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Food Preference and Niche Breadth of Largehead Hairtail (*Trichiurus lepturus* Linnaeus, 1758) Caught in Pangandaran Waters, West Java

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ABSTRACT

The commercially important largehead hairtail, *Trichiurus lepturus*, serves a crucial ecological role in the environment as a controller of mid- and lower-trophic populations through prey and predation processes. This study attempted to identify the composition, preferred foods, and food-niche breadth of hairtail captured in Pangandaran waters, West Java, Indonesia. A total of 234 fish samples caught using the fisherman's hand lines and gill nets were observed. Body weight, digestive tract length, diet composition, and body length were all measured for each sample. The length distribution, relative gut length, food composition, index of preponderance (IP), trophic level, niche breadth, and food overlapping were among the data examined. The largehead hairtail is a carnivorous fish with a trophic level of 4.42. The primary food items consumed by the hairtail were fish and shrimp (IP = 57.89 and 39.68%, respectively). Competition among fish sizes to get food is relatively low, and the type of food composition increases along with increasing body size.

INTRODUCTION

The commercially important teleost fish, hairtail (*Trichiurus* spp., Family Trichiuridae) is a benthopelagic fish that inhabits both tropical, temperate, and arctic waters **(Nakamura & Parin, 1993; Shin *et al*., 2022)**. This fish species has become an export commodity in global trade and has contributed economically to several countries, such as India **(Rohit *et al*., 2015)**, Japan **(Makino *et al*., 2017)**, Indonesia **(Apriliani *et al*., 2018)**, the Middle East **(Hashemi *et al*., 2020)**, China **(Liao *et al*., 2021)**, Korea **(Jeong *et al*., 2021)**, dan Brazil **(Boza *et al*., 2022a)**. Recent data showed that the world's total production of largehead hairtail in 2020 was 1.14 million tons (1.7 % of total finfish production) **(FAO, 2022)**. In Indonesia, the number of captured largehead hairtails in 2021 was 97,000 tons and has increased from the previous year (82,000 tons in 2020) **(Ministry of Marine Affairs and Fisheries, 2023)**. Due to its increasing commercial value and increasing catch volumes, the basic ecology, life history, population dynamics, habitat, and environmental conditions of the largehead hairtail are being widely studied

(Kim *et al*., 2005; He *et al*., 2014; Kim *et al*., 2020; Sun *et al*., 2020; Mammel *et al*., 2022). In addition to basic biological knowledge, food preferences and niche breadth are essential for the effective management and conservation of this specific fish population.

Largehead hairtail, *Trichiurus lepturus* is predominantly piscivorous and tends to cannibalism, which is associated with the diet of pelagic organisms **(Cruz-Torres *et al*., 2014)**. It controls small pelagic and benthic fish populations due to utilizing similar food sources in the habitat **(Yan *et al*., 2011)**. This species migrates to warmer waters and remains at certain times of the year to exploit prey that reproduces and of appropriate size in the environment **(Boza *et al*., 2022b)**. *Trichiurus lepturus* species, such as adult females, prefer to feed on prey species relative to the nutritional and caloric characteristics of their prey species **(Bittar *et al*., 2012)**.

Hairtail is widely distributed in almost all Indonesian waters, including the Southern Waters of Java Island (Fisheries Management Area (FMA) Number 573) and the Northern Waters of Java Island (FMA 712). This species is a highly predatory fish that plays an essential ecological role in controlling populations of mid- and lower-trophic levels of marine food webs (e.g., fish, squid, and crustaceans) through prey and predation processes **(Yan *et al*., 2011)**. Food availability is a crucial ecological factor that significantly influences the growth and condition of fish, as well as the growth and dynamics of populations **(Nikolsky, 1963)**. Growth depends upon the quantity and quality of food ingested, with inadequate nutrition retarding growth and delaying developmental transitions, such as the timing of the onset of sexual maturation **(Jobling, 2002)**.

Previous studies of hairtails showed a variety of results in food preferences. *Trichiurus margarites* inhabiting the South China Sea consume small fish (*Bregmaceros rarisquamosus* and *B. nectabanus*), and shrimp as their main food **(Yan *et al*., 2012)**. Meanwhile, *T. lepturus*, in the Northern waters of Rio de Janeiro, Brazil, feeds mainly on crustaceans **(Bittar and Di Beneditto, 2009)**. The variation of food preferences and niche breadth of hairtail might depend on prey availability and be influenced by predation at all trophic levels. Understanding the food habits of fish provides accurate quantification of diet composition, factors affecting diet composition, and feeding patterns to determine trophic ecological interactions in aquatic food webs and support aquatic fisheries management **(Chipps & Garvey, 2006)**. This study aims to determine the food preferences and niche area of *Trichiurus lepturus* caught in Pangandaran Coastal Waters, West Java.

MATERIALS AND METHODS

In total, 234 hairtails were collected using hand lines and gill nets with mesh sizes of 2 inches of fishermen's catch in Pangandaran waters, West Java (Fig. 1). Each sample obtained was measured for its total length (± 0.1cm) and weight (± 1g), and then dissected to observe the gonads and digestive tract. The intestine and stomach were separated, then the length of the fish intestine was measured using a ruler (accuracy 0.1cm), and the stomach was preserved in a solution of 4% formalin **(Berg, 1979)**. The stomach was dissected, and its contents were placed in a tube filled with distilled water. A sample of stomach contents in 1ml was placed in a Sedgwick rafter counting chamber containing a 2×2×1mm^3 box to calculate the volume of each type of food item in the fish stomach. The composition of the larger food items was identified visually, while the small food items were identified using a microscope at 4× and 10× magnification.

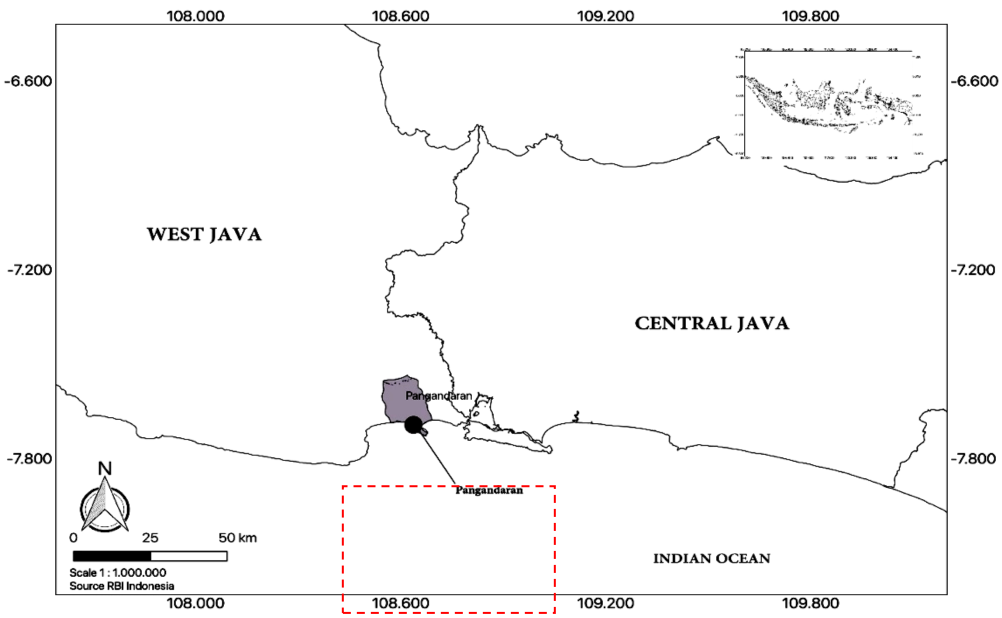

Fig. 1. Sampling locations and estimated fishing areas of largehead hairtail in Pangandaran Waters

The total length of samples were grouped into size classes using the Sturges rules **(Sturges, 1926)**. The determination of the number and length of size classes were calculated using the formula:

Number of classes (k) = 1+3.332 log(n)

Note: k = number of classes; n = number of observations

Relative gut length describes fish feeding habits according to the ratio of the length of the intestine to the fish's total length. **Nikolsky (1963)** stated that the relative gut length is categorized as carnivorous <1, omnivorous 1–3, and herbivorous >3 using the formula:

$$\textbf{Relative Gut Length = Total Gut Length/Total Length}$$

Food composition determines the type of food found in the fish's stomach and the percentage of each type of food. Each type of food item found in the stomach was analyzed using the frequency of occurrence method, which is determined by noting the presence of each organism in several fish digestive organs and expressed in percentage **(Effendie, 1979)**. The frequency of occurrence was calculated using the formula:

$$FK = (Ni/I) \times 100\%$$

Note: FK = Frequency of Occurrence; Ni = The total number of one type of organism; I = Total number of gut-filled

The index value of the largest part of fish food items was divided into three groups, namely main food (IP value >25%), complementary food (5% ≤ IP ≤ 25%), and additional food (IP value <5%) **(Biswas, 1993)**, which was calculated as:

$$IP = \frac{V_i O_i}{\sum_{i=1}^{n} V_i O_i}$$

Note: IP = Index of Preponderance; Vi = percentage of fish food volume type-i; Oi = percentage of occurrence frequency of food type-i; n = number of fish food organisms (i = 1,2,3,…, n)

The trophic level illustrates the position of a fish in the ecosystem's food web. The value of the trophic level was determined based on the relationship between the trophic level of the food organisms and the feeding habits of the fish. Fish trophic levels were classified into three categories: herbivores=2, omnivores=2,5 and carnivores ≥ 3 **(Caddy & Sharp, 1986)**. The trophic level was calculated using the formula:

$$Tp = 1 + Ttp \times Ip100$$

Note: Tp = trophic level; Ttp = trophic level of the food type-p; Ip = index of preponderance of food type-p

The niche breadth shows the ability of fish to adapt to the fluctuations in food availability in the ecosystem using Levins measure **(Krebs, 1989)**, it was calculated as follows:

$$B=\frac{1}{\sum p_j^2}$$

Note: Bij= niche breadth of fish size-i toward food resource-j; Pij = proportion of the fish size-i that is related to food resource-j; n = number of food in the fish groups (i = 1, 2, 3, ..., n); and m = number of food resources (j=1,2,3,…,m).

Standardizing the area of the food niche breadth to get scale of 0–1 using the formula **(Krebs, 1989)**:

$$B_A = (B-1)/(n-1)$$

Note: B_A = standardized Levins niche breadth (range 0–1); B = Levins niche breadth measure; n= the number of possible resources states. Levins standardized niche breadth ranges from 0 to 1 where 0 is the narrowest niche breadth when there is a single food resource used and 1 is the broadest niche breadth when the all category of food resources are equally used.

Niche overlapping describes multi-shared food resources, and is calculated as follows **(Krebs, 1989)**:

$$C_h=\frac{2\sum_i^n p_{ij}p_{ik}}{\sum_i^n p_{ij}^2+\sum_i^n p_{ik}^2}$$

Note: Ch = Simplified Morisita Index between the fish size j and the size k; Pij, Pik = Proportion of the resources-i from the total resources used by fish size the j and k (i = 1, 2, 3, ..., n).

RESULTS

1. Fish length distribution

The total number of samples observed was 234 individuals with food in the digestive tract. The distribution of the frequency of total length in Pangandaran waters can be seen in Fig. (2). The length range of hairtail fish in Pangandaran waters is from 36 to 55.5cm. The fish length class from 55 to 58.7cm is the largest size, with 2 fish (0.9%), while the length class from 36 to 39.7cm is the smallest with 14 fish (6%). Hairtail fish length in Pangandaran waters is dominated by 39.8 to 43.5cm, with a frequency of 115 individuals (49.1%).

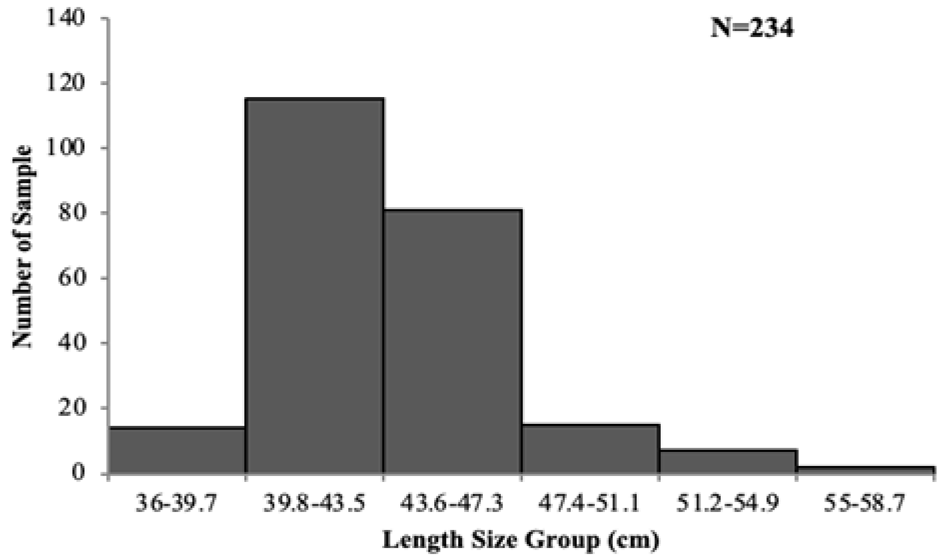

Fig. 2. Length frequency distribution of *Trichiurus lepturus* in Pangandaran waters

2. Relative gut length

The relative gut length can be used to observe the type of fish feeding habits based on its gut length. Largehead hairtails from Pangandaran waters are carnivorous, which is characterized by relatively short gut lengths, ranging from 0.11 to 0.37cm. The lowest relative intestinal length was between 36– 39.7cm (mean 0.24± 0.02) and the highest was between 55– 58.7cm (mean 0.24± 0.02). Table (1) presents the relative intestinal length of *T. lepturus* in Pangandaran waters.

Table 1. Gut length characteristic of largehead hairtail fish between length size group

Length size group	Gut length size (cm)	Relative gut length mean	Size (cm)	Mean
36-39.7	7.5-10	9.3±0.9	0.21-0.27	0.24±0.02
39.8-43.5	6.9-13.5	9.51.2	0.16-0.31	0.23±0.03
43.6-47.3	4.9-17	10.1±1.9	0.11-0.37	0.22±0.04
47.4-51.1	8-16	11.3±1.8	0.16-0.34	0.23±0.04
51.2-54.9	10.6-16.5	13.3±1.6	0.19-0.32	0.25±0.03
55-58.7	11.5-15	13.6±1.3	0.21-0.26	0.24±0.02

3. Food composition

There are three types of food found in the hairtail stomach: fish (whole, pieces of fishflesh, and fish bones), shrimp, and squid. Small fish dominated the hairtail food, with a composition of 73%; shrimps have a fairly large percentage of 18%; and squids make up 9% of the hairtail food composition.

4. Frequency of occurrence

The frequency of occurrence describes the intensity of each type of food found in a fish's digestive tract. Fish and shrimps are the two most common types of food found in the digestive system of largehead hairtails (Fig. 4).

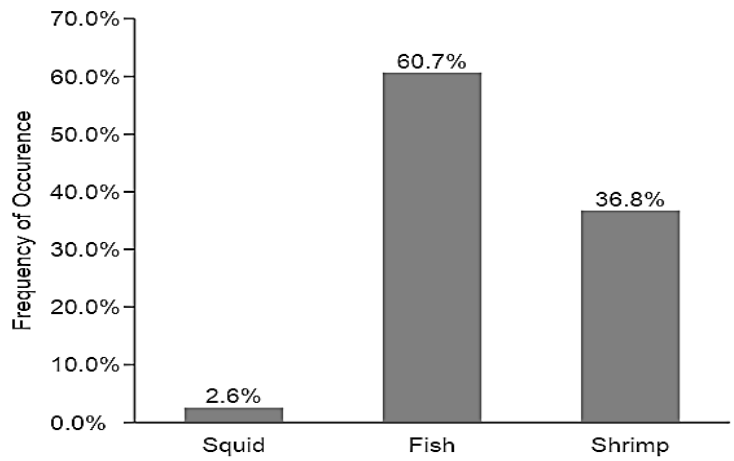

Fig. 4. Frequency of occurrence of *Trichiurus lepturus* in Pangandaran waters

5. Index of preponderance (IP)

The index of preponderance (IP) shows the type of main food and other food for hairtail fish (Table 2). Fish is the primary food for hairtails, whereas squid is the least common additional food and shrimp is a complementary food source in hairtails' stomachs. The index of the largest part of the hairtail found in Pangandaran waters, based on group size, reveals differences in the type of food consumed.

Table 2. Index of preponderance (IP) of *Trichiurus lepturus* in Pangandaran waters

Food type	Vi	Oi	ViOi	IP (%)	Category
Fish	723.6	142	102,751.2	86.49	Main Food
Shrimps	180.5	86	15,523	13.07	Complementary Food
Squids	87.7	6	526.2	0.44	Additional Food
Total		234	118,800	100	

The index of preponderance based on largeheadhairtail size group showed that fish and shrimp were the most preferred foods for the small fish and the larger fish, while squid was the least consumed by all size groups of hairtails. The young hairtails, with a length of less than 43.5cm, preferred small fish and small shrimp, while adult hairtails ate fish, shrimp, and squid. The youngest hairtail, with a length range 36 to 39.7cm, only consumed small shrimp, while the largest hairtail, with a length over 55cm, preferred to consume only fish. Hairtails with a length range of 47.4 to 51.1cm consumed the largest percentage of shrimp (76.74%). The index of preponderance of *T. lepturus* based on their length size group can be seen in Table (3).

Table 3. Index of preponderance (IP) of *Trichiurus lepturus* based on length size group in Pangandaran waters

IP (%)	Length size group (cm)					
	36-39.7	**39.8-43.5**	**43.6-47.3**	**47.4-51.1**	**51.2-54.9**	**55-58.7**
Fish	84.43	72.32	96.16	23.26	98.48	100
Shrimp	15.57	17.87	3.47	76.74	1.52	0
Squid	0	3.81	0.36	0	0	0
Total	100	100	100	100	100	100

6. Trophic level

The trophic level at Pangandaran Beach showed that largehead hairtail were carnivorous (mean 3.7 ± 0.3). Furthermore, the trophic value of largehead hairtail increases with increasing length. The highest value of the trophic level was in the length group >47.4cm, with a value of 4.21, while the smallest value was 3.52 in the group with a length of 55– 58.7cm. The results of the trophic level of largehead hairtail based on the length size group can be seen in Table (4).

Table 4. The trophic level of *Trichiurus lepturus* based on length size group in Pangandaran waters

Length size group (cm)	Trophic level	Description	Fishbase
36-39.7	3.66	Carnivore	4.4±0.4
39.8-43.5	3.71	Carnivore	4.4±0.4
43.6-47.3	3.55	Carnivore	4.4±0.4
47.4-51.1	4.21	Carnivore	4.4±0.4
51.2-54.9	3.53	Carnivore	4.4±0.4
55-58.7	3.52	Carnivore	4.4±0.4

7. Food niche breadth

The breadth of largehead hairtail food niches in Pangandaran waters ranged from 1 to 1.56. The lowest niche breadth values were found in the length-size group greater than 51.2cm. The length size group of 39.8 to 43.5cm and 47.4 to 51.1cm had the highest food niche breadth, with a value of 1.55 to 1.56 (standardized 0.27 to 0.28). Table (5) displays the results of the largehead hairtail food niche calculation in Pangandaran waters.

Table 5. Food niche breadth of *Trichiurus lepturus* in Pangandaran waters

Length size group (cm)	$\sum Pi^2$	Niche Breadth ($1/\sum Pi^2$)	Standardization
36-39.7	0.74	1.36	0.18
39.8-43.5	0.65	1.55	0.27
43.6-47.3	0.93	1.08	0.04
47.4-51.1	0.64	1.56	0.28
51.2-54.9	0.97	1.03	0.02
55-58.7	1	1	0

8. Overlapping food niches

The degree of overlap in the food niche of largehead hairtail in Pangandaran waters varies from 0.2984 to 0.999. The food overlap value reached its peak when comparing fish with length size ranging from 43.6 to 47.3cm with those above 51.2cm, suggesting intense competition for food resources. Conversely, 43.6 to 47.3cm length group did not compete for food resources with the 47.4 to 51.1cm length group, and the 47.4 to 51.1cm did not compete for food resources with the 51.2cm length group. Table (6) displays the overlap of food niches among largehead hairtails in Pangandaran waters.

Table 6. Overlapping food niches of *Trichiurus lepturus* in Pangandaran waters

Length size group (cm)	36-39.7	39.8-43.5	43.6-47.3	47.4-51.1	51.2-54.9	55-58.7
36-39.7	1	0.996	0.983	0.800	0.977	0.972
39.8-43.5		1	0.965	0.495	0.957	0.951
43.6-47.3			1	0.319	0.999	0.999
47.4-51.1				1	0.298	0.283
51.2-54.9					1	0.999
55-58.7						1

DISCUSSION

The hairtail caught in the Pangandaran waters was identified as largehead hairtail, *T. lepturus*. Hairtails have a different diet from juveniles and adults, where adult hairtails generally migrating vertically to find food near water surface during the day and moving to the bottom at night. In contrast, juveniles form groups to forage at night on the surface **(Nakamura & Parin, 1993)**. Fishermen in Pangandaran waters start fishing at midnight, when the sun has not yet risen. They landed at the fishing port at noon, so fishing activities might not coincide with fish feeding habits.

Largehead hairtails caught in Pangandaran waters have a total length ranging from 35.6 to 55.5cm. Juvenile groups of largehead hairtails, with total lengths ranging from 39.8 to 43.5cm, dominated the fish caught in Pangandaran waters. Length and size of largehead hairtails vary between pre-juveniles (<5cm), juveniles (5– 70cm), and adults (70– 160cm) **(Martins *et al*., 2005)**. Although hairtail fish can reach a maximum length of 120cm, they typically range from 50 to 100cm **(Nakamura & Parin, 1993)**. Several factors, such as food availability, water quality, heredity, sex, age, and disease, can cause differences in hairtail growth **(Effendie, 2002)**. Hairtail sampling was not carried out during fishing season due to high sea waves, making it difficult for fishermen to catch the fish.

Relative gut length indicates the type of food consumed by largehead hairtail. The relative gut length of largehead hairtails in Pangandaran waters, with a gut length value of 0.11 to 0.37, is similar to that of *T. lepturus* in India, reaching 0.084– 0.322. Furthermore, this study's findings on the relative gut length of *T. lepturus* indicate a highly carnivorous feeding behaviour in Indian coastal waters **(Koya *et al*., 2018)**.

The food consumed by largehead hairtails in Pangandaran waters consists of three major types of food: fish, shrimp, and squid. Largehead hairtails ate general food items such as fish, squid, and crustaceans **(Nakamura & Parin, 1993)**. The diet of *T. lepturus* collected from north-west coast of India mainly consisting of fishes (47%) and crustacean (45%) **(Koya *et al*., 2018)**. Anchovies, sardines, ponyfish, and white snapper are the types of food found in the digestive tract of the largehead hairtail (*T. lepturus*) in Bandengan coastal waters and Tawang waters. Different geographic locations between biotic and abiotic environmental conditions, such as temperature, light, space, and surface area, influence the food composition **(Abidin *et al*., 2013)**.

Largehead hairtails caught in Pangandaran waters frequently contain fish and shrimp in their stomachs, while their gut occasionally contains squid. Small proportion of mollusc in the diet of *T. lepturus* are also reported in other studies **(Koya *et al.*, 2018; Rajesh *et al.*, 2022)**. Gradual changes in the aquatic environment can affect different types of fish food, affecting food availability and subsequently altering fish behavior and feeding habits **(Effendie, 2002)**. Additionally, food size, color, taste, texture, the fish's preference for food, and the availability of food in the waters strongly influence the fish's preference for a particular type of food **(Effendie, 1979)**. For comparison, *T. lepturus* in Brazil's southern watershave different food types depending on their size. Larvae and pre-juveniles (<5cm) have a preference for copepods, while juveniles (5– 30cm) have a preference for crustacean zooplankton. Juveniles (30– 70cm) prefer euphausiids and small fish, and adults (70– 160cm) have a wider range of diets, with anchovies, cephalopods, and crustaceans being the main food items **(Martins *et al*., 2005)**.

The index of preponderance is used to assess the different food preferences of fish **(Effendie, 1979)**. Based on the results of calculating the index of preponderance, it was found that the main food for hairtail fish in Pangandaran waters was fish with a percentage of 86.49%. The calculation of the index of preponderance revealed that fish (86.49%) served as the primary food source for largehead hairtail fish in Pangandaran waters. Similar results were shown in *T. lepturus* from the southwest of Taiwan, which fed mainly on fish, with a percentage of 75.2%. The feeding activity and the amount of food consumed will increase as the body size of the hairtail fish increases **(Chiou *et al*., 2006)**. The variety of food preferences will increase as the length of the size group increases (Table 3). According to **Yousuf and Tabassum (2011)**, an increase in *T. lepturus* size leads to a corresponding increase in food items and feed intensity. *T. lepturus* diet changes with increasing body size, allowing fish to consume larger prey **(Gomathy & Vivekanandan, 2017)**.

The largehead hairtail (*T. lepturus*) in Pangandaran waters did not exhibit cannibalism since the majority of the hairtails were juveniles, measuring between 30 and 70cm. However, cannibalistic behavior in *T. lepturus* was reported in the southern waters of Brazil, where the larger fish ate the smaller ones due to the length of the hairtail fish, which ranges from <5 to 160cm. Cannibalism is induced by the gains of high protein and high caloric value **(Di Beneditto, 2015)**. Additionally, cannibalism activity is more common in summer when biological productivity decreases **(Martins *et al*., 2005)**. Cannibalism in certain fish in aquatic ecosystems can occur due to the decreased density and availability of food in these waters **(Chiou *et al*., 2006)**.

The largehead hairtail in Pangandaran waters has a trophic level value of 3.52 to 4.21, which indicates it is a carnivorous fish. **Murugesan *et al*. (2012)** reported similar results for *T. lepturus* in Parangipettai and Cuddalore, India, with a trophic level value of 4.4. Largehead airtail fish (*T. lepturus*) have a trophic level of 4.1 in the Egyptian Mediterranean Sea **(Bakhoum, 2007)**. The trophic level value of largehead hairtail fish (*T. lepturus*) increases as the total length increase **(Bakhoum, 2007)**. Hairtails play a role in aquatic ecosystems by regulating the number of lower trophic level organisms, such as fish, crustaceans, and cephalopods **(Yan *et al*., 2012)**.

The highest value of the niche area of the largehead hairtail is in the size group of 47.4 to 51.1cm, which indicates that this group of fish is widely utilized by more of the available food resource groups that are evenly distributed over the food available in these waters. **Colwell and Futuyma (1971)** stated that a large food niche indicates that fish consume various foods, while a small niche area indicates that fish are more specific in choosing their food. A large variety of food does not guarantee a large niche area, as the fish's ability to utilize available resources also influences the niche's value. The food niche's value is small in the fish size ranging from 51.2 to 54.9cm. Differences in food availability, abundance, and a fish's habitat can cause differences in the breadth of food niches. Small fish will use a small niche area, whereas larger fish will change their diet to use a large niche area **(Effendie, 2002)**.

Food overlap values describe the utilization of food resources by fish length and size groups. The similarity among the length-size groups can lead to competition. The length size group that ranged from 43.6 to 47.3cm had the highest food overlap value, with a value of 0.999, compared to those above 51.2cm. All higher length-size groups have a niche overlap value close to 1, which reflects similar food resources and leads to competition. In contrast, less competition was shown among the smaller size groups (47.4 to 51.1cm with 39.8 to 43.5cm; 43.6 to 47.3cm with more than 51.2cm). These length-size groups are more selective in choosing food according to their mouth opening, resulting in differences in food utilization. In the South China Sea, there was significant niche overlap among largehead hairtails, which were in the wide niche group **(He *et al*., 2022)**. Adult females of *T. lepturus* feed during the cold season, while adult males prefer warmer waters for feeding **(Martins & Haimovici, 2000)**.

CONCLUSION

Fish is the main food for largehead hairtail fish (*Trichiurus lepturus*) in Pangandaran waters, with an index of preponderance (IP) value of 57.89%. The largehead hairtail is a carnivorous species with a trophic level of 3.7. Less competition occurs between different sizes of fish for the same diet; larger largehead hairtail fish consume a more varied diet.

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