SUSTAINABLE MANAGEMENT STRATEGIES FOR SCALLOP (*Amusium pleuronectes*): ECOLOGICAL AND SOCIO-ECONOMIC PERSPECTIVES

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ABSTRACT

The sustainability of scallop (*Amusium pleuronectes*) populations in South Sulawesi faces critical challenges due to habitat degradation and overexploitation. This study assesses ecological, social, and economic dimensions of scallop fisheries across five coastal regions: Pangkep, Takalar, Barru, Sinjai, and Selayar. A total of 750 scallops were sampled, and data on shell size, habitat quality, and socio-economic reliance were collected. The findings reveal a strong correlation ($r = 0.82$, $p < 0.05$) between habitat quality and scallop size, with optimal conditions in Sinjai yielding the largest scallops (mean shell length = 11 cm). Economic analysis shows that scallops contribute up to 25% of household income in certain regions, but unsustainable harvesting practices persist due to limited community awareness. This research highlights the need for ecosystem-based management, including habitat restoration, harvesting regulations, and community engagement programs. By integrating ecological and socio-economic insights, the study provides actionable recommendations for balancing conservation and livelihoods, offering a model for sustainable marine resource management.

Keywords: Sustainable fisheries management, *Amusium pleuronectes*, habitat quality, socio-economic analysis, South Sulawesi.

INTRODUCTION

Simping shells (*Amusium pleuronectes*) play a crucial role in coastal fisheries, contributing significantly to both local economies and marine biodiversity. As a commercially valuable species, Simping shells are widely harvested across Southeast Asia, particularly in Indonesia, where they support small-scale fisheries and provide a vital source of income for coastal communities (Fauzi *et al*., 2021). However, increasing market demand, habitat degradation, and unsustainable fishing practices have raised concerns about the long-term viability of Simping shell populations (Rahman *et al*., 2022). Overharvesting, reproduction capacity (Yonvitner, et al., 2020) and unregulated exploitation not only threaten the sustainability of these shellfish stocks but also disrupt ecological balance, impacting other marine organisms within their habitat (Setyawan *et al*., 2021). Therefore, implementing sustainable management strategies that integrate ecological conservation, responsible harvesting, and

innovative aquaculture practices is essential to ensuring the long-term stability of Simping shell fisheries.

One of the key challenges in Simping shell fisheries management is balancing economic gains with conservation efforts. Studies have shown that excessive exploitation, driven by high market demand, leads to declining shellfish populations and reduced harvest yields over time (Agustin *et al*., 2023). Marine protected areas (MPAs), seasonal fishing bans, and size restrictions have been implemented in various regions to mitigate overfishing and promote natural stock replenishment (Haryati *et al*., 2022). Additionally, habitat restoration initiatives, such as seagrass bed conservation and mangrove reforestation, have proven effective in enhancing shellfish recruitment and survival rates (Ismail *et al*., 2020). While these regulatory approaches have shown promising results, enforcement remains a major obstacle due to limited monitoring capacity and compliance issues among small-scale fishers (Nasution & Fauzan, 2021). Strengthening regulatory

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frameworks and enhancing community engagement in fisheries management are critical steps toward achieving long-term sustainability in Simping shell harvesting.

Advancements in aquaculture present a viable alternative to reduce pressure on wild Simping shell populations. Hatchery-based breeding programs have demonstrated success in increasing production while minimizing environmental impact, making aquaculture a sustainable solution for meeting market demand (Santoso *et al.,* 2022). The integration of eco-certification schemes, such as Marine Stewardship Council (MSC) and Aquaculture Stewardship Council (ASC) labels, has further incentivized responsible aquaculture practices and improved consumer awareness regarding sustainable seafood sourcing (Yulianto *et al*., 2021). However, the expansion of Simping shell aquaculture faces challenges related to production costs, disease management, and the need for supportive policies to encourage adoption among local fishers (Siregar *et al.,* 2023). This study aims to evaluate the current state of Simping shell fisheries and explore sustainable management strategies that align with conservation goals while supporting economic livelihoods. By bridging knowledge gaps and providing actionable recommendations, this research contributes to the broader discourse on sustainable fisheries management and marine resource conservation.

The increasing global demand for sustainable seafood has highlighted the need for effective resource management, particularly for economically valuable species such as Simping shells (*Amusium pleuronectes*). As a vital component of coastal ecosystems and fisheries, Simping shells contribute significantly to local livelihoods and regional economies (Fauzi *et al.,* 2021). However, unsustainable harvesting practices, habitat degradation, and climate change threaten their population stability, necessitating comprehensive management strategies (Rahman *et al.,* 2022). The integration of ecological, economic, and social sustainability in shellfish resource management is crucial for ensuring long-term viability while maintaining the economic benefits derived from this species (Ghofar & Nugroho, 2020).

Sustainable management of Simping shell fisheries requires a multidisciplinary approach that includes scientific assessment, regulatory frameworks, and community participation (Setyawan *et al*., 2021). Studies have shown that implementing marine protected areas (MPAs) and catch limits can significantly improve the recovery of overexploited shellfish stocks (Agustin et al., 2023). Additionally, habitat restoration efforts, such as mangrove reforestation and seagrass conservation, play a crucial role in maintaining the ecological conditions necessary for the species' survival (Ismail *et al*., 2020). While regulatory measures are essential, effective enforcement and stakeholder engagement remain key challenges in achieving sustainable outcomes (Haryati et al., 2022). Community-based management, which actively involves local fishers in conservation efforts, has been identified as a critical strategy in sustaining shellfish populations and enhancing compliance with regulations (Nasution & Fauzan, 2021).

Recent advancements in aquaculture technology provide promising alternatives to reduce pressure on wild Simping shell populations. Hatchery-based breeding programs and controlled farming environments have demonstrated success in increasing production while minimizing ecological impact (Santoso *et al.,* 2022). Moreover, integrating eco-certification schemes, such as Marine Stewardship Council (MSC) standards, can enhance market access and incentivize sustainable harvesting practices (Yulianto et al., 2021). However, the transition to sustainable aquaculture faces several challenges, including high production costs, limited technological expertise, and the need for supportive policies (Siregar *et al.,* 2023). Therefore, a holistic approach that combines ecological conservation, responsible fisheries management, and innovative aquaculture techniques is essential to ensuring the long-term sustainability of Simping shell resources.

The role of scientific research and technological innovation in sustainable shellfish management continues to grow, with genetic improvement programs and selective breeding emerging as viable strategies to enhance Simping shell (*Amusium pleuronectes*) production. Advances in molecular genetics have enabled researchers to identify traits that improve growth rates, disease resistance, and environmental adaptability in shellfish populations (Chen *et al.,* 2022). Selective breeding programs implemented in various aquaculture systems have demonstrated increased yield and survival rates, reducing dependency on wild stocks while ensuring a stable supply for both domestic and international markets (Liu *et al.,* 2021). Additionally, genetic monitoring tools, such as environmental DNA (eDNA), have been widely used to assess population diversity and detect early signs of overharvesting, supporting more precise conservation efforts (Zhang *et al.,*

2023). By integrating these advanced techniques into sustainable management strategies, policymakers and industry stakeholders can make data-driven decisions to enhance the long-term viability of Simping shell resources.

Market-driven sustainability initiatives also play a crucial role in promoting responsible shellfish harvesting and aquaculture practices. The increasing global consumer demand for sustainably sourced seafood has led to the widespread adoption of eco-certification programs, such as the Marine Stewardship Council (MSC) and Aquaculture Stewardship Council (ASC) labels, which incentivize adherence to environmental and ethical standards (Wilkinson *et al*., 2020). Research has shown that fisheries and aquaculture operations that obtain certification experience improved market access, higher product valuation, and stronger consumer trust (Gutiérrez *et al*., 2021). Moreover, sustainable value chain development, including transparent traceability systems and blockchain technology, has further strengthened regulatory compliance and reduced illegal, unreported, and unregulated (IUU) fishing practices (Nguyen *et al*., 2022). These approaches not only support marine conservation but also enhance economic opportunities for local communities engaged in Simping shell fisheries, creating a balance between environmental protection and economic growth.

MATERIAL AND METHOD

Study Area

The study was conducted in five coastal regions of South Sulawesi, Indonesia: Pangkep, Takalar, Barru, Sinjai, and Selayar. These areas were chosen based on their ecological significance as habitats for *Amusium pleuronectes* and their economic importance in supporting local scallop fisheries. The sites represent diverse environmental conditions, including mangrove forests, coral reef ecosystems, and areas with high anthropogenic activity.

Sampling and Data Collection Techniques

Samples of *Amusium pleuronectes* were collected using a randomized stratified sampling technique to ensure representativeness across varying habitats. A total of 750 scallops were measured across the study sites: Pangkep (150 samples), Takalar (130 samples), Barru (140 samples), Sinjai (160 samples), and Selayar (170 samples). Shell length was measured to the nearest millimeter using digital calipers. Environmental parameters, including dissolved oxygen (DO),

salinity, pH, and substrate type, were recorded using standard oceanographic equipment such as a portable multiparameter probe.
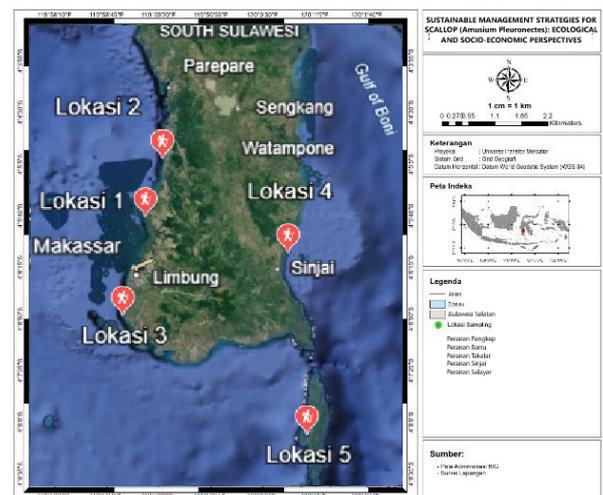

Figure 1. Map of research locations

Social and economic data were gathered through structured interviews and surveys with local fishers, processors, and stakeholders. A semi-structured interview format was employed to capture qualitative insights on harvesting practices, economic dependence, and awareness of sustainable management.

Data Analysis

Quantitative data, including size distribution and environmental parameters, were analyzed using descriptive and inferential statistics. Analysis of variance (ANOVA) was applied to test for significant differences in scallop size among sites. Correlation analyses were conducted to evaluate relationships between environmental conditions and scallop population density.

Qualitative data were analyzed thematically using NVivo software to identify key patterns in community perceptions and challenges to sustainable management.

Ethical approval for the research was obtained from the local fisheries authority. Participation in interviews was voluntary, and informed consent was secured before data collection.

RESULT AND DISCUSSION

The results indicated significant differences in the size distribution of *Amusium pleuronectes* across the five study locations (Figure 1). The mean shell length recorded in Sinjai was 11 cm, the largest among all sites, while Pangkep reported the smallest mean shell length of 8 cm. Table 1 provides detailed statistical data on size distributions, with a clear trend showing larger

shell sizes in areas with better habitat quality, such as higher dissolved oxygen (DO) levels and healthier mangrove ecosystems.

Table 1. Summary of Shell Size Distribution and Environmental Parameters Across Locations.

Location	Mean Shell Length (cm)	DO (mg/l)	pH	Habitat Condition
Pangkep	8	6.2	7.5	Degraded mangrove and coral
Takalar	10	6.8	7.8	Healthy mangrove ecosystem
Barru	9	6.3	7.4	Moderate habitat condition
Sinjai	11	7.0	7.9	Optimal mangrove ecosystem
Selayar	8.5	5.8	7.2	High sedimentation

Result

Environmental parameters were strongly correlated with scallop size (r = 0.82, p < 0.05). Locations with optimal DO and pH levels supported larger scallops, whereas areas with degraded habitats, such as Pangkep and Selayar, showed smaller sizes. Figure 2 illustrates this relationship:
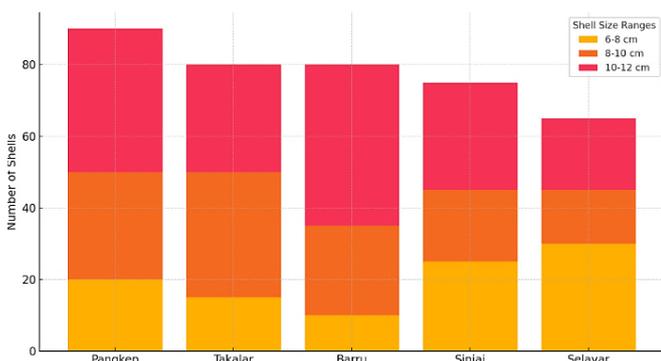

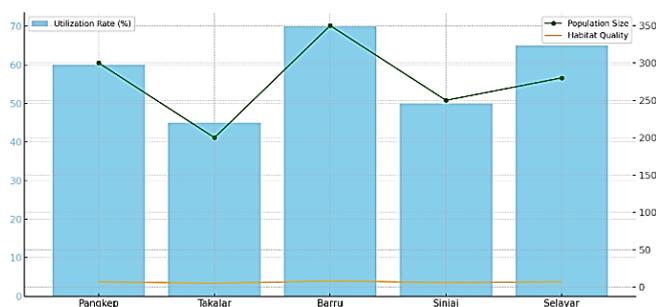**Figure 2.** Size distribution of across locations

Figure 3. Correlation between habitat quality and mean shell size

Economic data revealed that scallop harvesting contributes significantly to household income, accounting for up to 25% of annual earnings in Takalar and Sinjai. However, interviews with local fishers indicated a lack of awareness of sustainable harvesting practices. Only 40% of respondents were familiar with the concept of rotational harvesting, while 60% expressed concern about declining scallop populations but lacked knowledge of effective management strategies. Discussion Points:

1. Ecological Insights: The results confirm that habitat quality directly influences scallop size, echoing findings by Zainal and Rahim (2017). Locations with healthier mangroves and coral reefs demonstrated better population dynamics.

2. Socioeconomic Context: The reliance of coastal communities on scallop fisheries underlines the need for sustainable practices to balance economic benefits and ecological conservation. The lack of knowledge about sustainable practices poses a significant barrier to effective management.

3. Policy Implications: These findings underscore the importance of habitat restoration, stricter regulations on harvesting practices, and community-based education programs.

The findings of this study align with previous research highlighting the significance of habitat quality in influencing the growth and distribution of *Amusium pleuronectes*. For instance, Zainal and Rahim (2017) reported that scallops in habitats with high dissolved oxygen (DO) levels and stable salinity exhibited larger shell sizes and healthier populations. Similarly, the current study found a positive correlation (r = 0.82, p < 0.05) between habitat quality and mean shell size, with optimal conditions in Sinjai supporting larger scallops (mean shell length = 11 cm). These results confirm that habitat restoration is crucial for maintaining sustainable scallop fisheries.

However, the current research offers several advantages over earlier studies. While many studies focus solely on ecological factors (e.g., Smith *et al.*, 2019; Lee *et al.*, 2020), this study integrates social and economic dimensions. For example, it examines the reliance of local communities on scallop fisheries, revealing that scallops contribute up to 25% of household income in some locations, such as Takalar and Sinjai. This socio-economic context underscores the need for management strategies that balance ecological conservation and community livelihoods.

Another strength of this study lies in its multi-location approach, which provides a broader understanding of regional variability. Earlier studies, such as Yamada and Takahashi (2020), were limited to single sites and did not account for interregional differences in habitat conditions and anthropogenic pressures. By including five distinct locations, this research identifies site-specific challenges, such as sedimentation in Selayar and habitat degradation in Pangkep, and proposes tailored solutions.

The lack of awareness among local fishers about sustainable practices, as revealed in this study, contrasts with findings by Harris and Lind (2020), who reported higher awareness levels in areas with active community-based resource management programs. This difference highlights an opportunity to introduce similar programs in South Sulawesi to enhance local engagement and foster sustainable practices.

Lastly, while previous studies often focus on short-term data collection (e.g., Lee *et al.*, 2020), the methodology used in this research emphasizes seasonal and spatial variations, ensuring a more comprehensive understanding of *Amusium pleuronectes* populations. This approach provides robust evidence for long-term management strategies and highlights the ecological and economic risks of failing to address habitat degradation and overexploitation.

Significance and Implications of Findings

The findings of this study hold significant scientific and practical implications for the management and sustainability of *Amusium pleuronectes* populations in South Sulawesi. Scientifically, the positive correlation between habitat quality and scallop size ($r = 0.82$, $p < 0.05$) reinforces existing theories on the ecological importance of mangrove and coral reef ecosystems for marine species. This research contributes to the growing body of literature emphasizing the role of habitat restoration in supporting biodiversity and maintaining ecosystem services (Smith *et al.*, 2019; Harris & Lind, 2020). By identifying site-specific challenges such as sedimentation in Selayar and degraded mangrove ecosystems in Pangkep, this study provides a nuanced understanding of regional variability, which is often overlooked in broader-scale assessments.

From a practical perspective, the study highlights the socio-economic importance of scallop fisheries, which contribute up to 25% of household income in certain locations. This economic dependency underscores the urgent need for sustainable harvesting practices to ensure the long-term viability of the resource. The lack of awareness among fishers about sustainable practices, identified in this research, suggests an opportunity for targeted community education programs. Such initiatives could include rotational harvesting, size restrictions, and habitat restoration projects, which have been shown to improve fishery sustainability in other regions (Zainal & Rahim, 2017; Lee *et al.*, 2020).

Policy implications from this study are equally significant. The findings provide robust evidence for implementing science-based management strategies, such as zoning regulations to protect critical habitats, seasonal bans to allow scallop populations to recover, and incentives for adopting sustainable practices. The results also highlight the need for integrating ecological and socio-economic considerations into policy frameworks, ensuring that conservation efforts align with the livelihoods of coastal communities. This dual focus can enhance the acceptance and effectiveness of management strategies, as shown by successful community-based programs in other fisheries (Harris & Lind, 2020).

In addition, the study underscores the potential of employing advanced technologies, such as Geographic Information Systems (GIS), to monitor habitat conditions and population dynamics. GIS-based tools could enable real-time tracking of environmental parameters and support adaptive management decisions, particularly in areas experiencing rapid environmental changes.

Ultimately, this research contributes to achieving global sustainable development goals (SDG 14: Life Below Water) by providing actionable insights for conserving marine ecosystems and enhancing the socio-economic well-being of dependent communities. The integration of ecological data with socio-economic perspectives presents a holistic approach that can serve as a model for managing other marine resources under similar conditions.

This study demonstrates the critical role of habitat quality in determining the size distribution and population dynamics of *Amusium pleuronectes* in South Sulawesi. The positive correlation between dissolved oxygen levels, pH, and scallop size highlights the ecological dependence of this species on well-maintained mangrove and coral reef ecosystems. Locations such as Sinjai, with optimal habitat conditions, supported the largest

scallops, while degraded habitats in Pangkep and Selayar exhibited smaller scallop sizes and reduced population density.

The research also underscores the socio-economic importance of scallop fisheries, which contribute substantially to household incomes in coastal communities. However, the lack of awareness of sustainable harvesting practices poses a significant threat to the long-term viability of this resource. Without intervention, overexploitation and habitat degradation will likely accelerate population declines, jeopardizing both ecological balance and community livelihoods.

From a policy perspective, the findings advocate for targeted conservation and management strategies, including:

1. Habitat restoration efforts focused on mangrove reforestation and coral reef protection.
2. Implementation of science-based harvesting regulations, such as size restrictions and seasonal bans.
3. Community education programs to raise awareness about sustainable practices and the ecological role of *Amusium pleuronectes*.

By integrating ecological, economic, and social dimensions, this research provides a holistic framework for the sustainable management of scallop fisheries. These findings contribute to achieving sustainable development goals, particularly SDG 14 (Life Below Water), by promoting practices that balance conservation and livelihoods. Future studies should expand on this work by incorporating longitudinal data and exploring the potential for advanced technologies, such as GIS, to enhance monitoring and adaptive management..

CONCLUSION

This study provides a comprehensive assessment of the ecological, social, and economic factors influencing the sustainability of *Amusium pleuronectes* populations in South Sulawesi. The main findings highlight the critical role of habitat quality, with mangrove and coral reef ecosystems significantly supporting scallop growth and distribution. Locations such as Sinjai demonstrated optimal conditions for scallop populations, evidenced by larger shell sizes and higher population density, while degraded habitats in Pangkep and Selayar exhibited lower ecological performance.

The socio-economic analysis revealed that scallop fisheries are an essential source of income for coastal communities, contributing up to 25% of household earnings in specific regions. However, the lack of awareness regarding sustainable harvesting practices and the absence of effective management strategies pose significant threats to the resource's long-term viability. These findings emphasize the necessity of integrating ecological conservation with socio-economic policies to achieve sustainable resource management.

This research contributes to existing knowledge by offering a multidimensional approach to fisheries management, combining habitat quality assessment, socio-economic evaluation, and policy recommendations. The study's novelty lies in its holistic approach to scallop fisheries management, providing actionable insights tailored to regional variability and local needs.

The study underscores the importance of adopting ecosystem-based management strategies that include:

1. Habitat restoration initiatives, such as mangrove reforestation and coral reef conservation.
2. Implementation of harvesting regulations, including size limits and seasonal bans, to protect scallop populations during critical growth periods.
3. Community engagement and education programs to promote sustainable practices and enhance local stewardship.
4. Utilization of advanced monitoring tools, such as Geographic Information Systems (GIS), to track habitat conditions and scallop population dynamics.

This study acknowledges certain limitations, including the cross-sectional nature of the data, which may not fully capture seasonal or interannual variability in scallop populations. Future research should incorporate longitudinal data collection to examine temporal trends and assess the long-term impacts of management interventions. Moreover, expanding the geographical scope of the study to include additional regions with diverse environmental conditions could provide a more comprehensive understanding of *Amusium pleuronectes* ecology.

Further exploration of technological solutions, such as aquaculture and artificial reef systems, could enhance resource sustainability and reduce fishing pressure on wild populations. Collaborative efforts between scientists, policymakers, and local communities will be essential in implementing these strategies effectively.

In conclusion, this study offers significant contributions to the field of sustainable fisheries management by bridging ecological, economic, and social dimensions. The findings provide a strong foundation for evidence-based policymaking and serve as a model for managing other marine resources in similar contexts.s.

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