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STAKEHOLDER PERSPECTIVES ON MANAGING ABANDONED, LOST, OR DISCARDED FISHING GEAR IN REMBANG CRAB FISHERIES

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ABSTRACT

Abandoned, lost, or discarded fishing gear (ALDFG) poses a significant threat to natural marine habitats, causing damage to aquatic ecosystems and affecting fishing productivity. In this study, the Analytic Hierarchy Process (AHP) method was employed, and interviews were conducted with stakeholders to identify strategies for preventing the occurrence of ALDFG in crab fisheries in Rembang waters. The results indicate that the highest-priority criteria, as identified by stakeholders, include: marine debris: plastic bags; fishing gear waste: fishing traps; cause: entanglement with other fishing gear; impact: decreased income; solution: prohibition of modified purse seines; and actor: central government. These were considered the most significant by stakeholders. In contrast, the lowest-priority criteria were marine debris: sacks; fishing gear waste: nets or flags; cause: physical damage (cuts); impact: anxiety; solution: establishment of an oversight committee; and actor: business entities. It is hoped that these findings will offer stakeholders new insights and perspectives, which will accelerate the process of integrating diverse public opinions to develop more effective approaches to handle ALDFG.

Keywords: *Analytic Hierarchical Process, Abandoned, lost, or discarded fishing gear, Crab fisheries*

INTRODUCTION

Marine debris refers to durable solid materials generated from discarded or abandoned objects in coastal and aquatic environments. This waste primarily originates from land-based activities characterized by persistence and low degradation processes, mainly when deposited in the seabed (Bruemmer *et al*. 2023). Marine debris is not limited to coastal areas, but is also widely distributed across the ocean, including remote areas, seabeds, and polar regions, transported from other areas by water currents, winds, and river flows (Huang 2023). In addition, marine debris can impact marine fauna, such as fish, turtles, or whales, by causing them to ingest these materials, both natural and anthropogenic, and entangle them, ultimately leading to their death (Pramudianto 2020).

We can classify marine debris into two categories: non-fishery and fishery waste. Non-fishery marine debris is waste disposed of from human activities on land and dumped into the sea. Non-fishery marine debris can include organic and inorganic waste, i.e.,

plastic waste, glass, rubber, can lids, tissue, paper, cloth, wood, and their derivatives. Marine fisheries debris comprises any remnants from fishing operations, lost or discarded fishing gear. This forms as a result of improper and ignorant disposal by fishermen regarding the consequences of such waste on the sea, which is fish waste. Artisanal fishing ports in Peru generate a range of waste, including batteries and non-reusable plastics, among other materials. However, the lack of adequate waste handling infrastructure at these ports exacerbates the concern that they contribute to the marine litter problem (Guidino *et al.* 2024). The major linear contributors to Indian seafront litter are fishing rods, due to ghost fishing caused by plastics, ropes attached to fishing nets and buoys, as well as the entanglement of sea turtles that results from such appliances (Liotta *et al.* 2023).

Marine debris originating from fishing gear is a critical environmental issue resulting from several fishing activities, as well as the behavior of fishermen. Fishing gear, including nets, lines, and floats, has the potential to become marine debris when abandoned, lost, or discarded during the process of fish capture. Such a phenomenon is often referred to as ghost fishing, which can result in the unintentional capture and death of marine organisms (Liotta *et al.* 2023; Vieira de Araujo 2023). This phenomenon may lead to a depletion of fish, which in turn exacerbates illegal fishing practices. The lack of awareness and poor behavior of fishermen towards waste management due to unregulated and unreported (IUU) fishing encourages fishermen to intentionally abandon and deliberately discard their gear in an attempt to obscure evidence and avoid being caught (Yang 2022).

Marine debris has significant economic impacts on fisheries, tourism, and broader ecosystem services. Marine debris affects the fisheries sector, which will face increased operational costs due to a decrease in catches. (Luttenberger *et al.* 2023). In the tourism sector, the presence of marine debris will reduce the number of visitors to the beach, resulting in significant economic losses. The cost of cleaning and the reduction in the aesthetic value of the beach exacerbate the financial burden on the local economy (Thongphaijit 2020). The costs of marine debris management are often not borne by waste producers or polluters, but are typically covered by the community (Liu, Chang and Chen 2023). To address the economic consequences, a multidisciplinary approach involving all stakeholders, from the government to the local community, is necessary to develop effective and adaptive marine debris management strategies (Abalansa *et al.* 2020).

Loss of fishing gear at sea is a problem categorized under the term "abandoned, lost, or discarded fishing gear" (ALDFG); the reasons for this loss are numerous. Research by Richardson *et al.* (2021) identifies bad weather conditions as a primary factor contributing to fishing gear loss. Additionally, encounters with fishing vessels and their equipment play a significant role, leading to entanglement and other losses (Frenkel *et al.* 2023; Susanto *et al.* 2022). Entangled and stuck fishing gear with seabed objects such as rocks, coral reefs, and other submerged materials is also a cause of fishing gear loss, which typically occurs with fishing gear that operates on the seabed, including trawl nets and traps (Frenkel *et al.* 2023; Lovell 2023). Negligence and noncompliance with navigation rules of ship operators may also generate incidents that damage or displace fishing gear, as happened in Korean coastal waters (Choi *et al.* 2022). Other factors contributing to the loss of fishing gear at sea include damage, the difficulty in tracing the locations of lost gear, and the improper disposal of damaged equipment (Choi *et al.* 2022).

In general, the loss of fishing gear has profound environmental, economic, and social impacts. Environmentally, ALDFG plays a significant role in marine pollution because plastic gears may persistently outlast in the ocean for decades, causing habitat degradation and posing serious threats to marine wildlife due to entanglement or swallowing (Paul *et al.* 2024; Welden 2020). In addition, lost fishing gear has an impact on biodiversity, damaging coral reef ecosystems and increasing cetacean bycatch (Frenkel *et al.* 2023). Economically and socially, ALDFG has a significant influence on fishing productivity and the livelihoods of coastal communities (Yang 2022).

Preventing ALDFG has been carried out by the Indonesian government and global organizations worldwide, such as the Global Ghost Gear Initiative (GGGI). Presidential Regulation No. 83 (2018) was issued by the Indonesian government to minimize marine waste, including plastic, resulting from fishing activities (Cahyani *et al*. 2023). Additionally, Indonesia has initiated the Indonesian National Action Plan for Marine Plastic Debris

(NPOA-MPD 2017-2025), aimed at reducing marine plastic debris, including ALDFG, with a target of achieving a 70% reduction by 2025. The initiative highlights the efforts made to handle, recover, and recycle fishing gear, thereby mitigating its impact on the environment, economy, and society (World Bank 2022). Organized marking on fishing gear is an effort to prevent loss (Yang 2022), supported by the Global Ghost Gear Initiative (GGGI).

Furthermore, sensor and warning system applications on buoys attached to fishing gear could detect excessive movements. Those fishing gears can be retrieved immediately; hence, the number of fishing gear lost at sea would be prevented (Lee *et al*. 2023). Other preventive measures, including equipment maintenance and training programs for vessel crews, have been identified by fishermen to reduce fishing gear loss. Routine maintenance ensures fishing gear is in good condition, while training may improve fishermen's skills in managing and handling fishing gear (Richardson *et al.* 2022). Above all, awareness is the most needed among fishing communities, particularly (Ulfah *et al.* 2023), supported by collaborative endeavors between law enforcement, the private sector, and international partners so that waste management practices from fishing gear are accordingly with regulations and effective enforcement (Cahyani *et al.* 2023; Winarwati 2020).

The Gross Regional Domestic Product (GDP) of Rembang Regency accounts for 6.27 percent of the fisheries subsector. The production of marine fisheries includes crab. Crab fisheries contribute significantly to Rembang Regency, Central Java. The northern coastline of Rembang is the primary location for crab fishing activities, utilizing gillnets and traps as their primary fishing gear (Sari *et al.* 2025). The study by Satria et al. (2023) reveals that crab fisheries produce ALDFG, which consists of 86% metal and 14% plastic. This study proves the importance of research related to preventing ALDFG in Rembang waters.

Efforts to prevent ALDFG in crab fisheries in Rembang waters have not been effectively achieved due to the lack of understanding and collaboration between stakeholders on this issue. This study conducted an AHP analysis on the factors influencing the prevention of ALDFG, with the main idea focusing on the extent to which stakeholders play a significant role in preventing ALDFG in crab fisheries located in Rembang waters, aiming to prevent ghost fishing that impacts crab resources. Therefore, this study aims to explore the perspectives of various stakeholders in efforts to avoid ALDFG in Rembang waters and understand the efforts to mitigate conflicts in the management of ALDFG in crab fisheries.

The Analytic Hierarchy Process (AHP), a decision-making tool, is used to assess the relative importance of various factors (Ramík 2020). AHP has also been used to explore stakeholder preferences in preventing ALDFG in Taiwanese waters (Yang 2022). By combining the perspectives of different stakeholder groups, such as local fishermen, government officials, and environmental organizations, this approach can provide valuable insights into the complex socio-ecological dynamics (Rutting *et al.* 2021).

METHODS

This study was conducted in Rembang, Central Java, Indonesia (Figure 1), utilizing a questionnaire based on the AHP method by Saaty (Kibria et al., 2024) to determine how stakeholders can contribute to preventing ALDFG from occurring at sea.

Six (6) criteria are made for the AHP questionnaire framework (Figure 2). Data collection was carried out through an interview in a focus group discussion (FGD) in January 2024 with 29 participants from the local fisheries and marine service, fishing port managers, fish auction managers, the Ministry of Maritime Affairs and Fisheries, fish trap fishermen, crab net fishermen, fish trap waste collectors, and researchers. The AHP method enables participants to rank the level of importance of factors under each dimension according to their preferences and perceptions. This process allows participants to express their opinions on important issues, provide reasons and preferences for ranking elements, and minimize logical errors when comparing features. AHP is used to determine the relative importance of objectives and obtain a series of appropriate weights (Jawad *et al*. 2024).

The relative importance of each target is determined through a series of pairwise comparisons. The targets are arranged in pairs, and each participant is asked to rate the importance of one target compared to the other on a scale of 1 to 9. The rating scale is described in Table 1.

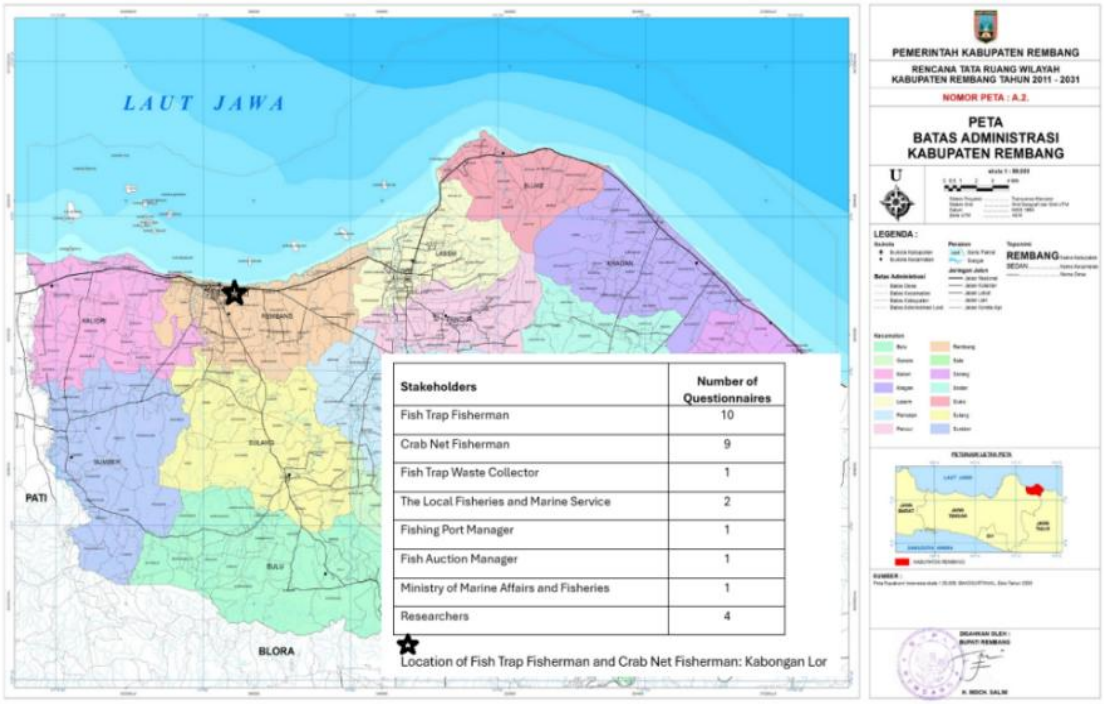

Figure 1 Location of data collection and questionnaire details in Rembang Regency (Source: https://rembangkab.go.id/peta/)

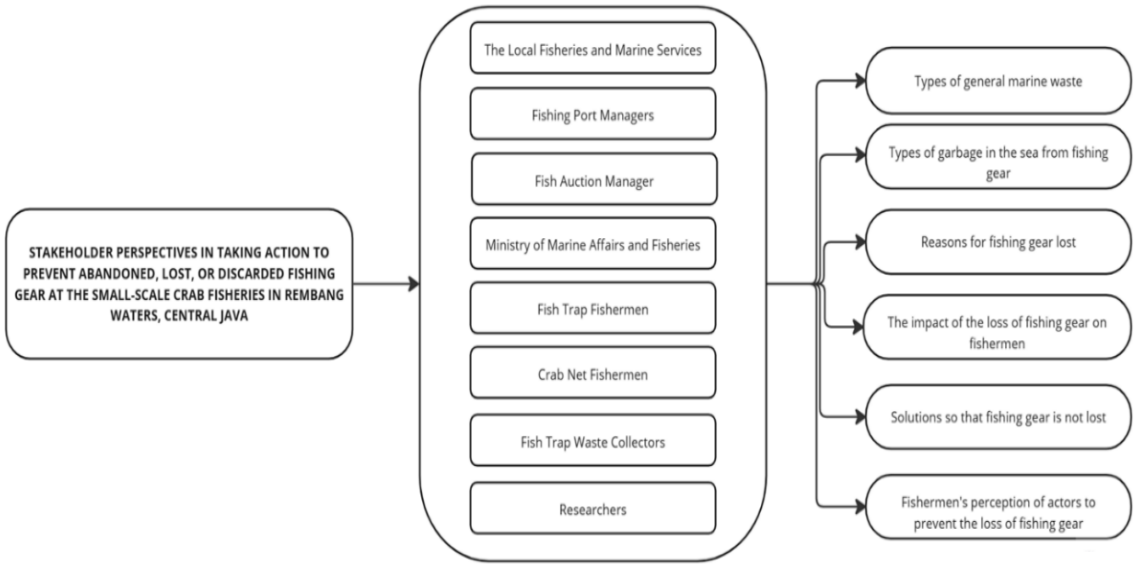

Figure 2 Analytical hierarchy process (AHP) framework

Table 1 Weight Scale

Value	Meaning	Explanation
1	Equally important	
3	A little more important	One element is more important than the other
5	Somewhat more important	One is more important than the other
7	Much more important	One is more chosen, and the dominance is real
9	Absolutely more important	One element is more strictly chosen
2, 4, 6, 8	The value between the numbers above	If a compromise is needed

RESULTS

Stakeholders Perceptions of Criteria

1. Types of general marine waste

The first question was used to explain the criteria for types of marine debris (Figure 3). Among all stakeholder groups, "plastic bags" were considered the priority. Participants also believed that "sacks" should be of the least priority. This figure shows that participants consider "plastic bags" to be a more essential type of waste compared to other kinds of marine debris. The results show that a participant's perception of "plastic/bags" is a type of waste often found in comparison to other types of waste in the ocean. Likewise, used water bottles are often found when fishing is performed. Plastic bag waste was generated not only from household activities but also from fishing activities. Plastic bags are used by fishermen to wrap food and supplies for going fishing.

Marine animals are found entangled or swallowing marine debris. Studies from the past few decades have shown that marine biota have been severely impacted by plastic debris, including ingestion, entanglement, and entrapment. Sea turtles, whales, seals, and seabirds have been found entangled and consuming large amounts of plastic, accumulating chemicals contained in plastic (Li and Leung 2024). Therefore, concrete steps must be taken to prevent plastic bags and bottles from becoming marine debris.

The perception of marine debris as identical to plastic bags is primarily due to the prevalence and visibility of plastic debris in the marine environment as well as its significant environmental impact (Bettencourt *et al.* 2023; Watson *et al.* 2022). Plastic bags dominate marine debris because they are durable, lightweight, and widely used in various products, resulting in their widespread presence in the ocean and coastal areas (Bettencourt *et al.* 2023; Prasetiawan *et al.* 2022; Ramos *et al.* 2024; Vieira de Araujo 2023). The presence of plastic bags supports these findings, which are often observed and reported by respondents surveyed on a large scale across eight European countries, indicating that 70% of respondents pay attention to marine debris (Van Oosterhout *et al.* 2022).

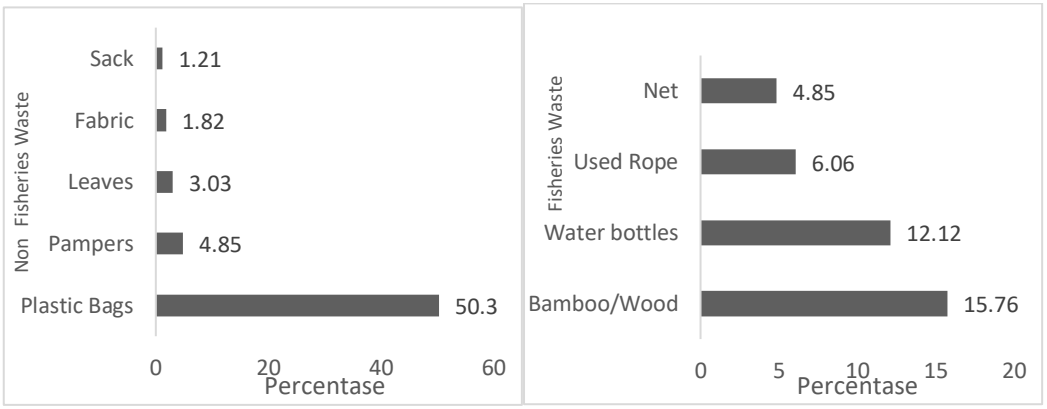

Figure 3 Percentage of marine debris from fisheries and non-fisheries.

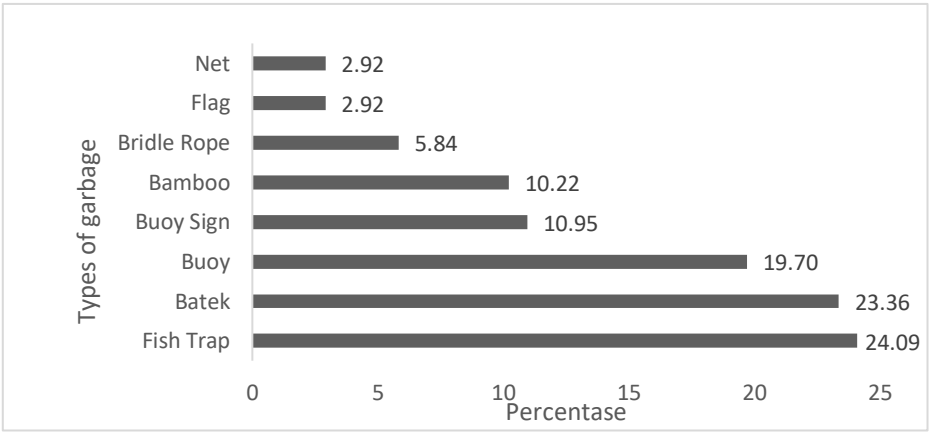

Figure 4 Results of priority selection of types of waste from fishing gear.

2. Types of waste at sea from fishing gear

In Indonesia, marine debris from fishing activities has a significant potential considering the high number of fishing units operating, especially in the northern part of Java. Parts of fishing gear are often found as debris in the ocean, especially when gears are separated, dismembered, or cut, such as wood, bamboo, pieces of nets, ropes, and buoy signs. The following are the types of waste from fishing gear and its components often found in the sea, according to the opinions of stakeholders participating in the focus group discussion (Figure 4).

Fishermen's opinions indicate that the most frequent types of waste from fishing gear in Rembang waters are fish traps, followed by bridle ropes and buoys, in that order. This data indicates that fish traps, bridle ropes, and buoys are key components of fishing gear that stakeholders consider crucial to manage correctly. Rembang fishermen use traps made of metal for crabs, which measure 60x30 centimeters and feature two maces. Later, nets with a mesh size of 33 millimeters will form the sides of traps. The net construction used either 1 inch or 1.25 inches in thickness, among other measurements.

In-depth interviews with Rembang fishermen explained that crab traps can become marine debris when they become entangled with other fishing gear, such as "cotok" (mini trawl). Fishermen preferred to throw the entangled fishing gear into the sea or abandon it if the fishing gear was attracted by other fishing gear rather than bring it ashore. They can be considered thieves had they been seen taking the traps home, even though they were disposing of them in a landfill. Additionally, damaged traps can occur due to corrosion or degraded materials, causing them to become detached from the ropes and separated from the set.

The respondent's perspective that fish traps are a source of marine debris is caused by several factors related to their construction techniques and materials. The fish trap, locally named "Bubu," is constructed from wood, rattan, and metal, which is economically efficient; however, it is easily lost or disposed of during fishing operations (Silvi *et al.* 2023). Had the fishing gear been disused and disposed of inappropriately, it could usually have become marine debris (Sharma *et al.* 2024; Thomas *et al.* 2023).. Buoys may also become debris from fishing gear due to several factors. First, buoys are vulnerable to wind and waves, making them easily be lost at sea (Seo and Park 2021). Second, buoys without monitoring would be difficult to locate and retrieve, ultimately becoming marine debris (Merlino *et al.* 2023). Furthermore, other fishing equipment, such as nets and ropes, contributes significantly to the presence of microplastic fibers in the marine environment (Stolte *et al.* 2020). Bamboo also becomes marine debris if it is used ineffectively (Nursidi *et al.* 2024).

3. Reasons for the loss of fishing gear

The criteria for the causes of the loss of fishing gear are shown in Figure 5. Most of the respondents stated that "being entangled in other fishing gear" is very important, with a value of 22.038. The cause of "being cut" is the last place of all reasons. However, the "weather" criterion is also the priority, but the weight value is lower than the "entangled in other fishing gear" criterion.

The majority of respondents indicated that being entangled in other fishing gear is due to several factors, such as other fishing gear operations. Other fishing gear, mini trawl (locally named "Cotok"), scrapes the seabed so that the fish trap unintentionally lifts off and separates from the set (Matrutty *et al.* 2023; Nedostup *et al.* 2022).

Cotok is a prohibited fishing gear, but fishermen widely use it; therefore, serious actions are needed to control it (Widayanto *et al*. 2022). It has been widely proven that weather conditions can cause loss of fishing gear. Richardson *et al.* (2021) prove that bad weather is the most common cause of the loss of fishing gear at sea in 7 countries around the world. Susanto *et al.* (2022) also state that bad weather is one cause of the loss of fishing gear in the Banten waters. In addition, Lovell (2023) states that adverse weather conditions and obstacles to benthic barriers are the primary reasons for the loss of fish traps in the East Caribbean. The theft of fishing gear is also a contributing factor, and Diggins (2023) has proven that this occurs due to competition in the fishing industry. This issue will impact the local economy and sustainable fishing practices (Nauen and Boschetti 2022; Witbooi *et al.* 2020). Due to water currents, large waves, and being cut are the least common causes, with the lowest weighing values by the experts.

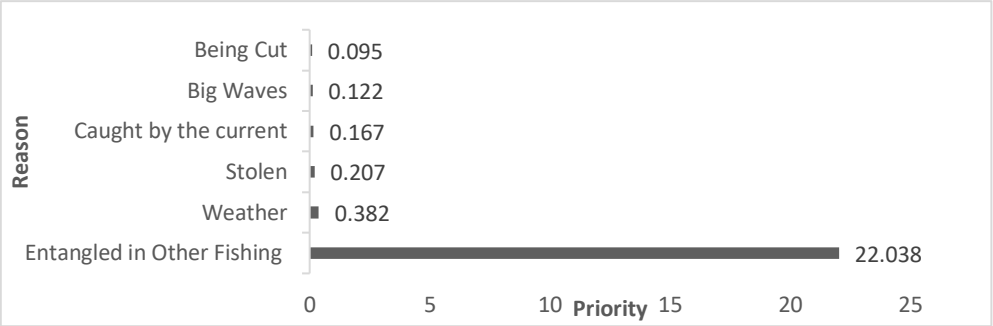

Figure 5 Priority is the choice of the cause of the loss of fishing gear.

4. The impact of the loss of fishing gear on fishermen

Concerning the impacts, the result analysis shows that some priorities of the effects of fishing gear loss are a reduction in income, environmental degradation, and conflict with friends. However, "lessen income" is the main impact based on participant perceptions, with the value of 0,6662. On the other hand, "anxious among people" has the lowest impact value due to fishing gear loss, with a value of 0,0161. Those results are analyzed in Figure 6.

The most significant impact is the loss of fishing gear for fishermen, which can substantially reduce their income for several reasons. First, fishing gear lost at sea can lead to ghost fishing, which may deplete fish stocks, reduce the availability of fish for active fishermen, and ultimately decrease their catches and income (Drakeford *et al*. 2023; Ghaouar et al. 2024). Second, defective and disfigured fishing gear led fishermen to incur additional repair costs for those broken gears and even prompted them to purchase new fishing gear. Those defective gears may also lead to inefficient production due to catch loss (Frenkel *et al.* 2023; Waileruny *et al.* 2023).

The third impact is declining in fish resources quality because fishing gear usually contains synthetic materials that remain in the marine environment for decades, and it contributes to microplastic accumulation that poses a severe threat to aquatic life and ecosystems (Richardson *et al.* 2022; Rijkure *et al*. 2024; Sharma *et al.* 2024; Syversen *et al.* 2022). Encountering two different types of fishing gear in different fishing vessels, such as between a Cotok and a Fish trap, which both operate on the seabed, would destroy both gears and even cause the loss of a Fish trap in the ocean (Widayanto *et al*. 2022). This moment would trigger conflict between user groups due to differing interests with the same limited resources (Abdurrahim *et al*. 2020). As a secondary priority, the loss of fishing gear creates conflicts that lead to risks to the ecosystem, including fish resource decline, as explained.

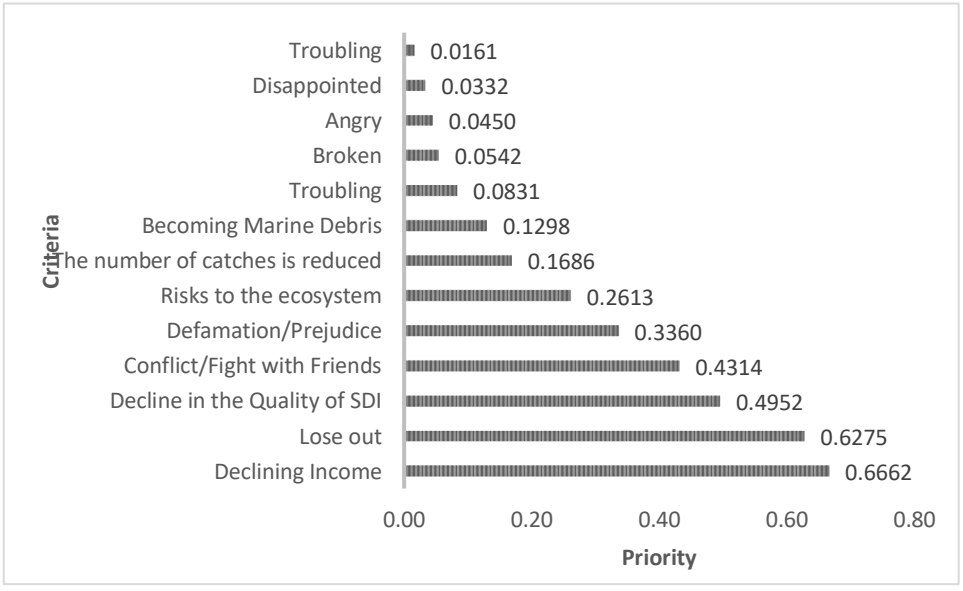

Figure 6 Priority selection of the impacts of the loss of fishing gear on fishermen

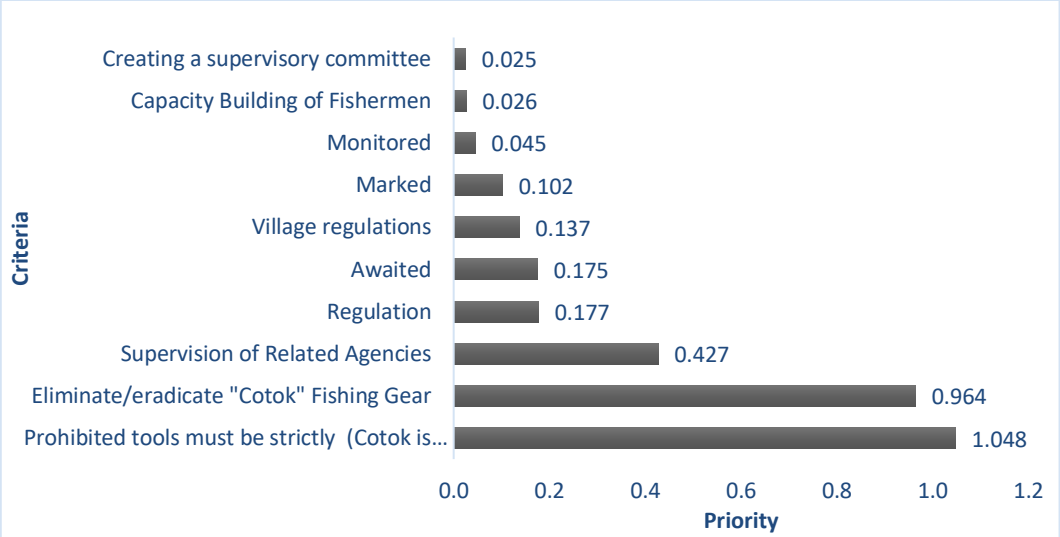

Figure 7 Priority is the choice of solution to prevent fishing gear from being lost.

5. Solutions so that fishing gear is not lost

A couple of factors that are important to consider are "prohibited fishing gear must be completely forbidden to operate (such as Cotok)" and "eliminate/eradicate Cotok fishing gear". However, prohibiting forbidden fishing gear is the most critical factor, with a value of 1.048. Forming a supervisory committee is the least important factor to consider, with a value of 0.025. These results are illustrated in Figure 7.

The prohibition of Cotok is the most prominent factor that needs to be implemented, as well as eradicating this gear to mitigate the fishing gear loss and lessen marine debris. These strategies had been attempted through local regulation in Rembang and Pati Regency (Widayanto *et al*. 2022). Supervision from related agencies, such as the local fisheries office, and dissemination of the regulation to fishermen and the local community are needed to ensure the Cotok prohibition regulation is implemented (Cacciatore and Eliantonio 2020). Local government supervision is upheld by Regulation No. 36 (2023) from the Minister of Maritime Affairs and Fisheries, which pertains to the placement of fishing gear and fishing aids in designated fishing zones and state fisheries management areas within the Republic of Indonesia's inland waters. The use of cotok and similar fishing gear is prohibited under this regulation, which specifically addresses the ban on trawl nets and trawls within the state fisheries management area of the Republic of Indonesia. The lack of regulatory content related to the prohibition allows respondents to choose the regulatory criteria as the third highest priority, with a value of 0.177. The criterion "always monitor the fishing gear" is another solution that the participants prefer to avoid loss.

However, this solution is only possible if the gears are plugged in for a day of fishing. Fishing traps are usually planted on the seabed for seven days, and crab is harvested after that. Local village regulations have been enacted and are derived from local government regulations related to the management of crab fisheries at Gedongmulyo Village, Rembang Regency. Fishing gear marking is another method to prevent the loss of fishing gear. Participants have chosen this strategy as the third priority. Fishing gear marking has been studied in the Sadeng area, Yogyakarta, and Pekalongan, Central Java (FAO 2018), and is expected to be applied in other places.

6. Fishermen's perception of actors to prevent the loss of fishing gear

Participants convey their opinion that the central government (particularly the Directorate General of Marine and Fisheries Resources Surveillance) is the leading actor that may prevent the loss of fishing gear with a value of 0.9576. Security forces are also a crucial factor under the central government. Business actors are the least important to prevent fishing gear loss, with a value of 0.0255.

The central government plays a crucial role in preventing the loss of fishing gear at sea due to its ability to implement and enforce regulations (Ardhiansyah *et al*. 2024). Additionally, security forces play a crucial role

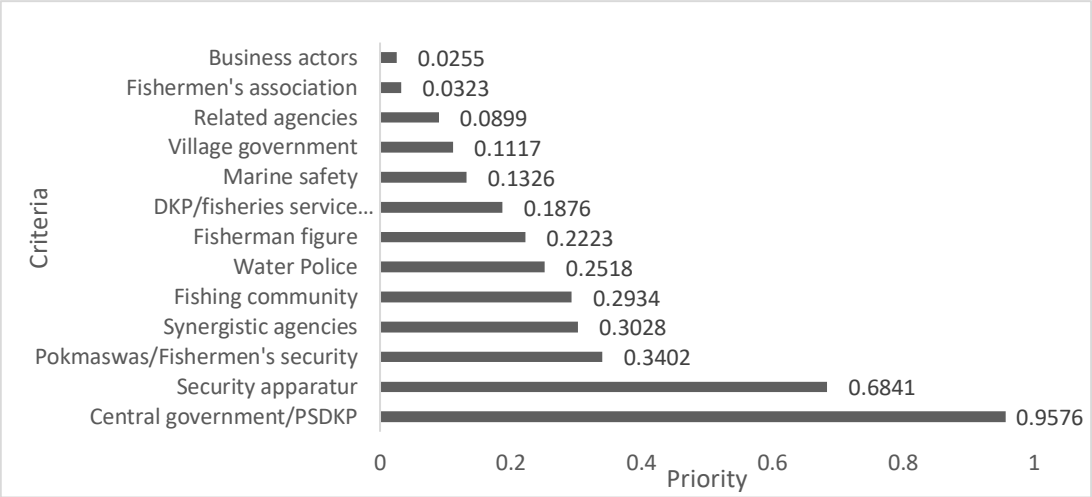

Figure 8 The priority of fishermen's perception of actors is to prevent the loss of fishing gear.

in enforcing rules designed to prevent the loss of fishing gear through rigorous supervision, thereby minimizing the risk of lost gear (Yang 2022).

The second essential actors from the participant perspective included community supervisory groups, synergistic agencies, fishing communities, water police, and fishermen leaders. The third important actor chosen by respondents is the local fisheries office, marine security, village government, related agencies, fishermen associations, and business actors.

DISCUSSION

The study's results indicated that plastic bags are the primary waste found in seawater, surpassing waste from fishing gear. Socialization of information through fishing groups or communities was a local wisdom of the fishing community in Rembang waters. This fishermen's community group is a platform for exchanging information and experiences on fishing-related issues, including information on marine debris from plastic bags. The information would lead fishermen to bring waste from the ocean to land while fishing (Setyono *et al.* 2023).

The most common marine waste in Rembang waters is Fishing traps. This finding aligns with the widespread use of Cotok-operated trawls, which results in an increase in ALDFG incidents from fish traps on the ocean floor as they become ensnared in the Cotok (Satria *et al*. 2023). This incident ultimately impacted fishermen's income due to additional costs to repair the damage and even replace the lost trap. Respondents agreed that the use of Cotok should be prohibited, and they wished the government had action strategies to prevent the loss of fishing gear in the future (Widayanto *et al*. 2022).

The results of this study provide new insights regarding the massive use of Cotok as an alternative fishing gear. Coastal areas commonly employ cotok, which exert a considerable impact on the environment. The use of Cotok has had a significant effect on reducing the loss of fishing gear, particularly with fish traps. The local government, in collaboration with the fishing community, should develop a new policy to evaluate the use of Cotok while ensuring that other fishing activities are not disrupted (Roisah *et al.* 2023).

An analytical hierarchy process (AHP) was used by Yang (2022) to determine stakeholder priorities in preventing ALDFG. The distinction between this study and Yang's (2022) is the number of dimensions used. Yang (2022) employed four dimensions and 16 key factors in a questionnaire framework to guide action in preventing ALDFG, as summarized from the list of best practices of the Global Ghost Gears Initiative organization. In contrast, this study employs six general criteria. Furthermore, the population in this study consisted of 29 individuals in one study area (Rembang district), whereas Yang (2022) involved 63 respondents, including stakeholders from fishing ports, local governments, and local fishermen's associations throughout Taiwan.

CONCLUSIONS

This study aims to see the prevalence of stakeholders in preventing ALDFG in crab fisheries in Rembang waters. Plastic is a non-biodegradable waste that is widely found,

whereas bamboo is a type of forestry waste that can become marine waste. Bubu fishing gear is marine debris derived from fishing gear. The reason for the loss of much fishing gear is exposure to other fishing gear. This results in a decrease in fishermen's income. The solution to overcome this is the prohibition of "cotok" as a fishing tool. The fishermen perceive that the central government is an actor in preventing the loss of fishing gear.

RECOMMENDATION

Future research is essential to prevent ALDFG at crab fisheries in Rembang waters effectively. An in-depth analysis, as implemented by the Global Ghost Gears Initiative questionnaire, needs to be conducted to engage more stakeholders and expand sampling locations to more than one study area. Future research also needs to engage a broader range of stakeholders, including those from fishing ports, local governments, and fishermen's associations throughout Indonesia, with a specific focus on the role of the fishing gear being used. In-depth research related to fishing gear marking should also be conducted immediately as a measure to prevent an increase in ALDFG incidents at sea.

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