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ECONOMIC VALUATION OF THE ARUAH ISLANDS MARINE PROTECTED AREA, INDONESIA

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Abstract

Conservation or protection is the right step in an effort to preserve and utilize biological natural resources and their ecosystems so that they can be sustainable. The Aruah Islands, as one of the protected areas in Riau Province, have marine biodiversity such as coral reefs and turtle spawning habitats. Currently, the most important issue in the Aruah Islands is the sustainability and conservation of environmental resources. Economic assessment is an effective operational tool to design policies related to its sustainable use. The method used is the survey method. The data collected are primary data and secondary data. Economic valuations are calculated using the Total Economic Value (NET). The results of the study show that the Aruah Islands marine protected area has a total economic value of IDR 6,669,882,695.04 per year, which is mostly contributed by the benefits of the existence of the region's ecosystem of 44.27 percent, or around IDR 2,951,521,667 per year.

Keywords*: Protected Area; Aruah Islands; Economic Valuation*

Introduction

Marine protected areas (MPAs) are increasingly recognized as effective policy instruments not only for biodiversity conservation but also for supporting coastal livelihoods and sustainable economic development [1], [2], [3]. Marine protected areas are areas where human activities are restricted, and management is carried out to protect coastal and marine biological resources to avoid the threat of excessive resources that have an impact on ecological damage [4]. Protected areas in coastal areas and small islands are coastal areas and small islands with certain characteristics that are protected by Law of the Republic of Indonesia Number 27 Years, 2007 [5]. The performance of a marine protected area is highly dependent on many elements such as design, management implementation, and regional characteristics [6], [7], [8]. Areas where marine protected areas have positive ecological effects, such as increased species abundance and improved habitat quality, as well as significant socio-economic effects for coastal communities [9], [10], [11]. International studies demonstrate that marine protected areas (MPAs) generate substantial economic value through ecosystem services such as fisheries enhancement, coastal

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protection, biodiversity conservation, and climate regulation, supporting both ecological sustainability and community welfare [12], [13].

Riau Province has fisheries potential, which includes marine fisheries and inland fisheries. This potential is a fishery business sector that includes fish production activities both through fishing for fish resources in the sea (capture fisheries) and fish cultivation on land (ponds and public waters) [14]. Riau Province in 2017 has carried out the Reserve of Coastal Protected Areas and Small Islands in the Aruah Islands, Rokan Hilir Regency. Riau Province has carried out stages in the reserve of the conservation area. Based on this, this conservation area has been designated as a park in the waters of the Aruah Islands, covering an area of 18,536.10 ha through Decree of the Minister of Maritime Affairs and Fisheries (Kepmen KP) of the Republic of Indonesia Number 73/Kepment KP/2021 [15] about the Aruah Islands Marine Protected Area in Riau Province.

Since the Aruah Islands were designated as a conservation area, community activities in meeting daily needs and developing community economic businesses, especially the utilization of marine resources in the Aruah Islands area, have been limited by a zoning system. The limited space conditions and opportunities for the use of plants and animals result in utilization efforts that are not environmentally friendly and do not obey the rules. The impact of all this is that resources will continue to experience pressure and threats, and protection efforts for sustainability will not run well. Economic valuation plays a critical role in translating ecosystem services into monetary terms, enabling policymakers to integrate environmental considerations into development planning [16]. Therefore, economic assessment of the ecosystem of conservation areas can provide a framework to encourage the efficiency of resource allocation and use in the context of public policies based on social welfare. The economic assessment reveals all the losses incurred from the use of marine protected areas and thus can provide justification for decision-makers to conserve and use the resources of the Aruah Islands marine protected areas in a sustainable manner.

Experimental part

Research Location

This research was conducted from February to June 2024. The research location was taken in 2 (two) sub-districts in Rokan Hilir Regency, namely Bangko District and Pasir Limau Kapas District. This is because Bangko District has direct access to the waters and is often used as a base for fisheries and marine tourism activities, while Pasir Limau Kapas District also has a water area rich in biodiversity, and its villages interact directly with conservation areas.

Sampling Techniques

The sampling technique took place in 2 (two) sub-districts that had been determined, namely Bangko and Pasir Limau Kapas Districts. Then interviews were conducted with respondents (fishermen and the community), and a list of questions (questionnaires) was made to find out the respondents' understanding of marine protected areas in the Aruah Islands and the amount of income they earned by utilizing the area.

Data Collection Techniques

The economic valuation of conservation areas is analyzed with the Total Economic Value (NET), which is usually used according to the type of functions and benefits that have been successfully identified from the natural resource ecosystem and the environment [17]-[25]. Recent valuation studies emphasize the use of benefit transfer and mixed valuation approaches to estimate ecosystem service value in data-limited marine protected areas, especially in developing countries [26]. Meanwhile, the contingent valuation method is used to estimate non-use values such as existence and bequest values, reflecting public preferences for ecosystem conservation [27].

The total economic value is formulated as follows:

$$TEV = UV + NUV = (DUV + IUV + OV) + (XV + BV) \quad (1)$$

where: TEV - *Total Economic Value;* UV - *Use Value;* NUV - *Non Use Value;* DUV - *Direct Use Value;* IUV- *Indirect Use Value;* OV - *Option Value;* XV - *Existence Value;* BV - *Bequest Value.*

Results and discussion

The Aruah Islands are the outermost region located in the Strait of Malacca and directly bordering the country of Malaysia. Administratively, the Aruah Islands are included in Pasir Limau Kapas District, Rokan Hilir Regency, Riau Province. Accessibility to the Aruah Islands: from Pekanbaru, the journey is carried out by road to Bagansiapi; from Bagansiapi, the journey continues by sea to Jemur Island, part of the Aruah Islands. Coastal area management based on Law No. 27 of 2007 on the Management of Coastal Areas and Small Islands involves local communities in the management and conservation of natural resources, increasing the capacity of local institutions for coastal resource management, collaboration with universities and the private sector for research and development, sustainable infrastructure development, and the preparation of strategic plans and zoning for the regulation of land use and resources.

The waters of the Aruah Islands are an area with high biodiversity and are one of the spawning grounds for green turtles. This makes it crucial for the conservation and preservation of various threatened marine species. This area has been designated as a conservation area with an area of 18,536.10 hectares. The management of this area is carried out as a park in the waters with various zones that have special designations to maintain a balance between conservation and utilization. The Aruah Islands have a variety of important ecosystems, such as coral reefs that support rich marine life. This biodiversity is not only important for ecosystem balance but also provides significant economic and ecological benefits, such as use value and non-use value.

Use Value

In the economic valuation study of marine protected areas in the Aruah Islands, the use value is calculated based on the results of the analysis of the suitability and carrying capacity of the area. Use value is divided into 3 types, namely *direct use value*, indirect *use value*, and option *value*.

Direct Use Value

Based on the results of the analysis of the suitability and carrying capacity of the area, the economic value obtained from the direct use of the Aruah Islands marine protected area includes benefits from fishing and transportation services.

The Value of Direct Use of Capture Fisheries

Conservation measures in MPAs have been shown to improve fish biomass and long-term fisheries productivity, generating positive economic impacts for local communities [28]. The value of the economic benefits of capture fisheries in the Aruah Islands marine protected area using *the Economic Opportunity Productivity* (EOP) technique, by conducting several analysis steps based on the demand function, namely $f(Q) = 629{,}752{,}166.27\ Q^{-1.20}$. This calculation was obtained based on interviews with 30 fishermen who were looking for fish with the characteristics of an average fisherman age of 43 years and the number of family members of 3 people. Multiple linear regression analysis was carried out to determine the relationship between catch (Q) and price (P) and fishermen's characteristics (age, trip fishing effort/year, operational costs, and fishermen's income).

The following is the fish demand curve in the Aruah Islands marine protected area based on the demand function (Fig. 1).

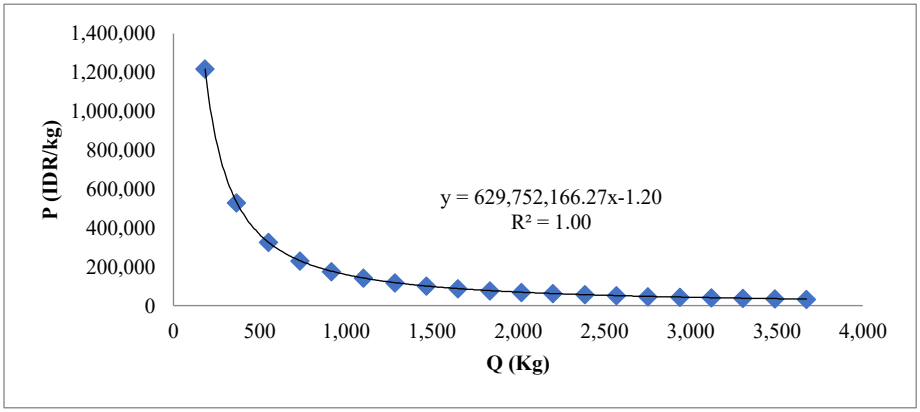

Fig. 1. Function of Capture Fisheries Demand in The Aruah Islands MPA

The curve above shows the relationship between the quantity of catch (Q) and the price willing to pay (P); that is, the price decreases significantly when the quantity of catch increases. Furthermore, to calculate the economic value of the Aruah Islands marine protected area based on its function as a provider of fish resources using the concept of consumer surplus (CS), it is IDR. 733,040,826.37. The economic value generated by the Aruah Islands marine protected area is IDR. 612,459,108.33 per year. Similar findings have been reported in other MPAs, where improved fisheries productivity contributes significantly to local livelihoods and regional economic benefits [29].

The Value of Direct Use of Transportation

The Aruah Islands marine protected area is used by the community as a transportation route to Panipahan and Jemur Island for various purposes, such as sightseeing tours and natural resources around the Aruah Islands area. To calculate the economic value of public transportation users in the Aruah Islands marine protected area, it is analyzed based on transportation costs, the number of users, and total receipts from transportation services. The transportation cost of IDR 280,000 for the total receipt of transportation services is presented in Table 1.

Table 1. Transportation Use Value

Day	Number of Users per Day (people)	Average Revenue per Day (IDR)	Total Revenue per Year (IDR)
Usual	80	22,400,000	7,728,000,000
Major	120	33,600,000	504,000,000
			8,232,000,000

The value of transportation users in a year can be calculated by assuming a few ordinary days and big days in a year. For example, in a year there are 345 ordinary days and 15 big days. With this assumption, the value of revenue from transportation services is IDR 8,232,000,000 per year. The depreciation costs for all components are as follows in Table 2.

The depreciation cost of components for one ferry is IDR 3,769,190,476 per year. If there are 2 transportation service providers, the cost component will shrink to IDR 7,538,380,952. To see the economic value of transportation service providers, the total revenue is subtracted by the total depreciation cost so that the economic value of transportation is obtained, which is IDR 693,619,048 per year.

Table 1. Component of Transportation Costs

No.	Type	Value (IDR/Year)
1	Asset depreciation	
	Ferry Vessels and Engines	333,333,333
	Machinery and Equipment	100,000,000
	Safety Equipment	50,000,000
	Interior and Facilities	50,000,000
2	Maintenance	12,857,143
3	Fuel	3,150,000,000
4	Supplies	72,000,000
5	Retribution	1,000,000
Total		**3,769,190,476**

The Value of Direct Use of Research

In 2024, there will be 6 researchers conducting research in the Aruah Islands marine protected area, consisting of 5 S1 students and 1 lecturer. The average time spent on research is one week with a frequency of visits as many as 2 times a year. The cost incurred by each researcher is IDR 7,100,000 (including transportation, consumption, lodging, and motorbike rental in the field). So that the direct use of researchers in the Aruah Islands marine protected area is 6 researchers x IDR 7,100,000 = IDR 42,600,000/year.

Indirect Use Value

The economic value obtained from the indirect use of the Aruah Islands marine protected area includes benefits from abrasion resistance and carbon sequestration (CO_2).

Abrasion Resistance

Coral reefs provide critical coastal protection services by reducing wave energy and preventing shoreline erosion, with global economic benefits estimated to exceed USD 100 billion per decade [30], [31]. The coral reef ecosystem found in the Aruah Islands marine protected area has various important ecological functions, especially as a coastal protector from abrasion and a habitat for fish and other marine life [32], [33], [34]. This function is classified as an *indirect use value*. Coral reefs serve as natural breakwaters that protect the coast from abrasion, and coral reefs provide shelter and food sources for various species of fish and the biota associated with them. To assess the physical function of the area using the *replacement cost approach,* estimate the cost needed to replace or restore the lost ecological function.

The coral reef ecosystems within the Aruah Islands marine protected area offer significant coastal protection services by buffering wave energy and reducing erosion dynamics, which in turn lowers the potential damage that coastal areas would otherwise face during high-energy storm events and sea-level fluctuations. Recent studies show that coral reef protection and restoration can be evaluated using nature-based valuation frameworks that quantify avoided flood damage and infrastructure losses, demonstrating that maintaining healthy reef structures often yields coastal risk reduction benefits that exceed the costs of alternative engineered defenses [35], [36], [37], [38]. The area of the Aruah Islands marine protected area protected by coral reefs is 358.4841 hectares at low tide [39], or about 3,584,841 m^2. The average standard cost used for every 1 m^3 is IDR 550,000. This refers to the cost standard used by previous researchers [40] in the Banda Neira Islands, assuming every 1 m of the length of the breakwater has a volume of 6 m^3. The value of the benefits of coral reefs in the Aruah Islands as a replacement for *breakwater* using the *replacement cost* method is IDR 657,220,850,000 with a service life of 10 years. So the value of indirect benefits as a breakwater is IDR 65,772,085,000 per year, or around IDR 183,333,333.3 per hectare per year.

Carbon Sequestration (CO_2)

Coral reef ecosystems contribute to climate change mitigation through carbon sequestration and carbonate production, forming part of the broader blue carbon framework [41]. Coral reef ecosystems in the waters of the Aruah Islands have an important role in carbon sequestration, which contributes significantly to climate change mitigation. According to [42], the value of 1 carbon is in

a price range of US$5 to US$35 per tCO_2e. According to [43], which mentioned the value of 1 carbon with a price range of US$1–US$28 with a carbon price of US$10 per ton, equivalent to IDR 140,800, the total primary productivity of coral reefs reaches 2500 g/m²/year. Furthermore, the economic value of coral reefs as carbon sinks is calculated by multiplying the area of coral reefs by the number of tons of carbon and the price of carbon per ton.

- 358,4841 ha x 10.000 m² x 2.500 gr/m²/year x 1/1.000.000 ton/gr = IDR 8,962.10
- Carbon value: US$10 per ton (exchange rate: US$1 = IDR 16,350.45 at the time of the study)
- Then the indirect economic value of coral reefs as carbon sinks in the Aruah Islands is IDR 1,465,885,037.47/year.

The carbon sequestration value by coral reef ecosystems in the Aruah Islands is smaller than the carbon sequestration value by coral reefs in the Kapoposang TWP, which reaches IDR 2,734,518,000 per year with an area of 1,156 ha [44]. This can be said to be natural because the coral reefs in the Kapoposang TWP are much wider than the coral reefs in the Aruah Islands.

Option Value

The assessment of the physical function of coral reef ecosystems in the Aruah Islands marine protected area is carried out using a benefit transfer approach, especially to calculate the *option value* of biodiversity provided by the ecosystem. The value refers to research [45], which states that the benefits of choosing coral reef ecosystems as biodiversity are IDR 100 per hectare, or IDR 1,635,045 per hectare at the exchange rate (IDR 16,350.45 per US$). The area of coral reef ecosystems in the Aruah Islands marine protected area is 358.4841 ha, so that a biodiversity selection value of IDR 586,137,635.3 per year is obtained. This value reflects the importance of coral reef ecosystems in providing significant ecological benefits through biodiversity.

Non-Use Value

Non-use value emphasizes the importance of the existence and preservation of marine protected areas in the Aruah Islands, even though they are not directly utilized. This is seen based on the willingness of individuals to pay for the ecosystem of the area. This value can be categorized into two types, namely, existence and bequest value.

Value of Existence

Local and global communities may be willing to pay for coral reef conservation in the Aruah Islands just to ensure that these ecosystems remain and are well preserved. Awareness campaigns and donations for coral reef conservation can attract funds from individuals who appreciate the existence of the region's ecosystems. Contingent valuation studies conducted after 2020 consistently show strong public willingness to pay for marine ecosystem conservation, even among non-users, indicating high social appreciation of ecosystem existence [46], [47]. The method used to assess the existence function is the *Contingent Valuation Method* (CVM) technique. CVM is an economic assessment method that measures people's willingness to pay to maintain the existence of an ecosystem. The assessment was carried out based on interviews with the surrounding community; the average willingness to pay of the community was IDR 78,333 per individual per year. The economic value of a conservation area is calculated by multiplying the average willingness to pay by the number of people around the area. As for the number of people around the area, totaling 37,679 people, the economic value of the area based on the function of existence is IDR 2,951,521,667/year. When compared to research [48], which obtained the value of the benefits of the existence of the Sawu Sea protected area in Kupang Regency of IDR 4,121,520,000/year, the value of existence in the study is smaller. This indicates that the perception of the community around the Sawu Sea protected area in Kupang Regency towards the ecosystem is very positive, so it can be used as an example for other areas. This community support is very important for the success of conservation efforts and preservation of the ecosystem of the area.

Bequest Value

Bequest value is the value provided by individuals or communities to ensure that certain natural resources remain and are enjoyed by future generations. This value reflects the desire to

pass on valuable natural resources to posterity so that they can enjoy and benefit from these resources in the future. The Aruah Islands marine protected area, which includes coral reef ecosystems and green turtle habitats on Jemur Island, is a valuable asset for humans, both now and in the future. The existence of the ecosystem is considered a heritage that has great value, especially for the local community in the conservation area. The value of the inheritance is calculated by a direct market value approach. The total economic value framework confirms that non-use components such as bequest and existence value capture people's preference for preserving ecosystems for future generations and contribute meaningfully to the overall estimated economic value of ecosystems in protected areas [49]. According to [50], the heritage value is not less than 10% of the value of the direct benefits of the ecosystem. The value of the direct benefit of the Aruah Islands marine protected area is IDR 1,348,678,155.95, so the inheritance value can be calculated by the formula 10% x (IDR 1,348,678,155.95) = IDR 134,867,815.59/year. This heritage value reflects the contribution of the ecosystem in providing sustainable ecological, economic, and social benefits for the community in the Aruah Islands marine protected area.

Total Economic Value of Aruah Islands Marine Protected Area

Based on the results of the analysis, the total economic value of the Aruah Islands marine protected area reaches more than 6 billion rupiahs (Table 3). This value includes various benefits obtained from the ecosystem of the Aruah Islands marine protected area. Most of the total economic value of the area is contributed by the existence value of more than 2 billion rupiahs, while based on the measured ecological parameters, the ecological value of the ecosystem contributes 24.72 percent of the total economic value with a value of 1 billion rupiahs.

Table 2. Total Economic Value of Aruah Islands Marine Protected Area

No.	Description	Value (IDR/Year)	Percentage
1	Direct		
	Capture Fisheries	612,459,108	9.18
	Transportation	693,619,048	10.40
	Research	42,600,000	0.64
	Total	1,348,678,156	20.22
2	Indirect		
	Abrasion resistance	183,333,333	2.75
	CO_2 Absorption	1,465,344,088	21.97
	Total	1,648,677,422	24.72
3	Options	586,137,635	8.79
4	Existence	2,951,521,667	44.25
5	Bequest Value	134,867,816	2.02
Total		**6,669,882,695.04**	**100.00**

Conclusions

The Aruah Islands marine protected area has a very large total economic value, with an economic value of more than 6 billion rupiahs per year, which includes a direct and indirect use value of more than 1 billion rupiah, a choice value of IDR 586,137,635, and an existence value of more than 2 billion rupiah, while the heritage value is around a hundred million more per year. This value is dominated by the value of existence that the community around the area is willing to pay to ensure the preservation of the ecosystem. Then ecological value accounts for around 24.72 percent of the total economic value, equivalent to 1 billion rupiahs. This value shows how important the ecological nature of the Aruah Islands marine protected area is, not only from an economic perspective but also from an ecological and environmental sustainability perspective.

Based on the results of the research on the economic value of the Aruah Islands marine protected area, the researcher has a suggestion to add other economic values for further research, as well as the area that has been designated as a conservation area to be preserved by increasing

the awareness of the community around the area about the importance of the economic value of regional resources to improve community welfare.

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References

[1] M. S. Hosain, S. J. Pogue, L. Trenchard, A. P. E. van Oudenhoven, C. L. Washbourne, E. W. Muiruri, and F. Resende, "Identifying future research directions for biodiversity, ecosystem services and sustainability: Perspectives from early-career researchers," *Int. J. Sustain. Dev. World Ecol.*, vol. 25, no. 3, pp. 249–261, 2018.

[2] P. Erm, A. Balmford, and M. H. Holden, "The biodiversity benefits of marine protected areas in well-regulated fisheries," *Biol. Conserv*., vol. 284, p. 110049, 2023.

[3] E. Sala, J. Mayorga, D. Bradley, R. B. Cabral, T. B. Atwood, A. Auber, W. Cheung, C. Castello, F. Ferretti, A. M. Friedlander, S. D. Gaines, C. Garilao, W. Goodell, B. S. Halpern, A. Hinson, K. Kaschner, K. Kesner-Reyes, F. Leprieur, J. McGowan, L. E. Morgan, D. Mouillot, J. Palacios-Abrantes, H. P. Possingham, K. D. Rechberger, B. Worm, and J. Lubchenco, "Protecting the global ocean for biodiversity, food and climate," *Nature*, vol. 592, pp. 397–402, 2021.

[4] C. Cleguer, A. Grech, C. Garrigue, and H. Marsh, "Spatial mismatch between marine protected areas and dugongs in New Caledonia," *Biol. Conserv.*, vol. 184, pp. 154–162, 2015.

[5] Republic of Indonesia, *Law of the Republic of Indonesia No. 27 of 2007 on Management of Coastal Areas and Small Islands*, 2007.

[6] M. D. Barnes, I. D. Craigie, N. Dudley, and M. Hockings, "Understanding local-scale drivers of biodiversity outcomes in terrestrial protected areas," *Ann. N. Y. Acad. Sci.*, vol. 1399, no. 1, pp. 42–60, 2016.

[7] T. Warningsih, Kusai, L. Bathara, Zulkarnain, and Deviasari, "Economic valuation of mangrove ecosystem services in Sungai Apit District, Siak Regency, Riau Province, Indonesia," in *IOP Conf. Ser.: Earth Environ. Sci.*, vol. 695, no. 1, Article Number: 012036, 2021, DOI: 10.1088/1755-1315/695/1/012036.

[8] Coordinating Ministry for Maritime Affairs (Indonesia), *Marine Protected Area Management Policy in Indonesia*. Jakarta, Indonesia: Assistant Deputy for Environment and Maritime Disasters, Deputy for Coordination of Natural Resources and Services, 2017, 174 p.

[9] E. M. De Santo, "Missing marine protected area (MPA) targets: How the push for quantity over quality undermines sustainability and social justice," *J. Environ. Manage.*, vol. 124, pp. 137–146, 2013.

[10] G. J. Edgar, R. D. Stuart-Smith, T. J. Willis, S. Kininmonth, S. C. Baker, S. Banks, and R. J. Thomson, "Global conservation outcomes depend on marine protected areas with five key features," *Nature*, vol. 506, no. 7487, pp. 216–220, 2014.

[11] D. Rodríguez-Rodríguez, S. E. Rees, L. D. Rodwell, and M. J. Attrill, "Assessing the socioeconomic effects of multiple-use MPAs in a European setting: A national stakeholders' perspective," *Environ. Sci. Policy*, vol. 48, pp. 115–127, 2015.

[12] J. Rolfe and J. De Valck, "Values for protecting the Great Barrier Reef: A review and synthesis of studies over the past 35 years," *Mar. Pollut. Bull*., vol. 169, p. 112531, 2021.

[13] OECD, *Marine Protected Areas: Economics, Management and Effective Policy Mixes*. Paris, France: OECD Publishing, 2017.

[14] Riau Province Marine Affairs and Fisheries Department, *Riau Province Fisheries Service Annual Report 2016*. Riau, Indonesia, 2016.

[15] Republic of Indonesia, Ministry of Marine Affairs and Fisheries, *Decree of the Minister of Marine Affairs and Fisheries (Kepmen KP) No. 73/Kepmen KP/2021 regarding the Archipelago Marine Protected Area*, 2021.
[16] P. Dasgupta, *The Economics of Biodiversity: The Dasgupta Review*. London, U.K.: HM Treasury, 2021.
[17] T. Warningsih, Kusai, Zulkarnain, L. Bathara, I. Mulyani, and Deviasari, "Economic valuation of mangrove ecosystem in coastal area of Rokan Hilir Regency, Riau Province," *J. Econ. Soc. Fish. Mar.*, vol. 7, no. 2, pp. 239–248, 2020.
[18] T. Warningsih, Kusai, L. Bathara, Zulkarnain, T. Ramadona, and Deviasari, "Management strategy of mangrove ecosystem in Siak Regency, Riau Province, Indonesia," *J. Econ. Soc. Fish. Mar.*, vol. 9, no. 1, pp. 60–71, 2021.
[19] T. Warningsih, Kusai, L. Bathara, Deviasari, M. Manalu, and Z. S. Syahzanani, "Economic valuation of tourism in Rupat Island, Bengkalis Regency, Riau Province using the travel cost method," *J. Fish. Mar. Res.*, vol. 5, no. 3, pp. 508–513, 2021.
[20] T. Warningsih, D. Efizon, N. Aulia, and Deviasari, "Economic value of carbon in mangrove ecosystem of Cawan Island, Indragiri Regency, Riau, Indonesia," in *IOP Conf. Ser.: Earth Environ. Sci.*, vol. 1118, no. 1, Article Number: 012080, 2022, DOI: 10.1088/1755-1315/1118/1/012080.
[21] T. D. Handayani, T. Warningsih, and L. Bathara, "The economic valuation of Marjoly Beach and resort tour with travel cost method, Bintan District, Riau Islands Province," *J. Perikanan dan Kelautan*, vol. 26, no. 2, pp. 115–124, 2021.
[22] Saprianto, T. Warningsih, and L. Bathara, "Economic valuation of the mangrove ecosystem in Rawa Mekar Jaya Village, Sungai Apit District, Siak Regency," *Asian J. Aquat. Sci.*, vol. 5, no. 2, pp. 228–233, 2022.
[23] S. N. Ulfia, T. Warningsih, and V. Amrifo, "Economic value of sea grapes (*Caulerpa racemosa*) in Mapur Island, Bintan Pesisir District, Kepulauan Riau Province," *Asian J. Aquat. Sci.*, vol. 6, no. 2, pp. 260–264, 2023.
[24] M. Costello, "Evidence of economic benefits from marine protected areas," *Sci. Mar*., vol. 88, no. 1, pp. e080, 2024.
[25] L. M. Brander, R. de Groot, J. P. Schagner, V. Guisado-Goni, V. van't Hoff, S. Solomonides, A. McVittie, F. Eppink, M. Sposato, L. Do, A. Ghermandi, M. Sinclair, and R. Thomas, "Economic values for ecosystem services: A global synthesis and way forward," *Ecosyst. Serv*., vol. 66, pp. 101606, 2024.
[26] F. Cavada-Blanco, A. Cróquer, E. Yerena, and J. P. Rodríguez, "Flow of economic benefits from coral reefs in a multi-use Caribbean marine protected area using network theory," *Front. Mar. Sci*., vol. 8, pp. 671024, 2021.
[27] B. G. Reguero, M. W. Beck, V. N. Agostini, P. Kramer, and B. Hancock, "Coral reefs for coastal protection: A new methodological approach and engineering case study in Grenada," *J. Environ. Manage*., vol. 210, pp. 146–161, 2018.
[28] H. S. Lenihan, J. P. Gallagher, J. R. Peters, A. C. Stier, J. K. K. Hofmeister, and D. C. Reed, "Evidence that spillover from marine protected areas benefits the spiny lobster (Panulirus interruptus) fishery in southern California," *Sci. Rep*., vol. 11, pp. 2663, 2021.
[29] S. Van Schoubroeck, S. Anougmar, M. F. e Silva, V. Ala-Harja, V. Statzu, G. Everaert, L. Watt, F. R. Barboza, and T. Compernolle, "Valuation of ecosystem services in marine protected areas: A comprehensive review of methods and needed developments," *Ecosyst. Serv*., vol. 70, pp. 101678, 2024.
[30] UNEP, *Status of Coral Reefs of the World*: 2020. Nairobi, Kenya: Global Coral Reef Monitoring Network (GCRMN) and International Coral Reef Initiative (ICRI), 2020.
[31] L. Burke and M. Spalding, "Shoreline protection by the world's coral reefs: Mapping the benefits to people, assets, and infrastructure," *Mar. Policy*, vol. 146, pp. 105311, 2022.
[32] X. Li and F. Zhao, "Integrated approaches to restore ecosystem functions in degraded coral reefs," *Int. J. Mar. Sci*., vol. 14, no. 6, pp. 350–358, 2024.

[33] J. Carlot, M. Vousdoukas, A. Rovere, T. Karambas, H. S. Lenihan, M. Kayal, M. Adjeroud, G. Pérez Rosales, L. Hedouin, and V. Parravicini, "Coral reef structural complexity loss exposes coastlines to waves," *Sci. Rep*., vol. 13, pp. 1683, 2023.
[34] J. T. Hill, A. D. Olds, B. L. Gilby, J. D. Mosman, A. L. James, and C. J. Henderson, "Seascape connectivity shapes fish functional diversity, ecosystem functioning and resilience in subtropical coral reefs," *Coral Reefs*, vol. 44, pp. 1771–1788, 2025.
[35] C. D. Storlazzi, B. G. Reguero, K. C. Alkins, J. B. Shope, C. Gaido-Lassarre, T. S. Viehman, and M. W. Beck, "Hybrid coral reef restoration can be a cost-effective nature-based solution to provide protection to vulnerable coastal populations," *Sci. Adv*., vol. 11, pp. eadn4004, 2025.
[36] R. R. Carlson, J. Klitzke, G. C. Daily, L. B. Crowder, B. G. Reguero, and G. P. Asner, "Coastal business perception of coral value and payment for coral restoration," *Sci. Rep*., vol. 15, pp. 9285, 2025.
[37] A. M. Pacifico, L. Mulazzani, and G. Malorgio, "Are the economic valuations of marine and coastal ecosystem services supporting policymakers? A systematic review and remaining gaps and challenges," *Front. Mar. Sci*., vol. 11, pp. 1501812, 2025.
[38] S. Mehvar, T. Filatova, A. Dastgheib, E. De Ruyter van Steveninck, and R. Ranasinghe, "Quantifying economic value of coastal ecosystem services: A review," *J. Mar. Sci. Eng*., vol. 6, no. 1, pp. 5, 2018.
[39] D. Setiady and E. Usman, "Coral reefs based on sea depth and the influence of sediment in the waters of the Aruah Islands, Rokan Hilir Regency, Riau Province," J. Lingkung. dan Bencana Geol., vol. 9, no. 1, pp. 21–30, 2018.
[40] M. Mira, S. Saptanto, and H. Hikmah, "Valuation of the economic value of coral reefs in Banda Neira," *J. Sosek KP*, vol. 12, no. 1, pp. 11–20, 2017.
[41] IDB, *Economic Valuation of Ecosystem Services Provided by Blue Economy Ecosystems in the Dominican Republic*. Washington, DC, USA: Inter-American Development Bank, 2024.
[42] S. Farahmand, N. Hilmi, and C. M. Duarte, "The rise and flows of blue carbon credits advance global climate and biodiversity goals," *npj Ocean Sustain*., vol. 4, p. 39, 2025.
[43] I. Soemarwoto, *Ecology, Environment and Development*. Jakarta, Indonesia: Djambatan, 2021.
[44] Haslinda, *Economic Valuation of Coral Reef Ecosystem of Kapoposang Marine Tourism Park, Pangkep Regency*. Makassar, Indonesia: Postgraduate Program, Hasanuddin University, 2012.
[45] H. Cesar, "Coral reefs: Their functions, threats and economic value," in *Collected Essays on the Economics of Coral Reefs*, H. Cesar, Ed. Kalmar, Sweden: Coral Reef Degradation in the Indian Ocean Program, Kalmar University, 2000, pp. 14–39.
[46] S. Ison, T. Ison, P. Marti-Puig, K. Needham, M. K. Tanner, and J. M. Roberts, "Tourist preferences for seamount conservation in the Galapagos Marine Reserve," *Front. Mar. Sci*., vol. 7, pp. 602767, 2021.
[47] R. Luque-Lora, A. Keane, J. A. Fisher, G. Holmes, and C. A. Sandbrook, "A global analysis of factors predicting conservationists' values," *People Nat*., vol. 4, pp. 1339–1351, 2022.
[48] D. U. Rahman, F. J. L. Risamasu, H. Upa, "Economic valuation of coral reefs after the establishment of the Sawu Sea conservation area in Kupang Regency," *J. Mar. Aquat. Sci.*, vol. 6, no. 1, pp. 22–26, 2020.
[49] S. Hanli, Z. Xin, L. E. E. Chunhung, J. I. A. Jingbo, and K. R. Hayat, "Tourists' willingness to pay for the non-use values of ecotourism resources in a national forest park," *J. Resour. Ecol*., vol. 14, no. 2, pp. 331–343, 2023.
[50] Hasmin, *Economic Assessment of Coral Reefs in the Waters of Kapoposang Island, Sarappo Keke, and Saugi Pangkep Regency*. Makassar, Indonesia: Postgraduate Program, Resource Economics Study Program, Hasanuddin University, 2006.

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