Economic analysis of flying fish roe harvesting: The case of Wakatobi fishers operating in the Aru Islands, Maluku Province

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Abstract. The substantial market value of flying fish roe on the international stage has catalyzed excessive harvesting activities across its fishing grounds around Aru Islands, Maluku Province and has attracted fishers from various places to engage in the fisheries. This study aims to outline the income dynamics of flying fish roe harvesters from Wakatobi District who participated in the fisheries. Data were collected between December 2019 and April 2020 in Binongko Subdistrict, Wakatobi District, Southeast Sulawesi. Analysis was carried out to calculate the operational cost and returns gained by the harvesters. Ten fishers, each represented one of ten different harvesting groups, were selected as respondents. The study found that each harvesting group undertook an average of five harvesting trips per season. The cumulative income per fishing boat amounted to IDR 690,375,110 per season (or a six month period). The income distribution was based on a profit-sharing scheme, with 2/5 shares going to the boat owner and 3/5 shares going to the combined fishers (the captain and crews). Consequently, a fisher can make IDR 59,175,009 on average per season. The study provides a fundamental information for developing policies in promoting sustainability of the fisheries in the economic perspective.

1 Introduction

Flying fishes, members of Exocoetidae, are small pelagic fishes distinguished by their remarkable ability to glide over the ocean surface with their enlarged pectoral fins [1, 3]. Approximately seventy-three species inhabit tropical and subtropical waters worldwide [4], meanwhile eighteen species were found in Indonesian waters [5], prominently around the Aru Islands - Maluku Province and around Sulawesi islands. The fish are locally consumed —whether fresh, dried, or smoked and marketed internationally [5, 6]. The roe, in particular, has gained prominence as an alternative to traditional caviar supplies [5].

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The global demand for flying fish roe has intensified harvesting activities in various fishing regions. The Makassar Strait, renowned as a prominent fishing ground, has been the site of traditional flying fish roe collection by the Pattorani fishers [4, 7] of Galesong, Takalar, a practice that dates back to the 13th century [8]. In addition, the Aru Islands in Maluku Province stand out as a significant hub for flying fish roe harvesting. This activity has not only become a vital source of income for local communities and has also attracted fishers from regions outside Aru Island. The economic implications of this practice, while offering lucrative returns, raise concerns regarding sustainability and the impact on marine ecosystems.

Each year, from April to September, fishers from Binongko Subdistrict in Wakatobi embark on a seasonal migration to Dobo in the the Maluku Province to engage in the harvesting of flying fish roe around the Aru Islands—an endeavor that spans approximately six months. The journey from Binongko to Dobo, which encompasses approximately 4 to 5 days, is motivated primarily by the abundance of flying fish population in the waters surrounding the Aru Island during this period. Additionally, the economic incentives associated with the lucrative trade of flying fish roe contribute significantly to the decision-making process, as the income generated from this activity serves as a vital source of livelihood for the fishers and their communities. Following their arrival in Dobo, a preparatory period of 15 days is allocated for organizing and readying the essential materials and equipment needed for the roe harvesting process.

Preliminary observations suggest that these fishers enjoy a relatively higher economic status compared to their counterparts who fish in local waters closer to Wakatobi. However, the financial yield from their dedicated harvesting of flying fish roe remains undetermined. The objective of this research is to evaluate the economic aspects of this activity by analyzing the operational costs and returns associated with the flying fish roe harvest as undertaken by the Wakatobi fishers. Such information on economic returns can shed light on the financial implications and sustainability [9] of their venture in the Aru Islands. By providing a clear picture of the economic aspects of flying fish roe harvesting, the research underscores the need for balanced approaches that support both the economic interests of local communities and the conservation of marine ecosystems.

2 Methods

Data collection was conducted in Wali Village, Binongko Subdistrict of Wakatobi District from December 2019 to April 2020, and focused on the distinctive fishing community known as *minte idobu*. This term, derived from *minte* meaning to go and *idobu* referring to Doboin the Aru Islands, identifies fishers who travel to Dobo for fishing activities, particularly for flying fish roe harvesting. Wakatobi, situated in the Province of Southeast Sulawesi, comprises primarily aquatic territory, accounting for 97% of its area, and encompasses four main small islands, including Binongko. Wali village was selected as study location as it hosts the highest concentration of *minte idobu* fishers in Binongko. In the village, there are ten boats dedicated to flying fish roe collection, each crewed by seven individuals. For this study, one representative from each boat/group was interviewed, totaling ten informants. These informants provided valuable insights into their income dynamics and profit-sharing practices.

Primary data were gathered through structured interviews with selected fishers, using a carefully designed questionnaire. These interviews were supplemented by direct field observations, providing a richer understanding of the local fishing practices and economic conditions. Secondary data comprised a thorough review of existing literature, including relevant publications and previous research reports, to provide context and support for our findings.

The study primarily revolved around several key variables, including the identification of fishers' groups (names of boats, captains, crew members, and their specific roles and profit-sharing mechanisms), personal demographics of the respondents (such as age, education, and fishing experience), and business-related details (like number of working days per season, workforce involved, costs of capture, and income generated). To ensure clarity and uniformity in our analysis, operational definitions were established for critical concepts like income, revenue, production, and costs.

Qualitatively, we focused on describing the contextual background of the fishing areas and the specific processes involved in flying fish roe harvesting. Quantitatively, we assessed the income of the fishers by computing the net returns (NR) through the formula: NR = TR - TC, where TR represents total revenue calculated as the product of the yield and the price per unit, and TC comprises both fixed costs and variable costs associated with the production process [10], [11]. This dual approach provided a better understanding of the economic implications of flying fish roe harvesting in this region.

3 Results and Discussion

3.1 Harvesting and handling of flying fish roe

The process of collecting and handling flying fish roe by the fishers of Wali Village involves a meticulous and traditional approach, enhanced by modern technology. Traditionally, the journey to the fishing grounds entails hours of travel, guided by the accumulated wisdom and ancestral knowledge of the fishers. Historical practices relied heavily on the experiential understanding of environmental cues and the subtle signs of abundant fish populations. However, with the use of modern technology, such as radios and GPS, fishers now benefit from enhanced navigational tools that streamline the process of locating optimal fishing grounds. The integration of radios allows for real-time communication among fishing boats, facilitating coordination and information exchange, while GPS technology provides precise location data, empowering fishers to navigate with greater accuracy. This blend of traditional wisdom with modern advancements contributes to the efficiency and sustainability of flying fish roe harvesting in Wali Village.

Once the appropriate area is found, the fishers commence the deployment of rumpons (fish aggregating devices) in a systematic manner. These devices, linked by ropes measuring 35-50 meters apart, are set in alignment with the wind direction. The deployment, which can occur day or night, involves letting the rumpons drift with the currents, with the fishing boat positioned at the rear. After a waiting period of 12-18 hours, each rumpon is carefully retrieved to prevent dislodging the attached roe. The operational duration per trip ranges from 20 to 40 days, depending on the availability of food and fuel supplies and the harvest's success. Environmental factors like wind speed, sea currents, and the location of fish schools significantly influence the success rate.

The effectiveness of flying fish roe harvesting is intricately linked to environmental conditions. Wind strength and direction play crucial roles in determining the movement and behavior of flying fish schools, influencing their aggregation around the rumpons. Calm seas and mild winds are optimal conditions for successful harvesting, as they facilitate the deployment and retrieval of the rumpons while minimizing disruptions to the fishing process. Conversely, extreme weather conditions, such as strong winds or turbulent seas, can pose significant challenges and adversely impact the catch. Additionally, fluctuations in sea currents can affect the distribution and concentration of flying fish, requiring fishers to adapt their strategies accordingly to maximize harvest yields. Understanding and navigating these

environmental influences are essential for ensuring the efficiency and sustainability of flying fish roe harvesting operations.

Post-collection, the roe is delicately separated from the coconut leaves of the rumpons and spread out on the deck of the boat for drying, marking the beginning of the quality control process. This drying process, crucial for preserving the quality of the roe, typically takes 4-7 days, depending on weather conditions. The goal is to achieve a moisture content of approximately 12-14% to ensure optimal shelf life and marketability. However, insufficiently dried roe poses a significant risk of spoilage due to mold growth when stored, potentially leading to substantial economic losses given the high market value of flying fish roe [1].

Upon returning to land, additional drying may occur to ensure the desired quality is achieved to maintain product standards. Subsequently, the dried roe undergoes measurement using either manual or digital scales to ascertain its weight accurately. This meticulous process, from collection to drying and measurement, underscores the intricate balance between traditional fishing practices and the economic considerations of flying fish roe harvesting. Achieving and maintaining high-quality standards throughout these stages is imperative for maximizing market value and ensuring the economic viability of the entire harvesting process.

Looking ahead, there is a strong need to prioritize sustainability and resilience in flying fish roe harvesting practices to safeguard the future of this vital resource. Adopting a forward-thinking approach, stakeholders must actively engage in initiatives aimed at promoting sustainable fishing practices, conserving marine ecosystems, and mitigating the impacts of climate change. Ecosystem-based management strategies, such as marine protected areas and seasonal fishing closures, can be implemented to help alleviate pressure on flying fish populations and enhance their reproductive success. Moreover, adopting eco-friendly fishing gear and techniques, alongside capacity-building programs for fishers, can minimize environmental impacts while maximizing yield and economic returns. Stakeholders must work together to forge a path towards a more sustainable and equitable future for flying fish roe harvesting, which balances ecological integrity with socio-economic prosperity for present and future generations.

3.2 Economic returns from flying fish roe harvesting

The economic analysis of flying fish roe harvesting among Wakatobi fishers operating in Wali Village, Binongko Subdistrict, reveals substantial financial implications, encompassing both costs and revenues. Table 1 presents a detailed breakdown of these economic aspects, vital for understanding the profitability and sustainability of this traditional practice.

The costs involved in flying fish roe harvesting are categorized into fixed and variable costs. Fixed costs amount to IDR 13,033,890 and primarily include depreciation costs of boats, engines, and other essential equipment. The boat, with a cost of IDR 60,000,000, represents the most significant fixed expense, highlighting its central role in the harvesting process.

The boat is a fundamental requirement in the activity of collecting flying fish roe, where the size of the boat used in this pursuit is of significant importance. The size of the boat greatly influences the fishers' activities during operations, allowing for more flexibility in operation and ensuring better safety. The search for flying fish roe employs engines as the primary propulsion mechanism, with various brands such as Jiandong and Yanmar. The use of larger propulsion engines facilitates faster travel to the fishing or landing sites. Each boat can utilize 1 to 3 engine units, depending on the power capacity of the engines. Currently, the fishers' groups (*minte idobu*) have also adopted additional support equipment, such as navigational tools like GPS for position determination and communication radios.

Variable costs total IDR 79,591,000. These costs are predominantly driven by items like rice (IDR 8,580,000), diesel fuel (IDR 53,760,000), and clean water (IDR 1,260,000),

illustrating the extensive resources required for extended fishing operations. Notably, the variable cost also includes expenditure on items crucial for the actual collection of roe, such as coconut leaves and bamboo.

The variable costs incurred by the *minte idobu* fishers include expenses for fishing gear, notably the rumpon, which is constructed from bamboo and equipped with dry coconut leaves. This fishing apparatus is floated on the water's surface. The rumpon, once deployed in the sea and tethered to the boat, is left for approximately 15-20 hours or until it accumulates a sufficient amount of roe. When it is adequately filled with roe, the rumpon is then retrieved for the harvesting process. The rumpon is considered more efficient as it can gather more flying fish roe due to its larger surface area, and it minimizes the incidental capture of adult fish, except those trapped while attaching their eggs. Additionally, other variable costs involve the consumption expenses of the fishers during their pursuit of flying fish roe.

The revenue from roe harvesting is significantly influenced by the volume of catch and market prices. The average catch amounts to 2,610 kg of roe per season, with the current market price standing at IDR 300,000/kg. This translates to an average revenue of IDR 783,000,000 per season.

Table 1. Net income from Flying Fish roe collection (IDR/boat/season)

Items	Value (IDR)	%
A. Variable cost		
- Coconut leaves	1,940,000	2.09
- Bamboo	280,000	0.30
- Rafia rope	200,000	0.22
- Rice	8,580,000	9.26
- Sugar	270,000	0.29
- Coffee	650,000	0.70
- Cigarette	3,375,000	3.64
- Coconut cooking oil	288,000	0.31
- Lubricating oil	4,958,000	5.35
- Diesel (fuel)	53,760,000	58.04
- Kerosene	2,880,000	3.11
- Clean water	1,260,000	1.36
- Kitchen seasonings	200,000	0.22
- Instant noodles	950,000	1.03
- Total variable cost	79,591,000	85.93
B. Fixed cost		
- Depreciation	13,033,890	14.07
- Total fixed cost	13,033,890	14.07
C. Total cost	92,624,890	100,00
D. Returns		
- Revenue	783,000,000	
- Total net returns (for boat owner and seven crew members)	690,375,110	
- Total net returns for all seven crew members	414,225,066	
- Net returns per fisher (or per each crew member)	59,175,009	

Notes: One season spans six months

The amount of flying fish roe in the collection depends on the number of 'rumpons', the more rumpons fishers who earn high revenues typically use 125 rumpons while those with lower revenues use only 45 rumpons.

The net income, a critical indicator of economic viability, is derived by subtracting the total costs from the total revenue. Table 1 shows that the total income from the flying fish roe harvesting business by the *minte idobu* fishers amounts to IDR 690,375,110 per season. This substantial figure reflects the economic potential of the flying fish roe harvesting industry in the region. Additionally, the income distribution follows a predetermined sharing mechanism, indicating a balance between the interests of the boat owners and the fishing crew. The total income is distributed using a profit-sharing mechanism, wherein 100% is divided into five parts: two parts for the boat and its owner, and three parts for the captain and crew members. This means that 40% of the returns goes to the boat and its owner, while the remaining 60% is allocated to the captain and crew. If the boat owner participates in the flying fish roe harvesting in Dobo, they also receive wages as part of the crew. Additionally, the captain receives a commission from the boat owner as a token of appreciation for managing the boat and delivering satisfactory results. Each fisher earns an income of IDR 59,175,009 per season.

The economic analysis underscores the importance of flying fish roe harvesting as a lucrative and sustainable economic activity for the local fishers. The high net returns, despite the substantial costs, highlight the potential for further development and optimization of this traditional practice. In comparison to other fishing activities in Wakatobi, flying fish roe harvesting yields substantially higher economic returns. Fyka's research on the socioeconomic conditions of coastal communities indicated an average income of IDR 9,636,060 per six months in Wakatobi District, and IDR 5,961,252 per six months in Wali Village, Binongko Subdistrict [12]. This trend holds even for fishers using specific fishing methods, such as the sero (a stationary net for migratory beach fish) and pancing tonda (a traditional technique for pelagic species using artificial bait). For instance, sero fishers in Kaledupa Subdistrict earn an average of IDR 29,124,930 per six months, while pancing tonda fishers average IDR 34,740,000 per six months [13, 14]. Additionally, seaweed farming in Wakatobi generates an average income of IDR 16,646,778 per six months for *Eucheuma spinosum* and IDR 22,811,211 per six months for *Kappaphycus alvarezii* [15]. Thus, the net income from flying fish roe collection significantly surpasses that of local fishers using various fishing gears over the course of six months.

Binongko Island, characterized by its rocky terrain and sparse soil, presents a challenging environment for agriculture, rendering fishing the primary industry. However, the island's remote location poses significant marketing challenges for its fish products. Consequently, many men seek employment across Indonesia to enhance their household welfare. In this regard, the lucrative returns from flying fish roe harvesting provide significant contribution not only to their household welfare, but also to their food security status [16], [17] and to local economic development in Binongko Subdistrict. On the other hand, this lucrative opportunity might attract additional fishers to engage in maritime ventures in the Aru Islands. However, such an increase in participation could lead to overfishing and resource depletion, as evidenced in other studies showing reduced catch sizes and quantities [5]. Consequently, this situation necessitates proactive intervention from the government and relevant stakeholders. It is crucial to implement sustainable practices and regulations to safeguard marine resources, ensuring the long-term viability of the fishing industry and the ecological balance of the region. This balanced approach is essential to maintain the prosperity of the fishing community while preserving the environmental integrity of the marine ecosystem.

4 Conclusion

This study concludes that fishers from Binongko Subdistrict, Wakatobi District, engaged in flying fish roe harvesting in the Aru Islands, achieve a significant total income of IDR 690,375,110 per season, defined as a six-month period. This income, notably higher than that

of fishers engaged in regular fishing in or around Wakatobi, is distributed using a five-part profit-sharing system. Consequently, each fisher earns an average income of IDR 59,175,009 per season, a substantial amount that implies an enhanced welfare for their households.

The economic returns from flying fish roe harvesting not only contribute to the financial stability and food security of fishers' families but also necessitate considerations for the sustainability of marine resources and the long-term viability of this harvesting practice. Therefore, this study recommends that future researchers, policymakers, and other stakeholders focus on developing strategies that balance economic gains with the conservation of marine ecosystems. This approach is crucial for ensuring the continued prosperity of the fishing community while preserving the environmental integrity of the fishing grounds.

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