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Diversity of Coral Reef and its Impact on the Availability of Angel Fish (*Pomacanthus* Sp.) Production in the Spermonde Pangkajene and Kepulauan Waters, South Sulawesi

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Abstract
The objective of this research was to estimate and analyze the availability of Angel fish (*Pomacanthus* sp.) based on the coral diversity conditions in the Spermonde waters of Pangkep Regency, South Sulawesi. The research method was based on parallel sampling of fish abundance (visual census) and coral cover percentage (Point Intercept Transect) at the study sites, namely Liukang Tumppabiring and Liukang Tangaya waters. The results showed that Liukang Tuppabiring had a fish abundance of 0.00005 individuals per square meter with a standing stock of 138 individuals, while Liukang Tangaya had a fish abundance of 0.005 individuals per square meter with a standing stock of 35,121 individuals. The abundance of Angel fish did not correlate positively with live coral cover, but its presence was influenced by the structural growth forms of the coral, namely branching, submassive, and massive coral in crevices. The production status of Angel fish in the Spermonde waters has exceeded the maximum sustainable yield (MSY). Therefore, additional fishing efforts would decrease the production of Angel fish. This indicates that the Angel fish has been overfished, which can affect its supply. In addition, the inverted curved supply curve indicates a decreasing supply, even with increasing fish prices, as it is suspected that the stock is decreasing.

Keywords— Diversity, Abundance, Production, Ornamental Fish, *Pomacanthus*

Introduction

South Sulawesi is a region with significant potential, characterized by its strategic geographical position, extensive coastline measuring 1,973.7 km, vast marine waters covering approximately 48,000 km^2, and the presence of 263 small islands (Kasmi, Kumalasari, et al. 2022). This region holds ecological, food security, economic, socio-cultural, and natural beauty importance. The coastal and marine biodiversity, including ornamental fish, shellfish, coral reefs, seagrass beds, mangrove forests, and other unique coastal landscapes, form captivating natural scenery (Paharuddin et al. 2022). The coral reefs in Pangkep Regency's coastal areas have vital biological value for the ecosystem and environment. Data shows that Pangkep Regency has exceptionally high biodiversity compared to several other regions worldwide. In fact, coral experts and researchers have stated that the waters of Pangkep are among the world's coral regions with immense biodiversity (Mastuti et al. 2022; Paharuddin et al. 2022). The abundance of coral reefs in Pangkep Regency serves as a significant asset for regional development and improving the welfare of communities, particularly those whose livelihoods rely on coastal ecosystems. The fisheries and marine tourism sectors are expected to become the main drivers of Pangkep Regency's economy.

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Marine ornamental fish are one of Indonesia's prized trading commodities, highly sought after in the global market. Business stakeholders and policymakers have been engaging in various activities to compete with other countries. Business operators and policymakers have synergized efforts to attract the global market as the largest exporter of marine ornamental fish. The vast waters with their coral reefs, inhabited by diverse marine organisms, serve as an exotic biota asset . Marine ornamental fish enterprises require significant initial investment and operational costs. These investments consist of fixed assets for long-term investment in the coming years. Investment decisions in such enterprises are based on various considerations, such as open business prospects, available market shares, and potential business feasibility analysis (Abdullah et al. 2021b; Kasmi, Ridwan, and others 2020).

Marine ornamental fish, particularly Angel fish (*Pomacanthus* sp.), are highly sought after by fish enthusiasts, especially in developing and developed countries with increasing populations (Kasmi, Sulkifli, and Asriany 2022). Consequently, fishing efforts have intensified in response to the growing demand for Angel fish. Angel fish have a close association with coral reefs as their habitat (Kasmi, Amir, et al. 2022). Conservation efforts for marine ornamental fish are inseparable from the preservation of coral reef ecosystems. However, coral reef ecosystems are continually subjected to pressures from various human activities. Angel fish production is a targeted industry due to their exotic nature and relatively high prices. Excessive fishing using indiscriminate fishing methods can significantly impact the quantity and quality of production (Abdullah et al. 2021a). Unfortunately, the sustainability of marine ornamental fish resources is often overlooked. The Spermonde Islands waters of Pangkajene and Kepulauan Regency present considerable potential for Angel fish fishing, as evident from the intensive fishing activities conducted by local fishermen. Consequently, there is a concern regarding the decline in the population of Angel fish (Kasmi, Asriany, et al. 2020).

Angel fish have high economic value, with body lengths reaching approximately 40 cm. They have black pectoral fins, while their dorsal and tail fins display yellow coloring. The dorsal fin features weak rays and black and yellow stripes along the body, while the tail fin is round or circular with a blue edge (Akmal Abdullah et al., 2020). The pelvic and anal fins are white with blue edges. The dorsal fin comprises 13-14 hard rays and 16-18 soft rays, while the anal fin consists of 3 hard rays and 16-18 soft rays (Kasmi 2014).

Literature Review

Several studies have focused on understanding the demand for Angelfish in the global market. (Kasmi 2012, 2013) have identified Angelfish as one of the most sought-after marine ornamental fish species in the international market. The high demand for Angelfish has led to its inclusion as a bargaining chip for suppliers, who often bundle it with other types of ornamental fish. This excess demand and higher prices compared to other ornamental fish species have driven increased fishing activities targeting Angelfish.

Research conducted in specific regions, such as the Spermonde Archipelago, has revealed that the abundance of Angelfish is not directly correlated with live coral cover. Instead, the presence of Angelfish is influenced by the structural characteristics of coral habitats, including branching, submassive, and massive formations. These findings suggest that the availability of suitable habitat, characterized by branching coral structures and branching coral crevices, plays a vital role in the distribution and abundance of Angelfish (Mortimer et al. 2021).

Furthermore, studies have examined the sustainability of Angelfish production and its implications for the fishery industry. It has been observed that the current production of Angelfish in certain regions, such as the Spermonde Archipelago, has surpassed the Maximum Sustainable

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Yield (MSY). This overfishing has led to a decline in Angelfish populations and negatively impacted the supply of this species. The backward-bending supply curve illustrates the decreasing trend in supply, even with increasing prices, suggesting a potential depletion of fish stocks.

To address these challenges, the importance of implementing sustainable management practices. Conservation measures and regulations are necessary to ensure the long-term sustainability of Angelfish populations and maintain a balance between supply and demand in the ornamental fish market. Management strategies may include the establishment of protected areas, implementation of catch limits, and the promotion of responsible fishing practices.

Research Method

A. Research Timeframe and Location

This research was conducted from March to April 2022 in two marine areas of Pangkajene and Kepulauan Regency, located in the following water regions:

Table 1. Research Locations

No.	Research Location	Name Coordinates	
		Longitude	Latitude
1	Liukang Tuppabiring:		
	1. Kondombali Island	119. 03168	04.391126
	2. Pamanggangan Island	119. 07540	04.391126
	3. Sarappo Keke Island	119. 03168	04.371124
2	Liukang Tangaya:		
	1. Sapuka Kecil Island	118.13189	07.13151
	2. Karang Koko Island	118.09470	07.08212
	3. Tinggalungan Island	118.04437	07.02933

Economic data and fish utilization information were obtained from fishermen, suppliers, exporters, associations, and relevant institutions involved in the marine ornamental fish industry.

B. Research Procedures

Habitat Condition Inventory and Habitat Grouping

The method used to assess the habitat condition was the Point Intercept Transect (PIT) method, following the guidelines provided by (Prasetya and Santoso 2022). This method was employed to obtain an overview of coral cover and the structural growth forms of the coral. Transects with a length of 100 m were established for each zone (reef flat, reef crest, reef slope), starting from the reef slope, then moving to the reef crest, and finally the reef flat as the shallowest zone. The distance between each zone ranged from 30 to 50 m, depending on the field conditions.

In this study, the coral cover components (life forms) that are associated with Angel fish include 19 categories, namely: 1) ACB (branching Acropora), 2) ACT (tabulate Acropora), 3) ACS (sub-massive Acropora), 4) ACD (dead Acropora), 5) ACE (encrusting Acropora), 6) CB (branching coral), 7) CS (sub-massive coral), 8) CE (encrusting coral), 9) CF (foliose coral), 10) CM (massive coral), 11) CMR (damaged massive coral), 12) SC (soft coral), 13) SP (sponge), 14)

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S (sand), 15) DCA (dead coral overgrown by fine algae), 16) DC (dead coral), 17) FS (macroalgae), 18) OT (other biota), and 19) R (broken branching coral).

The grouping of coral growth structures (coral forms) in this study was adopted from (Urbina-Barreto et al. 2021), and adjusted based on the requirements or associations with Angel fish. There are 11 coral growth structure types or habitat characteristics identified, including: 1) cbCM (under massive coral crevice), 2) csCM (side massive coral crevice), 3) aCS (between sub-massive corals), 4) acCB (between branching coral crevices), 5) CBA (branching coral overgrown by algae), 6) CSMA (sub-massive and massive coral overgrown by algae), 7) bACT (under tabulate Acropora), 8) cACT (tabulate Acropora crevice), 9) cCF (foliose coral crevice), 10) SAO (sand overgrown by algae and others), and 11) RAO (broken coral overgrown by algae and others). The abundance of Angel fish in Pangkep Regency is depicted through this characterization.

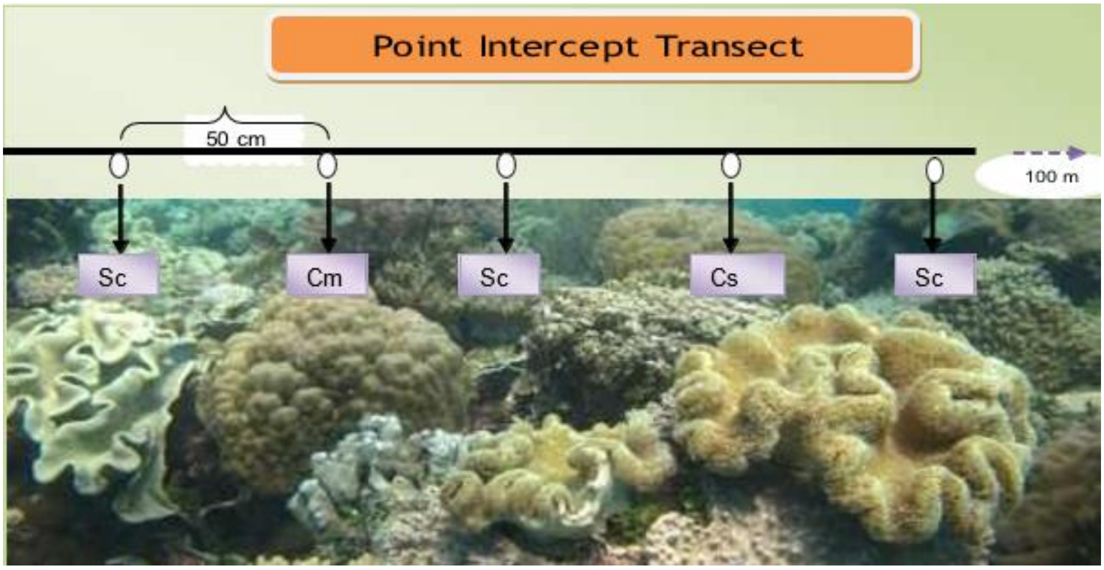

Figure 1. Data recording of live coral species (habitat characteristics) using the Point Intercept Transect (PIT) method.

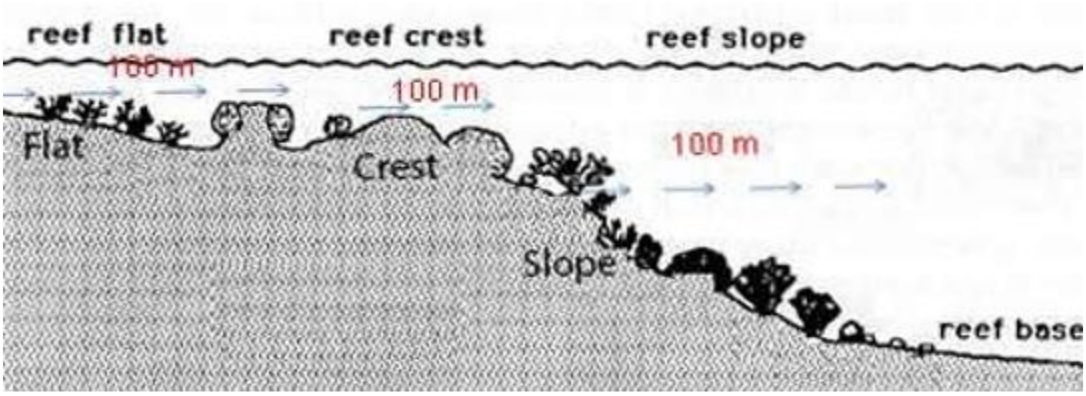

Figure 2. Zoning of coral reef forms as habitat characteristics for fish concentration.

The waters of the Spermonde Archipelago are the nearest fishing grounds to the mainland of South Sulawesi, making them more easily accessible and frequently exploited by fishermen. The coral reef conditions ranging from good to excellent are found on islands that are far from the mainland, such as Kapoposang Island and its surrounding areas. Therefore, as substations within the Spermonde Archipelago, Pamanggangan Island, Kondong Bali, and Sarappo Keke

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were chosen.

The waters of the Liukang Tangaya Archipelago are the main fishing grounds for ornamental fish, especially Angel fish, based on data from AKKII and Gapekhi (2022). This archipelago consists of several inhabited and uninhabited island clusters. The locations chosen as substations for the largest Angel fish catching sites, based on data from AKKII and Gapekhi (2022), are the waters surrounding Sapuka Kecil Island, Karang Koko, and Tinggalungan Island.

The commonly used criteria for assessing live coral cover to determine the condition of coral reefs are divided into four categories, namely:

1. Destroyed/damaged: 0-24.9%
2. Fair: 25-49.9%
3. Good: 50-74.9%
4. Very good: 75-100%.

To examine the grouping of habitat characteristics among observation stations, a multivariate statistical approach based on Principal Component Analysis (PCA) was used, following the methods described by (Yang et al. 2020). PCA is a descriptive statistical method aimed at presenting results in graphical and visual forms, capturing the maximum information contained in a data matrix. The data matrix consists of observation stations as statistical individuals (rows) and habitat characteristics (water quality, substrate, habitat cover conditions) and coral communities as quantitative variables (columns). Since the measured habitat characteristics data do not have a uniform measurement unit, they need to be normalized through centering and reduction before conducting Principal Component Analysis.

In essence, PCA employs Euclidean distance, which is the sum of squared differences between the environmental parameter stations and the corresponding coral community structure parameter data. The Euclidean distance is based on the formula for coral:

$$D^2(i,i') = \sum(Xij - Xi'j)^2$$

Where:

$D^2(i, i')$: Represents the squared Euclidean distance between two stations (i and i') in the analysis.

Xij: Denotes the value of the jth environmental parameter or habitat characteristic for station i.

Xi'j: Refers to the value of the jth environmental parameter or habitat characteristic for station *i'*.

This formula calculates the sum of squared differences between the corresponding environmental parameter values or habitat characteristics of two stations. It quantifies the dissimilarity or distance between the stations based on their environmental parameters. This Euclidean distance serves as a fundamental element in PCA to measure the relationships and similarities between different stations and their corresponding environmental and coral community structure parameters.

Fish Abundance Estimation

The abundance of Angel fish was assessed using the visual census method along transect lines, following the observation of coral cover forms in each zone. Observations were conducted along transect lines with a length of 100 m, with a visual range of 2.5 m to the left and 2.5 m to the right of the transect line (observations were made in the middle). The Angel fish species present were recorded along with their respective sizes. The size categories for Angel fish, based

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on market requirements from the Coral, Shell, and Ornamental Fish Association of Indonesia, are as follows:

1. Size range 5.1 - 8 cm: T
2. Size range 8.1 - 11 cm: S
5. Size range 11.1 - 15 cm: M
6. Size range 15.1 - 30 cm: L

C. Data Analysis

Habitat Characterization Clustering

To observe the clustering of habitat characteristics among observation stations, a descriptive analysis was conducted with the aim of presenting the results in the form of graphs and figures to maximize the information obtained in the field. The habitat characteristics, such as the percentage of live coral cover, dead coral cover, and other life forms, were calculated using the formulas as follows:

$$C = \frac{a}{A} \times 100\%$$

Where:
C = Percentage of life form i cover
a = Frequency of occurrence of life form i
A = Total life form i

Abundance of Ornamental Fish

The abundance of Angel fish was calculated using the formula proposed by (English et al., 1997 in Kasmi, 2012) as follows:

$$N_i = \frac{(\sum n_i)}{A}$$

Where:
Ni = Density of fish species i (individuals/m^2/ha)
$\sum n_i$ = Total number of individuals of species i
A = Sampled area (m^2/ha)
For abundance, the formula is as follows:

$$Abundance = Ni \; x \; Lt$$

Where:
Ni = Density of fish species i (individuals/m^2/ha)
Lt = Productive coral area (ha)

Results and Discussion (Times New Roman 14 bold)

Habitat and Abundance of Angel Fish (Pomacanthus sp.)

In the Liukang Tupabbiring waters, with moderate to good coral cover, fish were found in the reef crest and slope zones, with an average number of fish below 2 individuals. On the other hand, in the Liukang Tangaya waters, in the reef flat, crest, and slope zones, with moderate to good coral cover, a relatively larger number of fish were observed, averaging below 5 individuals compared to Liukang Tupabbiring. This indicates a positive correlation between the number of fish and coral cover, where the percentage of coral cover in the Liukang Tangaya waters was generally better in all zones compared to the Liukang Tupabbiring waters (Figure 3).

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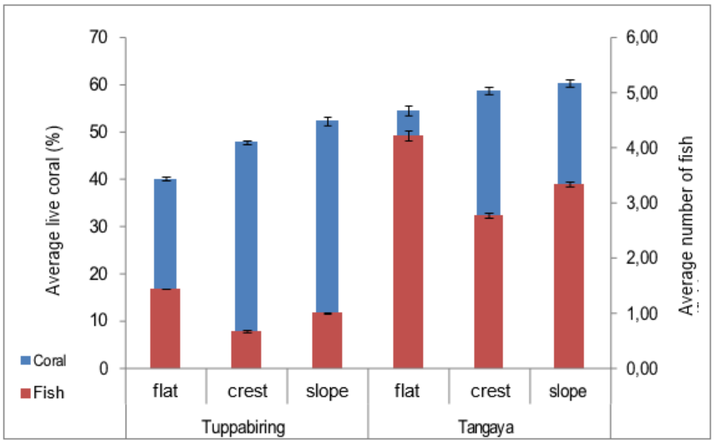

Figure 3. Relationship between coral cover (coral types) and average number of fish based on reef zones in Liukang Tupabbiring and Liukang Tangaya.

For the reef slope zone, fish typically found were of medium and large sizes, associated with submassive and massive coral growth forms. Many fish were found among the submassive corals (aCS), totaling 9 individuals or 7% of the overall fish population in the reef slope zone, ranging from small to large sizes (T, M, and L). This was followed by the crevice under massive coral (cbCM) with 8 individuals of medium and large sizes (M and L). The reef slope zone indicates that this area serves as a habitat for larger-sized fish, resulting in a scarcity of very small-sized fish.

The habitat characteristics, as the fish's living environment, were analyzed using Principal Component Analysis (PCA) to examine the relationship between the basic coral reef component variables (coral cover categories). The relationship between coral growth forms (coral type characteristics) and the abundance of angel fish found at each station was also investigated. Principal Component Analysis (PCA) is a descriptive statistical method that presents information in graphical form, capturing the maximum information from a data matrix.

The analyzed components include the variable of angel fish abundance and the habitat characteristic components (coral growth forms), which are the active variables. In this study, there are 20 variables, namely AN (angel fish), ACB (branching acropora), ACT (tabular acropora), ACS (submassive acropora), ACD (dead acropora), ACE (encrusting acropora), CB (branching coral), CS (submassive coral), CE (encrusting coral), CF (foliose coral), CM (massive coral), CMR (masrum coral), SC (soft coral), SP (sponge), S (sand), DCA (dead coral overgrown by filamentous algae), DC (dead coral), FS (macroalgae), OT (other biota), and R (branching coral fracture). In order to assess the strength of the relationships between variables, Appendix 3 presents the correlation matrix among variables. The matrix shows several variables that are closely and negatively correlated. This means that one variable has a negative influence on the other variable, or as one variable increases, the opposite variable decreases. Among the closely and negatively correlated variables are angel fish with submassive acropora, encrusting acropora, branching coral, encrusting coral, massive coral, sponge, sand, dead coral overgrown by filamentous algae, dead coral, other biota, and branching coral fracture. Conversely, the variables that show strong and positive correlations are angel fish with branching acropora, tabular acropora, dead acropora, foliose coral, submassive coral, masrum coral, soft coral, and macroalgae. Appendix 3, illustrated in Figure 4, shows the results of the principal component analysis of habitat characteristics, highlighting the correlation between variables and the main axes, as well as the station distribution (grouping).

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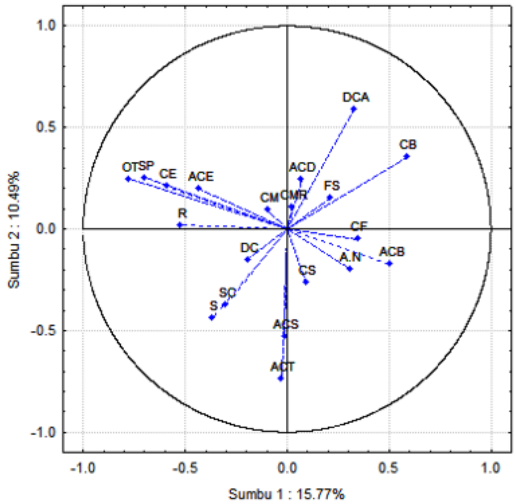

Figure 4. PCA Results: Relationship between habitat (coral type characteristics) and angel fish

From the analysis, it is evident that several variables have strong negative correlations, where an increase in one variable weakens its counterpart. Examples include the correlation between dead coral overgrown by algae and sand, dead coral overgrown by algae and soft coral, as well as branching coral and other biota, branching coral and soft coral, branching coral and encrusting coral, branching coral and encrusting acropora, branching coral and sand, and branching coral and soft coral.

Several variables exhibit strong positive correlations, where an increase in one variable leads to an increase in the neighboring variables. These include other biota with soft coral, encrusting coral, and encrusting acropora, as well as sand with soft coral, and tabular acropora with submassive acropora.

Some variables show weak negative correlations, such as submassive acropora with other biota, submassive acropora with soft coral, submassive acropora with encrusting coral, submassive acropora with encrusting acropora, submassive acropora with sand, and submassive acropora with soft coral. Similarly, angel fish exhibit weak negative correlations with other biota, soft coral, encrusting coral, and encrusting acropora.

There are also variables with weak positive correlations, such as angel fish with branching acropora, submassive coral, and foliose coral. Additionally, there is a weak positive correlation between dead coral overgrown by algae and branching coral.

Regarding the relationship between the abundance of angel fish and the variables of coral reef habitat components (coral type characteristics), it can be explained as follows:

Angel fish show a weak positive correlation with the characteristics of branching acropora, foliose coral, and submassive coral. This indicates that angel fish are commonly found among branching acropora, foliose coral, and submassive coral. Among these coral types, the strongest correlation is observed with branching coral. This suggests that angel fish are more frequently encountered in branching acropora coral compared to the other two coral types (foliose and submassive). Considering the growth form of these corals, both branching acropora, foliose coral, and submassive coral have crevices that can be occupied by organisms or marine animals such as fish for shelter and foraging. Therefore, angel fish are attracted to coral habitats with these characteristics as they provide opportunities for feeding and shelter.

Conversely, angel fish are rarely found in encrusting corals such as encrusting coral and encrusting acropora. This is because angel fish do not find suitable places for shelter or hiding,

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even though they can find food in these types of corals. Additionally, angel fish are also rarely found in soft corals for the same reasons mentioned earlier.

The distribution and density of coral fish are also influenced by biological and physical factors in the coral reef area, such as waves, currents, weather, sedimentation, water depth, physiography, and reef complexity. Therefore, there is no single process that affects the structure of coral fish communities (Jennings & Polunin, 1996). Generally, it can be stated that the diversity and density of coral fish are closely related to the complexity and health of the coral reef as a habitat.

Russell et al. (1978) stated that the spatial distribution of various coral fish species varies according to the conditions of the underwater environment, and the differences in coral reef habitats also result in variations in fish assemblages. In other words, both intra- and inter-species interactions play a significant role in determining spacing and territoriality. Each fish assemblage has preferences for specific habitats, leading to distinct territories occupied by different fish groups.

One of the reasons for the high species diversity in reefs is the variation in habitat or rugosity within the reef. Coral reefs consist not only of corals but also include areas of sand, different types of bays and crevices, algal regions, shallow and deep waters, and various zones traversing the reef. This diverse habitat explains the increased number of fish species present.

Apart from high habitat diversity, another factor to consider is the high level of specialization exhibited by each species. Many fish species have similar needs, resulting in active competition, both between different species and within the same species. This competition leads to the formation of narrower ecological niches. Consequently, in coral reef ecosystems, it is often observed that the movement of many fish species is highly localized, limited to specific areas, and there are distinct differences between fish that are active during day and night.

Based on the research, the habitat characteristics of angel fish in the three reef zones tend to be associated with branching corals, crevices, and cave-like formations of submassive and massive corals such as cbCM, csCM, aCS, acCB, CBA, CSCMA, bACT, cACT, cCF. These coral types typically feature large rocks, caves, holes, and crevices, which are preferred by angel fish as they provide safe shelter and a food source. Generally, adult-sized fish are found in the reef flat zone (sizes M and L), indicating that this area is transitional, resulting in varying fish sizes. On the other hand, in the crest zone, the fish sizes range from small to adult. Meanwhile, in the reef flat zone, mostly small-sized (juvenile) fish or sizes T and S are found (Kasmi, 2012). Angel fish are commonly found among branching acropora coral (ACB), foliose coral (CF), submassive coral (CS), and massive coral (CM). The strongest correlation is observed with the characteristic of branching acropora coral (ACB). This suggests that angel fish are more frequently encountered in branching acropora coral compared to other coral types. The growth forms of branching acropora coral (ACB), foliose coral (CF), submassive coral (CS), and massive coral (CM) share a common feature, which is the presence of crevices that can be occupied by organisms or marine animals such as fish for shelter, hiding, and foraging. Therefore, angel fish prefer coral types with these habitat characteristics as they provide food sources and shelter (Kasmi et al., 2011).

he density, standing stock of Angel fish, and coral reef area data are presented in the following paragraph. At the Kondongbali station, the coral reef area covered 359.41 hectares, with a fish density of 12 individuals per hectare. The transek area sampled was 4,500 square meters, resulting in a density of 0.000074 individuals per hectare and a standing stock of 266 individuals. Similarly, at the Pamanggangan station, the coral reef area was 199.1 hectares, with a fish density of 14 individuals per hectare. The transek area sampled was 4,500 square meters, resulting in a

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density of 0.000074 individuals per hectare and a standing stock of 147 individuals. The Sarappo Keke station had a smaller coral reef area of 15.9 hectares, with a fish density of 4 individuals per hectare. Despite the smaller area, the transek sampling resulted in a higher density of 0.0008889 individuals per hectare, but no standing stock was observed. Moving to the Tinggalungan station, the coral reef area covered 145.8 hectares, with a higher fish density of 39 individuals per hectare. The transek area sampled was 4,500 square meters, resulting in a density of 0.0086666 individuals per hectare and a standing stock of 12,636 individuals. The Karang Koko station encompassed a coral reef area of 78.24 hectares, with a fish density of 29 individuals per hectare. The transek area sampled was 4,500 square meters, resulting in a density of 0.0064444 individuals per hectare and a standing stock of 5,042 individuals. Lastly, the Sapuka Kecil station boasted the largest coral reef area of 1,272.87 hectares, with a fish density of 31 individuals per hectare. The transek area sampled was 4,500 square meters, resulting in a density of 0.00688889 individuals per hectare and a significantly higher standing stock of 87,687 individuals.

The relationship between coral reef area and fish abundance at each station was examined. In Liukang Tupabbiring, the Kondongbali station had a potential reef area of 359.41 hectares with a fish density of 12 individuals per hectare and a total abundance of 4,313 individuals. The Pamanggangan station had a reef area of 199.1 hectares, a fish density of 14 individuals per hectare, and an abundance of 2,787 individuals. At Sarappo Keke station, which had a smaller reef area of 15.9 hectares, the fish density was 4 individuals per hectare, resulting in an abundance of 64 individuals. In Liukang Tangaya, the Tinggalungan station had a reef area of 145.8 hectares, with a higher fish density of 39 individuals per hectare and an abundance of 5,686 individuals. The Karang Koko station covered a reef area of 78.24 hectares, with a fish density of 29 individuals per hectare and an abundance of 2,269 individuals. Finally, the Sapuka Kecil station had the largest reef area of 1,272.87 hectares, a fish density of 31 individuals per hectare, and the highest abundance of 39,459 individuals.

Production of Angel Fish

The production of Angel fish, as a popular species in the ornamental fish trade, plays a significant role in the global market. This section aims to provide insights into the production dynamics of Angel fish, considering aspects such as demand, supply, and market trends. The following discussion will examine the relationship between supply and demand, exploring the factors that influence the production and trade of Angel fish. Additionally, the challenges associated with maintaining sustainable production levels and the impact on market prices will be addressed. To better understand these dynamics, Figure 5 illustrates the demand and supply trends of Angel fish in the ornamental fish industry.

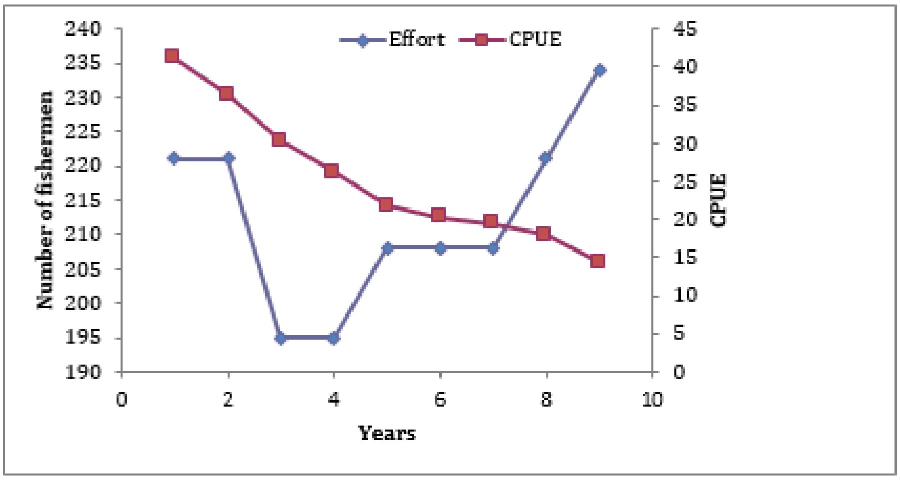

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Figure 5. Demand and Supply of Angel Fish

The exact demand for Angel fish cannot be determined in the field. However, in South Sulawesi, it has been observed that the market absorbs whatever quantity the fishermen are able to catch. According to (Kasmi 2012), Angel fish is one of the most sought-after marine ornamental fish in the global market. Regardless of the quantity caught, they are quickly sold, and even other types of ornamental fish are often sold along with them, making them highly desirable for exporters. However, these fish are only found in specific areas, resulting in limited stocks in ornamental fish farms.

Considering the increasing trend in the prices of Angel fish (Figure 6), according to the law of demand, the demand for these ornamental fish should decrease. However, since ornamental fish are considered unique goods, the law of demand cannot be applied here. The exception to the law of demand occurs when the supply of a product in the market decreases, which increases consumers' desire to own it and consequently drives up its price.

Based on the law of supply, as the price of a good or service increases, the supply by producers should also increase. However, in the case of ornamental fish exporters, this law does not apply.

The demand for fish is determined by a backward-sloping supply curve at the optimal level of fish production. Sometimes, a negatively sloped supply curve is observed, as in the case of diminishing fish populations in nature (Kasmi 2012, 2013). This refers to the curved supply curve in the Copes model, which is applicable to the production of Angel fish. Initially, there is an increase in production, followed by a continuous decrease due to high exploitation pressure despite increased efforts. Graphically, the supply curve shifts counterclockwise (or, in other words, becomes steeper) as fish stocks decline.

From historical data, it can be seen that the supply or production of fish in the waters of Pangkajene Islands and Taka Bonerate Islands continues to decrease while the price keeps increasing. The phenomenon observed in the fish supply aligns with (Kasmi 2012), which states that the equilibrium supply function is very simple for a stock of fish with open access following natural stock growth and fishing, where growth is equal to catch. Furthermore, the supply function will increase until it reaches the Maximum Sustainable Yield and then decrease towards zero as the price continues to rise. Therefore, the supply function results in a decreasing supply. This is supported by (Leonard et al. 2020), which indicates that the curve in open-access and regulated limited-access follows a backward-bending supply function for small-scale fishing efforts, and the supply function opposes the demand function for a conventional fish product.

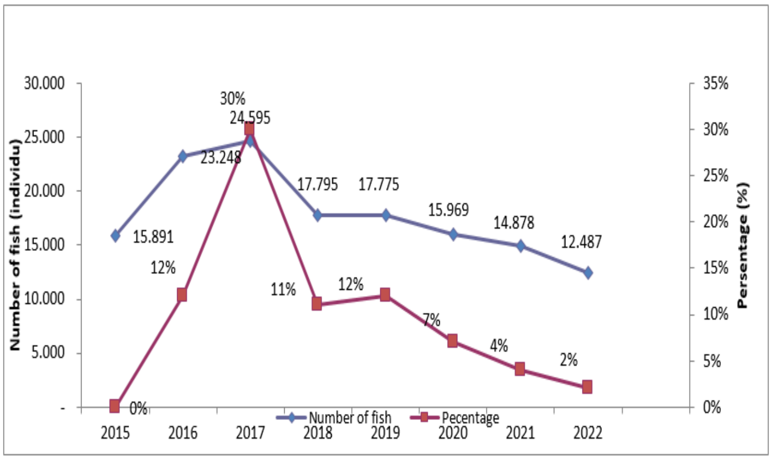

Figure 6. Angelfish supply curve in Indonesia

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Figure 6 illustrates the supply curve of Angelfish in Indonesia from 2015 to 2022. The data source for this figure is AKKII and AKIS 2015 (unpublished, modified). The graph shows the fluctuations in the supply or catch of Angelfish in the market over the years. The recorded figures indicate that the supply of Angelfish reached 15,891 individuals, then increased to 23,248 individuals, and further rose to 24,597 before declining to 17,795 individuals. Subsequently, the supply continued to decrease, reaching 12,487 individuals in 2022. This decline in supply is not due to reduced consumer demand but rather a result of diminishing fish stocks. The largest market demand for imported Angelfish comes from European Union countries, accounting for 50% of Indonesia's total Angelfish exports. The United States follows with a demand of 40%, and the remaining 10% comes from Asian countries.

Based on the obtained data, it is evident that the overall supply or production of fish in Indonesian waters has been continuously declining while prices have been increasing.

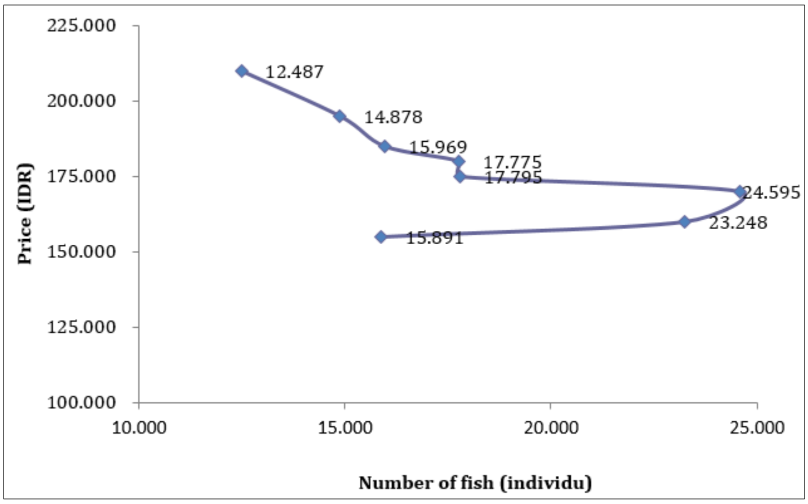

Figure 7. Backward Bending Supply Curve of Angelfish in Indonesia

Figure 7 represents the backward-bending supply curve of Angelfish in Indonesia from 2015 to 2022.

Excessive demand and higher prices compared to other ornamental fish species can result in an increase in fishing activities targeting Angelfish. The high interest in Angelfish is also evident by its use as a bargaining chip for fish suppliers to include the sale of other types of ornamental fish (Kasmi 2012). However, this can have negative consequences for the population of Pyama Angelfish as it continues to decline due to high exploitation pressure. As a result, the supply curve exhibits a negative slope (Figure 7), indicating an initial increase in supply followed by a subsequent decrease in supply.

Conclusion

In conclusion, the research conducted in the waters of Liukang Tupabbiring Islands revealed an abundance of Angel fish at a rate of 0.00005 individuals/m^2 with a standing stock of 138 individuals, while in the Liukang Tangaya subdistrict, the abundance was recorded at 0.005 individuals/m^2 with a standing stock of 35,121 individuals. The study indicated that the abundance of Angel fish was not positively correlated with live coral cover but was influenced by the structural growth forms of coral habitats, such as branching, submassive, and massive coral formations.

Furthermore, the research findings indicate that the production status of Angelfish in the Spermonde Archipelago has exceeded the Maximum Sustainable Yield (MSY). Therefore,

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increased fishing efforts would result in a decline in Angelfish production. This suggests that Angelfish has been subject to excessive fishing pressure, which can impact its supply. Additionally, the backward-bending supply curve demonstrates a decreasing supply trend despite increasing prices, indicating a likely decrease in fish stocks.

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