Socio-Economic dynamics of octopus fisheries for the livelihood sustainability of small-scale fishers in East Java, Indonesia

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Abstract. Octopus sp. is a significant economic asset in Indonesia, particularly for small-scale fishers in East Java. This study explores the socio-economic complexities of octopus capture fishing and its implications for livelihood sustainability. The sector faces significant challenges, including climate change, price volatility, low value-added products, high operational costs, limited market access, and the lack of specific octopus management regulations in Indonesia. Conducted in Banyuwangi, Sumenep, and Malang Regency from May to July 2024, the research utilized a mixed-method approach, gathering data through interviews with 153 small-scale octopus fishers, which were analysed qualitatively. Octopus fishing trips in East Java ranged from 3 to 30 times per month, with yields of 4 to 80 octopuses per trip, generating profits from IDR 30,000 to 8.5 million. Initial investment costs varied from IDR 3.1 to 165 million, while operational costs ranged from IDR 30,000 to 3.4 million, and maintenance expenses from IDR 264,000 to 18.3 million. The octopus supply chain is lengthy, marked by a persistent patron-client relationship between fishers and financiers. The study emphasizes the need for better governance, improved market access, and robust support systems to enhance the sustainability and profitability of octopus fishing in East Java, offering crucial policy recommendations.

1 Introduction

Small-scale fisheries provide livelihoods and food security for millions of fishers and local communities worldwide. Data on marine fish catches collected from 1950 to 2013 in Southeast Asia show that, up until the year 2000, small-scale fisheries produced more fish for human consumption compared to industrial fisheries. The term small-scale fisheries is used to describe this sub-sector, distinguishing it from medium- and large-scale fisheries. Due to the diversity of small-scale fisheries globally, it is difficult to establish a universally accepted definition. Small-scale fisheries in Indonesia are not fully regulated and are often excluded from various fisheries management policies. In Indonesia, the term used is "small fishers" rather than "small-scale fisheries" to describe this category of capture fisheries. The

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latest legislation defining small fishers is Law No.7/2016 on the Protection and Empowerment of Fishers, Fish Farmers, and Salt Farmers. In this law, small fishers are defined as "fishers who catch fish to meet their daily needs, either without using fishing vessels or using fishing vessels with a maximum size of 10 gross tons (GT)." This definition replaces the previous definition in Law No.45/2009 on Fisheries, which limited the size of small fishers' vessels to 5 GT [1].

Small-scale fisheries are a critical component of coastal communities' livelihoods [2-8], particularly in developing countries like Indonesia. The fishing sector not only provides food security but also plays a vital role in supporting the socio-economic structure of coastal regions. In East Java, Indonesia, octopus (*Octopus vulgaris*) capture fishing has become one of the main sources of income for many small-scale fishers. The high demand for octopus, both in local and international markets, has made this species a valuable commodity [9-11]. However, the dependence on this resource also presents various socio-economic challenges that could affect the long-term sustainability of both the fisheries and the livelihoods of the communities that rely on them.

Over the past decade, small-scale fishers in East Java have faced increasing challenges due to climate change, fluctuating market prices, and resource depletion. As octopus stocks fluctuate due to environmental changes, such as rising sea temperatures and habitat degradation, fishers often struggle to maintain consistent catches. This, combined with limited access to markets and a lack of resources for adopting sustainable fishing practices, has placed significant pressure on fishers' economic stability. Various factors, including household income, education level, fishing techniques, and community organization shape socio-economic dynamics in these fishing communities. Moreover, the social structure within fishing communities plays an important role in determining how fishers adapt to external pressures. The ability of fishers to diversify their livelihoods or modify fishing practices in response to declining stocks is often limited by both economic and social constraints. Consequently, many small-scale fishers remain trapped in cycles of poverty, further threatening the sustainability of their livelihoods. According to the 2023 fisheries statistics of East Java Province, octopus catches in the three research locations were Sumenep 1,080.70 tons, Banyuwangi 1,052.90 tons, and Malang 157.1 tons [12]

The need for a deeper understanding of these socio-economic dynamics is critical to developing effective policies that can help fishers cope with the challenges they face. Socio-economic dynamics refer to the complex interactions and changes within society that pertain to social and economic factors. This encompasses the influence of economic elements—such as income, employment, and wealth distribution—on social structures, interpersonal relationships, and collective behaviours [13]. By exploring the socio-economic conditions and adaptation strategies of small-scale octopus fishers in East Java, this research aims to shed light on how these fishers can sustain their livelihoods amidst growing environmental and economic pressures. The study will also provide insights into how policy interventions could better support the sustainability of small-scale fisheries in Indonesia, ensuring both the conservation of marine resources and the welfare of fishing communities.

The main objective of this study is to explore and analyse the socio-economic dynamics that influence the livelihoods of small-scale octopus fishers in East Java, Indonesia. Specifically, the research aims to investigate the socio-economic profile of small-scale octopus fishers, including their characteristics business capture of octopus, income sources, household structure, and dependence on octopus fishing. This study is significant as it provides valuable insights for policymakers to develop strategies that promote both sustainable octopus fishing practices and the economic resilience of small-scale fishing communities in coastal Indonesia. By examining the socio-economic conditions and challenges faced by these fishers, the research aims to enhance livelihood sustainability and inform adaptation strategies that can help communities cope with environmental and

economic pressures. Additionally, the study contributes to better marine resource management by highlighting the interplay between environmental sustainability and socio-economic well-being, ensuring the long-term viability of octopus stocks. Academically, this research fills a gap in the literature on small-scale octopus's fisheries in Indonesia, serving as a foundation for future studies in sustainable fisheries management.

2 Research methods

The field research locus is located on Kangean Island in Sumenep Regency, Banyuwangi Regency, and Malang Regency, which are divided into villages and sub-districts that are central to octopus fishing. These three locations are the largest octopus fishing centers in East Java Province (Fig. 1)**.** A mixed-method approach was adopted to collect data from May to July 2024. Structured questionnaires were used to gather quantitative data on the socio-economic characteristics of fishers. A purposive sampling technique is used to select participants for the study. The sample consists of 153 small-scale octopus fishers who represent a cross-section of the population in the study area. The sample includes fishers with different levels of experience, household structures, and fishing practices, ensuring a broad understanding of the socio-economic dynamics at play.

Fig. 1. Geographical location of study area.

Semi-structured interviews and focus group discussions (FGDs) are conducted with fishers, community leaders, and local stakeholders to gather in-depth insights into the socio-economic challenges, seasonal calendar, and livelihood strategies of the fishers. These interviews explore topics such as fishing practices, fishing ground, number of monthly fishing trips, business expenses, number of catches per trip, selling price, and business revenue, environmental challenges, access to resources, and community support systems. This data provides a socio-economic profile of the fishing community and allows for the identification of key patterns.

The survey data is analysed using descriptive statistics to provide a socio-economic profile of the fishers. Cross-tabulation is used to explore relationships between socio-economic factors and the sustainability of livelihoods. The study adheres to ethical research standards, ensuring that all participants provide informed consent before participating in interviews or surveys. The confidentiality of participants is maintained, and data is anonymized to protect the identities of the fishers. Additionally, the research is conducted with respect to the local culture and traditions of the communities involved.

3 Results and discussion

3.1 Ecological and economic aspects of Octopus *sp.* fisheries

There are two species of octopus caught by small-scale fishers in East Java, namely the Big Blue Octopus (*Octopus cyanea*) and the Common Octopus (*Octopus vulgaris*) (Fig. 2). The body of the octopus is divided into three parts: the head, neck, and body. The head has 8 arms that function for capturing prey and movement. The octopus also has two large, protruding eyes that can detect prey and enemies. Inside the arms of Octopus *spp*, there are tentacles.

O. cyanea has a distribution ranging from coastal waters to depths of 1,000 meters (continental shelf) [14]. *Octopus vulgaris* lives in coastal areas and is sedentary, mostly inhabiting depths between 0 and 100 meters; this species is rarely found at depths between 100 and 200 meters and is only occasionally found at greater depths [15]. In very shallow waters, *O. vulgaris* is mostly a resident of coral or rocky reefs, but in many areas, this species is equally or even more abundant on sandy and muddy bottoms or in seagrass beds. Along the arms of the reef octopus (*O. cyanea*), there is a pattern resembling bluish-white spots. This bluish-white spotted pattern is a key characteristic that distinguishes *O. cyanea* from other octopuses. This color pattern is related to *O. cyanea's* camouflage ability in various habitats. The color of O. cyanea turns dark brown when approached, touched, or disturbed [15].

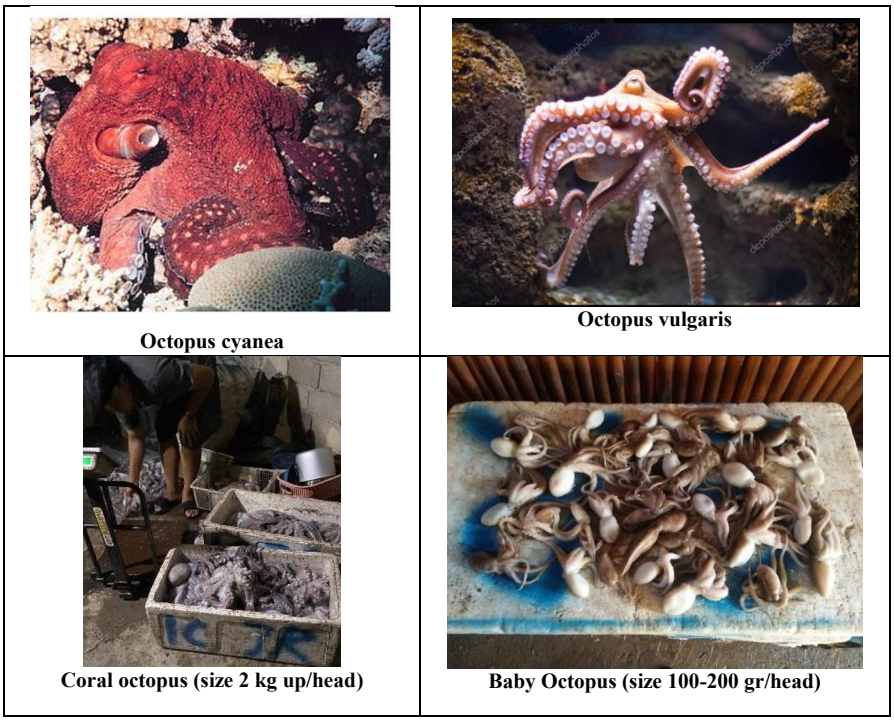

Fig. 2. Octopus species caught by small-scale fishermen in East Java, 2024.

Small-scale octopus fishers in the three research locations use small-scale fishing fleets, specifically motorized boats of less than 5 GT. Octopus fishing is generally carried out by traditional small-scale fishers, using simple fishing fleets (one 1 GT fibreglass boat/outrigger boat), along with three units of canoes and paddles). Fishing is conducted through one-day

fishing trips, while some spend a week at sea in the waters of the southern coast of Java. The fishing gear used by the fishers includes handlines with various types of hooks, locally referred to as "udang-udangan" or "pitingan." (Fig. 3).

Fig. 3. Types of small-scale octopus fishing fleets in three research locations Source: Researchers documentation, 2024

The fishing gear used by octopus fishers in the three research locations is an octopus handline. However, the local names for the octopus handline differ across the three locations. In Sumenep Regency, fishers call it kepitingan, pocongan, and konong-konong, while in Malang Regency, there is only one name, kepitingan. In Banyuwangi Regency, the names vary according to the type of octopus being caught. The hook for sand octopus/baby octopus is called udang-udangan, while for reef octopus, it is called kepitingan/pitingan (Fig. 4).

The materials used to make the udang-udangan octopus handline include painted wood or boat sponge in various shapes, such as patek fish, shrimp, and apollo, wrapped with silver scotlet/sticker. The bait is purchased in stores at a price of IDR 35,000 per unit. The silver color can reflect sunlight, dazzling and attracting the octopus. Before using scotlet, fishers used snack wrappers as bait. After trial and error, the use of silver scotlet-wrapped bait resulted in optimal octopus catches. The materials used to make the pitingan octopus handline include sea shells cast with lead. The price of an octopus handline is IDR 100,000 per unit if made by the fishers themselves, while the store-bought version is more expensive, priced at IDR 150,000 per unit. All octopus fishing gears in the study site are environmentally friendly, using no bombs, no cyanide, and no potassium [16]. Environmentally friendly fishing does not have a negative impact on the environment, such as damaging the bottom of the water, damaging biodiversity, and the small number of non-target fish caught. Prawns and hooks are selective fishing gear used only to catch octopus and only catch octopus of a certain size. They only catch a limited number of octopus, unlike nets, which can catch many species at once.

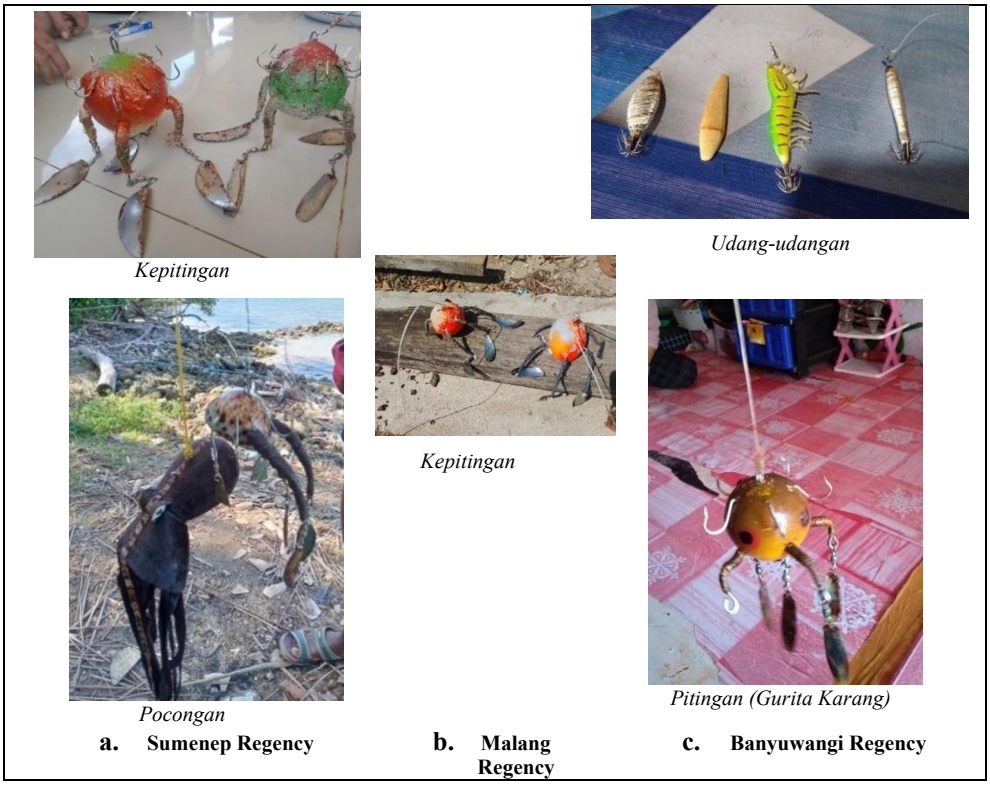

Fig. 3. C Types of octopus hooks at three research locations.

3.2 Characteristics of small-scale capture fishing businesses

Not only do the names of fishing gear differ across the three research locations, but the characteristics of the fishing practices also vary, such as the fishing grounds, fishing seasons, costs, prices, and business profits, as presented in Table 1. Octopus fishing trips must be conducted during daylight hours: departing at 6 AM and returning before sunset (the time when the octopus is caught). The depth at which an octopus is caught is between 15-20 meters. While fishing, fishers bring a kuntingan (canoe).

The challenges faced by small-scale octopus fishers include: (1) Fishing lines often break when they get caught on coral, causing the hooks to be lost. The high cost of fishing gear necessitates purchasing new equipment, (2) Accidents at sea occur during strong currents, which can drag fishers away, (3) Fishing lines get tangled in nets (sometimes losing up to 4 units of hooks), (4) The price of octopus continues to decline, (5) Catch yields decrease due to an increase in the number of octopus fishers, (6) The impact of destructive fishing (bombing, purse seining, potassium), and (7) The phenomenon of climate change (octopus season: during the rainy season, fishers do not go to sea due to strong winds and large waves, during the east season, strong winds make it difficult for fishers to go to sea, coastal erosion occurs during the west season, sea levels rise to residential areas, tornadoes, and thick fog in the morning).

Table 1 in the paper outlines the patterns of octopus capture fishing businesses in three research locations: Sumenep, Banyuwangi, and Malang Regencies. It compares various aspects such as fishing locations, monthly fishing trips, investment costs, operational

expenses, maintenance costs, catch quantity, selling prices, and profit margins. Additionally, it details the seasonal patterns of octopus fishing, including peak seasons, moderate seasons, and periods of scarcity. The table reveals that:

- Fishing locations vary by region, with Sumenep fishers working 15-40 miles offshore, Banyuwangi fishers catching baby octopuses near the shore and larger octopuses further out, and Malang fishers fishing within 5-25 miles of the coast.
- Monthly fishing trips range from 20-27 in Sumenep, 3-25 in Banyuwangi, and 4-30 in Malang.
- Investment costs for boats, machinery, and fishing gear are highest in Sumenep (up to IDR 165 million) and lowest in Malang (starting from IDR 3.08 million).
- Operational costs (fuel, bait, wages) and maintenance costs (for boats and taxes) are similarly high in Sumenep and Banyuwangi but are significantly lower in Malang.
- Catch quantities vary, with Sumenep reporting the largest catches by weight (57-250 kg per trip), while Malang has smaller catches (2-30 kg per trip).
- Selling prices for octopus also differ across regions, with Banyuwangi offering higher prices during peak seasons.

According to the Law of the Republic of Indonesia number 7 of 2016, small-scale fishermen are fishermen who catch fish to fulfil their daily needs, both those who do not use fishing vessels and those who use fishing vessels with a maximum size of 10 GT. Octopus fishermen in the study area use boats of around 3-10 GT so that according to the law they are included in small-scale fishermen. Octopus fishers are very dependent on weather conditions, usually they will not go to the sea if the weather in the sea is high waves and stormy. This is due to the limitations of their fleet, technology and safety aspects. Their income, which is only enough to fulfil their daily needs, does not give them the opportunity to develop their business, such as increasing their fishing fleet to a larger size, purchasing fishing technology such as GPS and Fishfinder to determine their fishing position, and the opportunity to own safety equipment. Traditional financial management and their dependence on formal and non-formal financial institutions emphasise their status as small-scale fishers. The highly dynamic activities of small-scale capture fisheries need to be clustered based on similar characteristics. These characteristics may include their response to natural conditions, attitudes and behaviours, fleet and gear ownership, ability to manage finances, the social structure of the fishing community, and the institutions in their area [17].

Table 1. *Octopus sp*. fishing capture business patterns in three research locations.

Business variables	**Perception of Respondent**		
	Sumenep	**Banyuwangi**	**Malang**
Fishing ground	15-40 mil: Kangean waters (Kayuaru, Kalisangka, Daandung).	● *Octopus cyanea* /*baby octopus*: 200 m - 2 km coastal line from Sari Lestari, Cemara Beach, Cungkingan Beach. ● *Octopus vulgaris*: 2-50 mil from Pancer, Plengkung, ship sinks Bali Strait, Blambangan Peninsula, Blue Bay, Alas Purwo).	0,5 – 25 mil: water of Ngliyep, Wediawu, Sendangbiru, Balearjo, Donomulyo, Sempu Island, Nglurung, Modangan, Sidoasri, Balekambang, Bajulmati, Tambakasri.
Trip/month	20-27	3 - 25	4 - 30

Business variables	Perception of Respondent		
	Sumenep	**Banyuwangi**	**Malang**
Investment cost: boat, engine, fishing gear, catching aids (million IDR)	13.350 – 165.000	5.645 – 70.000	3.080 – 85.200
Operational cost:gasoline, oil, food supplies, baits, ice, retribution, wagest (million IDR)	196-1.440	136-3.400	30 – 840
Maintenance costs: Investment cost: boat, engine, fishing gear (million IDR)	2.100-10.000	900-12.300	264-18.270
Total catch/trip	5,7-250 kg/trip 4-25 octopus/trip	2-30 kg/trip 5-80 octopus/trip	1,5-11 kg/trip 4-70 octopus/trip
Octopus price (million IDR/kg) *Disclaimer: prices at the collective trader level were taken during the researcher's field survey, May and July 2024*	● UP (> 2 kg) = IDR 40/kg ● Super (1-2 kg) = IDR 30/kg ● C (< 1 kg) = 20/kg	● 2 UP: peak season = IDR 85– 90/kg; off-season = IDR 55 – 60/kg ● 1 UP: peak season = IDR 45/kg; off-season = IDR 30/kg ● 0,5 kg: peak season = IDR 35	● 2 UP = IDR56/kg ● 1 UP = IDR46kg ● 0 – 5 ons = IDR 36/kg ● 0 – 3 ons = IDR 22/kg
Business revenue (million IDR)	210-8.500	32-1.900	90-840
Peak season of octopus (east monsoon)	October-April	October-March (gurita pasir) October-April (gurita karang size 2 kg UP/ekor)	September-January
Temperate season	October-November January-April	November-December January-June	April, July, December
Off-season	March-April	September (ukuran kecil) January-June	November, December, February, Maret
Stromy season (west monsoon)	May-September	July-August	Juni-August
Capture trends	Increased rapidly: 2% Increases slowly: 30% Steady: 6% **Decreases slowly: 62%**	Increased rapidly: 14% Increases slowly: 15% Steady: 27% **Decreases slowly: 38%** Decreases rapidly: 6%	Increased rapidly: 1% Increases slowly: 20% Steady: 1% **Decreases slowly: 62%** Decreases rapidly: 16%

Source: Primary data processed, 2024

3.3 Socio-economic complexities of octopus fishing and its implications for livelihood sustainability

The socio-economic complexities associated with octopus fishing involve a variety of interrelated factors that significantly impact the livelihoods of fishermen and coastal

communities. In the three research locations, octopus fishing has emerged as a viable alternative source of income for small-scale fishermen. While these fishermen primarily focus on pelagic fish, they shift to octopus harvesting when the capture of pelagic fish becomes more challenging during windy seasons. Notably, the peak catch season for octopus coincides with these adverse weather conditions when pelagic fish availability diminishes.

The robust demand in both local and international markets creates substantial economic opportunities. Between 2006 and 2010, the practice of octopus fishing among small-scale fishermen in Sumenep, Malang, and Banyuwangi gained traction as local buyers indicated that octopus could be sold for IDR 20,000 to 60,000 per kilogram, depending on size. However, this situation poses a risk of dependence on the octopus market, particularly in light of potential price fluctuations or declines in octopus populations. Fishermen have observed a noticeable reduction in octopus stocks over the years. For instance, octopus fishermen in Malang, who commenced fishing in 2010, previously captured a minimum of ten sacks of octopus per trip; however, current catches average only five sacks per trip. Similar trends have been reported by fishermen in Sumenep and Banyuwangi. A downward trend in octopus catches also occurred in the Selayar Islands from 2019 to 2021 due to higher demand from national and especially international markets [18]. If this condition continues, it will put high pressure on the sustainability of the octopus species. Therefore, an integrated management strategy is needed, starting from the local level to the central government level. Basic research on octopus species, distribution and stocks needs to be conducted in all octopus fishing centres in Indonesia.

Octopus fishermen frequently encounter inequalities in accessing resources and markets, with prices predominantly determined by octopus processing factories. Furthermore, many fishermen lack adequate fishing gear and access to efficient distribution networks, which adversely affects the prices received for their catches. Most octopus fishermen in East Java employ a lure referred to as 'kepitingan,' designed to mimic a crab, featuring multiple legs and colors that attract octopus. This fishing gear has evolved in terms of shape and color, influenced by the collective experiences of fishermen. Knowledge regarding these lures is shared among fishermen from various locations and is passed down through generations.

The practice of octopus fishing is often deeply rooted in local traditions and cultural heritage, with techniques being transmitted across generations, thereby shaping community identity. For instance, octopus fishermen in Malang utilize 'ilmu titen,' a method for predicting optimal fishing times based on the Javanese calendar, primarily relying on weather conditions as the key variable. Environmental changes, including climate change, pose challenges to these traditional practices. In response, fishermen are increasingly integrating their traditional knowledge with contemporary tools and climate data from reliable sources, such as the Meteorology, Climatology, and Geophysics Agency (BMKG), to obtain more accurate information.

The pressing necessity for regulations that promote sustainable fishing practices is evident. In the absence of proper management, unsustainable practices pose a significant threat to octopus populations and jeopardize the livelihoods of fishermen. Specifically, in Malang, local octopus fishermen have established community regulations that include prohibitions on certain fishing gear, such as explosives, potassium, and spears. These restrictions are rooted in the experiences of previous generations, during which the use of destructive gear negatively impacted coastal ecosystems, endangered lives, and led to a persistent decline in catch quality. Recognizing the severe consequences of employing such methods, octopus fishermen at Ngeleyep Beach in Malang have come to understand that maintaining a healthy ecosystem is integral to sustaining their livelihoods. This awareness fosters a deep connection between fishermen and their marine environment, thereby enhancing compliance with their self-imposed regulations. Furthermore, these fishermen allocate IDR 1,000 from every kilogram of octopus sold to cover operational costs associated

with conservation and organizational needs. A similar level of awareness is apparent in Banyuwangi; however, it is notably absent in Sumenep.

The variations in this sense of place significantly influence the conditions of octopus fishing zones across the three regions. Climate change and environmental degradation also affect the availability of octopus. Shifts in water temperature, pollution levels, and habitat destruction can disrupt octopus migration and reproduction patterns, consequently impacting fishermen's incomes. The adaptation strategies employed differ by location. In Malang and Banyuwangi, where there is a strong sense of place, adaptations focus on conservation efforts, resulting in modifications to fishing techniques and equipment. Conversely, fishermen in Sumenep lack a robust attachment to their octopus fishing grounds, and for them, octopus is not a primary commodity. This results in a diminished understanding and connection compared to their counterparts in the other two regions. Adaptation strategies in Sumenep emphasize overall fishing sustainability, including the evolution of boat design and the development of various fishing gear and supporting equipment.

This situation underscores the complexity that influences the sustainability of octopus fishermen's livelihoods, which is contingent upon the integration of social, economic, and environmental factors. Efforts to enhance sustainability must incorporate education and training initiatives aimed at improving fishermen's knowledge of sustainable fishing practices and resource management, encourage community participation in regulatory and resource management decision-making, and promote supportive policies. By grasping this socio-economic complexity, more effective strategies can be formulated to bolster the sustainability of small-scale fishermen's livelihoods in the future.

4 Conclusion

The paper provides an in-depth analysis of the socio-economic dynamics of small-scale octopus capture fishing in three regencies of East Java: Sumenep, Banyuwangi, and Malang. It highlights that octopus fishing is a significant livelihood for many fishers, offering a vital economic resource despite various challenges. The study underscores the importance of octopus capture fisheries in supporting local communities' livelihoods and food security, especially given the high demand for octopus in both domestic and international markets. Key findings include: 1) Variability in fishing practices and costs: There are significant differences in fishing locations, investment, operational costs, and maintenance expenses across the three regencies. Sumenep fishers typically have higher costs and larger catches compared to Malang and Banyuwangi, 2) Challenges faced by fishers: Fishers encounter numerous challenges, including rising costs of fishing gear, accidents at sea, the impact of destructive fishing practices, and the consequences of climate change, such as difficult weather conditions and reduced catches during certain seasons, and 3) Fluctuations in octopus prices and yields: The study notes that octopus prices fluctuate based on seasons and the size of the catch. Additionally, increasing competition among fishers and environmental factors have caused a gradual decline in overall catches. The paper concludes by emphasizing the need for improved governance, sustainable fishing practices, and better support systems to enhance the profitability and sustainability of small-scale octopus' fisheries in East Java. Policy recommendations are directed towards addressing market access issues, managing resources effectively, and adapting to the challenges posed by climate change.

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