The Dynamic of Fishermen's Income and the Influencing Factors on the West and East Coasts of Sumatra Island

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Abstract. Indonesia is known as a 'Paradise under the Sea,' with the richness and beauty of its coral reefs. This ecosystem is an important asset that has high economic value and a potential source of community income. However, this wealth has not been utilized optimally by coastal communities, especially fishermen. This is backed by their poor economic conditions. This paper discusses the dynamic of fishermen's income and the influencing factors on the West and East Coasts of Sumatra Island. The fishermen’s income on both coasts is dominated by income from capture fisheries, which fluctuates throughout the year. The income of east coast fishermen is higher and more varied than west coast fishermen. This paper identifies three factors that influence the differences: 1) technological capacity of the fishermen's fleet and fishing gear, 2) fish marketing and seasonal variations throughout the year, along with the degradation of coastal resources, and 3) policies and programs for fishermen's empowerment and development in coastal areas. This paper uses quantitative and qualitative methods from the assessment of social aspects of coral reefs conducted by the COREMAP LIPI team. The authors also utilize secondary data from related documents, research results, papers and books.

1. Introduction
1.1. Background
Indonesia is known as one of the world's coral reef centers with a rich biodiversity; a habitat for 569 species of the world's 845 coral species, contributing to two-thirds of the world's total coral species. The total area of coral reefs in Indonesia reaches 2.5 million hectares, unevenly scattered throughout the archipelago, with the largest being on Sulawesi Island (862,627 hectares). Meanwhile, coral reefs on Sumatra Island follows in the second position (478,587 hectares), accounting for almost one-fifth of Indonesian’s coral reefs. [1]

Coral reefs are productive assets that have high economic value for the welfare of the community. Although the wealth of coastal resources has not been utilized optimally, in various places it has been damaged with varying conditions between regions. In the western part of Indonesia, especially in Sumatra, damage to coral reefs has reached more than one third of the total area of coral reefs on the island. The percentage of coral reefs still in excellent condition is very small, less than 10 percent, but this percentage is slightly higher than in 2018. [2].

Furthermore, the condition of coral reefs in Sumatra varies between the East and West Coast. On the East Coast, most of the coral reefs are moderately damaged, except for Batam, where a small part of the area still has good coral reefs. The condition of most of the coral reefs on the West Coast is
similar to that on the East Coast. However, coral reefs that are still in good condition are more spread out in the districts, although their area are limited. [1,2].

Damage to coral reefs on the East and West Coast of Sumatra is closely related to anthropogenic factors. There are several causes of damage to coral reefs. The main ones are sedimentation and declining water quality due to domestic waste and land use. Meanwhile, turbidity and salinity of sea water halt the growth of coral reefs in this area [2]. Another important factor that damages coral reefs is the use of illegal fishing gear, especially potassium cyanide and bombs. This is down to two motives: economic motive, to get the maximum profit; and the non-economic motive, especially the lack of knowledge and awareness of the importance of preserving the ecosystem [3].

The condition of coral reefs and marine resources often hampers the socio-economic activities of coastal communities and small islands, even though most of them, especially fishermen, depend on these resources for their livelihoods. Most fishermen still do not benefit from the wealth of the sea which is an open access area [4, 5, 6, 7].

Fishermen with limited knowledge, skills and capital try to take advantage of this productive asset to increase their income. Their labor is strongly dependent on seasonal conditions, in contrast to people living on the mainland who can work all year round. Recently, the condition of fishermen has worsened with the frequent occurrence of extreme weather which prevents them from catching fish. In addition, fishermen with limited capabilities often have to compete with other fishermen from outside the area who enter their fishing areas they use better tools and boats with a much larger capacity than the local fishing fleet [3, 8].

In an effort to manage coral reefs and respond to community problems in coastal areas, the government issues policies and programs for managing coastal and marine resources, including through a coral reef rescue program known as Coral Reef Rehabilitation and Management Program (COREMAP). This program aims to conserve coral reefs and improve community welfare. To achieve this goal, coastal and small island communities—especially fishermen—are involved in the program, so that they will not only take advantage of these ecosystems but also monitor these ecosystems in order to achieve sustainable management. [3].

1.2. Objectives
This paper discusses the dynamic of fishermen's income and the influencing factors on the East and West Coast of Sumatra. The discussion focused on the variation of fishermen's income from capture fisheries and mariculture activities, as well as fishermen's income by season. Discussions on the factors that influence the dynamics of fishermen are grouped into three parts: internal, external and structural factors. Internal factors consist of the technological capabilities of the fleet (boat/body and engine), fishing gear and fishing areas. External factors include economic influences with a focus on marketing fisherman's catch and environmental aspect, namely the influence of seasonal variation during the year and the degradation of coastal resources, especially coral reefs. Meanwhile, structural factors are related to coastal management policies and programs as well as other developments implemented in coastal areas and small islands.

2. Methods
The data and information used in this paper were mostly sourced from the basic data of the socio-economic study of coral reefs and related ecosystems conducted by the COREMAP-LIPI research team in 2015. In western Indonesia, this baseline study focused on 7 districts/cities on the East and West Coast of the Sumatra. In the East Coast, the study was carried out in three districts and one city: Natuna District, Batam City, Bintan District and Lingga District. Meanwhile in the West Coast, it was done in the Districts of North Nias, Central Tapanuli and Mentawai.

The collection of baseline data for this socio-economic study referred to the methodology set out in the Handbook for Socio-Economic Studies of Coral Reefs and Related Ecosystems [9]. The baseline of this study used a quantitative and qualitative approach. Quantitative data were collected through a survey of selected households in the sample villages. Quantitative data collected included
demographic characteristics of household members and household economic conditions (including household income). The number of villages in survey locations in each district/city varied according to the characteristics and diversity of the village (Table 1). Data collection was based on a survey using a closed-question questionnaire set. The survey was conducted on approximately 200 respondents who could represent the population of coastal communities in each research location.

Table 1. Location of coral reef socio-economic baseline study on the East and West Coast of Sumatra.

| Coast in Sumatra | District/City | Village                                      |
|------------------|---------------|----------------------------------------------|
| East coast       | Natuna        | Kelanga, Cemaga Tengah and Sededap           |
|                  | Batam         | Pulau Abang and Pulau Karas                 |
|                  | Lingga        | Sekanah and Limbung                         |
|                  | Bintan        | Mapur, Pengudang and Berakit                 |
| West coast       | North Nias    | Pasar Lahewa, Balefadorotuho, Seriawu and Teluk Bangkuang |
|                  | Central Tapanuli | Sitardas, Jago-jago and Tapianauli 1             |
|                  | Mentawai      | Pasakkiat and Katurai                        |

Source: Socio-economic baseline study of coral reefs and related ecosystems, COREMAP-LIPI, 2015

Meanwhile, qualitative data were obtained through various data collection techniques, such as open interviews, Focus Group Discussions (FGDs) and field observations. Qualitative data collection aimed to gain deeper understanding of various aspects concerning the living conditions of the community and their relation to the use of coastal and marine resources, especially coral reefs. Qualitative data was also collected to explore various information obtained from the survey.

In addition, to complete the data and fully understand the problems in a holistic manner, the authors also used data from secondary sources. This sources included various documents, research reports, papers and books that were relevant to the topic of this paper.

3. Results and discussions
3.1. Variation of the fishermen's income
Income from fishing activities was a combination of income from capture fisheries and mariculture. Income from capture fisheries activities was the income that had been earned by fishermen throughout the previous year (one year before the survey) which was broken down according to seasons: calm wave season (peak), transition season (moderate) and strong wave season (famine). Meanwhile, income from mariculture included income from all types of cultivation that had been carried out during the previous year.

3.1.1. Fishermen's income from capture fisheries activities. In general, the average income of fishermen from capture fisheries per month in the East Coast of Sumatra was higher than the average in the West Coast. In the East Coast, the highest average income per month was in Lingga District (Rp3,684,915), and the lowest was in Natuna District (Rp1,668,910). Meanwhile in the West Coast, the highest average income was in Central Tapanuli District (Rp1,700,576) and the lowest is in Mentawai District (Rp544,130). The highest average monthly income from capture fisheries activities in the West Coast (Central Tapanuli District) was almost the same as the lowest average income in the East Coast (Natuna District). See Table 2 for further details.
Table 2. Average of fishermen’ income per month from capture fisheries, by districts/city in the West and the East Coasts of Sumatera, 2015.

| Coasts in Sumatera | District/city     | Average income from capture fisheries (in Rp) | Number of respondents |
|--------------------|-------------------|-----------------------------------------------|-----------------------|
| The East Coast     | Natuna District   | 1,668,190                                     | 95                    |
|                    | Batam City        | 2,561,700                                     | 167                   |
|                    | Lingga District   | 3,684,915                                     | 160                   |
| The West Coast     | North Nias District | 1,136,470                                    | 176                   |
|                    | Central Tapanuli District | 1,700,576                        | 101                   |
|                    | Mentawai District | 544,130                                       | 34                    |

Source: Socio-Economic Baseline Study of coral reefs and related ecosystems, COREMAP-LIPI, 2015

The difference in average income from capture fisheries on the East Coast and West Coast of Sumatra is related to differences in geographical location, fishery potential and the economic value of fish on the two coasts. The East Coast which is located in the Karimata Strait, Natuna Sea and South China Sea had potential fish resources reaching 1,143,341 tons per year. This potential was smaller than the potential of fish resources on the West Coast (1,228,601 tons per year). But the economic value of fish on the East Coast was much higher than on the West Coast. On the East Coast the dominant fish were reef fish, which were very expensive, and pelagic fish, while on the West Coast the dominant fish were only pelagic fish, which were much cheaper than reef fish. [10, 11].

Fishermen's catchment areas in coastal areas and small islands to the west of Sumatra were located in the Indian Ocean. Most fishermen on the West Coast were generally small-scale fishermen, using small boats and simple fishing gear such as nets (jaring), fishing rods (pancing), traps (cucu) and lift nets (bagan tanca). In transitional and high wave season, it would be very dangerous for them to fish due to the bad weather, high wave, and strong winds. Many of them were forced to stop fishing and thus became unemployed, until the arrival of a more favorable season. Therefore, in the transitional and high wave season, the number of fishermen catches decreased significantly. To make it worse, the types of catches by the fishermen in the West Coast were generally those with low economic values such as various types of small pelagic fish, including mackerel (selar), sardine (tembang), long-jawed mackerel (kembung), and anchovy (teri) [12, 13, 14].

The East Coast of Sumatra had a high potential for fish resources with the dominant fish species including large pelagic, small pelagic and various types of reef fish that had high economic value. Several types of fish dominantly caught by fishermen included tuna, catfish (manyung), squid (cucut), mackerel (selar), sardine (tembang), and long jawed mackerel (kembung). Types of reef fish that became the target of fishermen include napoleon, grouper, snapper, yellow tail fish, and lobster. Napoleon fish, grouper and lobster had high economic values; they were exported to Singapore, Hong Kong and Malaysia. There were several centers of reef fish production in Natuna, Lingga, Bintan and Batam City [15, 16, 17, 18].

3.1.2. Fishermen's income from fishing activities by season. The income of fishermen was strongly influenced by season. This study categorized the seasons into three: low-wave season, transitional season and high-wave season. The length of each season in each area varied according to its geographical location. During the low wave season, all fishermen were able to catch almost every day. However, in the transitional season and high wave season, only some fishermen were able to catch, especially those who had better fishing boats and gears. It means that fishermen's average income tends to be high in the low wave season and then decrease in the transitional and high wave season.
Table 3. Average of fishermen’s income per month from capture fisheries by season and district/city in the West and East Coasts of Sumatra Island, 2015

| The coasts of Sumatra | District/city        | Low wave season | Transition season | High wave season |
|-----------------------|----------------------|-----------------|-------------------|------------------|
| The East Coast         | Natuna District      | 3,136,600       | 1,538,370         | 496,450          |
|                       | Batam City           | 3,016,480       | 1,726,740         | 2,631,710        |
|                       | Lingga District      | 5,091,490       | 1,661,080         | 2,510,280        |
|                       | Bintan District      | 3,671,330       | 2,874,760         | 2,429,000        |
| The West Coast         | North Nias District  | 1,642,030       | 1,259,690         | 613,425          |
|                       | Central Tapanuli District | 2,417,770     | 1,582,730         | 853,915          |
|                       | Mentawai District    | 905,200         | 440,250           | 229,200          |

Source: Socio-Economic Baseline Study of coral reefs and related ecosystems, COREMAP-LIPI, 2015

Table 3 shows the average of fishermen’s income by season. The study found that the difference of fishermen’s income according to seasons in the West Coast was more linear than in the East Coast. The fishermen’s income in the three districts of the West Coast, namely North Nias, Central Tapanuli and Mentawai had the same pattern: lower income in transitional season, and the lowest in high wave season. In the transitional season, the fishermen’s income decreased by about half to a third, compared to income in the low wave season. For example, fishermen’s income in the Central Tapanuli and North Nias Districts decreased by a half during the transitional season. Fishermen's income declined more sharply in the high wave season, to only a third of what they could get in the low wave season. Coping with unpredictable weather in the transitional season, fishermen were forced to reduce fishing activity from every day a week to three or four times a week. Meanwhile due to the bad weather and strong winds in the high wave season, the fishermen could reduce their fishing activity even more, to once or twice a week only.

In the West Coast, the sharpest decline in the strong wave season was recorded in Mentawai District, with only Rp220,200 (25% of income during the low wave season). Fishermen in this district, especially in the research location, were not classified as commercial fishermen; they were generally subsistence fishermen using simple and traditional boats and fishing gears. The main source of income for coastal communities in this district was agricultural products [14].

Although the raw numbers were not as small as in Mentawai, fishermen in Central Tapanuli and North Nias also suffered when faced with seasonal changes. The majority of the fishermen in the Central Tapanuli had small boats and low engines. It would be hard for them to reach their catchment areas in Indian Ocean in the strong wave season. In addition, most of the fishermen who used lift nets (bagan tancap) did not operate during the high wave season because some of their lift nets were damaged due to bad weather and strong winds [14].

In North Nias during the transitional season, the frequency of fishing decreased as the condition in their normal fishing area was unstable; they needed to sail further away from the area to get a good catch. In the long run, this had an impact on their overall catches. In the high wave season, the frequency was even less, to a point that some fishermen stopped sailing. As a result, their income fell sharply [13].

Meanwhile, unlike in the West Coast which showed a linear pattern throughout the region, the income of fishermen according to seasons on the East Coast was varied. For example, in Natuna and
Bintan Districts, the lowest income was in the high wave season. However, in Batam City and Lingga District, the lowest income of fishermen occurred in the transitional season. Still, the highest income was unsurprisingly only possible in low tide season, the same as in the West Coast. A significant decrease in fishermen's income during the transitional and strong wave season occurred in Natuna District. During the transitional season, the income of fishermen in this district decreased to about half of the income in the low wave season. Their revenue would decline significantly in the high season to one-sixth (16 percent). The most significant decrease in fishermen's income during strong waves occurred in the research villages where most of the fishermen caught reef fish (grouper, napoleon) which had high economic value. In the low wave season, fishermen in these villages were able to catch fish optimally throughout the season. The catch was good, and their income was quite high. However, during the high wave season, fishermen's income drops sharply because most were unable to catch fish due to strong winds and bad weather. Only a small number of fishermen were still looking for fish in the waters around the coast [15].

The same as in Natuna District, the income of fishermen in Bintan District also decreased parallely along with the change of season from low season to high season. In the low wave season the fishermen had a high income, because they went to sea almost every day. Their income gradually declined during the transitional season and high wave season. Fishermen's income decreased by 24 percent and 34 percent, respectively.

Based on their fishing areas, fishermen in Bintan District could be divided into two types: coastal fishermen and non-coastal fishermen. Fishing areas for coastal fishermen were closer to the coast (no more than 5 miles from the coast) and their fishing gear included nets, floating nets (bagan apung), fishing trails and traps. The fishermen who used floating nets targeting anchovies (teri) were able to catch almost all seasons. Meanwhile, non-coastal fishermen’s fishing grounds were extended, more than 10 miles from the coast, and they still caught fish during the transitional and high waves season. Non-coastal fishermen used traps to target live grouper. However, during the high wave season, some coastal and non-coastal fishermen still catch fish with the target of catching mackerel which had high economic value. They fished in groups and their fishing grounds were even more extended, up to 40 miles from the coast. During the high season wave (north wind) the stock of Spanish mackerel was increasing. Therefore, in the transitional and high waves season, fishermen's income only decreased slightly. [18].

However, the income of fishermen according to seasons in Batam City and Lingga District had a different pattern from those in Natuna and Bintan District. Their lowest income occurred in the transitional season. Unpredictable winds and weathers in this season were the reasons for fishermen to reduce their fishing frequency. In addition, during the transitional season, the stock of fish resources generally decreased so that the number of catches also declined significantly, to a point that fishermen could not get any catches. During the high wave season, some fishermen were still looking for fish with the target of catching _ikan dingkis_ white-spotted spinefood fish ( _Siganus canaliculatus_). Dingkis fish has a high economic value due to the large market demand of the Chinese community in Batam and Singapore during the Chinese New Year celebration [16].

In Lingga District, most fishermen preferred to stop fishing because of the uncertain weather. If they continued to fish in transitional season, they would not get any results and they risked losing operating costs. Therefore, their income in this season was decreasing sharply. During the high wave season, however, the frequency of fishing was only slightly declined compared to the low wave season. The fishermen were still fishing, adjusting with weather condition during the high wave season [17].
3.1.3. Fishermen’s income from mariculture. Mariculture was still underdeveloped in the East and West Coast of Sumatra, indicated by the small number of households that engaged in this activity, as well as the low income earned from it. Our survey showed that the actual number to households that carried out mariculture was measly (Table 4). On the West Coast, cultivation activities were only found in Mentawai District (4 families). The same situation was also in East Coast; the number of households that carry out cultivation activities was also small, but it was higher than in the West Coast. In Lingga District, the number of families conducted this activity was 43 families and other districts/cities ranged from 7 to 10 families.

Table 4. Average of fishermen’s income from mariculture activities, by districts/city in the West and the East Coasts of Sumatera Island, 2015

| The coast of Sumatra | District/City    | Average of fishermen’s income from mariculture activities |
|----------------------|-----------------|----------------------------------------------------------|
| The East Coast        | Natuna District | 582,333                                                  |
|                      | Batam City      | 744,170                                                  |
|                      | Lingga District | 408,756                                                  |
|                      | Bintan District | 342,619                                                  |
| The West Coast        | North Nias District | --            |
|                      | Central Tapanuli District | --            |
|                      | Mentawai District | 243,330                                                |

Source: Socio-Economic Baseline Study of coral reefs and related ecosystems, COREMAP-LIPI, 2015

According to the Department of Fisheries and Maritime Affairs of the Riau Islands Province, the potential for mariculture in the Lingga District and Batam City was quite high. In the Lingga, the potential of mariculture in the coastal areas reached 10,054 hectares, and in the open sea about 226,500 hectares. Types of mariculture potential to be developed were floating net cages and sticks nets. Meanwhile, brackish water cultivation was shrimp ponds. The potential of mariculture in the coastal areas and open sea in the Batam City were 10,772 hectares and 50,442 hectares, respectively [19,20].

3.2. The Influencing factors

This paper identifies three important factors that affect the income of fishermen in the East and West Coast of Sumatra: internal factors (originating from individuals or groups of fishermen), external factors (related to economic and environmental aspects from outside the fishermen), and structural factors (related to policies and programs from the government and stakeholders). These three factors had both positive impact (increasing fishermen's income) and negative impact (limiting or even reducing fishermen's income). This effect varied according to the type of factor and location, both within one coastal area and between coasts.

3.2.1. Internal Factor. Internal factors that affect fishermen's income are closely related to the technological capabilities of the fleet (boat/body and engine) and fishing gear. The technology used by fishermen determined the reach of the fishing area, how far they could find the fishing ground for the fishing. Meanwhile, fishing gear affected the types of fish to be caught and the number of fish they were able to catch.
Limitations of fishing fleet and equipment

This paper reveals that the technology used by most fishermen was still limited, indicated by the simplicity of the fleets and fishing gears. This description to the fishermen on the East and West Coast, with varying conditions between the two coasts. Most fishermen in both coastal areas used boats with medium to low engine sizes, only a small number of fishermen operated large boats. A small number of fishermen also used traditional boats; boats without engines (sampan) that only relied on the fishermen's rowing abilities. The capacity of this boat was very low, it could only be used in waters around the coast and was very vulnerable to seasonal influences, especially the transitional season and high waves or strong winds. The limited fishing fleet used by fishermen had an impact on the limited production (catch) and income of fishermen as described in the previous section.

The condition of fishermen's technology in the East Coast was better than the technology of in the West Coast. In 2015, the percentage of fishermen owning and using relatively large boats in the East Coast was much higher, about ten times (30% average) compared to the percentage in the West (3% average). Fishermen who had large capacity motor boats, especially those equipped with GPS and fish finder, were very limited in number. Meanwhile, the other fishing fleets, such as boats with engines (outboard and inboard) and boats without engines were relatively balanced between the two coasts. [15,16, 17, 18, 12, 13, 14].

In the East Coast, fishermen in Batam had better fishing fleet technology than fishermen in other districts. Fishermen in Batam had the largest number of engine boats (half of the total respondents), while the fewest owners of fishing boats were in Lingga (around tenth of the total respondents). Also, Bintan and Natuna had the same proportion (one third of the total respondents). In Bintan, engine boats were mostly owned by toke (fish boss/fish trading agent) who came from Mapur Village, which was located in the the Mapur Island. The fishermen needed this faster and more powerful fishing fleet to set fish traps far away, about 40 miles from the coast, and to reach fish shelters or sell fish in the town. The engine boat capacity varied by district/city, but the difference was not significant, with an average of 2–5 GT and an average engine of 5–15 PK. [16, 18, 15].

In the West Coast, the condition of the fishing fleet technology varied between districts with the most limited condition being in the Mentawai District. The number of fishermen who owned and operated large-capacity fishing fleets were very minimal, occurring in all districts on this coast. In contrast, fishermen who used the simplest fleet (sampan), varied in number with the highest proportion from Mentawai District. This condition might be related to the economic limitations of Mentawai fishermen with backgrounds dominated by gardening culture. Meanwhile, fishermen who operated motorized boats were mostly from North Nias District; two thirds of the total respondents owned and operated motorized boats, but the number of fishermen who used traditional boats was still large, almost a quarter of the total respondents in this district. [13, 14].

The technology of fishing gear owned and used by fishermen was also still limited on both sides of Sumatra. The most common types of fishing gear used were fishing rods and nets. The proportion of fishing gear varied by type and district/city with the largest proportions for these two types of gear found in Bintan and Lingga for the East Coast, and North Nias on the West Coast.

The fishing gear owned and used by fishermen in the East Coast was more varied when compared to fishermen in the West Coast. Fishermen on the East Coast were more likely to own and use fish cages, nets and traps. Ownership of cages was very limited, because they were quite expensive, usually owned by traders who collected live reef fish. A similar picture also occurred in the ownership of bagan (fishing gear included in the classification of lift nets). Fishermen who owned bagan were still limited in the East Coast and scant in the West Coast. Fishermen in Natuna and North Nias districts even had almost no bagan, only a few. Some fishermen also used traditional fishing gear that was very simple, such as serok (fish scoop), tangguk (fish bowl), and kelong (fishing gear in the form of a wooden building with a net installed in the middle). In addition, some fishermen on both coasts also used materials and fishing gears that might damage marine resources—especially coral reefs—such as bombs, potassium cyanide, and trawls (details are in the marine resource degradation section). [15, 13].
The fishing gear of fishermen was usually adjusted to the type of target fish. In the East Coast, fishermen in Natuna used fishing rods to catch live reef fish such as grouper and sunu, while longline fishing rods for tuna; and nets were used to catch *ketambak* fish (from the family Lethrinidae), catfish (*manyung*) and mullet. Meanwhile, fishermen in Bintan used fishing rods for live reef fish and mackerel; fishing rods and nets for mackerel, trout, seabass and other surface fish; and traps for live reef fish. [15, 18].

**Catch area**

The fishing area varied from area near the coast to far in the deep sea; the conditions also differed according to districts/cities within a coastal area and between coasts. However, in general, the fishing area for most fishermen was still limited to the village’s sea waters and its surroundings. This condition was closely related to the limited capacity of boats and engines owned by most fishermen. Only a small number of fishermen were able to go far to the deep sea.

The fishing areas in the East Coast districts/cities were much wider and varied when compared to the fishing areas in the West Coast. Fishermen from the village of Mapur Bintan set their traps in distant ocean waters, about 40 miles from village waters [18]. A small number of fishermen in Natuna went to the deep sea (50–100 miles from the coast) which was also a fishing area for vessels from outside the region, such as from Java (Tegal), Kalimantan (Pontianak), and Sumatra (Batam, Tanjung Pinang and Medan). Natuna fishermen, whose boat and engine capacity were relatively limited, were unable to compete with those fishermen who used large-capacity fishing vessels and more modern fishing gear. This condition was further exacerbated because the fishing area was also often entered by foreign fishermen, such as from Vietnam, China, Malaysia and Thailand. [21, 8, 3].

Fishermen in the West Coast generally caught fish in the waters of the village and its surroundings. Mentawai fishermen went to sea in an area of less than 10 miles for safety reason, considering their limited fishing fleet capacity. The fishing area of North Nias was even more limited, only in village waters, while the fishermen of Central Tapanuli fished around Tapian Bay, 1–2 miles from the coast. The competition for fishing in village waters was therefore quite high due to the increasing number of active fishermen. Fishermen competition was even fiercer in North Nias and Central Tapanuli because they also competed with fishermen from outside the region using better fleets and equipment [12, 14, 13].

The fishing area of fishermen also varied according to the type of fish caught. In the East Coast, Natuna fishermen caught live reef fish in the reef area and dead reef fish not too far from the coast, about 10 miles from the shoreline. Meanwhile, to catch anchovies, the fishing area was further from dead reef fish, which was outside the village waters. The fishing area was further away when the target fish was tuna, reaching 50 to 10 miles from the coast [15]. The same as the fishermen from Mapur Bintan who would catch mackerel, they also had to cover a distance of about 40 miles from the coast [18].

In addition, fishing areas also changed according to seasons (wind and waves), influencing fishermen in all districts/cities on the two coasts. In the high wind/high wave season, most fishermen usually only went to sea in the waters near settlements and villages; in that season many fishermen could not catch fish. On the other hand, in the low wave season, fishermen caught fish in an expanded areas with varying distances according to the capacity of the fishing fleet and the type of fish to be caught. For example, fishermen from Sededap Village in Natuna went to sea only around the waters of Pulau Tiga during the high/strong wave season, but during the low wave season, they caught fish as far as Midai Island which was the outermost island of Indonesia [15].
3.2.2. External factor. External factors that affect fishermen's income were how fishermen marketed their catches, variation in seasonal condition, and damage to natural resources in coastal areas.

Marketing of fish
Marketing of fishermen's catches fluctuated throughout the year, depending on the number of catches, market availability, fish demand and seasons. Marketing of the catch of most fishermen was still limited and varied by type of fish and location. Fishermen on the East West Coast generally sold their catch directly to consumers or through fish collectors/traders. Fishermen who directly sold fish were usually small-scale fishermen, assisted by family members (wife or children), peddling fish in ports, fish landing places or around their settlement. Fishermen who sold fish to traders would go through a marketing chain that varied in length to reach consumers. To provide an example, fishermen sold their fish to local fish collectors, and later these collectors might: 1) sold the fish directly to consumers in settlements; 2) sold the fish to markets in nearby towns—district/city capital; or 3) sold the fish to other larger collectors/traders or inter-island fish traders within one district/city, between districts/cities, or even between provinces to international markets. [21, 15, 3].

The marketing of fishermen's catches on the East Coast was more varied and extensive compared to the marketing in the West Coast. In the East Coast, fish marketing in Natuna, Batam, Bintan and Lingga was very broad, reaching international markets, especially Singapore and Hong Kong. The demand for live reef fish from the international market was quite high. Fish that were widely marketed were fish that have high economic value, such as live reef fish (grouper and sunu) and large pelagic fish, such as tuna and Spanish mackerel. The marketing chain varied between districts/cities. In Natuna, the marketing of live reef fish to Hong Kong has a fairly short chain, from fishermen to local/village fish collectors and to N traders or collector agents who directly sold the fish to Hong Kong fishing boats that come to Natuna Port on a regular basis. Trader N dominated and even monopolized the export fish trade in this district. This condition was unfavorable for fishermen, especially in determining prices at the fisherman level, moreover N was also a trader who supplies fishing gear and helps fishermen in meeting their fishing equipment needs.

Marketing of fish export commodities in Batam was more focused on the Singapore and Malaysia’s market. Fishermen sold fish to fish collectors who were usually a toke (boss). Toke then sold fish to traders in Batam City, and from this city, the fish were directly sold to traders in Singapore. Fishermen usually had an attachment to toke because toke provided assistance in procuring the fleet and the needs of fishing equipment. As compensation, fishermen 'had to' sell their fish to toke. A similar marketing pattern also occurred in Bintan and Lingga where fishermen sold their catches to village collectors who supplied fish to large collectors in Kelong or Bintan (Bintan District) or traders in Tanjung Pinang and Batam City, after which the fish were sent to traders in Singapore [15, 16, 18, 17].

In contrast to live reef fish, marketing of dead fish was more focused on markets in big cities, both within districts/cities and between districts/cities, and even between provinces and islands. Marketing of dead fish from Bintan was mostly sold in the markets of Tanjung Pinang City or Kijang Harbor which was the economic center of the district. The marketing of anchovy from Lingga had exceeded the district boundaries (Tanjung Pinang City and Batam) but was still in one province (Riau Islands Province). The market for fresh fish (tuna, Spanish mackerel) from Natuna was even wider, extending beyond district boundaries within one province (Batam), and for swordfish (pedak - processed fish) beyond provincial and island boundaries, in Pontianak on the Island of Kalimantan, the Province of West Kalimantan [16, 15].

That condition in the East Coast were vastly different from the marketing of fish in the West Coast. Fish marketing in all districts in the West Coast was still limited to the surrounding cities, especially in North Nias where marketing was only concentrated on Nias Island. This was closely related to its location, directly adjacent to the high seas, and the distance of North Nias to cities which were quite far, so that marketing was not profitable due to the high cost of transportation. Fish marketing in Central Tapanuli was wider than in North Nias where the fish were sold to Sibolga City (between districts/cities), especially large shrimp and squid. Meanwhile in Mentawai, apart from being marketed
around the village, the fish were also marketed between islands (one district), namely Siberut Island (location of the Mentawai capital city) especially in markets and tourist spots (surfing areas and national parks). [12, 13, 14].

Seasonal variation
Seasons were very influential on the activities and income of fishermen, mainly due to the limited fishing fleet of most fishermen on the East and West Coast of Sumatra. In the East Coast, the most influential season was the northern season, when the wind was strong and the sea waves were strong/high. The influence of the north season was felt by fishermen in Natuna and Bintan districts. In this season, most fishermen in Natuna were halted from going to sea due to the limited capacity of their fishing fleet, the high cost of fishing, and the high risk of fishermen's safety. As a result, fishermen's income had decreased significantly this season. Fishermen called this northern season, the ‘famine’ season. A small number of fishermen who continued to go to sea had to adjust the fishing gear used, such as replacing fishing rods with fishing nets, because they were no longer able to use fishing rods. In addition, fishermen also adjusted the type of fish caught, such as fishermen in Bintan describing the northern season as the season for mackerel, while fishermen in Natuna marked this season as the season for tuna. [21, 15, 18].

Different conditions occurred in Batam and Lingga where the most influential season was the transitional season. This was indicated by the lowest income of fishermen occurring in this season. The income of fishermen in the strong wave season was higher due to the fact that the price of live reef fish was very high during the strong wave season, even though the frequency of fishing was lower compared to strong wave season.

The influence of strong winds and strong waves was also felt by fishermen on the West Coast. This season was known by the fishermen of Central Tapanuli as the “west season”. Like fishermen on the East Coast, in this season most fishermen were unable to go to sea for the same reasons, namely technological limitations, limited time to go to sea and fishermen's safety factors. Fishermen in North Nias only went to sea 2–4 times a month [14]. Some fishing gear could not be used by fishermen this season, such as fishing rods and nets in Central Tapanuli [12].

The low wave season was the harvest season for fishermen, so the income of fishermen in all districts/cities on the two coasts was also the highest throughout the year. In this season all fishermen went to sea, and their fishing area was generally wider than other seasons. Fishermen could also use more types of fishing gear, so that the fish caught were more varied in type and volume, and their harvests were abundant this season.

Degradation of coastal and marine resources
The degradation of coastal and marine resources was marked by the damage to coral reefs, fishery resources and mangrove forests. Coral reefs on Sumatra had generally been damaged, indicated by the absence of districts/cities on the East Coast and West Coast that had coral reefs in excellent condition (Table 5). On the East Coast, most of the coral reefs were in moderate condition there were very few coral reefs that were still good, only found in the sea waters of Batam City. The most damaged coral reefs were found in Natuna District where almost three quarters of the total sites studied were in the damaged category. Meanwhile, the district with the least damaged coral reefs was in Bintan.

In the West Coast, the condition of coral reefs varied from good to damaged. Mentawai District had coral reefs that were in the best condition. Conversely, the worst condition was in North Nias District; all sites studied in this district had damaged coral reefs. The coral reefs in Sibolga and Central Tapanuli were in between the two districts. [14, 12].

Damage to coral reefs on the East Coast and West Coast was closely related to destructive human behavior, especially the use of illegal fishing materials and tools that occurred in all districts/cities on both coasts. Cyanide was still often used by some fishermen, both local fishermen and/or fishermen from outside the area, especially to catch live reef fish in all districts/cities on the two coasts. The use of cyanide was much more than that of bombs and its impact was also on a wider area. Fishermen,
especially North Nias on the West Coast and Kelanga Natuna on the East Coast, also used *tuba* which had a similar effect to potassium cyanide.

The use of bombs was also still happening, although the frequency had been much reduced. In several locations, such as Bintan and Natuna, the use of bombs had stopped, but only for a short time because recently these activities were carried out in secret. However, fishermen claimed that bombs were not carried out by local fishermen, but rather by fishermen from outside who catch fish in the surrounding area. In the West Coast, bombings in North Nias were carried out by fishermen from Aceh and Sibolga, while in Mentawai by fishermen from Sibolga and Nias. In the East Coast, bombings at Sededap Natuna was carried out by fishermen from Tarempa and Midai. [15, 14, 18, 21].

**Table 5.** Condition of coral reefs on the East Coast and West Coasts of Sumatra Island

| The coasts of Sumatra | District/City       | Site | Excellent<sup>a</sup> | Good<sup>b</sup> | Moderate<sup>c</sup> | Damaged<sup>d</sup> |
|-----------------------|--------------------|-----|-----------------------|-----------------|---------------------|---------------------|
| The East Coast        | Natuna             | 18  | 0                     | 0               | 5                   | 13                  |
|                       | Batam              | 19  | 0                     | 3               | 11                  | 5                   |
|                       | Bintan             | 14  | 0                     | 0               | 12                  | 2                   |
|                       | Senayang-Lingga    | 11  | 0                     | 0               | 7                   | 4                   |
| The West Coast        | North Nias         | 10  | 0                     | 0               | 0                   | 10                  |
|                       | Sibolga & Central  | 13  | 0                     | 1               | 2                   | 10                  |
|                       | Tapanuli           |     |                       |                 |                     |                     |
| Western Indonesia (%) |                    |     | 8,92 %                | 22,43 %         | 33,64 %             | 35,01 %             |
| Indonesia (%)         |                    |     | 6,56 %                | 22,96 %         | 34,30 %             | 36,18 %             |

Notes: <sup>a</sup>coral cover 75–100%, <sup>b</sup>coral cover 51–75%, <sup>c</sup>coral cover 25–50%, <sup>d</sup>coral cover 0–25%

Source: Hadi et al 2018: Status of Indonesia's Coral Reefs 2018

Meanwhile, damage to fishery resources was closely related to the use of tiger trawl nets (*pukat harimau*) and coastal trawlers. In the East Coast, the use of trawls were found in the Natuna Sea, but mostly done by fishermen from outside, such as fishermen from Tegal and Pontianak. Meanwhile on the West Coast, fishermen in Central Tapanuli used coastal trawls similar to tiger trawls. This trawl was in the form of a net with a small mesh that was given an iron weight and pulled all fish, both large and small fish. As with tiger trawls, the use of coastal trawlers resulted in a significant reduction in fish and biota numbers, as well as slowing fish regeneration as the young were also caught in the net [15, 12]. The use of illegal materials and gears was carried out by fishermen to get a lot of fish in a short time. This was mainly related to the limited ability of fishermen to catch fish due to the use of fishing fleets that were still traditional and/or simple, even though the number of fishermen was increasing.

This condition created competition in utilizing fishery resources in the region. Competition was getting higher due to the existence of foreign fishermen in their fishing areas. Foreign fishermen who
entered the fishing areas often used destructive fishing gear, and this also triggers local fishermen to use these fishing gears to increase their catch and income. This condition occurred in almost all districts, especially Natuna and Bintan on the East Coast and North Nias and Central Tapanuli on the West Coast.

Most fishermen understood that the use of bombs, cyanide and trawling was prohibited, but some fishermen continued to use them with the aim of making profit. This illegal activity still existed because law enforcement was still limited; even some fishermen in Natuna say that the fish poison users received backing from law enforcement officials, although support was getting less and less due to the incessant ban on the use of bombs and cyanide, as well as the implementation of rescue coral reefs programs (COREMAP) in the district. However, surveillance activities had decreased after COREMAP Phase II and the enactment of Law No. 23 of 2014 which regulated the authority for marine management at the provincial level to expand to an area of 0–4 miles which was previously the authority of district/city governments [22].

This paper also identified the damage to coastal resources due to the logging of mangrove forests. In the East Coast, excessive logging of mangroves, especially in Batam, caused damage to the mangrove ecosystem. This activity was carried out by people from outside the village with the aim of making charcoal, were sold abroad. Local fishermen could not prohibit the chopping of mangroves because they had permits [16].

In addition, pollution in the sea was also the cause of the degradation of coastal resources. In the East Coast, the problem of waste oil was found in Bintan, which originates from waste oil disposal from large ships, especially cargo ships with foreign flags, which sail in international waters, often dumping their oil residue near Indonesian waters [18]. Meanwhile, on the West Coast, the problem of marine pollution that damaged coral reefs was found in Tapian Bay in Central Tapanuli which was sourced from the waste from the plywood industry and steam power plant activities [12].

3.2.3. Structural factor. Fishermen’s income was also influenced by structural factors, namely factors related to policies, programs and activities carried out by the government and related stakeholders in the research location. The program consisted of managing coastal and marine resources and other developments in coastal areas and small islands.

Marine resource management programs, especially coral reef management, were available in all districts/cities in the East Coast and West Coast of Sumatra. This program was known as Coral Reef Rehabilitation and Management Program (COREMAP). This program aimed to manage coral reef ecosystems in a sustainable manner in order to improve the welfare of the community. All of these districts/cities were chosen as COREMAP locations on the grounds of potential for coral reefs and the occurrence of ecosystem degradation in all these areas.

COREMAP was a coral reef management program designed by the central government with a top-down and bottom-up approach. The implementation of COREMAP was designed in three phases starting in 2004. In Phases I and II, this program consisted of four strategic components, namely community based management (CBM), public communication (PC), supervision and control (monitoring), controlling and surveillance (MCS), and a coral reef information and research center (Coral Reef Information and Training Center - CRITC). Although designed from the center, the planning was based on the needs at community level where community involvement was central in coral reef management [8, 21, 23, 24]. COREMAP activities in the early stages focused on increasing public awareness about the importance of coral reef conservation and establishing COREMAP management institutions in selected locations. This program carried out various activities, including capacity building of community institutions, community economic enterprises, and monitoring of coral reefs by community groups.

This program has not been fully successful, but several components had shown a significant impact on community awareness in coral reef management, especially the use of bombs and cyanide poisoning in all districts where COREMAP was located on the East and West Coast of Sumatra. Increasing public awareness activities, especially in program locations, had significantly reduced this
destructive fishing activity. [7, 15, 18]. However, after COREMAP Phase II, there was a delay for the implementation of Phase III, resulting in reduced public awareness and surveillance activities at these locations. This had resulted in an increase of illegal activities, such as the use of cyanide and fish bombing by fishermen, especially fishermen from outside the area. This condition occurred in Natuna and Bintan in the East Coast, and North Nias and Mentawai in the West Coast.

In addition to COREMAP, fishermen in all districts/cities on both coasts also received other development programs. The programs were the National Community Empowerment Program (PNPM) in the form of physical development, particularly public facilities and infrastructure and social assistance in the form of rice for poor people (raskin) which was given to all families in a village, although it should only be for poor families. Environmental sanitation programs existed in all districts/cities on the East Coast. Fishermen on the East Coast received more development programs than fishermen on the West Coast. In general, the impact of these programs on fishermen's income was still limited.

4. Conclusion

This paper reveals that the income of fishermen in the East and West Coast of Sumatra Island was dominated by revenue from capture fisheries, while income from mariculture was still very limited. The income of fishermen varied by district/city, where the income in the East Coast was higher than the West Coast, except in Natuna where the income was only slightly lower than the highest income in the West Coast. This condition was closely related to the geographical conditions of the East Coast which were more supportive and the potential for fisheries was higher when compared to the West Coast. In addition, the technology of the fleets and fishing gears used by a small number of fishermen on the East Coast was better compared to the fishermen in the West, although most fishermen in both coastal areas generally used technology that was still limited. A small number of East Coast fishermen, whose fishing fleet capacity were larger, were able to go further into the deep sea, reaching a wider fishing area while they could still operate during the strong wave season, although the frequency was greatly reduced when compared to the calm and transitional wave season. Fishermen caught export fish (live reef fish: grouper, sunu, napoleon) which have a high selling value in the international market, especially Singapore and Hong Kong and large pelagic fish (tuna, cob and Spanish mackerel) at a fairly high price. In contrast to the East Coast, the fishing ability of fishermen on the West Coast was very limited, they were dealing directly with the high seas. This became a barrier for them because they only used simple fleets and fishing gears. Fishermen only went to sea near the village and surrounding waters; they caught small pelagic fish (bloated, salar/trout and anchovies) which selling value was relatively cheap, especially during the calm wave season when the catches were abundant.

The income of fishermen also varied by district/city in the same coastal area. In the East Coast, fishermen in Lingga District had the highest income and on the contrary, fishermen in Natuna had the lowest income. Although the fishing fleet capacity in Lingga was relatively lower when compared to Batam and Bintan, Lingga fishermen used more varied fishing gear, including cages which function to accommodate and raise live reef fish. Meanwhile in the West Coast, fishermen from Central Tapanuli had the highest income, whose fishing fleet capacity was slightly better than other districts and the marketing of their catch, especially squid and shrimp, was also wider to Sibolga City. Fishermen in this district, apart from selling fresh fish, also processed their catch into salted fish and anchovies, thus providing added value to their income.

Fishermen's income fluctuated throughout the year and varied according to season and coastal area, except for income in the calm wave season which tended to be consistently highest throughout the year in all locations. In the East Coast, income fluctuations in the three wave seasons were more varied. The income of fishermen in Batam City and Lingga Districts decreased significantly during the transition season and rose again during the strong wave season. In contrast to the incomes of fishermen in Natuna and Bintan Districts, their incomes suffered from decline in the transitional season and continued to decline during the strong wave season. In the West Coast, the income pattern
of fishermen was the same in all locations; there was a gradation of income declined in the transition season and strong wave season.

The variation in fishermen's income was also related to the degradation of coastal resources, especially coral reefs, which occurred in all districts/cities, both in the East Coast and West Coast of Sumatra Island. Degradation was mainly caused by the use of illegal fishing gears, such as poison (potassium cyanide and tuba), bombs, and trawls. The use of these materials and fishing gear had been banned by the government and this had been massively socialized through the coral reef management program (COREMAP), but these activities were still ongoing. The use of cyanide had decreased even though the intensity and frequency were still relatively high. While the use of bombs had decreased significantly, in some villages fishermen had started using bombs again secretly. The diminishing surveillance activities were claimed to be the cause of the ongoing illegal activities, especially after the COREMAP Phase II and the enactment of Law No. 23 of 2014 concerning changes in the authority of sea management (0–4 miles) from the district/city government to the provincial government. In addition to damage to coral reefs, the degradation of coastal resources was also caused by excessive mangrove logging and marine pollution originating from waste oil and industrial activities. This degradation had an impact on decreasing fish and other biota in coastal waters, especially on the East Coast.

This paper emphasizes the urgent need to reduce damage to coastal resources, especially coral reefs, so that efforts to manage ecosystems in a sustainable manner and increase fishermen's income can be achieved. Fishermen as prime users must play an important role; therefore, increasing the capacity of the fleets and fishing gears, as well as developing mariculture businesses need serious attention in all districts/cities both in the East Coast and West Coast of Sumatra Island.

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