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Education on the Protection of Aquatic Biodiversity as an Economic Support for Coastal Communities in the Estuarine Area of Gampong Alue Naga

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Abstrak: kawasan estuaria Gampong Alue Naga merupakan ekosistem pesisir yang memiliki keanekaragaman biota akuatik tinggi dan menjadi sumber penghidupan utama masyarakat setempat. Namun, tekanan ekologis seperti penangkapan berlebih, penurunan kualitas habitat mangrove, dan pencemaran perairan telah menyebabkan penurunan populasi beberapa spesies bernilai ekonomi. Penelitian ini bertujuan untuk mendeskripsikan keragaman biota akuatik di kawasan estuaria serta merumuskan bentuk edukasi perlindungan yang mendukung keberlanjutan ekonomi masyarakat pesisir Metode penelitian yang digunakan adalah deskriptif kuantitatif dengan pendekatan partisipatif (*participatory action research*). Teknik pengumpulan data menggunakan *teknik purposive sampling*. Instumen penelitian (pedoman observasi, wawancara dan dokumentasi lapangan). Analisis data yang digunakan adalah deskripstif kuantitatif. Hasil penelitian menunjukkan adanya lebih dari 40 spesies biota akuatik dari kelompok moluska, krustasea, dan ikan, seperti *Anadara granosa*, *Scylla serrata*, dan *Penaeus monodon* yang memiliki nilai ekonomi signifikan. Namun, beberapa spesies mengalami penurunan ukuran dan jumlah tangkapan. Edukasi konservasi berbasis masyarakat yang mengintegrasikan pengetahuan lokal, praktik penangkapan berkelanjutan, dan diversifikasi hasil olahan laut dinilai efektif dalam menjaga kelestarian ekosistem sekaligus memperkuat ketahanan ekonomi pesisir. Dengan demikian, perlindungan biota akuatik melalui edukasi partisipatif menjadi strategi penting untuk mencapai keberlanjutan ekologi dan kesejahteraan masyarakat.

Kata kunci: Biota akuatik; Edukasi lingkungan; Ekonomi pesisir; Estuaria; Konservasi.

Abstract: The estuarine area of Gampong Alue Naga supports high aquatic biodiversity and serves as a primary livelihood source for the local coastal community. However, ecological pressures such as overfishing, mangrove habitat degradation, and water pollution have led to a decline in economically valuable species. The research method used was quantitative descriptive with a participatory approach (participatory action research). Data collection used purposive

sampling. The research instruments used were observation guidelines, interviews, and field documentation. Data analysis used quantitative descriptive. The findings indicate the presence of more than 40 aquatic species, including molluscs, crustaceans, and fish, such as *Anadara granosa*, *Scylla serrata*, and *Penaeus monodon*, which hold significant economic value. However, a reduction in size and population was observed in several key species. Community-oriented conservation education integrating local ecological knowledge, sustainable harvesting practices, and value-added seafood processing is recommended to maintain ecological balance and strengthen local economic resilience. Therefore, participatory environmental education plays a strategic role in achieving sustainable ecosystem management and improving coastal community welfare.

Keywords: Aquatic biodiversity; Coastal economy; Conservation; Estuary; Environmental education.

1. Introduction

Estuaries are coastal ecosystems with high biological productivity and play a strategic role in supporting ecological balance and the socio-economic well-being of coastal communities. Estuaries are characterized by the confluence of freshwater from rivers and seawater, creating an environment with fluctuating physical and chemical characteristics yet rich in nutrients. These conditions enable the growth and development of various aquatic organisms such as fish, mollusks, crustaceans, plankton, and other benthic biota, which form a complex and productive food chain. states that estuaries function as nursery grounds, feeding grounds, and migration routes for numerous marine and freshwater species [1]. Therefore, estuaries not only have ecological value but also significant economic value, especially for communities dependent on fisheries and seafood processing for their livelihoods.

In Aceh Province, particularly in the coastal area of Banda Aceh City, there is a significant estuary area, namely Gampong Alue Naga in Syiah Kuala District. Geographically, Alue Naga lies at the confluence of the Krueng Cut River and the Indian Ocean, giving it distinctive physical and biological characteristics. Mangrove vegetation grows extensively along the riverbanks and estuaries, providing a vital habitat for various species of fish, crabs, oysters, clams, and other organisms. Local communities have long utilized these

resources as part of their coastal household economic systems. Fishing, collecting clams and oysters, and processing seafood are the primary livelihoods of most local residents [2] [3]. Therefore, the presence of aquatic biota not only has ecological value but also serves as a crucial pillar for local economic sustainability.

However, the condition of aquatic resources and estuarine habitats in Alue Naga is not free from various ecological pressures. With increasing population, changes in coastal spatial planning, and unregulated resource exploitation activities, environmental quality has declined and populations of several biota have declined [4]. Noted a decline in mangrove cover and increased sedimentation, which have directly impacted the ecological function of the estuary. The use of environmentally unfriendly fishing gear, the dumping of household and industrial waste into rivers, and a declining public awareness of the importance of ecosystem balance have all accelerated this degradation. As a result, economically valuable biota such as mangrove crabs, estuarine fish, and various mollusks have begun to decline drastically, both in number and size [5].

Research conducted by Rafsanjani, Ibrahim, and Jalaluddin (2025) on the diversity of aquatic biota in the Gampong Jawa and Alue Naga estuaries indicates that these areas harbor more than 40 species of organisms from the Mollusca, Arthropoda, and Pisces groups, which have significant economic value for the surrounding community. However, the study also found indications of a decline in the abundance of certain species due to environmental changes and exploitation pressure. This study reinforces the findings of [6], who identified histopathological changes in the hepatopancreas of the mangrove crab (*Scylla serrata, Sp)*, which are indicators of environmental stress and exposure to contaminants in the organisms consumed by humans. This phenomenon indicates that ecological imbalance not only threatens the sustainability of the organisms but also directly impacts the quality of consumption and public health.

In a socioeconomic context, the Alue Naga community relies heavily on a daily catch-based economy. Income from the sale of catches is often used up

to meet daily needs, leaving no capital reserves for investment or diversification of income sources [7]. This economic model is highly vulnerable to seasonal fluctuations, weather changes, environmental damage, and natural disasters. The 2004 tsunami that struck the region marked a major turning point in the region's social and ecological structure. Much local knowledge regarding coastal resource management was lost, and traditional adaptation systems were no longer consistently applied [8]. Therefore, an education- and empowerment-based intervention is needed to restore traditional ecological knowledge and increase the community's economic adaptive capacity [9].

In this context, conservation education plays a crucial role. Conservation education is not merely the transfer of information about the importance of environmental protection, but rather a social learning process that encourages transformation in the way communities think, utilize resources, and make decisions about managing their coastal areas. Emphasizes that effective environmental education must be participatory, contextual, and grounded in the real needs of the community [10]. Educational approaches must be able to link environmental conservation with improved well-being, so that communities view conservation not as a burden but as a strategy for economic sustainability.

This loss of local knowledge goes hand in hand with the weakening of community-based resource management practices. While communities once had customary rules or informal agreements regarding fishing times and locations to ensure the availability of biota, these rules are now rarely enforced [12]. The loss of these "social and environmental rules" has led to more free and uncontrolled exploitation. Meanwhile, general government regulations are often not translated into practical language relevant to the daily lives of fishermen. As a result, a gap exists between scientific conservation knowledge and the reality of field practice. This reinforces the need for an educational mechanism that is not only informative, but also collaborative and contextual, integrating modern science with local wisdom that has proven adaptive to the dynamics of coastal nature[13].

Conservation education in Alue Naga can be developed through several approaches, such as aquatic biota field schools, training in environmentally friendly fishing techniques, improving seafood processing skills, and developing community-based ecotourism [14]. Emphasized that in many coastal communities in Indonesia, women play a crucial role in the seafood production chain, particularly in collection, processing, and marketing. Therefore, the involvement of women is a key factor in the success of conservation education, as they are both economic actors and social agents who can strengthen collective awareness at the family and community levels.

Educational efforts must also address the economic structure of coastal households, which tends to be vulnerable. Income derived from aquatic biota fishing activities is often unstable and influenced by seasons, weather, and tidal conditions. This uncertainty places communities in a volatile economic situation, leading them to prioritize short-term economic needs over long-term conservation efforts. Therefore, conservation education must be accompanied by strategies to increase economic added value. For example, training in processing seafood into products with higher economic value, such as fish floss, fish skin chips, oyster sauce, fermented shellfish, or hygienic packaging techniques for urban markets. This strategy not only helps increase income but also reduces overfishing pressure on estuarine biota.

Beyond ecological and economic issues, the socio-cultural conditions of the coastal communities of Alue Naga also play a role in shaping patterns of human interaction with the estuarine environment. Coastal communities generally have a historical relationship with the sea influenced by local wisdom, traditions passed down from generation to generation, and social structures developed through collective experience in navigating the dynamics of nature. Before rapid environmental change and modernization, local knowledge systems regarding seasons, fish migration patterns, non-destructive fishing techniques, and the wise use of mangroves were fundamental to maintaining ecosystem balance [15] [16]. However, generational change and shifting economic patterns have caused much of this local knowledge to be abandoned. Young people in Alue Naga, for example, prefer to work in the informal urban

sector rather than continue their careers as fishermen, thus disrupting the intergenerational transfer of ecological knowledge [17] [18]. This has resulted in a weakening of collective awareness for preserving natural resources. Furthermore, the potential for developing educational ecotourism in the Alue Naga area can also be utilized as a sustainable alternative source of income. Ecotourism, in this context, does not involve the development of large-scale tourist attractions that can damage the environment, but rather community-based activities such as mangrove observation tours, estuary explorations, eco-friendly fishing tours, or nature school education for students. These activities provide visitors with hands-on experience in understanding the ecological function of estuaries while simultaneously generating new income for the community [19] [20] [21]. Community-based ecotourism development has proven effective in many coastal areas in Indonesia as a strategy for actively engaging communities in environmental conservation, as they see the direct economic benefits of preserving nature [22].

Beyond economic strategies, a fundamental aspect of conservation education is the involvement of youth and women's groups. Youth play a crucial role as agents of change, bringing innovation and new technologies to the table, such as the use of catch recording apps, publicizing estuary conditions on social media, or creating digital educational content about local ecosystems [23] [24]. Women often play a significant role in household economic stability and family financial management. By involving women in training in seafood processing and local marketing, conservation education becomes more than just theoretical but also embedded in everyday economic practices. This social transformation will create a more harmonious pattern of relationships between humans and the environment because community involvement becomes comprehensive, not just certain groups.

Furthermore, conservation education efforts require strong institutional support. The involvement of local governments, academics, non-governmental organizations, and local community leaders is crucial to ensuring program sustainability. The government can provide regulations and supporting

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facilities, academics play a role in providing scientific data and educational methods, NGOs can assist in community mentoring, and community leaders serve as a bridge between scientific knowledge and local customs. This collaboration between stakeholders will create a dialogue that encourages community involvement in conscious and planned resource management.

Considering this overall context, it is clear that efforts to protect the diversity of aquatic biota in Gampong Alue Naga cannot be achieved solely through environmental policies or fishing restrictions. These efforts must be built through in-depth and sustainable education, which not only teaches ecological concepts but also connects environmental sustainability with economic sustainability and social well-being. This education must flow through formal learning spaces such as schools and universities, as well as informal learning spaces such as fishermen's groups, village councils, coastal women's communities, and village youth forums [25].

This the overarching narrative we hope to build through this research and educational program on aquatic biodiversity protection is the creation of independent coastal communities capable of sustainably managing their natural resources, maintaining ecological balance, and simultaneously improving their own economic well-being. Conservation is not simply about preserving nature, but also about ensuring human life remains dignified and sustainable [26] [27].

2. Research Method

This study uses a quantitative descriptive approach with the aim of describing the condition of aquatic biota diversity and forms of environmental protection education related to improving the economy of coastal communities in the estuary area of Gampong Alue Naga. The research location was selected purposively because this area has the characteristics of an estuary aquatic ecosystem rich in biota and is a center of community economic activities such as fishing, crabs, and shellfish. Data collection was conducted through field observations, in-depth interviews with traditional fishermen, fish farmers, community leaders, village officials, and academics who understand

environmental issues, as well as documentation in the form of village data, activity photos, and local government reports. Informants were determined using a snowball sampling technique until information was considered saturated. Data were analyzed using the interactive analysis model of Miles, Huberman, and Saldana, which includes data reduction, data presentation, and drawing conclusions. Data validity was guaranteed through triangulation of sources and techniques, as well as confirmation of findings with informants (member checking) so that the data obtained were considered valid and scientifically accountable.

3. Results and Discussion

a. Aquatic Biota Diversity in the Gampong Alue Naga Estuary

Field observations indicate that the Gampong Alue Naga estuary area has a high level of aquatic biota diversity, particularly among fish, mollusks, and crustaceans.

Table 1. Aquatic Biota Diversity in the Gampong Alue Naga Estuary Area

Family	Species	Local Name
Neritidae	*Nerita columbella*	*Keong batik*
	Nerita Melanotragus	*Keong hitam*
Arcidae	*Anadara granosa*	*Kerang darah*
Ostreidae	*Alectryonella plicatula*	*Tiram bakau*
Mytilidae	*Verna viridis*	*Kerang hijau*
Mactridae	*Spisula solida*	*Kerang putih*
Pachychilidae	*Sulcospira* sp.	*Keong air tawar*
	Melania testudinaria	*Sumpil*
Lottiidae	*Lottia limunata*	*Keong pipih*
Unionidae	*Anodonta woodiana*	*Kijing*
Corbiculidae	*Curbicula* sp.	*Remis*
Ocypodidae	*Uca demani*	*Kepiting binatu*
Penaeidae	*Parapenaeopsis sculptilis*	*Udang Belang*
	Penaeus monodon	*Udang windu*
	Metapenaeus ensis	*Udang putih*
Portunidae	*Charybdis cruciate*	*Rajungan karang*
Paguridae	*Pagurus*	*Kelomang*
Ocypodidae	*Ocypode cetatophthalmus*	*Kepiting Gelenteng*

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Family	Species	Local Name
Portunidae	*Portunus sanguinolentus*	*Rajungan bintang*
	Thalamita crenata	*Rajungan Hijau*
	Scylla serrata	*Kepitin bakau*
Grapsidae	*Grapsus tenuicristatus*	*Kepiting batu*
Ocypodidae	*Ocypode cordimanus*	*Kepiting lambogo*
Sepiidae	*Sepiida suborder*	*Sotong*
Loliginidae	*Loligo* sp.	*Cumi-cumi*
Palaemonidae	*Macrobraciun rosenbergii*	*Udang galah*
Carangidae	*Alepes* sp.	*Churok/Gerongong*
	A. kleinii	*Tumbo/Mata Besar*
	Carangoides malabricus	*Mirah Mata/ Kuweh*
	Scomber lysan	*Talang-talang*
Polynemidae	*Eleutheronema tetradactylum*	*Senagin*
Dorosomatidae	*Sardinella jussieui*	*Tamban*
Engraulidae	*Setipinna taty*	*Billis Kelampa*
	Stolephorus indicus	*Billis Nasi*
Leiognathidae	*Secutor rocunius*	*Petek*
	Equulites elongatus	*Cirik Buju*
Mullidae	*Upeneus sulphurous*	*Kuniran/ikan Pisang*
Platycephalidae	*Grammoplites scaber*	*Baji/Paut-paut*
Pristigasteridae	*Ilisha elongate*	*Krisi/Beliak Mata*
Sciaenidae	*Johnius coitor*	*Gulama/Kepala Batu*
Trichiuridae	*Trichiurus lepturus*	*Layur*
Belonidae	*Tylosurus crocodilus*	*Caroang/Todak*
Gerreidae	*Gerres erytrhrourus*	*Kapas-kapas/Kalam*
Cichlidae	*Pterophyllum imei*	*layang-layang*
Ariidae	*Arius maculatus*	*Lundu/Bagok*
Siganidae	*Siganus canaliculatus*	*Baronang*
Mugilidae	*Crenimugil seheli*	*Belanak/kadra*
Scatophagidae	*Scatophagus argus*	*Cabe-cabe/Kiper*

Identification data shows that the Gampong Alue Naga estuary area boasts a high diversity of aquatic biota, consisting of several main groups, namely mollusks, crustaceans, and fish. This diversity reflects the ecological function of estuaries as transitional areas between river and marine ecosystems, providing important habitats for various aquatic organisms. Estuaries are known for their high biological productivity due to the input of nutrients from land and sea, which increases the availability of natural food. These conditions enable the formation of complex food chains and support the survival of various species.

Within the mollusk group, several families were found, including Neritidae, Arcidae, Ostreidae, Mytilidae, Mactridae, and Unionidae. Species such as Nerita columbella and Nerita melanotragus are often found in coastal rocky areas and mangroves, indicating that these areas provide suitable substrates for the growth and protection of these gastropods. Meanwhile, *Anadara granosa* (blood cockle) and *Alectryonella plicatula* (mangrove oyster) were found in mud sediments and mangrove roots, underscoring the importance of mangrove vegetation as a protective habitat and attachment site. The presence of oysters and clams also indicates relatively good water conditions, as these organisms are sensitive to pollution and changes in water quality. In addition to their ecological value, mollusks also have economic value as a food ingredient widely consumed and traded locally.

Crustaceans were also found in diverse numbers and species, including members of the families Ocypodidae, Portunidae, Paguridae, Penaeidae, and Grapsidae. The most commonly utilized species are *Scylla serrata* (mangrove crab), *Portunus sanguinolentus* (star crab), and *Penaeus monodon* (tiger prawn). These species have high market value and are a primary source of income for local fishermen. However, some fishermen reported that the size of mangrove crabs is decreasing, indicating high exploitation pressure. This aligns with the findings of who found that overfishing in estuarine ecosystems can lead to population decline and impact the economic stability of coastal communities. Therefore, conservation strategies such as establishing fishing seasons and restocking are crucial.

In the fish group, the diversity found is quite extensive, encompassing the families Carangidae, Dorosomatidae, Engraulidae, Leiognathidae, Mullidae, Sciaenidae, Belonidae, Gerreidae, Ariidae, Siganidae, Mugilidae, and Scatophagidae. The presence of small pelagic fish such as *Sardinella jussieui* (*tamban*) and *Stolephorus indicus* (*billis nasi*) indicates that this area serves as a migration route and feeding ground for schooling fish. Meanwhile, demersal fish such as *Johnius coitor* (gulama) and *Crenimugil seheli* (mullet) demonstrate the estuary's fundamental function as a spawning and nursery ground. These

species serve as a source of protein for local communities and are also a valuable commodity traded in traditional markets in Banda Aceh.

Overall, the high diversity of aquatic biota in the Gampong Alue Naga estuary demonstrates that this area holds significant ecological and economic value. However, the sustainability of this ecosystem depends heavily on wise resource management. Without conservation education and sustainable fishing practices, overexploitation can threaten the biota's sustainability and the economic stability of fishing households. Therefore, efforts to educate and protect aquatic biota need to be continuously developed through collaboration between the community, village government, academics, and environmental organizations as a foundation for a sustainable coastal economy.

b. The Role of Estuarine Ecosystems in the Coastal Community Economy

The people of Gampong Alue Naga have a significant economic dependence on aquatic biota. Their primary economic activities include traditional fishing and crab fishing using longlines, traps, and nets, as well as aquaculture in brackish water ponds. Catches such as crabs and blood cockles have a high market value in the local Banda Aceh market and serve as a source of daily income for residents. However, interviews indicate that fishermen's income fluctuates and is heavily influenced by the season, weather conditions, and the availability of aquatic biota. This dependence underscores the importance of maintaining the sustainability of estuarine ecosystems to ensure their long-term productivity. Therefore, biota conservation is not only an ecological issue but also linked to the socio-economic stability of the community.

c. Challenges of Ecosystem Damage and Biota Population Decline

Research also found ecological pressures that have the potential to threaten the sustainability of aquatic biota in estuaries. Several factors identified include increased river sedimentation, overfishing, the use of environmentally unfriendly fishing gear, and pollution from residential activities and household waste. Several fishermen reported that the size and number of mangrove crabs

are currently declining compared to five to ten years ago. This finding aligns with research. Which states that estuarine ecosystems in Aceh are experiencing degradation due to pressure from human activities. This situation indicates that without sustainable conservation management and education, the existence of aquatic biota will be increasingly threatened, impacting community incomes.

d. Education on Aquatic Biota Protection as an Effort to Strengthen a Sustainable Economy

Public education on the importance of aquatic biota protection is a strategic aspect in maintaining a balance between resource utilization and conservation. In this context, educational activities involving village governments, academics, and environmental organizations have begun through outreach, coaching on selective fishing practices, and strengthening conservation-aware fisher groups. This education not only emphasizes ecological aspects but also demonstrates how conservation can increase long-term economic value through sustainable harvesting, the development of mangrove ecotourism, and the diversification of value-added seafood processing businesses. Thus, conservation education can be a crucial instrument in building sustainable economic independence for coastal communities.

4. Conclusion

This study shows that the Gampong Alue Naga estuary has a high diversity of aquatic biota, particularly mollusks, crustaceans, and fish, which play a vital role in supporting the ecosystem and the socio-economic life of coastal communities. Species such as *Anadara granosa, Scylla serrata,* and *Penaeus monodon* have strategic economic value and are a primary source of income for local fishermen. However, the declining trend in catches indicates pressure from resource exploitation that could threaten the sustainability of the estuarine ecosystem. Therefore, aquatic biota conservation needs to be carried out through environmental education approaches, sustainable fishing practices, and strengthening the role of communities in coastal resource management.

These efforts not only serve to maintain ecological balance but also support the sustainable economic resilience of coastal communities.

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