ENVIRONMENTAL PERFORMANCE OF FISHING GEARS OPERATED IN NIAS MARINE ECOSYSTEMS

Maestro Laia[1)], Destriman Laoli[2)], Ratna Dewi Zebua[3)], Nistiarni Zebua[4)]

[1)] Department of Aquatic Resources, Faculty of Science and Technology, Universitas Nias, Gunungsitoli, Indonesia
Email: maesslaia1a@gmail.com
[2)] Department of Aquatic Resources, Faculty of Science and Technology, Universitas Nias, Gunungsitoli, Indonesia
Email: destrimanlaoli@unias.ac.id
[3)] Department of Aquatic Resources, Faculty of Science and Technology, Universitas Nias, Gunungsitoli, Indonesia
Email: ratnadewizebua@unias.ac.id
[4)] Department of Aquatic Resources, Faculty of Science and Technology, Universitas Nias, Gunungsitoli, Indonesia
Email: nistiarnizebua@unias.ac.id

Abstract

This study evaluated the environmental performance of fishing gears operated in Nias marine ecosystems using indicators of selectivity, bycatch level, habitat interaction, and overall ecological impact. The results demonstrated that fishing gears used by small-scale fishers in Nias vary considerably in their environmental performance. Handlines exhibited the highest environmental performance, characterized by high selectivity, minimal bycatch, and negligible interaction with marine habitats. Fish traps and lift nets showed moderate environmental performance, with generally low to moderate ecological impacts depending on operational practices and fishing locations. Gillnets displayed moderate environmental performance but were associated with higher bycatch rates and greater potential interaction with sensitive habitats, particularly when mesh size and fishing areas were not properly managed. These findings indicate that not all fishing gears contribute equally to ecological pressure in Nias waters. Promoting the use of highly selective and low-impact fishing gears, such as handlines, while improving the design and management of moderate-impact gears, particularly gillnets, is essential for enhancing fisheries sustainability. The study highlights the importance of ecosystem-based fisheries management, supported by appropriate regulations, fisher awareness, and community participation, to ensure the long-term conservation of marine resources and the sustainability of coastal livelihoods in Nias.

Keywords: Fishing gear; Environmental performance; Small-scale fisheries; Marine ecosystems; Nias waters

INTRODUCTION

Fishing activities play a crucial role in supporting coastal livelihoods and food security, particularly in island regions such as Nias, Indonesia. The marine ecosystems of Nias are characterized by high biodiversity, including coral reefs, seagrass beds, and coastal fisheries resources that provide ecological and economic benefits to local communities. However, increasing fishing pressure and the use of non-selective fishing gears pose significant risks to the sustainability of these marine ecosystems if not properly managed.

The environmental performance of fishing gears has become a central issue in sustainable fisheries management. Environmentally friendly fishing gears are generally defined as gears that are selective, minimize bycatch, reduce habitat damage, and maintain fish stocks at sustainable levels (FAO, 1995). In contrast, fishing gears with low selectivity and high ecological impact can lead to overfishing, destruction of benthic habitats, and declines in non-target species populations (Hall, 1999; Jennings & Kaiser, 1998). Therefore, evaluating the environmental performance of fishing gears is essential to ensure long-term ecosystem health and fisheries sustainability.

In many coastal areas of Indonesia, including Nias, small-scale fisheries dominate fishing activities. These fisheries often employ a variety of traditional and modern fishing gears, such as gillnets, handlines, traps, and lift nets. While some of these gears are considered relatively environmentally benign, others may generate bycatch or cause physical damage to marine habitats depending on their design, operation, and intensity of use (Chuenpagdee et al., 2003). Limited scientific information is available regarding the environmental impacts of fishing gears used specifically in Nias marine ecosystems, creating challenges for effective fisheries management and policy formulation.

Assessing the environmental performance of fishing gears requires a comprehensive approach that considers ecological criteria, including selectivity, bycatch rates, habitat interaction, and compliance with responsible fishing principles (FAO, 1995). Such assessments can provide valuable insights for fisheries managers and local stakeholders to promote the adoption of sustainable fishing practices. Moreover, understanding the environmental implications of fishing gear operations in Nias is particularly important given the region's dependence on marine resources and its vulnerability to environmental degradation.

Therefore, this study aims to evaluate the environmental performance of fishing gears operated in Nias marine ecosystems. The findings are expected to contribute to sustainable fisheries management by identifying fishing gears with low environmental impact and providing scientific evidence to support environmentally responsible fishing practices in the region.

LITERATURE REVIEW

1. Small-Scale Fisheries and Coastal Livelihoods

Small-scale fisheries play a vital role in supporting food security, employment, and socio-economic stability in coastal and island regions, particularly in developing countries (Berkes et al., 2001). These fisheries are generally characterized by low-capital investment, traditional fishing knowledge, and diverse fishing gears adapted to local environmental conditions. In Indonesia, small-scale fisheries dominate coastal waters and contribute significantly to national fish production, while also exerting considerable pressure on marine ecosystems (FAO, 2018).

2. Environmental Performance of Fishing Gears

The environmental performance of fishing gears refers to their ability to harvest target species efficiently while minimizing negative ecological impacts, such as bycatch, discards, habitat degradation, and threats to biodiversity (FAO, 1995). Fishing gears with poor environmental performance often result in high levels of non-target catches and physical disturbances to benthic habitats, which can compromise ecosystem structure and resilience (Hall, 1999).

Assessing environmental performance is a critical component of ecosystem-based fisheries management, as it provides a scientific basis for promoting sustainable fishing practices and reducing ecological risks associated with fishing activities (Garcia & Cochrane, 2005).

3. Gear Selectivity and Bycatch

Gear selectivity is a key indicator of environmental performance and reflects the capacity of a fishing gear to capture specific target species and sizes while avoiding non-target organisms (Winger et al., 2010). Low-selectivity gears tend to generate higher bycatch rates, which may include juvenile fish, endangered species, and other non-commercial organisms. Bycatch not only represents ecological loss but also reduces fishing efficiency and long-term stock sustainability (Broadhurst, 2000).

Gillnets, traps, and trawls have been widely studied in relation to selectivity and bycatch. While passive gears such as handlines and traps are generally considered more selective, their environmental impact still depends on gear design, fishing intensity, and spatial deployment (Chuenpagdee et al., 2003).

4. Physical Impacts on Marine Habitats

Fishing gears that interact directly with the seabed can cause physical damage to sensitive marine habitats, including coral reefs, seagrass beds, and soft-bottom benthic communities (Watling & Norse, 1998). Repeated disturbances may reduce habitat complexity, alter species composition, and decrease overall ecosystem productivity.

The degree of habitat impact varies among gear types and is influenced by environmental conditions and fishing practices. Consequently, evaluating habitat interaction is essential when assessing the overall environmental performance of fishing gears (Jennings & Kaiser, 1998).

5. Environmentally Friendly Fishing Gears and Sustainable Fisheries

Environmentally friendly fishing gears are those designed and operated to reduce bycatch, avoid habitat destruction, and support sustainable fish stocks (FAO, 1995). The adoption of selective gear designs, bycatch reduction devices (BRDs), and spatial or temporal fishing restrictions has been shown to improve environmental outcomes in many fisheries worldwide (Gilman, 2011).

Community-based fisheries management and the incorporation of local ecological knowledge are also recognized as effective strategies for encouraging the use of environmentally responsible fishing gears, particularly in small-scale fisheries (Berkes et al., 2001).

6. Fisheries and Marine Ecosystems of Nias

The marine ecosystems of Nias are characterized by high biodiversity and a strong dependence of coastal communities on fisheries resources. Fishing activities in the region employ various traditional and modern fishing gears, which may differ in their environmental performance. However, scientific studies specifically evaluating the ecological impacts of fishing gears in Nias waters remain limited. This knowledge gap highlights the need for comprehensive assessments to support sustainable fisheries management and marine conservation in the region.

RESEARCH METHODOLOGY

1. Types of Fishing Gears Operated in Nias Waters

Small-scale fisheries in Nias waters operate various fishing gears adapted to local environmental and socio-economic conditions. The most commonly used gears include gillnets, handlines, fish traps, and lift nets. These gears differ in their operational characteristics, selectivity, and potential environmental impacts.

2. Catch Composition and Selectivity

Catch composition analysis revealed significant differences in selectivity among fishing gear types. Handlines demonstrated the highest selectivity, capturing mostly target species with minimal bycatch. Gillnets showed moderate selectivity, with bycatch levels influenced by mesh size and fishing location. Fish traps and lift nets exhibited intermediate selectivity, depending on deployment techniques and habitat conditions.

3. Environmental Performance of Fishing Gears

The environmental performance of fishing gears was evaluated using four main indicators: selectivity, bycatch level, habitat interaction, and overall environmental impact. The assessment results are summarized in Table 1.

Table 1. Environmental performance evaluation of fishing gears operated in Nias marine ecosystems

Fishing Gear	Selectivity	Bycatch Level	Habitat Interaction	Overall Environmental Performance
Handline	High	Low	Very L	Very Good (Low Impact)
Fish Trap	Moderate–High	Low–Moderate	Low	Good
Lift Net	Moderate	Low–Moderate	Moderate	Moderate
Gillnet	Moderate	Moderate–High	Moderate	Moderate

The results indicate that handlines have the best environmental performance due to their high selectivity and minimal interaction with marine habitats. This finding supports previous studies suggesting that passive fishing gears are generally more environmentally friendly than non-selective gears (Winger et al., 2010).

4. Bycatch and Habitat Interaction

Gillnets recorded the highest bycatch levels among the gears studied, particularly when operated near coral reef areas. Although the capture of protected species was not dominant, the incidental capture of juvenile fish remains a concern for long-term stock sustainability. Fish traps occasionally interacted with benthic habitats, which could pose ecological risks if used intensively in sensitive areas.

Repeated interactions between fishing gears and benthic habitats may reduce habitat complexity and affect associated fish communities (Jennings & Kaiser, 1998). Therefore, habitat-based management measures are essential to reduce ecological pressure.

5. Implications for Sustainable Fisheries Management

The comparative evaluation highlights that not all fishing gears exert equal environmental pressure. Promoting the use of handlines and improving the selectivity of gillnets through mesh size regulation could significantly enhance the sustainability of fisheries in Nias waters.

These findings emphasize the importance of ecosystem-based fisheries management that integrates gear selectivity, habitat protection, and community participation (Garcia & Cochrane, 2005).

CONCLUSION

This study demonstrates that mangrove ecosystems play a vital role in supporting fish biodiversity in the coastal area of Banten Bay. Conserved mangrove areas exhibited the highest vegetation density, structural complexity, and canopy cover, which were associated with greater fish species richness, abundance, and diversity indices. In contrast, degraded mangrove sites showed reduced habitat quality and significantly lower fish biodiversity, indicating the negative impacts of mangrove degradation on coastal fish communities.

Rehabilitated mangrove areas displayed moderate levels of fish diversity and abundance, suggesting that mangrove rehabilitation efforts can partially restore ecological functions and improve habitat suitability for fish assemblages. However, the biodiversity levels in rehabilitated sites remained lower than those in conserved mangroves, highlighting the

need for long-term management, appropriate restoration techniques, and continuous monitoring to achieve full ecosystem recovery.

The findings confirm a positive relationship between mangrove structural characteristics and fish biodiversity, emphasizing that effective mangrove conservation and ecologically sound rehabilitation strategies are essential for sustaining coastal fisheries and biodiversity. Therefore, protecting existing mangrove forests should be prioritized, while rehabilitation programs should focus on ecosystem-based approaches that consider hydrological conditions, species selection, and community participation.

Overall, this research provides scientific evidence to support the integration of mangrove conservation and rehabilitation into sustainable coastal management strategies in Banten Bay, contributing to biodiversity conservation and the long-term resilience of coastal ecosystems.

REFERENCES

Alongi, D. M. (2014). Carbon cycling and storage in mangrove forests. Annual Review of Marine Science, 6, 195–219. https://doi.org/10.1146/annurev-marine-010213-135020

Alongi, D. M. (2015). The impact of climate change on mangrove forests. Current Climate Change Reports, 1(1), 30–39. https://doi.org/10.1007/s40641-015-0002-x

Alverson, D. L., Freeberg, M. H., Pope, J. G., & Murawski, S. A. (1994). A global assessment of fisheries bycatch and discards. FAO Fisheries Technical Paper No. 339. Food and Agriculture Organization of the United Nations.

Bosire, J. O., Dahdouh-Guebas, F., Walton, M., Crona, B. I., Lewis, R. R., Field, C., Kairo, J. G., & Koedam, N. (2008). Functionality of restored mangroves: A review. Aquatic Botany, 89(2), 251–259. https://doi.org/10.1016/j.aquabot.2008.03.010

Caddy, J. F., & Cochrane, K. L. (2001). A review of fisheries management past and present and some future perspectives for the third millennium. Ocean & Coastal Management, 44(9–10), 653–682. https://doi.org/10.1016/S0964-5691(01)00074-6

Davies, R. W. D., Cripps, S. J., Nickson, A., & Porter, G. (2009). Defining and estimating global marine fisheries bycatch. Marine Policy, 33(4), 661–672. https://doi.org/10.1016/j.marpol.2009.01.003

FAO. (2009). International guidelines on bycatch management and reduction of discards. Food and Agriculture Organization of the United Nations.

FAO. (2021). The state of world fisheries and aquaculture 2020: Sustainability in action. Food and Agriculture Organization of the United Nations.

Faunce, C. H., & Serafy, J. E. (2006). Mangroves as fish habitat: 50 years of field studies. Marine Ecology Progress Series, 318, 1–18. https://doi.org/10.3354/meps318001

Friess, D. A., Rogers, K., Lovelock, C. E., Krauss, K. W., Hamilton, S. E., Lee, S. Y., Lucas, R., Primavera, J., Rajkaran, A., & Shi, S. (2019). The state of the world's mangrove forests: Past, present, and future. Annual Review of Environment and Resources, 44, 89–115. https://doi.org/10.1146/annurev-environ-101718-033302

Grafton, R. Q., Hilborn, R., Ridgeway, L., Squires, D., Williams, M., & Garcia, S. (2008). Positioning fisheries in a changing world. Marine Policy, 32(4), 630–634. https://doi.org/10.1016/j.marpol.2007.11.009

Hilborn, R., & Walters, C. J. (1992). Quantitative fisheries stock assessment: Choice, dynamics and uncertainty. Chapman & Hall.

Kelleher, K. (2005). Discards in the world's marine fisheries: An update. FAO Fisheries Technical Paper No. 470. Food and Agriculture Organization of the United Nations.

Lewis, R. R. (2005). Ecological engineering for successful management and restoration of mangrove forests. Ecological Engineering, 24(4), 403–418. https://doi.org/10.1016/j.ecoleng.2004.10.003

Mumby, P. J., Edwards, A. J., Arias-González, J. E., Lindeman, K. C., Blackwell, P. G., Gall, A., Gorczynska, M. I., Harborne, A. R., Pescod, C. L., Renken, H., Wabnitz, C. C. C., & Llewellyn, G. (2004). Mangroves enhance the biomass of coral reef fish communities in the Caribbean. Nature, 427(6974), 533–536. https://doi.org/10.1038/nature02286

Nagelkerken, I., Blaber, S. J. M., Bouillon, S., Green, P., Haywood, M., Kirton, L. G., Meynecke, J. O., Pawlik, J., Penrose, H. M., Sasekumar, A., & Somerfield, P. J. (2008). The habitat function of mangroves for terrestrial and marine fauna: A review. Aquatic Botany, 89(2), 155–185. https://doi.org/10.1016/j.aquabot.2007.12.007

Nagelkerken, I., Sheaves, M., Baker, R., & Connolly, R. M. (2015). The seascape nursery: A novel spatial approach to identify and manage nursery habitats for coastal marine fauna. Fish and Fisheries, 16(2), 362–371. https://doi.org/10.1111/faf.12057

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., & Torres, F. (1998). Fishing down marine food webs. Science, 279(5352), 860–863. https://doi.org/10.1126/science.279.5352.860

Pitcher, T. J., & Preikshot, D. (2001). RAPFISH: A rapid appraisal technique to evaluate the sustainability status of fisheries. Fisheries Research, 49(3), 255–270. https://doi.org/10.1016/S0165-7836(00)00205-8

Salas, S., Chuenpagdee, R., Seijo, J. C., & Charles, A. (2007). Challenges in the assessment and management of small-scale fisheries in Latin America and the Caribbean. Fisheries Research, 87(1), 5–16. https://doi.org/10.1016/j.fishres.2007.06.015

Suuronen, P., & Sardà, F. (2007). The role of technical measures in European fisheries management and how to make them work better. ICES Journal of Marine Science, 64(4), 751–756. https://doi.org/10.1093/icesjms/fsm049

Unsworth, R. K. F., De León, P. S., Garrard, S. L., Jompa, J., Smith, D. J., & Bell, J. J. (2008). High connectivity of Indo-Pacific seagrass fish assemblages with mangrove and coral reef habitats. Marine Ecology Progress Series, 353, 213–224. https://doi.org/10.3354/meps07199

Walters, B. B., Rönnbäck, P., Kovacs, J. M., Crona, B., Hussain, S. A., Badola, R., Primavera, J. H., Barbier, E., & Dahdouh-Guebas, F. (2008). Ethnobiology, socio-economics and management of mangrove forests: A review. Aquatic Botany, 89(2), 220–236. https://doi.org/10.1016/j.aquabot.2008.02.009