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Feeding Preference of Cutlassfish (*Trichiurus lepturus* Linnaeus) in Coastal Waters of Gunungkidul, Yogyakarta

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Abstract

Research on cutlassfish’s diet has been carried out in several areas, but similar research does not exist or still rarely found in Gunungkidul. The aim of this study is to determine the overall composition of the cutlassfish's food, the most dominant type of food and cutlassfish's growth pattern. Methods including random sampling in the field, measurement of length and weight and identification of food types using stomach analysis method and proximate analysis on both cutlassfish’s muscle and diet. The results of the study then analyzed using the formula by Walpole (1992), length-weight relationship formula according to Le Cren (1951) followed by determining the value of b with the *t-test* at confidence interval of 96% and condition factor. Food composition and preferences were calculated using numerical and volumetric methods to find the IP (*Index of Preponderance*) and IRI (*Index Relative Importance*) values. Composition based on types of food is dominated by fish at 89% with Engraulidae as the main group with total percentage of IP 45.58 and IRI 76.47, respectively. Proximate analysis values indicate low levels of protein (with highest value of 23.82%) and high-moisture content (with highest value of 71.98%) caused by cold temperatures during storage. The regression showed that cutlassfish have an allometric positive growth pattern. The results revealed that the food is sufficient for the growth of cutlassfish (*Trichiurus lepturus*).

Keywords: stomach content analysis, *Trichiurus lepturus*, Gunungkidul, length-weight relationship

1. Introduction

Gunungkidul is an area that has abundant fish resources. This resource is widely used by fishermen which makes this area the main producer of capture fisheries products in Yogyakarta Province. According to Department of Marine and Fisheries of Yogyakarta (Bappeda), cutlassfish caught in Gunungkidul Regency in 2019 reached a proportion of up to 667.50 tons from the total of fisheries production as much as 121625.25 tons.

The coastal and marine areas in the southern part of Yogyakarta has several important commodities including tuna, skipjack, marlin, lobster, cutlassfish, snapper, and shrimp (Sahubawa et al, 2009). Cutlassfish is an economically important fish commodity since there is an export demands from several countries in Asia such as China, Korea and Japan (Anita & Nurani, 2004). Cutlassfish is a demersal fish which widely found in the southern waters of Java (Ardani, 2012). Demersal fish generally lives in the area near the bottom of the sea (Nontji, 1987). These fish tend to be sedentary, not clustered within the same group of fishes which caused them to have a low resistance towards excessive fishing and more vulnerable to exploitation (Agustina et al, 2015).

Food is an ecological factor that plays an important role in determining the level of density, dynamics, population growth and condition of fish (Nikolsky, 1963). The type of fish diet usually depends on maturity, place and time (Effendie, 1997). Fish diet signify the integration of many ecological elements such as behavior, organism's conditions, habitat use, energy intake and inter or intraspecific interactions (Nath et al, 2015). In addition, in the canning industry, returning certain population size of fish depends on knowledge of its food preferences (Colt, 1986).

In this research, we are using *Trichiurus lepturus* belonging to the Trichiuridae family as the focus on this study. This family consists of many species that are widespread in various parts of the world but in general *T. lepturus* often found in the southern parts of Java based on several interviews with fishermen near Gunungkidul area. *T. lepturus* is characterized by an elongated and flattened body like a ribbon and tapering at one-point. This species lacks anal and caudal fins, the body is usually silvery blue. *T. lepturus* generally has a length of 50 to 100 cm and a maximum of up to 1.2 m (Nakamura and Parin, 1993). Larvae are usually pelagic and the early juvenile stages are carried by currents into shallow water and sometimes up to estuaries (Benson, 1982). This fish swims in a vertical position where the head is at the top (Badrudin and Wudianto, 2004). Young cutlassfish mostly eat small planktonic crustaceans in waters such as *Paracalanus*, *Acartia*, *Oncaea*, and others as well as small fish. Adult cutlassfish turn into piscivores and eat anchovies, sardines, groups of Myctophidae (lantern fish), Bregmacerotidae, Carangidae, Sphyraenidae, Atherinidae, Sciaenidae, Scomber fish genera, *Trichiurus*, and sometimes squid and crustaceans. Juvenile and adult fish has the opposite complementary vertical diurnal feeding migrations (Nakamura and Parin, 1993).

Several studies on cutlassfish feeding preferences have been carried out in several areas such as Pelabuhanratu (Sari, 2008), Banyuwangi and Trenggalek (Nuarinta, 2015), Aceh (Nasution et al, 2018), Jepara (Abidin et al, 2013), Cilacap and Banten (Prihatiningsih and Nurulludin, 2014), but similar research or studies covered Gunungkidul coastal waters area does not exist. *T. lepturus* based on several studies has differences in food composition, with mainly fish like anchovies, Leiognathidae and Scombrids (Nasution et al, 2018; Nuarinta, 2015; Abidin et al, 2013) but the growth patterns are likely the same. The aim is to determine the overall composition of cutlassfish's food, the most dominant type of food and testing the hypothesis that adult *T. lepturus* mainly prey on fish (anchovies), beside growth pattern as a tool to understand cutlassfish's feeding habit and food availability on its habitat. So, it's necessary to continue the study on cutlassfish feeding preference to determine the specific type of food as one of biological aspects.

2. Materials and Method

2.1 Study Area

Gunungkidul Regency is one of districts in the Special Region of Yogyakarta (DIY), and located between 7'46 '- 8'09' South Latitude and 110'50 'East Longitude (Pokja Sanitasi Kabupaten Gunungkidul, 2010). The amount of sea surface temperature along the southern coast of Gunungkidul in March ranged from 29.6 ℃ -30.1 ℃. Salinity varies between 30.0-31.8 psu. The range of salinity is quite wide, around 1.8 psu. The sea waves size quite high and varies between 0.3-3.0 m with an average wave height of ≥ 1.2 m. Some coastal waters generally have wave periods between 6.0-18.6 seconds with an average wave period of ≥ 10 seconds. The distribution of temperature and salinity in March reflects a very favorable conditions for aquatic ecology and the level of tolerance for aquatic biota. This area descriptions are taken based on study conducted by Nurhayati (2015).

2.2 Data Sampling

Data sampling was conducted for 2 times, at March 15th and March 28th 2020. Fish are caught using nets by fishermen in Gunungkidul coastal waters at a depth of 30-50 m which is done in the afternoon from 5 in the evening to 6 in the morning, duration of the data collection were adjusted depends on the weather's condition. Samples then separated according to the size groups. Fish with a certain size group are separated based on stomach fullness. Cutlassfish samples then measured in total weight and length. Fish length and weight values then inserted into a table provided.

Sample dissected using surgical kit starting from the anus to the ventral part below the lateral line to the back of the operculum, from the ventral to the lower side of the abdomen. The digestive organs which were analyzed including stomach, *pyloric caeca*, and intestines. The digestive apparatus then put into a bottle with ethanol 70% and labeled according to the sample's code and date of collection.

Observation of cutlassfish's food composition carried out by cleaning the digestive tract from alcohol with distilled water and drying it with a tissue or filter paper. Food inside the stomach are separated based on each type of food and then measured by weight and volume. The total weight of food for each stomach calculated using digital scale. Volume of cutlassfish's food is determined using displacement method. The types of food were observed and identified directly using binocular microscope. Food identification referred to Holthuis (1980) and White et al. (2013). Data obtained and analyzed using numerical, volumetric and gravimetric methods as a part of stomach content analysis to find the IP (*Index of Preponderance*) (Natarajan and Jhingran, 1961) and IRI (*Index Relative Importance*) (Pinkas et al, 1971) values.

Proximate analysis is performed after the type of food has been observed and identified. Proximate analysis is carried out by mixing all types of food to determine the content of moisture, fat, ash, protein and carbohydrates in general. In addition, this analysis also carried out on cutlassfish's muscle. Mixed types of food then divided into two parts, weighing 30 grams each and divided it into two samples with the same type and composition of food organism (sample I and sample II) and then put it into airtight plastic bag. Fish muscle (sample III) were taken from a total of 35 fish then mixed and weighed, the proximate analysis result will be the average mixture of all fish muscles. The samples were then taken to the Universitas Gadjah Mada's Food and Nutrition Laboratory for further analysis.

This quantitative analysis is presented in the form of %. Analysis of moisture and ash content was carried out using a thermo-gravimetric method where the principle is to evaporate water from the material by heating it until it reaches a constant weight. Analysis of lipid levels using the Soxhlet extraction method followed by protein analysis using the macro-Kjeldahl method. In this method, the total nitrogen content in the sample was measured.

2.3 Data Analysis

Fish length measured and then divided based on frequency of each length class refer to formula by Walpole (1992). To determine the number of length groups using formula:

$$n = 1 + 3{,}32 \log N \tag{1}$$

Then, we determine the width of each class with formula:

$$C = \frac{a - b}{n} \tag{2}$$

The analysis of the length-weight relationship is needed to determine the growth pattern of fish in nature and can be used as a basis for comparing feeding habits between length and feeding activities (Effendie, 1979). The relationship of length and weight is calculated using the formula by Le Cren (1951):

$$W = aL^b \text{ expressed as } lnW = lna + \text{blnL} \tag{3}$$

The b value used to estimate the growth pattern of the two parameters analyzed, with the hypothesis b = 3 indicates an isometric growth pattern while b ≠ 3 indicates an allometric growth pattern. Determination of b value is done by using the *t-test* at a confidence interval of 96% (α = 0.05) (Steel and Torie, 1989).

The number of individuals for each food category on every stomach recorded and calculated as a percentage (Hynes, 1950). Percentage value of each food category is calculated using the formula:

$$\%Ni = \frac{Ni}{Nt}\ x\ 100 \quad (4)$$

Where, Ni is the number of food category i

Stomach contents are examined, food category on each stomach separated and identified. The amount of stomachs contains the same food category then recorded and expressed as a percentage of the total number of stomachs examined (Baker et al, 2014).

$$Oi = \frac{Ji}{P} \quad (5)$$

Where, J_i is the number of stomachs containing prey I and P is the total number of fish with food in their stomach.

Volumetric method is quantitative analysis method, as one part of the stomach content analysis. In this study we used displacement method for assessing the volume of each food category. The volume of each food category is measured in a graduated container and calculate using formula:

$$\%Vi = \frac{Vi}{Vt}\ x\ 100 \quad (6)$$

Where, V_i is the volume of prey i

Index of Preponderance (IP) provides a brief overview of the frequency of occurrence as well as the major portions of various food category. IP value of each food category can be evaluated by a combination of volumetric and gravimetric methods (Natarajan and Jhingran, 1961).

$$\textit{Index of Preponderance},\ \mathrm{IP} = \frac{ViOi}{\Sigma ViOi} x100 \quad (7)$$

Where V_i and O_i are the volume and occurrence of food category i

Index Relative Importance (IRI) is an integrated measurement of number, volume, and frequency of occurrence to assist in the evaluation of the relationship between various types of food found in the stomach. This index is calculated by adding the numeric and volumetric percentage values and multiplying it with frequency of occurrence (Pinkas et al, 1971).

$$IRIi = (\%Ni + \%Vi)\ \%Oi \tag{8}$$

3. Results

3.1 Index of Preponderance and Index Relative Importance

A total of 35 *T. lepturus* were caught in March. Total of 28 fishes were caught in March 15th and the rest of them caught in March 28th 2020. Fish sample were used depends on the availability of the species in one location. Based on the IP value obtained, which can be seen on the histogram (Figure 1), the fish dominates the IP value of 99.940% followed by shrimp and sea eel at 0.047% and 0.013%.

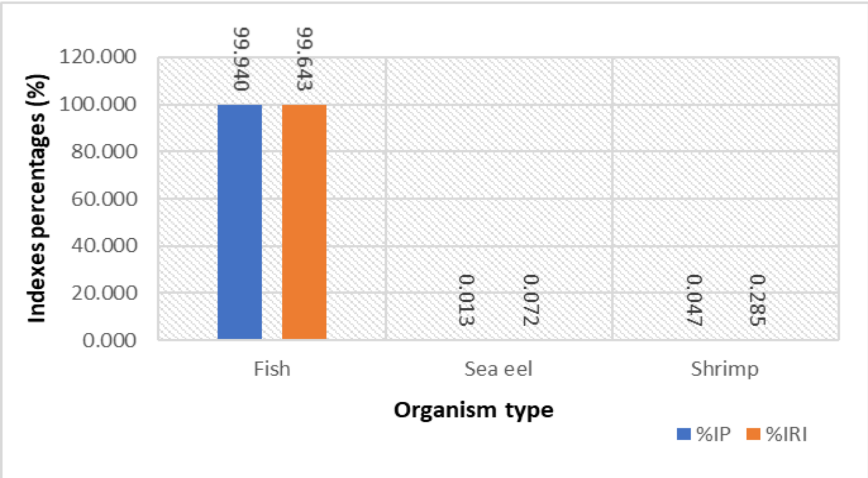

Figure 1. Index of Preponderance (IP) and Index of Relative Importance (IRI) of the stomach contents based on the type of organism

Engraulidae or anchovy had the highest IP and IRI values, with a total IP of 41.52% and followed by unidentified fish as much as 33.62% (Figure 2). This number indicates the dominance of anchovy (Engraulidae) as one organism preferred by *T. lepturus*. The IRI percentage of Engraulidae is 76.10%, followed by unidentified fish with 13.97%. From the results it showed that anchovy is the most important food compared to other types of food.

The IP number basically shows the dominance of the type of food consisting of Engraulidae (45.12%), not identified (33.62%), Megalopidae (13.6%), Lutjanidae (5.71%), Leiognathidae (3.26%) and Scorpaenidae (2.45%) (Figure 2). The dominance of this type of food can be related to the availability of food in its natural habitat.

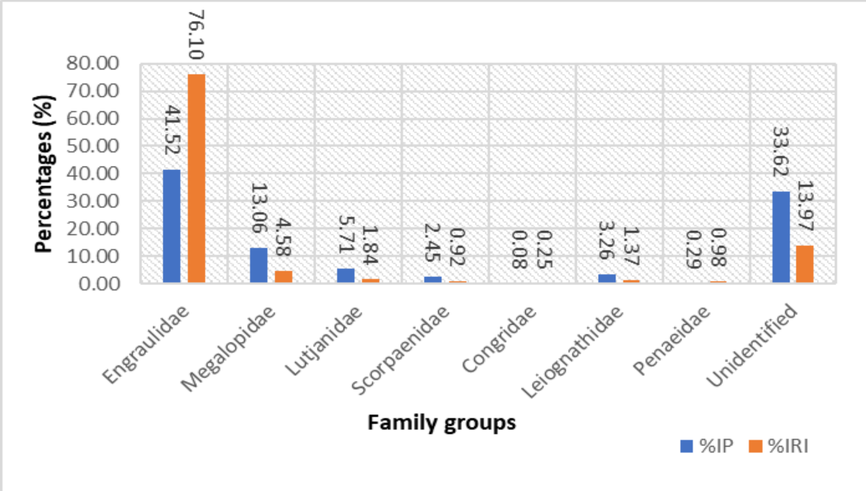

Figure 2. Index of Preponderance (IP) and Index of Relative Importance (IRI) of the stomach contents based on the family groups

3.2 Food Composition

Food composition in the fish stomach were calculated based on the frequency of occurrence (%O_i), where this figure shows the occurrences of each type of food based on the total number of stomachs containing food. Food composition is distinguished by the type of organism and family groups. Fish has the highest frequency of occurrence found in a total of 24 stomachs containing food (Figure 3) with 88%, followed by shrimp and eel with the number of 8% and 4%, respectively.

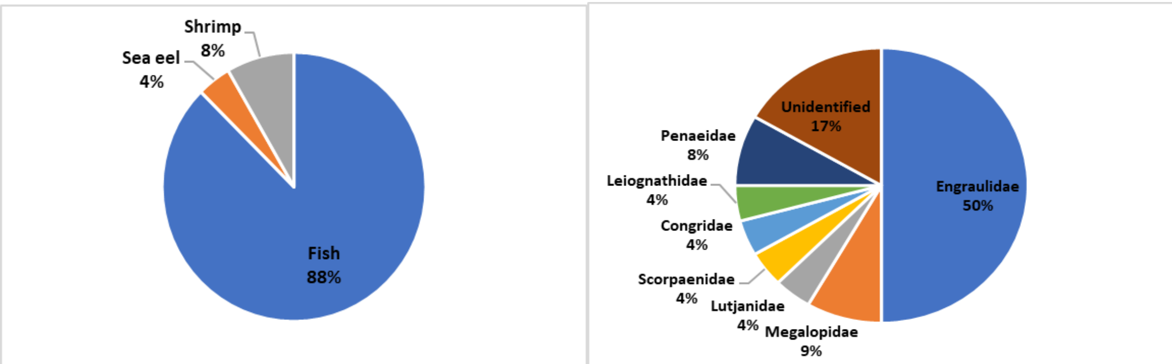

Figure 3. Proportion of cutlassfish's stomach content based on: type of organism (left), and family group (right)

After calculating the frequency of occurence (O_i%) to determine the composition of the stomach contents, the types of food is then divided again based on stomach contents per length class measurement. It can be seen in Figure 4 that all length classes has fish as the main food, especially stomach observed from 595-621 mm and 759-785 mm length classes. There were no food found in the stomach of fish belongs to the 704-730 mm and 731-758 mm length classes. Shrimp were found in 622-648 mm and 649-676 mm length classes with percentage amount of 25% and 11%, followed by sea eel which only can be found in 677-703 mm length class by 13%.

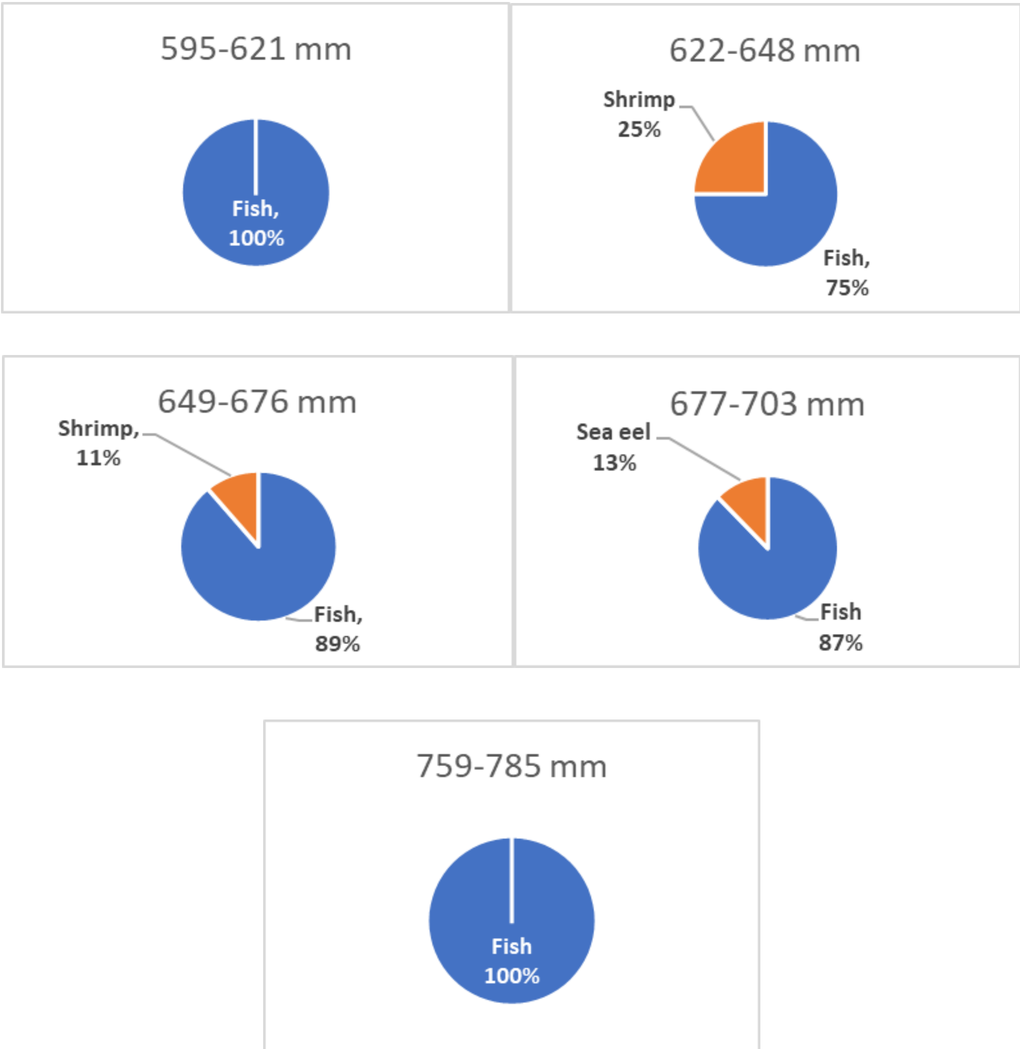

Figure 4. The composition of *T. lepturus* food based on length class according to the type of organism

The food composition of *T. lepturus* fish based on length class were also divided based on family groups. Engraulidae dominated in the first 4 length classes, where the second largest number are unidentified fish followed by Megalopidae which are found in length class 649-676 mm and 677-703 mm (Figure 5).

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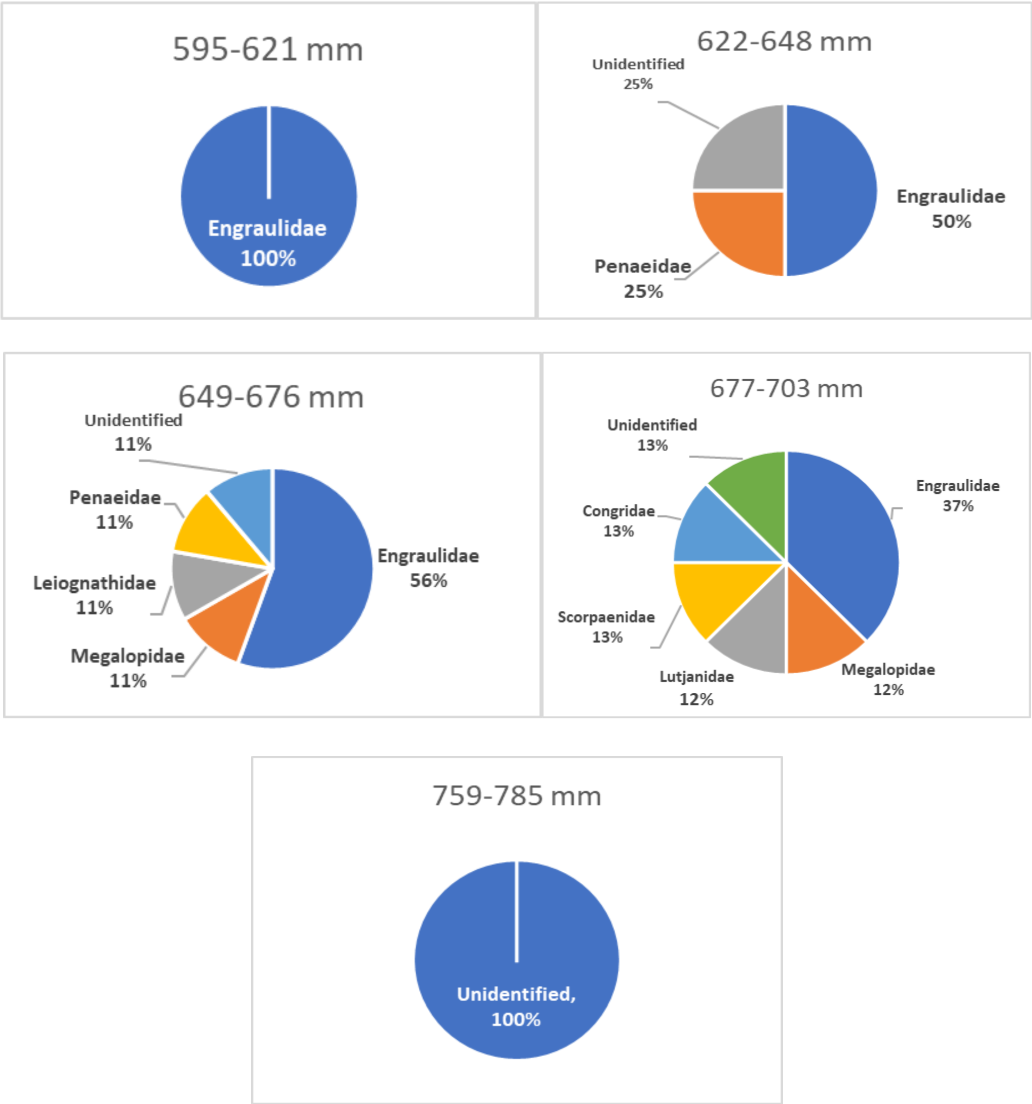

Figure 5. The composition of *T. lepturus* food based on length class according to the family groups

Length class of cutlassfish didn't signify relationship between length and the types of food as a whole. However, the types of food obtained are more varied in the length class sizes between 649-676 mm and 677-703 mm.

3.3 Length Distribution

There were total of 35 *T. lepturus* fish observed during the study with total of 8 male fish and 27 female fish. The fish were caught and then divided into 7 length classes with interval of 273 mm. The total length range of *T. lepturus* captured were between 595-779 mm. The highest number of fish caught were belong to length class of 649-676 mm with total 14 individuals, followed by the second highest number from 677-703 mm length class with the total of 10 fishes.

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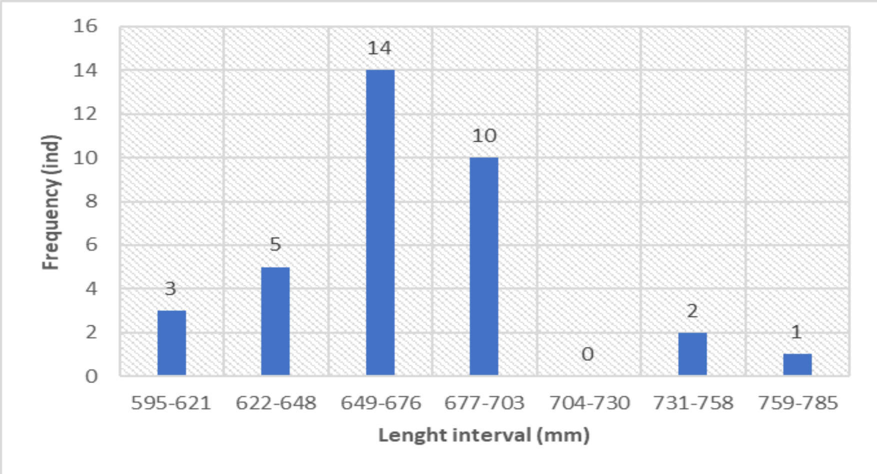

Figure 6. Length distribution of *T. lepturus* based on length class

3.4 Length-Weight Relationship

From the regression we got the value of W = 0.0359L4.0516 with coefficient of determination (R^2) of 0.8052. Before the coefficient of determination obtained, data were calculated to find the b value. The b value that we get through this calculation is 3,541. From the t-test analysis, it showed that T_{count}> T_{table} so in conclusion, the growth pattern observed from cutlassfish was positive allometric because b ≠ 3 and we get b> 3 which means the growth of cutlassfish were optimum.

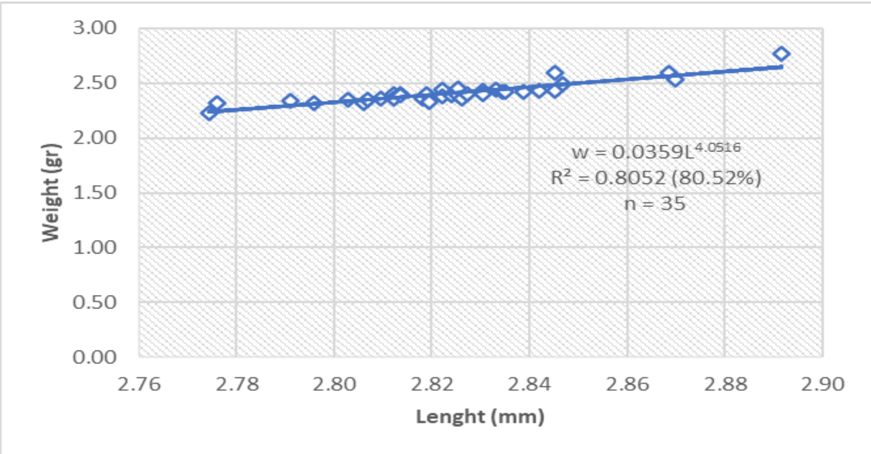

Figure 7. The length-weight relationship of the total sample (n = 35) of *T. lepturus*

3.5 Condition Factor

The condition factor from the total number of fish caught showed in figure 8. The condition factor ranges from 0.97 to 1.30. The highest number of condition factor is in the length class 759-785 mm, with the lowest number from the length class 649-676 mm. The value of condition factor in the length class 649-676 mm is 0.9852 followed by length class 677-703 mm with the second largest number of individuals (total 10), with condition factor of 0.9779. The value of these two condition factors is lower than the three other length class.

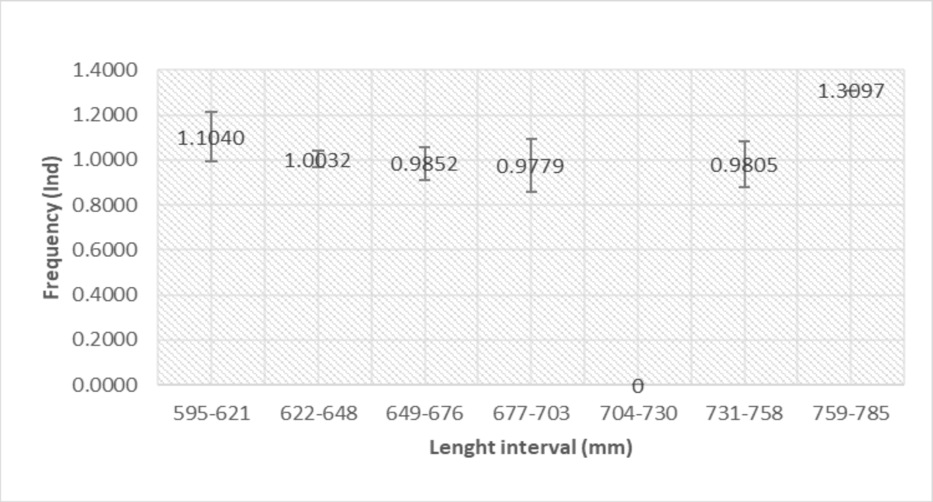

Figure 8. Condition factor of *T. lepturus* fish based on length class

3.6 Proximate Analysis

Lipid and protein results were obtained in crude form. The highest moisture content was obtained from sample II (71.98%). The highest ash content in sample I (2.05%), The highest lipid percentage obtained was 0.61% and protein 23.82%. Specifically, for the analysis results obtained on cutlassfish's muscle, the highest moisture content is 73.88%, 2.55% ash, 4.12% fat, 19.82% protein and 1.43% carbohydrate.

Table 1. Proximate analysis of the food organisms and *T. lepturus*'s muscle

No	**Sample type**	**Sample's code**	**Content**				
			Moisture %	Ash %	Lipid %	Protein %	Carbohydrate by difference
1	Cutlassfish's diet	I	69.98	2.05	0.59	23.82	3.56
			70.12	1.86	0.59	23.38	4.05
		II	70.62	0.65	0.61	21.78	6.34
			71.98	0.69	0.51	22.15	4.57
2	Cutlassfish's muscle	III	73.66	1.28	4.12	19.51	1.43
			73.85	2.55	3.47	19.82	0.31

4. Discussion

IP (Index of Preponderance) and IRI (Index Relative Importance) was calculated to see the differences between two methods and result of calculation beside determining the dominance and the importance of specific food types found in the stomach. Mohan and Sankaran (1988) stated that this value has a good advantage in studying the diet of fish in open water where fish feeding on a wide variety of organisms.

IP value expresses the dominance value of a specific type of food, but this technique can't separate the importance of a type of food and is not suitable as a comparison between one food type and another. In contrast, the IRI value is a composite index that combines the number with the volume or weight and multiplied by the occurrence of one food type. The dominance of food types can be related to the availability of food in their natural habitat. Fish, especially those that belong to the anchovies' group (Engraulidae), is the most dominant and important food components according to the IP and IRI values. Megalopidae, Lutjanidae, Scorpaenidae, and Leiognathidae were concluded as secondary food, while Congridae and Penaeidae concluded into a substitute or tertiary food category.

Some of the fish were included in the unidentified category because in the stomach it had been torn apart, were in pieces or had been crushed. The number of semi-digested foods that cannot be identified in the sample (the IRI value is the second highest after Engraulidae) according to Chiou et al. (2006) indicated that fish slice their prey using teeth similar to fangs and / or it takes a long time to digest. The physical condition of the food that goes into the mouth varies depending on the types of predator and the types of food. Apart from this based on research by Bakhoum (2007) and Chiou et al. (2006), semi-digested food is the most important component in the diet of *T. lepturus* from the Egyptian Mediterranean and coastal waters of southwest Taiwan. Anchovies (Engraulidae), Leiognathidae and scorpion fish (Scorpaenidae) were easiest to identify in this study due to their distinctive body shape and pattern. While most of the anchovies are found intact or undigested.

The large number of anchovy (Engraulidae) found in the stomach of cutlassfish can be due to the abundance or availability of these fish groups in the natural habitat of their predator. The existence of other pelagic fish besides anchovies (Engraulidae) can also be related to the discovery of Megalopidae. Several researchers in a study by De la Cruz-Torres (2014) suggested that the habit of piscivore fish is mainly associated with feeding on pelagic fish, namely fish that live in columns up to sea level and usually form groups according to their migration area. The tendency to prey on fish or pelagic organisms according to Nakamura and Parin (1993) is associated with the habit of cutlassfish to migrate during the day, where the cutlassfish will then prey on the pelagic organisms on the surface.

The low diversity of food types in different length classes according to Munekiyo (1990) is due to the aggregation of the distribution of the main food groups (such as anchovies), and the limited mobility of cutlassfish, where cutlassfish usually eat dense groups of prey and follow their vertical migration. This habit is a strategy to minimize foraging time, which stimulates an increase in energy to meet their nutritional needs. Schwingel and Castello (1994) found that cutlassfish are well adapted to feed planktonic and nektonic organisms that are abundant both on the coast and continental shelf. Most of the energy obtained by cutlassfish is a short pelagic food chain, however in dietary selection cutlassfish is flexible enough to switch from pelagic to demersal and benthic organisms when needed. Flexibility in choosing food is indicated by the presence of Scorpaenidae and Congridae (eels) in the stomach. Both of these groups are benthic organisms while Penaeidae is a group of demersal organisms.

T. lepturus can reach a total length of 1200 mm, and most of the them are 500-1000 mm in size (Nakamura and Parin, 1993). According to Rizvi and Nautiyal (2002), the minimum size of *T. lepturus* to reach maturity is 517 mm long, and usually fish that have a length exceeding 517 mm showed an extraordinary change in condition factor. The fish samples caught in this study indicated that it had reached maturity.

Condition factors can state the quality of the fish. Besides, condition factors are also used to compare the condition and health of fish that are affected by biotic and abiotic environments (Oni et al, 1983) by assuming that heavier fish at the same length have better physiological conditions (Bagenal, 1978). According to Vazzoler and Vazzoler (1965), the condition factor does not reflect feeding condition at the adult stage only, but also gonad development based on the consumption of fat stored in the body and the spawning period. Meaning, a low condition factor indicates that the fish have more developed gonads. Female *T. lepturus* fish matured faster than males (Kwok, 1999). When the gonads mature, the ovaries will enlarge and gain weight, this can affect the value of the condition factor. Gupta (1967) stated for the young *T. Savala* condition factor is usually determined based on feeding intensity. Condition factor can be associated with the regression where the positive allometric growth indicates a dominant weight gain. This number also can be interpreted as the value of condition factor is in line with weight gain, meaning that the food is sufficient for growth needs.

Proximate analysis of the cutlassfish's muscle was compared with the results of the analysis conducted by Jacoeb et al. (2020) where the moisture content is almost the same with amount of 77.68%, ash by 1.00%, fat by 1.07%, protein by 18.35% and carbohydrates by 1.90%. The relatively low percentage of protein in cutlassfish's food and muscle can be caused by the cooling process that takes place during storage (Pandey et al, 2018) which resulting in protein denaturation (McGill et al, 1974). The high moisture content according to Pandey et al. (2018) in the cutlassfish sample can be caused by prolonged cold storage. There is a process of decreasing muscle pH which causes a decrease in the ability to bind water in the muscle due to increased contraction of actomyosin. The formation of actomyosin can cause water from outside easily enter the muscle tissue. Moisture content in fish generally ranges from 70% -80% (Gultom et al., 2015). Protein content in cutlassfish's muscle is lower than the diet, this can indicate the use of protein as the main energy source for the growth and development of cutlassfish. Protein content in a study by Bittar et al. (2012) showed a link with the caloric value of a food. The strong link between protein and caloric value and low lipid value may indicate that predators meet their energy demands through protein obtained from their prey (Wilson, 2002).

It can be seen that there is a decrease in ash content when sample A and B are compared. Decreased ash content according to Daramola et al. (2007) and Garcia-Arias et al. (2003) can be caused due to the cooling process of muscle tissue, the ratio of muscle and bone in the sample and skin activity when melting ice in a cold storage. The difference in ash content in the muscle and cutlassfish's diet can be attributed to the difference in the ratio of muscle to bone between the two. The lipid content in cutlassfish's muscle was higher than its prey. The increase in lipid content can be due to oxidation process during the sample storage (Josephson and Lindsay, 1987). Low fat content in muscle below 3% can be related to their habitat in demersal areas where fish do not need to store a lot of fat in their muscles to swim (Craig et al, 2000). In addition, differences in crude fat content according to Kumar et al. (2014) and Pandey et al. (2018) can result from differences in food species, season, geography, age and maturity of the same species.

Each category did not show any significant change such as the percentage of moisture, fat and protein when compared with the analysis results from the included reference studies. The high percentage of moisture other than the cooling factor can be attributed to the samples analyzed in the form of wet solids. The differences between proximate compositions according to Perez (1994) can show differences in the structure of the prey's body, life cycle, reproductive phase, season and stomach fullness.

Our study suggests that the condition factor is closely related to growth patterns that are affected by the availability of food. The higher value of protein content in food compared to fat indicates that predators such as cutlassfish meet their main energy needs through the protein content on their diet. Food preference is likely a consequence of local resource availability, habitat, and feeding habits of the predator. Hence, understanding food preference and growth pattern might be useful to monitor fishing activities and maintains the fish populations in their natural habitat.

5. Conclusion

Cutlassfish's food was dominated by fish by 88%, with Engraulidae (anchovies) as the main composition with total of 50%. Engraulidae also dominated the IP and IRI values compared to other type of organism, this value shows that Engraulidae (anchovy) is the most dominant and important organism in cutlassfish's food. The growth pattern of *T. lepturus* is allometric positive, where the weight of the fish increases along with increasing length.

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