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Potential aquatic fauna in the food chain system in the coastal mangrove ecosystem of Tomini Bay Boalemo Gorontalo

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ABSTRACT
Background: Mangrove forests are one of the potential coastal and marine natural resources owned by Indonesia, one of the areas in Indonesia that has the largest mangrove forest is the coast of Tomini Bay Gorontalo and is a habitat for aquatic fauna. The coastal mangrove ecosystem area of Tomini Bay Gorontalo is known to have decreased in mangrove area from year to year due to conversion into agricultural land, fisheries, and housing as happened in the mangrove forest of Boalemo Regency. The loss of mangrove vegetation has caused disturbances in ecological balance and has an impact on the loss of various species of aquatic fauna If the rate of mangrove damage is not stopped immediately, it is feared that it will have a negative impact on the diversity of aquatic fauna living in the coastal mangrove forest of Gorontalo Tomini Bay. **Methods:** The method used in this research is survey method, which is a method of collecting data directly at the research location. Data analysis using the calculation of density index (Di), abundance index, species diversity, dominance index (C) and mangrove ecosystem food chain model analysis using model diagram. **Findings:** The results showed that there were several types of aquatic fauna found, namely the Pisces class found 3 orders and 5 families. Crustacean class found 1 order and 2 families. In the Gastropoda class found 3 orders and 3 families. **Conclusion:** The mangrove ecosystem food chain model at level I consumers are inhabited by mollusc classes, crustaceans, and a small portion of the pisces class. Second-level consumers belong to the class of crustaceans of the genus Scylla and pisces and the highest consumers are occupied by pelagic fish species belonging to the Carangidae family. **Novelty/Originality of This Study:** The novelty in this study is to create a series of mangrove ecosystem food chain models in the Tomini Bay area.

KEYWORDS: aquatic fauna; food chain; mangroves.

1. Introduction

Mangrove forests are plants that are influenced by tides and tolerant of salinity, inundation duration and substrate. Mangrove forests contribute to the life of biota, abiotic components (substrates and waters) and community life (Abubakar et al, 2021). Mangrove forests are one of the potential coastal and marine natural resources owned by Indonesia, as one of the archipelagic countries with an abundant amount. The area of mangrove forests in Indonesia is approximately 3,490,000 ha or equal to 21% of the world's mangrove forest area (Puspaningrum et al, 2023). Mangrove ecosystems are important areas for mangrove

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fauna, because they have various functions both ecological, physical, and socio-economic (Baderan et al., 2017). However, currently mangrove forests in Indonesia are mostly degraded. This degradation is caused by various activities of land conversion into ponds and also some natural phenomena such as abrasion, tidal floods and so on. The impact of the reduction of mangrove forests due to human activities causes mangrove forests to no longer function as a feeding ground, nursery ground and spawning ground for aquatic fauna that live in mangrove ecosystems (Aprilia, 2022).

One of the areas in Indonesia that has the largest mangrove forest is the coast of Tomini Bay Gorontalo and is a habitat for aquatic fauna. The coastal mangrove ecosystem area of Tomini Bay Gorontalo is known to have decreased in mangrove area from year to year. The decline in the area of mangrove ecosystems on the coast of Tomini Bay Gorontalo is increasingly alarming, due to the conversion to agricultural land, fisheries, and housing as happened in the mangrove forest of Boalemo Regency. This situation is in accordance with conditions in various regions in Tomini Bay, as stated by Rahim et al. (2023) that mangrove forests are under pressure due to increasing needs and increasing community activities in coastal areas, which can endanger their existence. The majority of coastal communities disturb mangrove ecosystems by converting mangrove-covered land into ponds, developing industrial settlements, and conducting illegal logging for various purposes. This change, of course, has an impact on changes in the population of aquatic fauna living in mangrove areas and has an impact on the food chain process that occurs in the ecosystem. The loss of mangrove vegetation has disrupted the ecological balance and resulted in the loss of various species of aquatic fauna. If the rate of mangrove destruction is not stopped immediately, it will have a negative impact on the diversity of aquatic fauna living in several locations in the coastal mangrove forest of Tomini Bay Gorontalo.

The availability of various types of food found in mangrove ecosystems has made it a source of energy for various types of biota associated with it such as shrimp, crabs, fish, shellfish and so on which form a complex food chain where energy transfers occur from lower tropic levels to higher tropic levels and finally as a supplier of organic matter for the aquatic environment. The process of energy transfer in the food chain will become more complex with the number of organisms contained in an ecosystem. So that it will form a food web system (Utina & Baderan, 2015). So that further studies are needed on how the potential of aquatic fauna and food chain systems in the coastal mangrove ecosystem of Tomini Bay, Boalemo Gorontalo Regency.

2. Methods

The method used in this research is a survey method, which is a method of collecting data directly at the research location. The research location is in the mangrove ecosystem of Tomini Bay, Boalemo Gorontalo Regency. The tools used in this study are nets, used to capture aquatic fauna of the Pisces and Crustacea classes. The gill nets used have a length of 150 meters, a net width of 115 centimeters, and a mesh area of 1 cm x 1 cm. The net is made of nylon string with a mesh width of 1 cm x 1 cm and a net weight of 5 kilograms. In addition to nets, a *seser* tool with a diameter of approximately 45 centimeters is also used to reach places that cannot be accessed by nets. Other supporting tools include jars, labels, vectors, cameras, specimen boards, and cool boxes.

Aquatic fauna belonging to the Pisces and Crustacea classes were collected using simple fishing gear, including nets, fishing rods, and *seser*. This strategy was chosen because fauna in these two classes exhibit active movements, requiring tools that facilitate effective sampling. Meanwhile, Mollusca sampling was conducted in each 10m x 10m ($100m^2$) plot within three quadrants at each station. Within each plot, crab sampling was conducted using three 1m x 1m ($1m^2$) quadrats, resulting in a total of three plots per station (see Fig. 3).

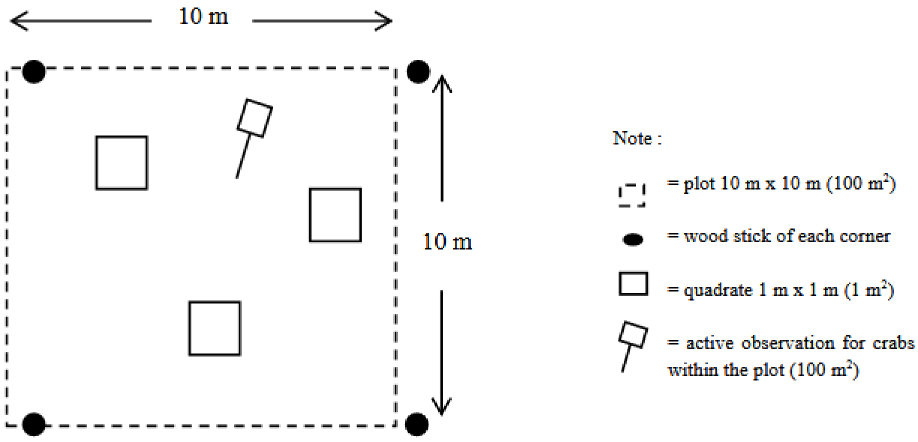

Fig. 1. Transect and plot location in one research station (Chapman, 1998)

2.1 Biodiversity of aquatic fauna species

2.1.1 Aquatic fauna density (Di)

The types of crabs obtained, calculated the density of each species and relative density using the equation (Krebs, 1989) as follows:

$$Di = \frac{\Sigma ni}{A} \quad \text{(Eq. 1)}$$

$$RDi = \frac{ni}{\Sigma n} \times 100\% \quad \text{(Eq. 2)}$$

Where: Di = Species density (ind/ha); RDi = Relative density; ni = Number of individuals of the i-th species; ∑ ni = total number of individuals of the i-th species; Σn = Total number of individuals of all species; A = Area of sampling area*Inderks Kelimpahan*

2.1.2 Fauna akuatik

$$K = \sum ni/A \quad \text{(Eq. 3)}$$

K = species abundance (ind/ha), ∑ni = number of individual species, A = sampling plot area Relative Abundance Index (RAI) = ni/N x 100% N; where KR = relative abundance index (%); ni = number of individuals of the i-th species, N = total individuals of all species.

2.1.3 Aquatic fauna species diversity index

Diversity Index (Brower *et al*. 1990).

$$H' = -\sum \frac{ni}{N} \, ln \frac{ni}{N} \quad \text{(Eq. 4)}$$

Where: H'= Shannon-Wiener diversity index; Ni= Σ of each species; N= Σ of total species.

2.1.3 Species evenness index

$$E = H/lnS \quad \text{(Eq. 5)}$$

Where E = evenness index; H' = species diversity index; S = number of species.

2.1.4 Dominance Index (C)

$$C = \sum(ni)^2 N \quad \text{(Eq. 6)}$$

Where C = Simpson's dominance index; ni = number of individuals of the i-th species; N = number of individuals of all species.

2.2 Food chain model analysis

Analysis of the mangrove ecosystem food chain model using the Model Diagram. Model diagram is a scheme made to describe the food chain process that occurs in mangrove ecosystems that contains data that has been obtained during the research. Furthermore, the model diagram is described in detail to clarify the model diagram scheme. This analysis refers to research conducted by Utina et al., (2016). Determination of trophic levels in modeling using literature studies related to food chain models in aquatic ecosystems.

3. Results and Discussion

3.1 Biodiversity of Aquatic Fauna

Geographically the study area is located between the coordinates N 00031'03.99" and E 122026'53.71". 2. The aquatic fauna group, consisting of two types, namely the first group of animals that live in the water column, especially various types of fish and shrimp and secondly Occupy both hard (roots and stems of mangroves) and soft (mud) substrates, especially crabs, shellfish and various types of other invertebrates. This group includes mangrove crabs, shellfish, fish and shrimp (Bustaman, 2014).

Based on the results of the study there are several types of aquatic fauna found in the research location, where 4 classes were found (Table. 1), namely the Pisces class found 3 orders and 5 families. The Crustacea class found 1 order namely Decapoda and 2 families namely Portunidae and Penaeidae. In the Gastropoda class found 3 orders and 3 families where 3 orders namely Caenogastropoda, Neritimorpha, and Hypsogastropoda, and 3 families namely Potamididae, Neritidae, and Huricidae. There are many types of aquatic fauna in mangrove ecosystems because all aquatic fauna are associated with mangroves, about 49% of demersal fish, and in the whole of Southeast Asia about 30% of fish and almost 100% of shrimp are directly related to the mangrove environment (Setyawan, 2006).

Table 1. Aquatic Fauna Found at the Research Site

Class	Family	Genus	Species
Pisces	Terapontidae	Pelates	*Pelates quadrilineatus*
	Polynemidae	Polynemus	*Polynemus sp.*
	Carangidae	Carangoides	*C. malabaricus*
		Megalaspis	*Megalaspis cordyla*
	Mugilidae	Liza	*Liza melinoptera*
	Belonidae	Strongylura	*Strongylura notate*
Crustacea	Portunidae	Scylla	*Scylla serrata*
			Scylla olivacea
			Scylla tranquebarica
		Carcinus	*Carcinus maenas*
	Penaeidae	Metapenaeus	*Metapenaeus elegans*
		Penaeus	*Penaeus latisulcatus*
		Metapenaeus	*Metapenaeus affinis*
Gastropoda	Potamididae	Terebralia	*Terebralia sulcata*
			Terebralia palustris.
	Neritidae	Nerita	*Nerita articulate*

	Huricidae	Hexaplex	*Hexaplex trunculus.*
Pelecypoda	Arcidae	Anadara	*Anadara granosa*
	Mactridae	Mactra	*Mactra grandis*

3.2 Community structure of aquatic fauna

3.2.1 Mollusca class

Based on the results of the calculation of abundance, diversity, and density of the Mollusca phylum, there are several species that have the highest value. In the gastropod class, the highest value is Nerita articulata with an abundance value of 30.41%, diversity of 0.36, and density of 0.17 ind/m2, followed by Terebralia sulcata with an abundance value of 28.07%, diversity of 0.36, and density of 0.16 ind/m2. While the lowest is owned by Terebralia palustris with an abundance value of 17.54%, diversity of 0.31, and density of 0.10 ind/m2. The results of the calculation of abundance, diversity, and density of Mollusca phylum in the research location are presented in Table 2.

Aquatic fauna in the mollusca class is dominated by the species of Nerita articulate *(gastropoda)* and Anadara granosa *(Pelecypoda)*. These two species dominate in the area because they are related to habitat, and the way of life of each species. The type of Nerita articulate generally lives in groups and is often found attached to roots, stems, leaves, rocks and wood weathering. This is in accordance with the statement of Nontji. (2006) which explains that Nerita articulate species are generally found in groups with diverse populations. In the supralittoral area, this community can be found with the characteristic of sticking, both on the roots, stems and leaves on vegetation that grows in the area as a form of migration due to high sea levels. Foraging activities in this species are active at night and water conditions are not in high tide conditions because of its nature as a scafenger.

Based on Table 2, it can also be seen that the values of abundance, diversity, and density in the bivalve class have different values. The type of Anadara granosa has an abundance value of 53.06%, diversity of 0.34, and density of 0.08 ind/m2 while Mactra grandis has an abundance value of 46.94%, diversity of 0.36, and density of 0.07 ind/m2. The type of Anadara granosa (blood clam) is found in the research location because it is associated with muddy substrate conditions. According to Latifah (2011), blood clams are infauna, which live by immersing themselves under the surface of the mud. Blood clams are usually found more in areas farther from the river mouth because the river mouth is the area most affected by pollutants and fisheries activities that can overexploit clams (Dahuri, 1996). This condition is in line with the conditions at the research site where the substrate is characterized by muddy and far from the river mouth. Therefore, this species dominates the area.

Table 2. Abundance, diversity, and density of Mollusca phylum in the research location.

Class	Species	Number Individuals	K (%)	H'	D (ind/m^2)	RDi (%)
Gastropoda	*Terebralia sulcata*	48	28.07	0.36	0.16	28.2
	Terebralia palustris	30	17.54	0.31	0.10	17.5
	Nerita articulata	52	30.41	0.36	0.17	30.4
	Hexaplex trunculus.	41	23.98	0.34	0.13	23.9
Total		171	100.00	1.37	0.56	100
Bivalvia	*Anadara granosa*	26	53.06	0.34	0.08	53.06
	Mactra grandis	23	46.94	0.36	0.07	46.04
Total		49	100.00	0.70	0.15	100

3.2.2 Pisces class

The abundance and diversity values of each species in the pisces class vary. The abundance and diversity values of the pisces class are presented in Table 3.

Table 3. Abundance and diversity of Pisces class in the research location

Family	Species	Number Individuals	K (%)	H'
Terapontidae	*Pelates quadrilineatus*	19	34,55	0,37
Polynemidae	*Polynemus sp.*	11	20,00	0,32
Carangidae	*Carangoides malabaricus*	9	16,36	0,30
	Megalaspis cordyla	1	1,82	0,07
Mugilidae	*Liza melinoptera*	8	14,54	0,28
Belonidae	*Strongylura notata*	7	12,73	0,26
	Total	55	100.00	1,60

The highest abundance and diversity are owned by Pelates quadrilineatus with a value of 34.55%, and 0.37, followed by Polynemus sp. with an abundance value (34.55%) and diversity of 0.37 followed by Carangoides malabaricus, Liza melinoptera, Strongylura notate, Megalaspis cordyla. The diversity value in the pisces class reached 1.60. The abundance of this type of fish at the study site is influenced by the type of food that is abundant at the study site. Pelates quadrilineatus is classified as a trophic crustasivora (crustacean eater) with a food trophic percentage of 78.8% crustaceans, 20.1% zooplankton and 1.1% teleosis (Zahid, 2013). This is also supported by the large number of species and the number of individuals found in the research location in the crustacean class, so that this type of fish is able to live very well.

3.2.3 Class crustaceae

The crustace class of abundance value, and species diversity in having different amounts. In the family Portunidae, the type of Scylla serrata has the highest value with an abundance value of 26.79%, diversity reached 0.35. Furthermore, the types of Scylla olivacea and Carcinus maenas with an abundance value of 25.00% and a diversity of 0.35. And the lowest is Scylla tranquebarica 23.21%. The diversity value in the Portunidae family reached 1.10. Calculation of the abundance and diversity of the Crustacean class at the research site is presented in Table 3. Crustacean class, the species that have the highest value are Scylla serrata (Portunidae) and Penaeus latisulcatus (Penaeidae). The high value of these two species is also related to the way of life, life cycle and habitat inhabited by these two species. The natural habitat of mangrove crabs is brackish water areas that are muddy and located along coastlines that are overgrown with mangroves (Suryani, 2006). Furthermore, Kasry (1996) stated that mangrove crabs in living their lives travel from coastal waters to sea waters, then the mother and her children will try to return to the waters of the mangrove forest to protect, find food or raise themselves.

Table 3. Abundance and diversity of Crustacean classes in the study site.

Family	Species	Number Individuals	K (%)	H'
Portunidae	*Scylla serrata*	15	26.79	0.35
	Scylla olivacea	14	25.00	0.35
	Scylla tranquebarica	13	23.21	0.34
	Carcinus maenas	14	25.00	0.35
	Total	56	100.00	1.39
Penaeidae	*Metapenaeus elegans*	19	35.18	0.37
	Penaeus latisulcatus	20	37.04	0.37
	Metapenaeus affinis	15	27.78	0.36
	Total	54	100.00	1.10

Table 3 above, shows that the Penaeidae family has several dominant species. The type of Penaeus latisulcatus has an abundance value of 37.04%, the diversity value reaches 0.37, indicating that this type is more dominant in the Crustace class. The Penaide family has a diversity value of 1.10. Based on the criteria that have been determined, the crustace class has an abundance that is classified in the many category in all types. Diversity in the crustace class is in the medium category. According to Pratiwi (2008), adult shrimp live and breed in the middle of the sea (away from the coast). Some time before mating, female shrimp molt first. Mother shrimp mature eggs will release their eggs (spawning) in the mangrove at night. The eggs will hatch, become larvae (in the form of several levels) and are planktonic.

3.3 Aquatic fauna food chain model

The description of the food chain and web model presented in Figure 2 is based on tropic levels sourced from literature relevant to the condition of food chains in mangrove ecosystems. The species that play a role in the food chain are species that are in the mangrove ecosystem in Boalemo Regency.

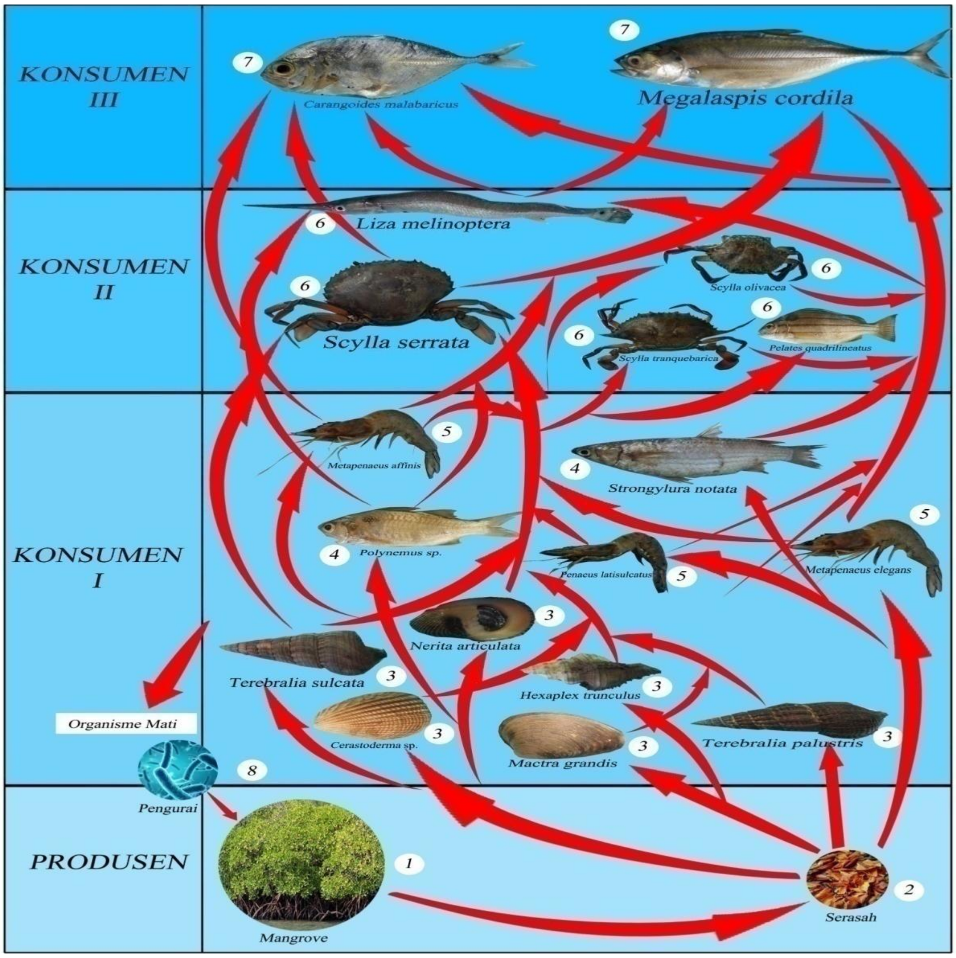

Fig. 2. Mangrove ecosystem food chain and web model

The food chain is the transfer of energy from its source in plants through a series of organisms that eat and are eaten (Ridwanaz, 2010). The food chain in the mangrove ecosystem for aquatic biota is the detritus food chain. Litter that falls will undergo a process of decomposition by microorganisms into detritus. The more litter produced in a mangrove area, the more detritus produced. Detritus is a highly nutritious food source for various types of aquatic organisms (especially detritifor) which can then be utilized by higher organisms (large fish, birds of prey, snakes, or humans) in the food web (Zamroni & Rohyani, 2008).

Litter that falls into the water does not directly enter the energy flow, the litter must first be converted into detritus. This is supported by the statement of Naibaho (2015) explaining that litter that falls such as leaves, twigs, flowers and fruit to be utilized by organisms contained in mangrove forests, the litter needs to be decomposed first into other materials that can be a food source in the food chain process for these organisms.

Zamroni & Rohyani. (2008) explained that mangrove litter in the form of leaves, twigs and other biomass that fall into the source of food for aquatic biota and nutrients that determine the productivity of marine fisheries. Furthermore, Mahmudi et al. (2011) emphasized that the decomposition process is an important process in ecosystem function. Decomposition of mangrove litter, especially leaf litter, contributes most of the nutrients to sediments and surrounding waters. Only a small proportion of decayed leaves are consumed directly by herbivorous animals, while mangrove detritus provides a potential source of organic matter for the estuary food web.

Litter from fallen leaves, twigs, flowers and fruits will be the main source of energy in the water. Organic matter derived from mangrove litter is the main link in the food web in the ecosystem. Bengen (2002) states that the basic component of the food chain in mangrove ecosystems is not the mangrove plants themselves, but the litter derived from mangrove plants (leaves, stems, fruits, twigs, and so on). The litter produced directly is consumed by microorganisms and decomposing organisms so that it enters the energy system.

Species with symbols number 3, 4, and 5 are species that utilize the results of litter decomposition in the form of detritus as food. These species are classified as level I consumers. Level I consumers in mangrove ecosystems are usually inhabited by mollusc classes, crustaceans, and a small number of pisces classes. This is supported by the statement of Hidayat (2010), level 1 consumers are small fish and shrimp that directly eat the fallen mangrove litter. Level 2 consumers are carnivorous organisms that eat small fish and shrimp. Level 3 consumers consist of large fish and fish-eating birds. These protein-rich leaf particles will be broken down by bacterial colonies and then eaten by small fish. The breakdown of these leaf particles will continue until they become very small particles (detritus) and will then be eaten by detritus-eating animals, such as molluscs and small crustaceans. During this breakdown, dissolved organic substances derived from mangrove debris will partly be released as useful material for phytoplankton and partly absorbed by sediment particles that support the food chain (Soeroyo, 2003).

Level II consumers are types of animals that belong to the class of crustaceans and pisces. This level is dominated by the genus Scylla. This type of crab is an omnivore or eater of everything. As adults, this type of crab often consumes small fish, shrimp, and animals belonging to the mollusca class. This is supported by the statement of Kasry (1996), where in its natural habitat the Scylla mangrove crab consumes various types of food including algae, roots and nuts, snails, toads, frogs, clam meat, shrimp, fish, and animal carcasses, so that the mangrove crab is an omnivore (all eater).

The highest consumers are pelagic fish belonging to the Carangidae family, which are fish that always migrate to find food. This is in accordance with the statement of Nelwan et al (2012) that pelagic fish are a group of fish that have the nature of free swimming by migrating vertically or horizontally near the surface in search of food. Pelagic fish food in the form of shrimp, crabs, small fish, and several types of mollusca.

According to Fauziyah. (2010) pelagic fish are grouped into 3 subgroups namely Carangidae (Layang, Selar and Sunglir), Klupeid (Teri, Japuh, Tembang, Lemuru and Siro) and Skombroid (Mackerel). These fish species utilize mangrove forests as a place to find food and a place to hatch their eggs. When the larvae of this type of fish will survive in the mangrove forest area to avoid predators, after the adult fish species will return to the coral reefs and the high seas. Then when laying eggs this type of fish will return to the mangrove area. This is supported by the statement according to Fauziyah. (2010) that mangrove roots are utilized by small pelagic fish from predators. When the fish become adults, the fish will leave the brackish and move to estuaries, reefs, and the high seas. At the research site, pelagic fish found only belonged to the family carangidae and the number was not too much only 10 individuals. The abundance value ranges from 1.82% - 16.36% this proves that pelagic fish do not spend their entire life in mangrove areas. Furthermore, dead microorganisms will be decomposed by decomposers (No. 8) into nutrients that can be utilized by mangroves as nutrients to grow and develop. This energy flow process will continue to flow from one organism to another. This flow of energy will be disrupted if one of the components will be lost.

4. Conclusions

Based on the results of the study found the potential of aquatic fauna that inhabit the location. Aquatic fauna found include the Pisces class found 3 orders and 5 families. Crustacean class found 1 order and 2 families. In the Gastropoda class, 3 orders and 3 families were found. In the gastropod class that has the highest value is Nerita articulata with an abundance value of 30.41%, diversity of 0.36, and a density of 0.17 ind/m2, bivalve class Anadara granosa has an abundance value of 53.06%, diversity of 0.34, and density of 0.08 ind/m2. The highest abundance and diversity value of the pisces class is owned by Pelates quadrilineatus with a value of 34.55%, and 0.37. The aquatic fauna found is interrelated between each other which forms a food chain and food web. Level I consumers in mangrove ecosystems are inhabited by mollusca classes, crustaceans, and a small number of pisces classes. Second-level consumers belong to the class of crustaceans of the genus Scylla and pisces and the highest consumers are occupied by pelagic fish species belonging to the Carangidae family.

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Author Contribution

Study's conception and design, F.S.M., D.W.K.B and H; Methodology, D.W.K.B and H.; Software, F.S.M; Validation, D.W.K.B, and H.; Formal Analysis, D.W.K.B.; Investigation, H.; Resources, F.S.M., D.W.K.B and H; Data Curation, F.S.M., D.W.K.B. and H.; Writing - Initial Draft Preparation, F.S.M.; Writing - Review & Editing, D.W.K.B., H.; Visualization, D.W.K.B.; Supervision, H.; Project Administration, D.W.K.B.; and Funding Acquisition, F.S.M., D.W.K.B., and H.,".

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Ethical Review Board Statement

Not available.

Informed Consent Statement

Not available.

Data Availability Statement

Not available.

Conflicts of Interest

No conflict of interest occurred in this study.

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