Distribution fisheries resources of Small Island in Estuary Area: An assessment in Bunyu Island, North Kalimantan, Indonesia

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Abstract. Understanding the spatial distribution of potential fish resources can optimize the management of capture fisheries, especially in coastal areas on small islands with limited supporting activities factors. Swept analysis is applied to the study of distribution of fish resources in waters around Bunyu Island in order to estimate spatial distribution of fish populations in Bunyu Island waters of North Kalimantan based on biomass, weight and number of fish abundance and to examine the effect of different sampling location and time difference of observation. Observations were made in 8 sampling areas around Bunyu Island waters in 3 periods, namely the southern season, the peak of southern seasons and the transition of the southern seasons to the northern seasons. Fish resources found in Bunyu Island waters are 59 species and non fish are 18 species, consist of 61 species of demersal fish and 16 pelagic species. Types of dominant demersal fish caught are 6 species and always found in 3 sampling periods namely Gulamah (Belanger's croaker, Johnius belangerii), Kuniran (Goat fishes, Upeneus sulphureus), Kurisi (Threadfin bream, Nemipterus sp.), Ote-Ote/Manyung (catfishes/Arius caelatus), Pepetek (ponyfish, Leiognathus sp.), and Puput (ray-finned fishes, Ilisha elongata). By area, the total biomass of fish resources from the three surveys showed variation. The lowest biomass of fish resources was found in the southeast of Bunyu Island (area H) of 890.92 kg/km2 and the highest was found in the southern area of Bunyu Island (area G) of 3804.11 kg/km2. Area H shows consistency in the least amount of biomass in each survey. Differences in biomass of fish resources are affected by the migration of fish determined by changes in sea current patterns, food availability, and predation.

1. Introduction
Fisheries resources in Indonesia have a very diverse biodiversity and become an important part of the economy of coastal communities, especially those who work as fishermen. On the other hand, it has been indicated that the decline in fish resources in Indonesia's coastal waters is caused by: (1) environmental damage and pollution, (2) over fishing and (3) unfriendly environmentally fishing method. Damage to coastal ecosystems such as mangroves, seagrass and coral reefs which are fish habitats has occurred in various coastal areas. Overfishing have occurred among them in the Java Sea.
While unfriendly environmentally fishing method such as the use of trawling, fish bombs and fish poisons have destroyed fish habitat.

The waters around Bunyu Island, Bulungan Regency, North Kalimantan Province have an important role as a source of economically important fish resources that are utilized not only by local fishermen of Bunyu Island, but also by surrounding fishermen such as from Tarakan, Sebatik and Nunukan. Fish resources in the waters around Bunuy Island cannot be separated from the conditions of the surrounding waters such as Tarakan and Nunukan waters. The diversity of Tarakan aquatic fish species is relatively low due to the increasingly heavy fishing pressure factor [7]. Pepija fish (Harpadon nehereus) which live in the northern waters of Tarakan Island or northwest of Bunyu Island have experienced a decrease in stock due to overfishing and degraded mangrove ecosystems [3].

In estuary waters, there are fish with characteristics that are able to survive in salinity differences due to mixing of fresh water from rivers and sea water. While the habitat of reef fish such as grouper is coral reef which is dominated by massive coral, non-coral and other dead substrates [4]. In the waters around Tarakan and Bunyu, there were 86 caught demersal fish species from ten dominant fish families. Pony fish (Leiognathidae) and Croaker fish (Sciaenidae) are dominated the catch [7].

The objective of this study is to estimate the spatial distribution of fish populations in the waters of Bunyu Island in North Kalimantan based on biomass, weight and number of individual fishes and examine the effect of differences in sampling locations and differences in observation time.

2. Material and Methods

The estimated value of the amount or magnitude of fish biomass based on the type of fish in a certain period of time is approached by calculating the concept of fish stocks. Considering that fish are dynamic animals that always move (migrate), both to find food and to spawn, it is quite difficult to determine the amount of biomass. Fisheries biology researchers have produced a breakthrough approach to estimating fish stocks such as using Swept Area.

Data from Swept Area is then calculated by biomass and the results are presented on the spatial distribution map of fish biomass using Arcgis 10.5 software. Cluster analysis was carried out to determine area grouping based on weight factors and number of individual fish. Whereas to determine the effect of differences in location and sampling time on biomass magnitude, one-way analysis of variance (ANOVA) was carried out using SPSS version 15.0 software.

2.1. Study area

The study area is in the waters around Bunyu Island. Bunyu Island is located in Bulungan Regency and is adjacent to Tarakan City in North Kalimantan Province. The waters around Bunyu Island are bordered by Sesayap River estuary in the north and Sulawesi Sea in the East and South. In the west to southwest bordering the sea waters of Tarakan City.

There are 2 characteristics of fish habitat around the waters of Bunyu Island, namely the estuary waters and the high seas. Characteristics of estuary waters are places where fresh water mixes from river flows and saltwater from the sea. Estuary waters are located in the north, west and northeast of Bunyu Island. Furthermore, the characteristics of the high seas are in the eastern and southern parts of Bunyu Island with the characteristics of waters that are influenced by ocean currents and depths of the waters than the estuaries. In the eastern part of the island of Bunyu, the sea beds are coral and sand and it is a habitat for reef fish.

| No | Period             | Time                | Remarks                          |
|----|--------------------|---------------------|----------------------------------|
| 1  | Swept Area Period 1| 5 – 8 July 2017     | Representative of south season   |
| 2  | Swept Area Period 2| 17 – 20 September 2017 | Peak of south season          |
| 3  | Swept Area Period 3| 8 – 11 November 2017 | Representative of transition from south season to north season |
2.2. Data collection

Data collection activities was conducted during 3 periods by considering the seasonal patterns and secondary data captured by fishermen as presented in Table 1.

The swept area sampling location was carried out with the principle of purposive sampling with the aim of knowing the distribution of fish resources around the waters of Bunyu Island representing the estuary waters and the high seas. The 2 Gross Ton size fishing vessel used in this research equipped fishing gear with 9 meters of rope length and 18 meters of net length of mini trawl.

![Figure 1. Study area of swept area around Bunyu Island Waters.](image)

3. Data Analysis

3.1. Estimation of fish biomass

Estimation of abundance of fish stocks in the form of biomass as a results of the swept area method was analyzed [6]. The calculation is based on the area of the swept area (a), the length of the area covered by “swept area” (D) and the length of head-roppe (hr). Swept length (D) is calculated from time spent trawling (t) and velocity of the trawl over the ground (V), with the formulation as follows:

\[ D = V \cdot t \]

![Figure 2. Swept area method.](image)
Considering the exact position of the start and end of the haul, both latitude and longitude of a haul are recorded with GPS, then the swept length \( D \) is calculated by the following formulation:

\[
D = 60 \sqrt{((\text{Lat}1 - \text{Lat}2)^2 + (\text{Lon}1 - \text{Lon}2)^2) \times \cos^2(0.5(\text{Lat}1 + \text{Lat}2))}
\]  

\( D \) in Nautical mile (NM) and 1 NM = 1852 m.

Swept area is:

\[
a = D \times \text{hr} \times X_1
\]  

The spread width of wing trawl (wing spread, \( H \)) is the multiplication between the widths of the mouth trawl opening with the head rope fraction and also known as the constant or the boundary between two trawl opening straps (\( X_1 \)), the width of the wing trawl opening is:

\[
H = \text{hr} \times X_1
\]  

\( X_1 \) ranged from 0.4 [6] and 0.66 (SCSP 1978 [6]). It is recommended to use the value of \( X_1 = 0.5 \) as the best consideration [5].

The swept area can also be determined by the following formulation:

\[
a = D \times H
\]  

For estimating biomass, catch rate data is used, either in the form of catch per haul or catch per hour or catch per unit of area (CPUA). If \( C_w \) is the catch volume in one haul, then \( C_w / t \) is the catch in weight per hour and \( t \) is the spent hauling in hours. If \( a \) is the area swept and \( a/t \) area swept per hour, then the catch per unit area (CPUA in kg km\(^{-2}\)) is:

\[
CPUA = \frac{C_w}{a} = \frac{C_w}{a} (kg km^{-2})
\]  

If \( X_2 \) is biomass fraction from effective swept and caught, so \( \frac{C_w}{a} \) is the mean catch per unit area, then the biomass average per unit area (\( \overline{b} \) in kg km\(^{-2}\)) are:

\[
\overline{b} = \frac{C_w}{X_2} (kg km^{-2})
\]  

The \( X_2 \) value for Indonesian waters is 0.5.

3.2. Cluster analysis and variants

The results of the biomass data calculation then analyzed by the cluster hierarchy to identify the grouping of each area based on weight factors and the number of individual fish in the 8 observation areas. Furthermore, to determine the effect of differences in location and time of observation of fish biomass, one-way ANOVA analysis was used using SPSS software Version 15.0.

4. Results and Discussion

4.1. Distribution of weight and number of fish

Map of distribution of the number of fish species caught during the 3 swept area periods in the waters of Bunyu Island (Figure 3) shows that the number of fish species around the estuary (Area A, B, C, F) has a greater compared to the number of fish species in the direction of the high seas (Area D, E, H, except area G). This fact indicate that the estuary waters around Bunyu Island is become the main habitat
of fish, especially as spawning and nursery ground areas as mentioned that the estuary has an important ecological role according to: as a source nutrients and organic matter transported through tidal circulation, the habitat provider for a number of animal species that depend on the estuary as a place of shelter, as feeding ground and also as a place to reproduce and/or as nursery ground, especially for a number of fish and shrimp species.

Figure 3. Map of the comparison of the number of fish species per sampling area in the waters around Bunyu Island.

The characteristics of sediment in the waters area around Bunyu Island are mud, sand and coral. The results of J. The result of other study to indicated that there are 3 types sedimentary texture groups in the waters of Bunyu Island, namely sandy clay, sandy and sandy silt or muddy sand [1].

In general, the waters of Bunyu Island near the Sesayap River estuary have a type of mud sediment. This is as consequence of the soil sedimentation process flowed by Sesayap watershed. The more towards the sea, the sediment is sand and silt. According to the results of other research [2], the type of marine geology in the waters of the Tarakan sub-basin from the land to the high seas (off the coast of Tarakan Island and Bunyu Island) is sand, silt sand, sandy silt and silt. Seabed sediment types together with seawater quality affect fish habitat patterns, especially fish that live in seabed (Demersal Fish). Demersal fish that live in muddy waters are Nomei fish, croaker fish, Tongue fish, shrimp, whereas fish whose habitat is in coral such as grouper, red snapper.

Fish resources are spread throughout the waters of Bunyu Island. Based on the catch during the survey period, fish resources found in the waters of Bunyu Island are 59 species and 18 non-fish species. Based on type of fish habitat, consist of 61 types of demersal fish and 16 pelagic fish. Demersal fish species are dominantly caught because they are in accordance with trawling characters that sweep the bottom of the waters. During the survey, the weight and number of 6 dominant fish species that are always found in the 3 survey periods are Croaker fish (Gulamah), Gold-saddle goatfish (Kuniran), Threadfin bream (Kurisi), Marine catfish (Ote-Ote/Manyung), Pony Fish (Pepetek) and ray-finned fishes (Puput). Figure 4 showed that in area H (southeast of Bunyu Island) it was a sampling area with the lowest catch, while the highest weight and number of catches are found in area B. In addition, the
area G which is south of Bunyu Island also shows results with a high weight and amount compared to the C and F areas as well as areas D and E.

Figure 4. Weight distribution and number of fish individual on each survey area.

Furthermore, hierarchy cluster analysis was applied to identify the clustering of each area based on weight factor and number of fish individuals in 8 observation areas. The results of the analysis show that there are 2 clusters of weight and the number of individual fishes. The areas B, G and H become one cluster whereas the other clusters are area A, F, D, C, and E. According to sediment distribution, then the areas B, G, H have characteristic sandy sediment to rust, while areas A, F, D, C, and E are dominated by sandy mud sediments. Based on oceanographic aspects, areas B, G, H located more towards the Sulawesi Sea so that the influence of open sea is greater than the influence of freshwater input from the estuary. On the other hand, areas A, C, F are more affected by freshwater inputs coming from the Sesayap River. There are exceptions in Location D and E where it is currently an area of anchoring of the coal transport vessels so that fish habitat may be slightly disturbed.

Figure 5. Dendrogram results of cluster analysis for weight and number of fish individuals using SPSS software.
Based on the distribution of fish catch in the swept area the following fish: Gold-saddle goatfish, Pony Fish, and cuttlefish (Sepia sp.) are scattered throughout the area during the survey, as well as several other types such as Silver Pomfret, Yellow Tail, Croaker, Marine catfish, ray-finned fishes and Shrimp were found almost in all areas of fishing ground.

As the dominant species of fish, Gold-saddle goatfish, Pony Fish, and cuttlefish are found in every survey period. Although it is present during each survey period, however, these three fishes are not found in any observation area. This means that the distribution of these dominant fish spatial shows the difference but temporarily does not show any difference. For example, the Gold-saddle goatfish fish is consistently found in areas D and H in each survey, while in areas A, B, and C are found only once in different surveys. The same condition occurs on pony fish, consistently found in areas B, D, E, F, and H in each survey period.

Gold-saddle goatfish and Pony Fish show the same presence in the D and H areas consistently. This indicate that this area is supposed to be a schooling area for these dominant fish. Whereas cuttlefish shows different results, which are consistent in areas C and G. This difference is influenced by environmental suitability, including factors of food availability for each type of fish. This reasoning is also strengthened by the size distribution of dominant fish (Gold-saddle goatfish and Pony Fish) is small to medium size fish. In general, small to medium sized fish tend to have a preference high food availability due to their limited ability to find prey.

4.2. Fish biomass

The abundance of fish resources in the form of total biomass varies in each survey period. Except in area B, the biomass of fish resources tends to increase from the first survey to the third survey and total biomass from all observation areas also increased from the first survey to the third survey. Biomass of fish resources for 3 survey period are 5,381.57 kg/km²; 6.007.90 kg/km² and 9,226.01 kg/km² respectively (Table 2). Based on time surveyed, the third survey period is a better period of fish caught in terms of the abundance of biomass in fish resources. Based on the area, the total biomass of fish resources from the three surveys also showed variation. The lowest fish resource biomass was found in area H of 890.92 kg/km² and the highest was found in area G of 3804.11 kg/km². Area H shows consistency in the least amount of biomass in each survey.

| Area survey | Biomass (Kg/Km²) |
|-------------|-----------------|
|             | Survey 1 | Survey 2 | Survey 3 | Total | Mean |
| A           | 857,30   | 887,22   | 1,456,64 | 3,201,16 | 1,067,05 |
| B           | 1,543,06** | 1,117,33** | 893,36 | 3,553,75 | 1,184,58 |
| C           | 556,34   | 458,55   | 962,36   | 1,977,26 | 659,08 |
| D           | 579,65   | 923,27   | 1,237,68 | 2,740,60 | 913,53 |
| E           | 921,96   | 634,97   | 911,91   | 2,468,84 | 822,95 |
| F           | 225,30*  | 691,63   | 1,061,91 | 1,978,83 | 659,61 |
| G           | 471,57   | 1093,59  | 2,238,95** | 3,804,11** | 1,268,04 |
| H           | 226,39   | 201,33*  | 463,20*  | 890,92*  | 296,97 |
| Total       | 5,381,57 | 6,007,90 | 9,226,01 |

Note: *) = lowest; **) = highest

The largest biomass of fish resources is found in area B (surveys 1 and 2) and area G for survey 3. Based on the distribution of fishing areas, the largest fish biomass is mostly in areas with relatively shallow waters and far apart from Bunyu Island. Based on the biomass of fish resources from the swept area, areas A, B and G have an average abundance that is higher than other areas. The largest biomass in the fishing area is determined by the size of the fish and the number of fish caught. In this area, the catch is dominated by fish in large quantities even though the weight of each individual is small, such
as pony fish and ray-finned fishes. In addition, in this area also found large size fish, such as Croaker fish and Marine catfish. Map of fish biomass comparison per unit survey area in the study area is presented in Figure 6.

Area A and B have consistent biomass for 3 large sampling periods. Area H consistently has the smallest biomass for 3 times survey. Area C, D, E, F, has a biomass value that fluctuates during 3 survey periods. This condition is presumably due to the availability of high fish food sources in areas A and B which are the estuary / Sesayap river estuaries. In contrast, in the H area, which is located in the southeast of Bunyu Island, it is affected by the strong Indonesian ocean currents (ARLINDO) in the Sulawesi Sea. So that differences in fish resources biomass are influenced by fish movements which are determined by changes in current patterns, food availability, and predation.

![Figure 6. Map of the comparison of fish biomass per survey area in the waters around Bunyu Island.](image)

The effect of differences in location and time of observation of fish biomass analyzed by one-way variants (one-way Analysis of variants) using SPSS Version 15.0 software shows that the calculated F value (0.962195) is smaller than F table (3.4668) so the Hypothesis Ho is accepted which means there is no biomass difference between 3 seasons/time of survey.

This means that fish biomass in the location around the waters of Bunyu Island is relatively steady in these 3 survey period. The presence of pony fish which is always caught in each survey period in almost all locations shows that the dominance of pony fish contributes to the stability of fish biomass in the waters around Bunyu Island. Meanwhile the presence of pony fish shows that this fish have a high growth rate so they always survive even though they are often caught in large volumes. The influence of fishing pressure can trigger changes in the value of the diversity index because it relates to disruption of community structures such as reduced species wealth, disruption of the balance of community structures and a shift in the dominance of fish species caught [7].

5. Conclusion
The distribution of fish resources and the abundance of fish species are more diverse in locations around the river mouth than the waters towards the high seas (east and southeast of Bunyu Island). The diversity
of fish around the estuary (Area A, B, C, F) has a greater number of species compared to fish caught in the direction of the high seas (Station D, E, H, except area G). This shows that the estuary waters are fertile areas and become the main habitat of fish, especially as spawning and nursery ground. On the mud substrate at the river mouth around the waters of Bunyu Island, fish species are found, including Nomei fish, Croaker fish, and Indian halibut fish. While the sand and coral substrate is dominated by reef fish such as grouper and snapper.

Cluster analysis results for the parameters of weights and number of individuals from the swept fish, the area B, G and H become one cluster while the other clusters consist of areas A, F, D, C, and E. According to sediment distribution, the area B, G, H has sandy to coral sediment characteristics, while area A, F, D, C, and E are dominated by sandy muddy sediments. In term of oceanographic characteristic, area B, G, H is located more towards the Sulawesi Sea so that the influence of the high seas is greater than the influence of freshwater input from the river mouth. On the other hand, locations A, C, F are more affected by freshwater inputs coming from the Sesayap River estuary.

The effect of differences in location and time of observation of fish biomass identified by one-way analysis of variance (ANOVA) showed that no biomass differences between the 3 seasons/survey time.

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