Males (TL)	Females (TL)
PMS	110	69.7-107	45-116
SWMS	104	56-104.8	56.2-116.5
POMS	98	53.5-114.5	67.2-110.4
WS	84	65.5-99.2	73.4-122

PMS - Pre-monsoon Season (summer), March – May; SWMS - Southwest Monsoon Season (June – September); POMS - Post-monsoon Season (autumn), October – November; WS - Winter Season (December – February); *n* - number of specimens examined; TL in cm

Table 2 — Overall diet composition of *Ablennes hians* (%F = percentage frequency of occurrence; %N = Percentage numerical composition; %W = Percentage gravimetric composition; IRI = Index of Relative Importance)

Food items	%N	%W	%F	QI	%QI	IRI	%IRI
Teleosts							
Carangidae (Carangids)							
Decapterus russelli	1.21	35.82	13.47	43.23	10.21	498.64	17.75
Alepes sp.	0.02	0.11	0.29	0.00	< 0.1	0.04	< 0.1
Carangid	0.19	6.56	1.72	1.24	0.29	11.60	0.41
Clupeidae (Sardines)							
Sardinella longiceps	0.24	5.32	2.58	1.26	0.30	14.33	0.51
Engraulidae (Anchovies)							
Stolephorus sp.	0.66	1.02	1.72	0.67	0.16	2.89	0.10
Bregmacerotidae (Codlets)							
Bregmaceros mcclellandi	1.37	0.60	2.01	0.82	0.19	3.95	0.14
Nemipteridae (Threadfin breams)							
Nemipterus japonicus	0.07	1.71	0.86	0.12	0.03	1.53	0.05
Hemiramphidae (Halfbeaks)							
Hemiramphus sp.	0.07	0.32	0.29	0.02	0.01	0.11	< 0.1
Tetraodontidae (Puffers)							
Lagocephalus sp.	0.02	0.04	0.29	0.00	< 0.1	0.02	< 0.1
Unidentified fishes	2.77	39.38	30.95	1304.45	46.44	109.04	25.76
Total Teleosts	6.63	90.88	54.15	156.41	36.95	1837.56	65.43
Crustaceans							
Trachysalambria curvirostris	0.78	3.49	5.44	2.73	0.64	23.27	0.83
Acetes sp.	8.28	0.64	2.58	5.30	1.25	23.01	0.82
Unidentified shrimps	0.07	0.09	0.57	0.01	< 0.1	0.09	< 0.1
Unidentified crabs	0.78	0.51	0.29	0.40	0.09	0.37	0.01
Total Crustaceans	9.91	4.73	8.88	8.43	1.99	46.74	1.66
Molluscs							
Cephalopods							
Unidentified Squid	0.24	0.90	1.72	0.21	0.05	1.95	0.07
Pteropods							
Cavolinia longirostris	79.72	3.23	10.89	257.39	60.80	903.17	32.16
Cavolinia tridentata	3.45	0.26	5.16	0.88	0.21	19.14	
Total Molluscs	83.41	4.38	17.77	258.49	61.06	924.27	32.91
Others							
Plastics	0.05	0.00	0.57	0.00	< 0.1	0.03	< 0.1

Table 3 — Classification of prey groups of *Ablennes hians* based on the Index of Relative Importance (IRI)

Food items	IRI	% IRI	Prey type
Teleost	1837.56	65.43	Preferential
Crustacean	46.74	1.66	Accessory
Molluscs	924.27	32.91	Secondary
Others	0.03	< 0.1	Accessory

For the IRI, prey groups are classified as preferential prey if contribution of group is 50 % or more of IRI, 25 to 49.99 % contributors are secondary, and the remaining *i.e.* < 25 % is considered as accessory prey group

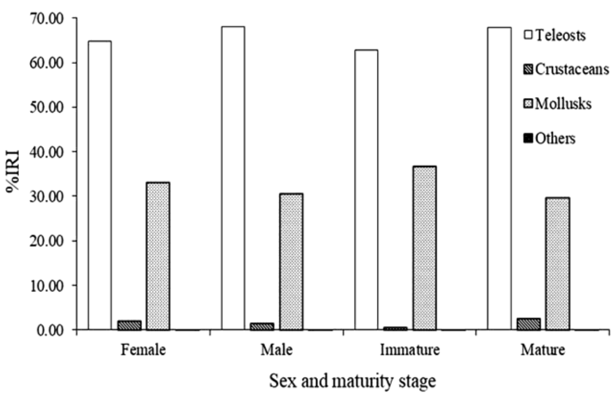

Fig. 3 — Prey preferences for sexes and maturity stages based on %IRI

0.83); and molluscs: *Cavolinia longirostris* (%IRI = 32.16) and *Cavolinia tridentata* (%IRI = 0.68). However, a major portion of teleosts remain unidentified (%IRI = 25.76) due to excessive digestion (Table 2). Similar prey preference was also noticed among both sexes and maturity stages (Fig. 3).

Diet in relation to season

Flat needlefishes consumed the highest number prey items during the Post-Monsoon Season (POMS) followed by Southwest Monsoon Season (SWMS) and lowest was during Pre-Monsoon Season (PMS). The Index of Relative Importance (%IRI) indicated that the teleosts were the primary prey category across all the seasons followed by crustaceans (Table 4). Among the food items, unidentified fishes form the major prey during PMS and SWMS; whereas, *Decapterus russelli*, unidentified fish and *Cavolinia longirostris* were the major prey items during POMS and dry Winter Season (WS) (Table 4).

Prey diversity estimates

The values of Shannon–Wiener diversity index (H′), Pielou's index of evenness (J′), Margalef's index of richness (d), and Hill's Number for the diet of both sexes and maturity stages of flat needlefishes are presented in the Table 5. Prey item diversity analysis revealed that there was no significant variation in the biodiversity indices within the groups. Maximum prey diversity was observed in the stomach content of mature female specimens. Similarly, species richness and evenness was also noted to be highest in case of mature female specimens (Table 5).

Gut fullness

The analysis of stomach content of 396 flat needlefishes revealed 349 stomachs with food and remaining 47 without food called as empty stomachs and the overall Vacuity Index (VI) was estimated to be 11.87 %. There was no significant difference in VI for female (%VI = 11.05) and male (%VI = 12.62) specimens (χ^2 = 2.0, p > 0.05); however, the mature specimens (both male and females) were found to be with lower VI (%VI = 6.80) in comparison with the immature specimens (%VI = 26.47). Similarly, analysis of the Fullness Index (FI) indicted that there was no significant differences in feeding behaviour between female and male specimens (Mann–Whitney U test, p > 0.05) and same was observed between immature and mature specimens of needlefishes (Mann–Whitney U test, p > 0.05) (Table 6). Likewise, comparison of immature female, mature female, immature male and mature male specimens did not show significant differences in FI values indicating similar kind of feeding behaviour (Kruskal–Wallis test, p > 0.05).

Mean number and mean weight of prey items per stomach

Additionally, analysis of mean number of prey items per stomach (Nm/ST) showed higher value in female (14.53) and immature individuals (26.64) in comparison to male (9.83) and mature individuals (8.13), respectively. Similarly, Nm/ST value found to be higher in immature female and mature male whereas lower for mature female and immature male needlefishes (Table 6). Analysis of mean weight of prey per stomach (Wm/ST) showed higher value in female (9.77) and mature specimens (9.53) in comparison with male (7.41) and immature specimens (4.98), respectively. Similarly, higher Wm/ST was observed for mature female and male and lower in case of immature female and male needlefishes.

Analysis of similarities (ANOSIM) test clearly indicated that there was no difference in prey types and preferences between females and males of flat needlefishes (global R = -0.25, p > 0.05). Similar

Table 4 — Seasonal diet variations based on estimates of %IRI for *Ablennes hians* collected between October 2015 to September 2017

Food items	PMS	SWMS	POMS	WS
Teleosts				
Carangidae (Carangids)				
Decapterus russelli	18.82	11.35	34.23	16.16
Alepes sp.	0.00	0.00	0.00	0.01
Carangid	0.00	0.14	0.31	1.47
Clupeidae (Sardines)				
Sardinella longiceps	1.11	0.0000	0.03	1.42
Engraulidae (Anchovies)				
Stolephorus sp.	1.07	0.06	0.05	0.00
Bregmacerotidae (Codlets)				
Bregmaceros mcclellandi	0.00	0.58	0.62	0.00
Nemipteridae (Threadfin breams)				
Nemipterus japonicus	0.65	0.00	0.00	0.00
Hemiramphidae (Halfbeaks)				
Hemiramphus sp.	0.00	0.03	0.00	0.00
Tetraodontidae (Puffers)				
Lagocephalus sp.	0.00	0.00	< 0.01	0.01
Unidentified fishes	60.41	20.11	31.80	28.52
Total Teleosts	82.06	32.26	67.05	47.59
Crustaceans				
Trachysalambria curvirostris	0.16	0.03	0.16	5.51
Acetes sp.	0.00	0.001	0.02	0.00
Unidentified shrimps	0.02	0.02	0.00	0.01
Unidentified crabs	0.07	0.00	0.00	0.00
Total Crustaceans	0.24	0.04	0.18	5.52
Molluscs				
Cephalopods				
Unidentified Squid	0.00	0.01	0.01	0.08
Pteropods				
Cavolinia longirostris	13.16	17.68	32.76	42.44
Cavolinia tridentata	4.53	0.00	0.00	4.35
Total Molluscs	17.69	17.69	32.77	46.87
Others				
Plastics	0.00	0.00	0.00	0.02

PMS - Pre-monsoon Season (summer), March – May; SWMS - Southwest Monsoon Season (June – September); POMS - Post-monsoon Season (autumn), October – November; WS - Winter Season (December – February)

Table 5 — Diversity indices for the food items of *Ablennes hians*

Sex and stages	H′	J′	d	N1
Female	1.29	0.48	3.04	3.63
Male	1.05	0.41	2.61	2.86
Immature female	1.23	0.63	1.30	3.41
Mature female	1.97	0.71	3.26	7.19
Immature male	1.55	0.67	1.95	4.73
Mature male	1.67	0.65	2.61	5.32

H′: Shannon–Wiener diversity index; J′: Pielou's index of evenness; d: Margalef's index of richness; and N1: Hill's Number

result was also obtained between immature and mature individuals (global R = 0.5, $p > 0.05$). Cluster analysis with Similarity Profile Analysis (SIMPROF) test revealed a non-significant difference in prey preference between mature males and mature females having resemblance of 76.37 % (SIMPROF, $p > 0.05$). Similar result was also obtained between immature males and immature females (resemblance, 67.54 %); immature males and mature females (resemblance, 66.95 %) and immature females and mature males (resemblance, 59.39 %) (SIMPROF, $p > 0.05$). The findings of the cluster analysis were presented in the form of resemblance dendrogram plot (Fig. 4). Non-metric Multi-Dimensional Scaling (MDS) analysis has showed low stress in two dimensions and the plot gave the similar result as the dendrogram plot (Fig. 5).

Discussion

The study provides the first reference on the detailed information on diet composition, feeding habits, feeding behaviour and prey preference of flat needlefishes from southeastern Arabian Sea. The

Table 6 — Comparison of feeding intensity of *Ablennes hians* between the sexes and size groups

Sex and maturity stages	S	N	N_i	W_i	Nm/ST	Wm/ST	VI	FI
Female	190	169	2456	1651.41	14.53	9.77	11.05	1.35^{a*}
Male	206	180	1770	1333.81	9.83	7.41	12.62	1.28^{a*}
Immature	102	75	1998	373.7	26.64	4.98	26.47	1.60^{a*}
Mature	294	274	2228	2611.44	8.13	9.53	6.80	1.23^{a*}
Immature female	39	26	1693	148.39	65.12	5.71	33.33	$1.92^{a\#}$
Mature female	151	143	763	1503.02	5.34	10.51	5.30	$1.25^{a\#}$
Immature male	63	49	307	225.3	6.27	4.60	22.22	$1.44^{a\#}$
Mature male	143	131	1463	1108.51	11.17	8.46	8.39	$1.22^{a\#}$
Total	396	349	4226	2985.14	12.11	8.55	11.87	-

S - number of stomachs analysed; N - number of stomachs containing food; N_i - number of prey items; W_i - weight of prey items; Nm/ST - mean number of prey per stomach; Wm/ST - mean weight of prey per stomach; VI - vacuity index and FI - fullness index; *Mann–Whitney U test results, values with same superscript are non-significant ($p > 0.05$); #Kruskal–Wallis test results, values with same superscript are non-significantly ($p > 0.05$)

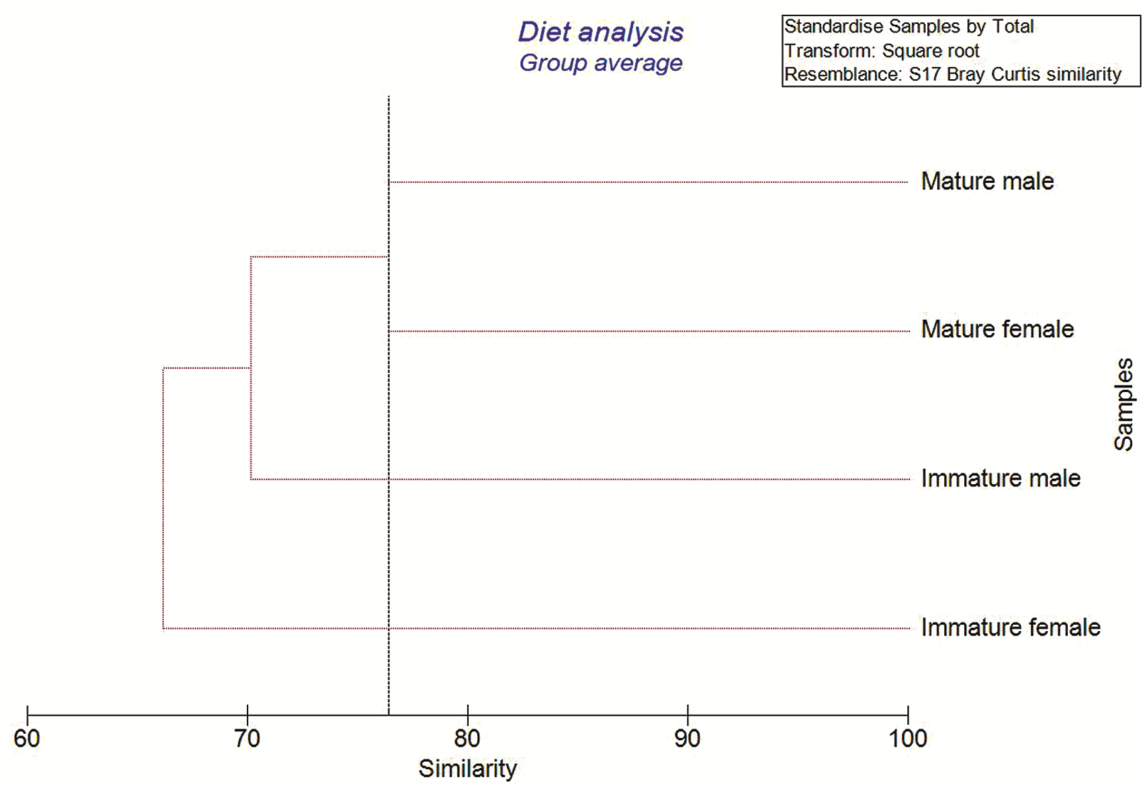

Fig. 4 — Dendrogram plot showing the grouping of the mature and immature female and male needlefish by CLUSTER analysis with SIMPROF test using their resemblance in terms of prey preference

stomach content analysis of flat needlefishes indicate that the fish is a carnivorous pelagic predator, predominately consuming teleost fishes, constituting more than 50 % of the total IRI, and therefore this prey group can be considered as main food group as well as preferential food source (%IRI = 65.43). Molluscs were found to be secondary prey group (%IRI = 32.91), while crustaceans (%IRI = 1.66) were observed as less important, can be called as occasional food or accidental food group. The carnivorous feeding behaviour of flat needlefishes has also been reported by few earlier reports[17-19].

Some of the earlier studies indicate that flat needlefishes feed mainly on small bony fishes[17-18] and the present study is also in agreement with these reports and several other studies[20-22]. Analysis of stomach content of Mediterranean needlefish *Tylosurus acus imperialis* of Tunisia showed that the

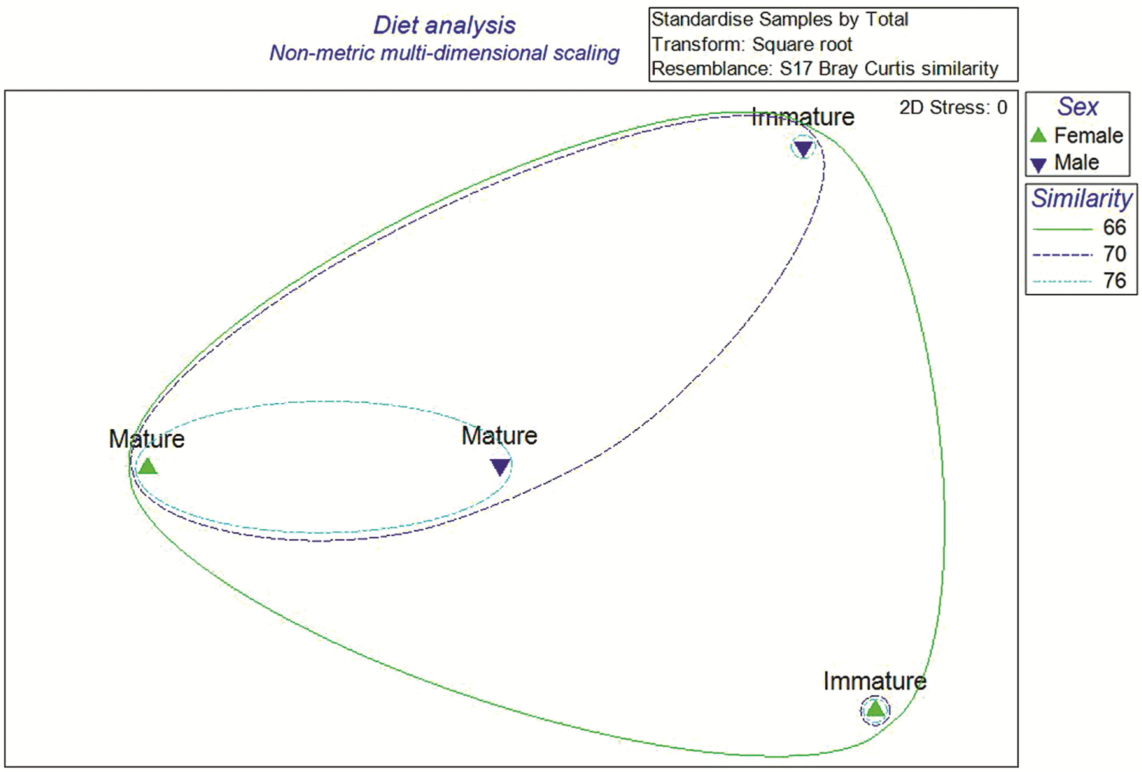

Fig. 5 — Non-metric multi-dimensional scaling (MDS) plot with overlaid cluster from dendrogram plot showing the similarities and dissimilarities among the mature and immature female and male needle fish

needlefish prefer to feed on teleost fishes and crustaceans, especially decapods[22]. Randall[20] in a study on feeding habits of reef fishes of the West Indies concluded that needlefishes feed voraciously on small fishes, especially clupeoids. Cannibalism has also been reported in few needle fish species. Among them, Châari *et al*.[22] recorded cannibalism in *T. acus imperialis* where the fish feeds on small individuals of its own kind and this was confirmed based on the green coloration of skeleton and spine in the gut content. Randall[20] and Sever *et al.*[23] also reported cannibalism in *T. acus acus* and *Belone belone*, respectively. However, the present study could not find any evidence for cannibalism in flat needlefishes from southeastern Arabian Sea.

Seasonal variation in diets is well documented in fishes. Overall estimates of seasonal IRI showed variation among the four seasons, which may be attributed to several reasons such as method of capture, preservation techniques, and abundance of prey items in the southeastern Arabian Sea. Flat needlefish consumed the highest number of prey items during the post-monsoon season and southwest monsoon season which clearly indicates that the fish feed actively during the post spawning period due to a greater energy demand, as reported in several other species from different areas[24-25]. Ontogenetic shift in feeding habits is also well documented in fishes[26,27], mostly occurred due to changes in body characteristics such as size of the mouth and the anatomical characteristics of its digestive tract that determine the physical restrictions on prey size and selectivity[28-30]. Santos-Filho[31] stated that individuals in a population of similar body sizes probably might have the similar levels of prey capture and preferences, which will be capable of utilizing the same range of resources[31]. This might be true for the present study as no significant differences are observed in prey types and preference within the same size groups. Obodai[19] reported that the flat needlefish feeds mainly on small crustaceans such as copepods and aquatic insects in its early stages and suddenly changes to piscivorous, predominantly feeding on fishes as the animal grow in size. However, the present study could not examine the food and feeding habits of early juvenile stages of flat needlefishes due to non-representation of smaller size groups (< 45 cm TL) in the captured population.

Sexual differences in feeding habits are more evident in species having marked dimorphism in size and is a widely observed phenomenon in animals[32]. There are some reports on sexual morphological differences in few fish species which could cause a lower feeding overlap and lower intraspecific competition[33,34]. However, the diet analysis in the present study didn't provide any significant difference in prey types and preferences between males and females and might be sharing the same trophic niches in the ecosystem. Cluster analysis and MDS diagram also indicated high similarity in prey types and preferences between immature and mature specimens of both the sexes.

From the diet composition of flat needlefishes, it is evident that most of the prey items were from the pelagic zone such as carangids, sardines, anchovies, codlets, halfbeaks, paste shrimp and pteropods with few others from the benthic zone such as threadfin breams, puffers, penaeid shrimps, brachyuran crab and squid. This clearly indicated that the fish is an active pelagic predator and an opportunistic feeder which might perform vertical migrations to feed using a well-developed swim bladder. A similar finding was also reported in *T. acus imperialis* off the Gulf of Gabès, Southeastern Tunisian coast[22] and in *T. acus* in Bermudian waters[35]. The present study, also reports *Cavolinia longirostris* (%IRI = 32.16) and carangids *Decapterus russeli* (%IRI = 17.75) as most dominant prey species in the diet of flat needlefishes possibly due to their high preference and selectivity towards these prey items in the studied area. Additionally, stomach content of few specimens was found with plastic debris which might be ingested accidentally by fishes while feeding. Recently, Roul *et al.*[36] also reported macro plastic debris from the stomach content of flat needlefishes from the same area. The occurrence of plastic debris in the oceans is a growing concern for health of marine ecosystem[37]. Presence of such debris can create potential adverse impact in the marine food web through ingestion by several marine organisms, ranging from zooplankton to apex predators[38-42]. Therefore, monitoring of this marine debris should be the one of the prime objectives of countries, worldwide.

A maritime state, Kerala, having the coastline of 590 km and continental shelf area of 39,139 sq. km in the Arabian Sea with several productive ecosystems such as backwater, mangrove, rocky shores, sandy shores, coral, mud bank, Wadge bank and Quilon bank offer the most favourable feeding grounds with diversified prey for such predatory fishes like needlefishes. Even though the needlefishes consumes only few selected prey items which may be attributed to its selective nature of feeding.

Feeding intensity is negatively related to the percentage of empty stomachs[43]. Higher Vacuity Index (VI) and Fullness Index (FI) were observed in immature individuals than mature individuals which clearly indicated that mature individuals of larger size group (> 76 cm TL) are having the active feeding behaviour than the immature individuals of smaller length group (< 76 cm TL). However, mean number of prey per stomach was found to be higher in immature individuals in comparison with the mature individuals. In contrary, mean weight of prey per stomach was found be higher in mature individuals than the immature individuals. This clearly indicates that the flat needlefishes consume more number of smaller size preys when immature; whereas, mature individuals feed actively on larger prey but in smaller number. Mean prey size increases with increasing predator size in order to optimize the energy input for growth[44]. This gradual change of diets may be due to the increasing need for more proteins and lipids for body growth and gonad development and thus also reduces the inter-specific competition[45]. In general, width and gape of the mouth of a predator is linearly related to its prey size[46] and increased body and mouth size permits fishes to capture a broader range of prey size and prey type. Present study is also in agreement with the above statement and the flat needlefishes found to be more active and able to consume larger prey items after attaining the body size of ~ 76.0 cm TL.

Conclusion

The diet composition and feeding habits of flat needlefishes showed that the fish is a carnivorous and active pelagic predator, predominately consuming teleost fishes and also an opportunistic feeder which performs vertical migrations for feeding. Prey types and prey preferences were found similar in flat needlefishes irrespective of sexes and maturity stages and the fish is found to be more active and able to consume larger size prey items after attaining the maturity. The size range covered in the present study is not fully comparable as the size class below 45 cm TL were not covered in this study due to certain limitations such as sampling from commercial catches which are highly selective in nature. The prey types and feeding habits below 45 cm TL of individuals are still unknown. Hence, further studies with a standardized sampling method are needed to obtain an unbiased sample, representing the full spectrum of population of the species including juveniles. The data generated in this study provides a first reference on the detailed feeding habits of flat needlefishes from the studied area which can be used as baseline information for proper management and conservation of the species along the region.

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Conflict of Interest

The authors declare no conflict of interest.

Ethical Approval

This article does not contain any experimental studies with animals by any of the authors.

Author Contributions

SKR: Conceptualization, data analysis, and manuscript writing. UG helped in analysis and draft preparation. EMA, AKJ and PR corrected the manuscript.

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