Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(5): 2307 – 2325 (2025)
www.ejabf.journals.ekb.eg

Social-Ecological Systems Study of Biodiversity Threats and Mangrove Ecosystem Degradation in Yotefa Bay, Jayapura City, Indonesia

Yunus Pajanjan Paulangan[1*], Basa Tunggul Rumahorbo[1,2], Sudirman Adibrata[3], Khristhoper Aris Arianto Manalu[1,2], Muhammad Hisyam[1,2], Fitra Yunia Ramba[1,2], Tamara Louraine Jeanette Kainama[1,2], Natan Baransano[2]

[1]Marine Science Study Program, Cenderawasih University, Kampus Uncen Waena Camp Wolker Street, Jayapura, Indonesia 99358
[2]Center for Marine Resources and Fisheries Studies, Cenderawasih University, Kampus Uncen Waena Camp Wolker Street, Indonesia 99358
[3]Marine Science Department, Faculty of Agriculture, Fisheries and Marine, Bangka Belitung University, Kampus Terpadu UBB Gd. D Ds Balunijuk Kec. Merawang, Bangka Belitung Islands, Indonesia 33171

[*]Corresponding Author: ypaulangan@gmail.com

ARTICLE INFO

Article History:
Received: Feb. 20, 2025
Accepted: Sep. 15, 2025
Online: Oct. 10, 2025

Keywords:
Social-ecological System,
Mangrove,
Biodiversity,
Yotefa Bay

ABSTRACT

Papua is known as a megabiodiversity area, mangroves in Yotefa Bay. However, Yotefa Bay is currently facing significant degradation, threatening both its biodiversity and the livelihoods of the local community. This study aimed to assess SES conditions related to mangrove ecosystem management in Yotefa Bay. Data were collected through literature reviews, structured in-depth interviews, and focus group discussion. The analysis was conducted using the DPSIR framework, a systems thinking approach that explores the causal relationships between social-economic, and environmental components. The study's findings indicate that the mangrove area in Yotefa Bay is shrinking by 37.98 hectares over the past 10 years, namely from 2014 to 2024, driven by population growth, undervaluation of the mangrove ecosystem's economic significance, limited livelihood opportunities for the community, low incomes, and limited knowledge of mangrove management. As a result, water quality is declining, mangrove areas are diminishing, ecosystem biodiversity is decreasing, conflicts over land use are escalating, and decreased carrying capacity. We recommend the following actions: 1) Reducing the rate of pollution by increasing environmental education for communities in pollution source areas; 2) Rehabilitatig and restoring damaged or lost mangrove areas; 3) Educating the community on the benefits and importance of mangrove ecosystems and sustainable management practices by environmental education; 4) Developing a collaborative management model for better resource governance; 5) Promoting and developing ecotourism as a means to enhance economic benefits while supporting conservation efforts; 6) Ensuring consistent implementation of the applicable rules and regulations; and 7) Construction of a wave damper in front of Cibery Beach.

INTRODUCTION

Papua is widely recognized for its extraordinary biodiversity, encompassing a vast array of flora and fauna across both terrestrial and marine environments. This remarkable diversity has earned Papua the distinction of being a megabiodiversity area **(Kartikasari *et al*., 2012; Cámara-Leret *et al*., 2020; Murdjoko *et al*., 2020; Murdjoko *et al*., 2021)**. Numerous expeditions on the island, including those focusing on coastal and marine ecosystems such as mangroves, have highlighted this richness. According to *The Ecology of Papua*, the region's mangrove ecosystems support a wide variety of species, including approximately 30 species of reptiles, 12 species of amphibians, 250 species of birds, 50 species of mammals, 195 species of fish, 95 species of mollusks, and 80 species of crustaceans **(Kartikasari *et al*., 2012)**. This biodiversity is largely attributed to the relatively undisturbed state of Papua's waters, the diversity of ecosystems and their interactions, along with the region's unique geographical location and geological history **(Tomascik *et al*., 1997; Suripto, 2000; Indrawan *et al*., 2007)**.

Ironically, several mangrove areas in Papua are beginning to degrade, including Yotefa Bay. This area is now facing significant degradation (**Manalu *et al*., 2011; Paulangan, 2014; Kalor & Paiki, 2021**), posing a serious threat to biodiversity and the livelihoods of surrounding communities, particularly indigenous communities who hold customary rights to these resources **(Paulangan *et al*., 2014; Elisabeth, 2019; Rumahorbo *et al*., 2020; Kalor & Paiki, 2021)**. This damage is closely linked to the local community's understanding and perception, particularly among those with customary rights, of the economic and socio-cultural value of the mangrove ecosystem. It is known that mangrove ecosystems play a crucial role in supporting the local economy, yet the community's dependence on these ecosystems also poses a threat to their long-term sustainability **(Auliansyah *et al*., 2020)**. In the broader context of coastal and marine area management, these dynamics are framed within the Socio-Ecological Systems (SES) paradigm approach **(Adrianto & Aziz, 2006; Paulangan *et al*., 2021)**.

This concept emphasizes the interconnectedness of humans and nature, viewing human and ecological systems as interrelated components of a single, integrated whole **(Costanza, 1999; Berkes *et al*., 2000; Costanza *et al*., 2000; Berkes *et al*., 2003; Glaser & Glaeser, 2010)**. This concept also emphasizes the need to view humans as an integral part of nature and the functional interdependence between social and ecological changes **(Berkes & Folke, 1998)**. This is crucial for effective management, as SES are complex adaptive systems **(Anderies *et al*., 2004; Levin *et al*., 2013; Petrosillo *et al*., 2015; Kanwar, 2018)**. Understanding SES interaction and its connectivity is crucial in integrated management **(Sidlea *et al*., 2013; Gillson *et al*., 2014)**, especially in addressing anthropogenic impacts **(Virapongse & Alessa, 2016; Kanwar, 2018)**. The complexity of these dynamics is best described through the SES framework **(Ostrom, 2009; De Vos *et al*., 2019)**. One SES approach is to use the Driver-Pressure-State-

Impact-Response (DPSIR) analysis, which assumes a causal relationship **(Bradley & Yee, 2015)**.

This study aimed to identify the condition of SES and its connectivity to determine the driving factors, pressures, impacts, and responses related to mangrove degradation in Yotefa Bay using Driver-Pressure-State-Impact-Response (DPSIR) analysis. Therefore, this research combined social and ecological understanding in addressing biodiversity loss and mangrove degradation in Yotefa Bay with the SES paradigm approach.

MATERIALS AND METHODS

Time and location of research

This study was conducted over a period of 7 (seven) months in 3 (three) villages within the Yotefa Bay area: Enggros Village, Tobati Village, and Nafri Village. These villages were selected for their representation of mangrove ecosystems and communal (customary) ownership rights in Yotefa Bay (Fig. 1).

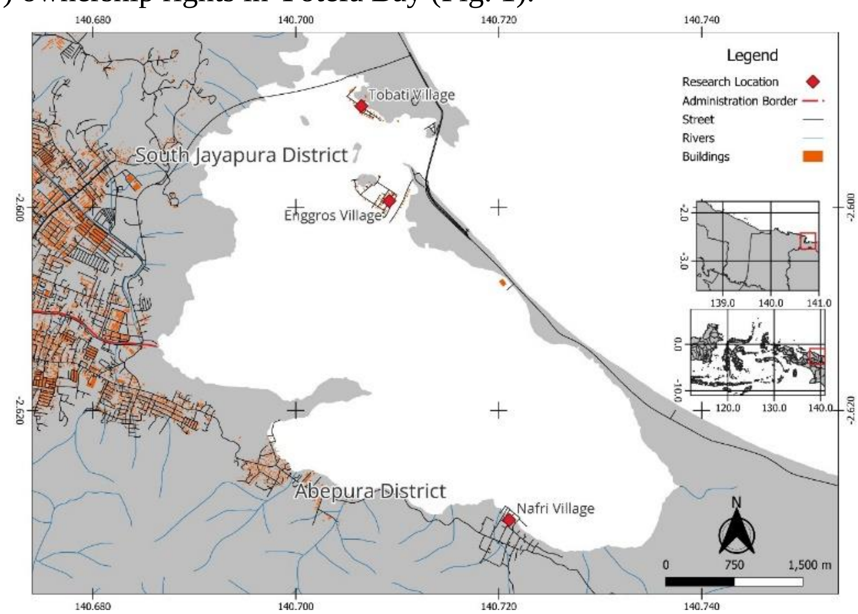

Fig. 1. Research location map

Data collection techniques

This study employed three primary methods for data collection: (1) literature review, (2) structured in-depth interviews using questionnaires, and (3) focus group discussions. The survey was conducted in the Yotefa Bay mangrove ecosystem, covering both mangrove forests and socio-economic infrastructure. Interviews were carried out with 40 respondents from each selected village, as well as 40 other stakeholders, totaling 120 respondents. This sample size was deemed sufficient to represent the conditions and perceptions of the community in each village.

Respondents were selected through purposive sampling, based on criteria such as their understanding of the issues being studied, their ability to articulate opinions and ideas, and their representation of various characteristics and backgrounds (e.g., position, education, age, and gender). Additionally, respondents had to be willing to participate.

Measuring the extent of degradation in mangrove in Youtefa Bay was carried out by digitizing the mangrove area to form polygons from Sentinel-2 satellite imagery in 2014 and 2024 using ArcGIS 10.2 **(Rosalina *et al*., 2023)**. The 2014 digitization results were overlaid with the 2024 digitization results using the normalized difference vegetation index (NDVI) to detect the differences **(Aritonang *et al.*, 2022)**.

Water quality sampling locations were selected to represent the overall water quality of all water sources within each village. Water samples were collected following standard procedures SNI 6989.57: 2008 concerning surface water sampling methods **(BSN, 2008)**. Temperature, salinity, pH, and DO were measured *in situ*. Meanwhile, BOD_5, nitrate, phosphate and ammonia were analyzed at the Papua Province Regional Hospital Laboratory. Water samples were taken in polyethylene bottles that had been previously cleaned using improvized sampling methods. Samples for analysis were stored in a cool box at a temperature of around 4-6^{0}C and were taken to the laboratory for chemical analysis **(Bouhayene & Djebar, 2014)**. Secondary data were gathered through literature reviews of relevant journals, research reports, and other scientific sources.

Data analysis

The obtained water quality parameter data were discussed descriptively. The data produced in this research were compared with quality standards based on Minister of Environment Decree Number 51 of 2004, Government Regulation Number 22 of 2021 concerning the Implementation of Environmentsl Protection and Management and the results of previous research.

The DPSIR (Driver-Pressure-State-Impact-Response) analysis was conducted descriptively, presenting qualitative and quantitative data in the form of diagrams and tables. The DPSIR approach was used to identify and analyze the relationships between the factors exerting pressure on the mangrove ecosystem, allowing for an assessment of the intensity of human resource use and activities in coastal areas. The DPSIR conceptual model is a widely recognized framework that illustrates the causal relationships between environmental and human systems and has been extensively used for analyzing and assessing social-ecological system (SES) issues **(Piragnolo *et al.*, 2014; Petrosillo *et al*., 2015; Balzan *et al*., 2019)**. The modified DPSIR framework, adapted from **Baldwin *et al.* (2016)**, is depicted in Fig. (2).

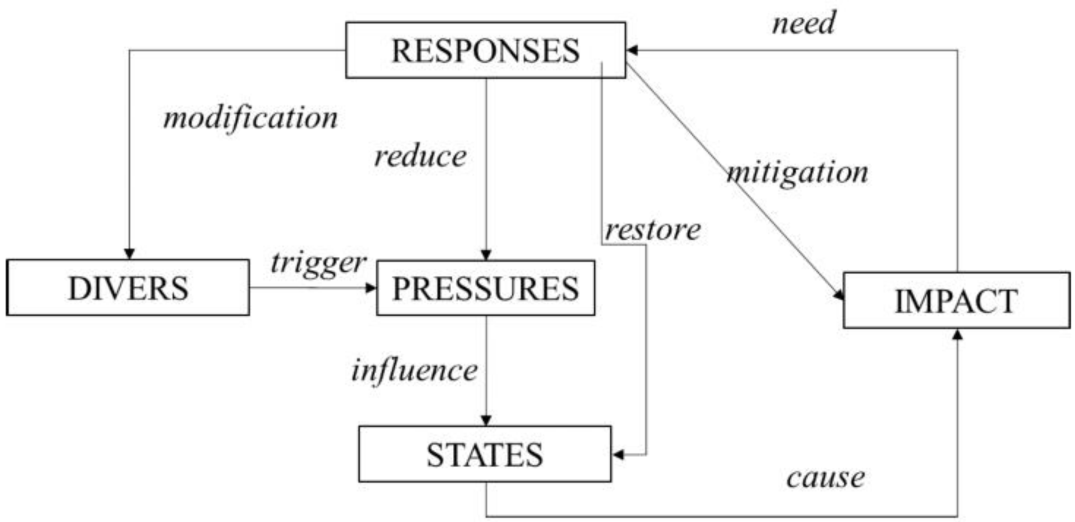

Fig. 2. DPSIR concept (adopted from **Baldwin *et al.*, 2016**)

Connectivity network analysis was conducted based on established connectivity patterns **(Anderies *et al.*, 2004)**. The results are presented graphically and discussed using descriptive analysis and triangulation methods **(Mudjiyanto, 2018)**.

Management strategy recommendations using the interpretative structural modeling (ISM) method developed by **Saxena *et al*. (1992)** were followed as a strategic planning model for identifying and concluding various relationships between factors in a particular problem or issue **(Paulangan *et al.*, 2022)**. This method helps identify factors related to the problem and analyze the reciprocal interactions between these factors as well as determine the rank order of factors and directions for solving complex problems **(Wankhade & Kundu, 2020)**. This method also provides a relationship between driving force and dependency factors **(Kumar & Sing, 2019)**.

RESULTS

Hydrological, oceanographic, and water environmental conditions

Jayapura City features a diverse topography, ranging from plains to sloping, hilly/mountainous areas, flat, slightly steep to very steep, each of which has potential and obstacles in water infiltration, evaporation, erosion, surface flow, landslides. Yotefa Bay is situated in a coastal region characterized by a semi-closed **(Tebay *et al*., 2014; Mandey, 2019)** and is located within Yos Sudarso Bay, Jayapura City, making it a bay within a bay **(Mandey, 2019)**.

Jayapura City is home to four major rivers: the Acai River and the Kamp Wolker River in Abepura District, the Anfri River in North Jayapura, and the Tami River in Tami District. Specifically, two rivers, the Acai River and the Entrop River, flow into the Yotefa Bay area. According to data from BMKG and Pushidros TNI-AL, the tide pattern in Jayapura City is classified as a mixed tide with a prevailing semidiurnal pattern. The tidal height can reach up to 1.2 meters **(https://pasanglaut.com/id/papua/kota-jayapura; BMKG, 2023)**. According to data from 2022-2023, wave heights in the waters of Jayapura City reach their peak between December and February, ranging from 1.25 to 2 meters, which is classified as moderate. The lowest wave heights occur between June and September, ranging from 0.50 to 1.00 meters, classified as low **(BMKG, 2023)**. The quality of the aquatic environment in Yotefa Bay has been documented in several research studies. The findings are summarized in Table (1).

Table 1. Condition of the aquatic environment quality in Yotefa Bay

Parameter	Unit	Quality Standard[1,2]	Analysis Results (2024)	Mandey, 2019	Manalu *et al.*, 2011	Kalor & Paiki (2021)	Handono,. *et al.*, (2014)
Temperature	^{O}C	28-32	28-31	30-31	-	24	
Salinity	mg/l	s/d 34	23-28	22-29	-	24	4.55–24.48
DO	ppm	>5	4-7,5		2.13 – 5.79	4.6	
pH	-	7-8.5	7,2-8,2	6.8-8.1	7-8.5	6.8	7.01–7.22
BOD_5	mg/l	20	8,00-20,4	-	8.06-24.5	-	-
TSS*	mg/l	80	78-186	-	89-267.5	-	-
Nitrate (NO3-N	mg/l	0.008	1.85-1.98	-	0.004-0.03	-	-
Phosphate (PO4-P)	mg/l	0.015	0.86-1.80	-	0.02-1.65	-	-
Ammonia(NH3-N)	mg/l	0.3	2.06-3.27	-	0.03-0.24	-	-

Source: PP No. 22/2021 concerning the Implementation of Environmental Protection and Management, [2]KepmenLH No. 51 of 2004 concerning Sea Water Quality Standards; *Mangrove; (-) no data.

Based on pollution index calculations, the waters of Yotefa Bay are generally classified as lightly polluted **(Manalu *et al*., 2011)**. According to the data presented in Table (1), the water quality in Yotefa Bay mostly meets seawater quality standards. However, several parameters exceed these standards at certain points, including dissolved oxygen (DO), biochemical oxygen demand (BOD_5), total suspended solids (TSS), nitrate (NO_3-N), phosphate (PO_4-P), and ammonia (NH_3-N).

This suggests a significant influx of organic waste into Yotefa Bay from various rivers, leading to elevated BOD_5 levels. High nitrate and phosphate levels are likely attributed to nearby land use **()**, with wastewater discharge also contributing to increased nitrate and phosphate concentrations **(Pangaribuan *et al*., 2013; Kritiyasari *et al*., 2021; Putera *et al*., 2021; Paembonan *et al*., 2022)**. Waste discharge is notably high, particularly from the Yotefa and Buaya Rivers. Additionally, ammonia levels have exceeded quality standards. Ammonia in aquatic environments typically originates from the nitrogen cycle, involving the decomposition of organic matter or excretion by aquatic organisms. This inorganic compound, a form of total ammonia nitrogen (TAN), is toxic and can pose a threat to aquatic life.

Biophysical conditions of mangrove ecosystems

The mangroves in the Yotefa Bay area have suffered significant damage over the years **(Handono *et al*., 2014; Paulangan, 2014; Antoh, 2015; Hamuna & Tanjung, 2018)**. Analysis indicates that, as of 2024, only 173.47 hectares of mangrove area remain (Fig. 8). Thus, there has been a decrease in the mangrove area of 37.98 hectares over the last 10 years, namely from 2014 to 2024.

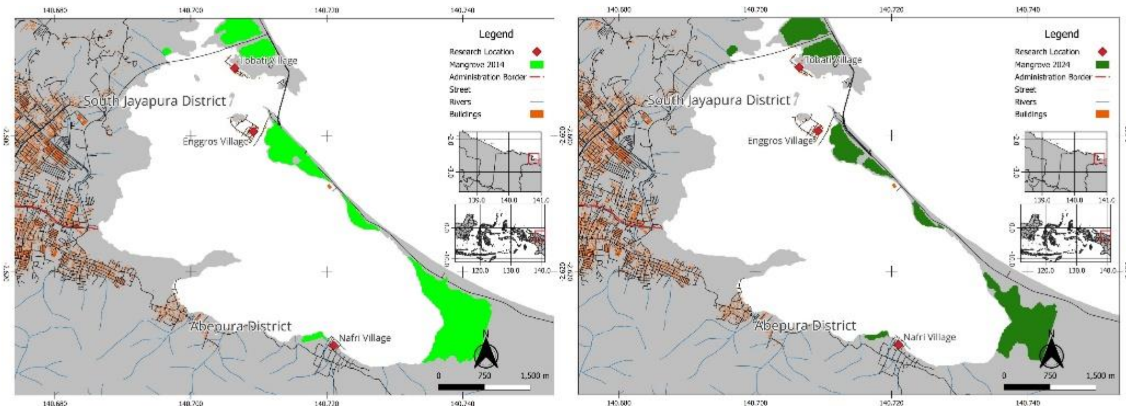

Fig. 8. Mangrove area comparison: 2014 vs. 2024 based on analysis results

The most substantial reduction in mangrove area occurred between 1967 and 2000, as illustrated in Fig. (9). This decline is largely attributed to the conversion of mangrove areas into residential and commercial developments, particularly in the Entrop and Hamadi regions.

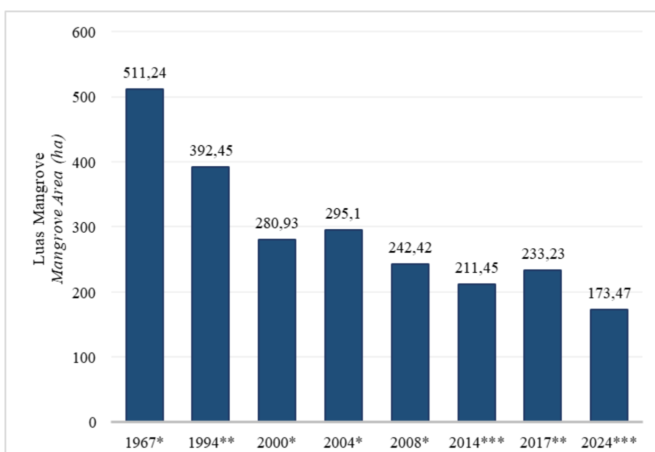

Fig. 9. Graph of changes in mangrove area

Source: *BPKH Region X Papua in **Handono *et al.* (2014)**; **__Hamuna *et al.* (2018)__**; ***__Analysis Results (2024)__**

Yotefa Bay is home to 24 mangrove species (Table 2). The mangrove vegetation in this area is predominantly composed of *Rhizophora apiculata*, followed by *Rhizophora mucronata* and *Rhizophora stylosa* **(Lewaherilla, 2007; Paulangan, 2007; Hamuna *et al*., 2018; Handono *et al*., 2018; Randongkir *et al*., 2019)**.

Table 2. Mangrove species found in Yotefa Bay

Mangrove Species	Randongkir, *et al.* (2019)	Lewaherilla, (2007)	Hamuna, *et al.* (2018)	Handono, *et al.* (2018)	Paulangan (2007)	Analysis Result (2024)
Rhizophora mucronate	-	√	√	√	√	√
R. apiculate	√	√	√	√	√	√
R. alba	-	√	-	-	-	-
R. Stylosa	-	-	√	√	√	√
Avicennia alba	√	-	√	√	√	√
A.marina	-	-	-	-	√	√
Acrosticum spesiosum	√	-	-	-	-	√
Ceripos decandra	√	-	-	-	-	√
Ceriops tagal	-	√	-	√	√	-
Aegiceras corniculatum	-	-	-	-	√	-
Scyphyphora hydrophylacea	-	-	-	-	√	√
Pandanus tectorius	√	-	-	-	-	√
Sonneratia caseolaris	-	√	-	√	-	√
S. ovata	-	√	√	√	-	√
S. alba	√	-	√	√	√	√
Xylocarpus menkongensis	√	-	-	-	-	-
X. granatum	-	-	√	√	√	√
X. mollucensis	-	-	-	-	√	-
Acrostichum speciosum	√	-	-	-	-	-
Bruguiera cylindrica	√	-	√	-	√	√
B. gymnorrhiza	-	-	√	√	√	√
Casuarina sp.	√	-	-	-	-	√
Derris trifolia	√	-	-	-	-	-
Nifa fruticans		√			√	

Note: (√) indicates presence; (-) indicates absence

Community perceptions on mangrove degradation, deforestation, and its impacts

Research and interviews with communities in the three villages reveal that mangrove degradation and deforestation are primarily driven by the conversion of mangrove land into residential areas, clearing of mangrove forests for road and bridge construction, pond creation, and extraction of building materials. All respondents indicated that the mangrove condition has significantly deteriorated over the past 20 years. Additionally, respondents reported a decrease in fish catches, consistent with several studies indicating that fisheries production is closely linked to the extent of mangrove forests **(Botero *et al*., 2019; Carrasquilla-Henao *et al*., 2019; Ismail *et al*., 2019)**.

Social characteristics

The total population in the three study villages is 1,914 individuals, as detailed in Table (3).

Table 3. Population of Enggros, Tobati, and Nafri Villages

Village Name	Number of people		Total
	Men	Women	
Tobati Village	181	172	353
Enggros Village	265	260	525
Nafri Village	506	530	1036
Total	952	962	1914

Source: Village Profile Data (2023).

Based on the occupational groups by household head (Table 4), fishing is the most dominant occupation across the three villages, with the highest concentration in Enggros Village.

Table 4. Occupational groups by head of household

Occupational Groups*	Enggros Village	Tobati Village	Nafri Village	Total
Fishermen	116	30	44	190
Civil Servants	26	29	38	93
Military/Police	7	5	8	20
Farmers	-	20	118	138
Total	149	84	208	441

Source: Village Profile Data (2023).

DISCUSSION

The DPSIR condition of the Yotefa Bay mangrove ecosystem is illustrated in Fig. (11) as follows:

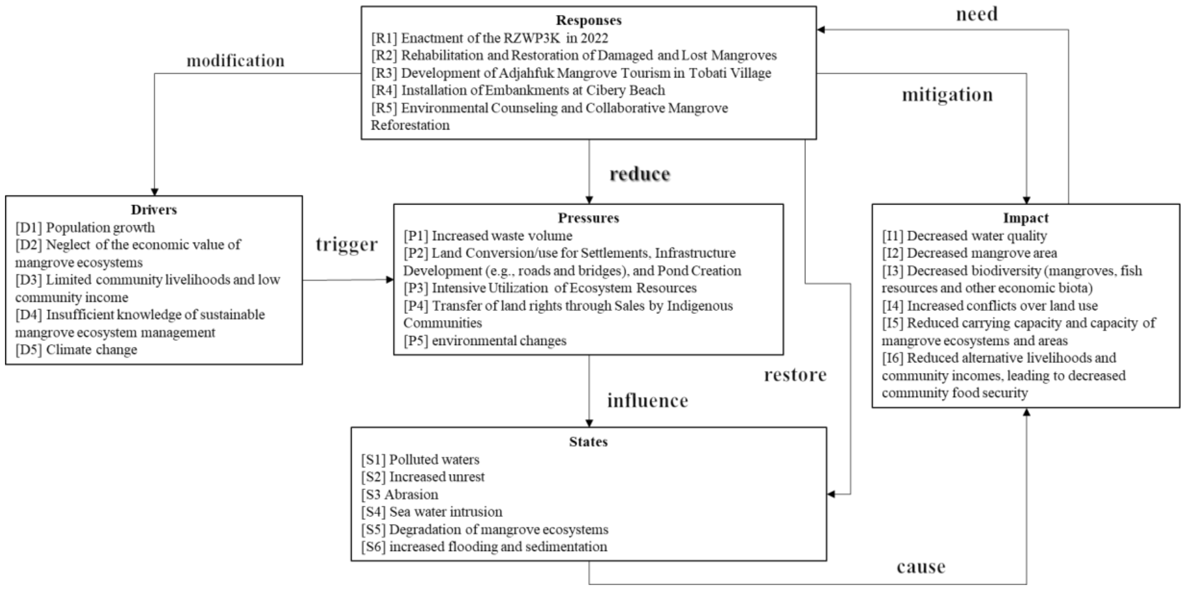

Fig. 11. SES framework in mangrove ecosystem in Yotefa Bay

As depicted in Fig. (11), the damage and loss of biodiversity in the Yotefa Bay mangrove ecosystem **(Manalu *et al*., 2011; Paulangan, 2014; Kalor & Paiki, 2021)** are driven by several factors, including population growth, undervaluation of the mangrove ecosystem's economic benefits, limited community livelihoods, low incomes, inadequate knowledge of sustainable mangrove management and climate change. These factors contribute to various issues, such as deteriorating water quality, reduction in mangrove area, loss of biodiversity (affecting mangroves, fish resources, and other economically important species), increased conflicts over land use, and a decline in the overall carrying capacity of the mangrove ecosystem. Damage to the mangrove ecosystem and loss of biodiversity will ultimately impact the native communities around the Yotefa Bay area **(Paulangan *et al*., 2014; Elisabeth, 2019; Rumahorbo *et al*., 2020; Kalor & Paiki, 2021)**.

Currently, the government and other stakeholders have implemented several responses, including: the formulation of the RZWP3K (Coastal Area and Small Islands Zoning Plan) for Papua Province, enacted in 2022; the rehabilitation and restoration of damaged and lost mangroves through a collaborative mangrove planting program; the development of Adjahfuk mangrove tourism in Tobati Village; the installation of embankments at Cibery Beach; and the promotion of environmental education.

The primary threats to the mangrove ecosystem in Yotefa Bay include: increased waste volume, land conversion for settlement and infrastructure development (such as roads and bridges), pond creation, intensive ecosystem utilization, and the transfer of land rights through sales by indigenous peoples. Pollution in Yotefa Bay is notably high, particularly from solid waste entering via the Yotefa River and Buaya River, which significantly impacts communities in Enggros, Tobati, and Nafri Villages **(Manalu *et al*., 2011)**.

The conversion of mangrove areas for settlements and businesses is particularly pronounced in the Hamadi area of Tobati Village. Investigations reveal that most mangrove areas in Hamadi have been sold and certified, largely due to its strategic location near urban areas and the expansion following the construction of the ring road. This area has seen significant transformation into settlements. Additionally, the transfer of land rights from indigenous peoples to private entities has been ongoing for some time.

Another significant threat is coastal erosion around Cibery Beach, exacerbated by the construction of the Yotefa Bridge. The bridge's pillars have altered current patterns, leading to increased erosion of the Cibery Beach area.

DPSIR SES connectivity in Yotefa Bay

The DPSIR connectivity of the SES in Yotefa Bay is illustrated in Fig. (12).

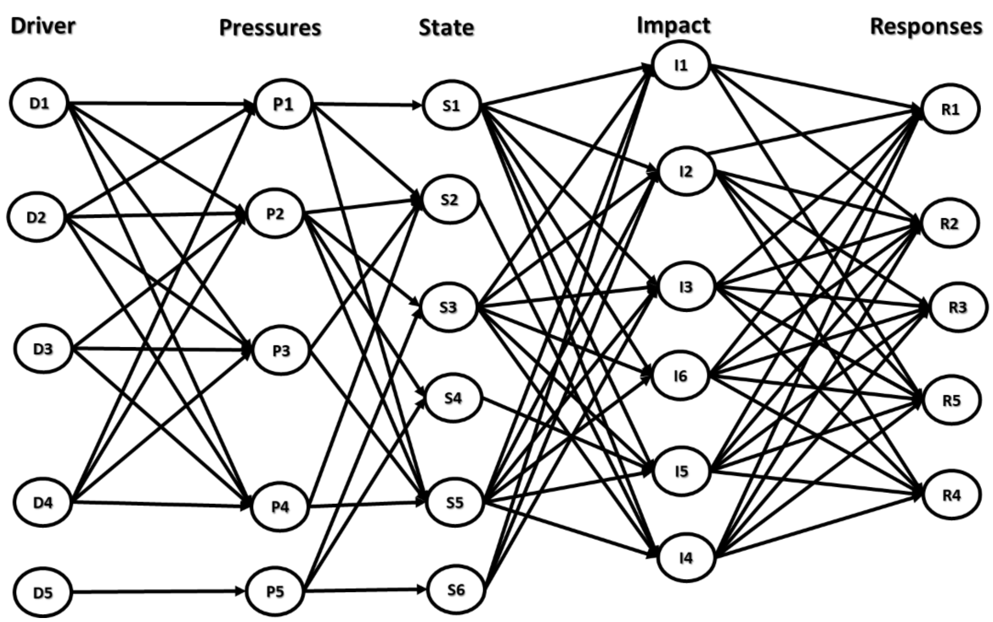

Fig. 12. Complex DPSIR connectivity model of the mangrove ecosystem in Yotefa Bay

The community in Yotefa Bay, with its varied social conditions, can influence the ecological system, and conversely, changes in the ecological system can impact social and cultural conditions. The dynamics of the mangrove ecosystem in Yotefa Bay affect local community activities, including those of fishermen, wood collectors, building material gatherers, tourism operators, and others.

The SES connectivity pattern in Yotefa Bay illustrates how changes and damage to the mangrove ecosystem impact community livelihoods. The network model derived from the connectivity of the DPSIR SES components in Yotefa Bay represents a complex system (Fig. 12). The study's findings indicate that factors such as population growth, the undervaluation of the mangrove ecosystem's economic benefits, limited livelihood opportunities, low incomes, and insufficient knowledge of sustainable mangrove management contribute to ecosystem damage and biodiversity loss in Yotefa Bay.

Identify management strategies

Based on the results of the analysis, it was found that there are 4 issues and problems that are in quadrant 3 (linkage) which means they have high influence and dependence so that these issues and problems need to receive main attention (Fig. 13), namely increasing water pollution (waste: solid and liquid) [I5]; massive conversion of mangrove land (opening of roads and bridges, ponds and settlements) [I6]; transfer of ownership rights (buying and selling land) by the community [I7], abrasion on Cibery Beach [I8]. In other words, in the context of managing the mangrove ecosystem in Yotefa Bay, these issues and problems need to receive a major response in their resolution.

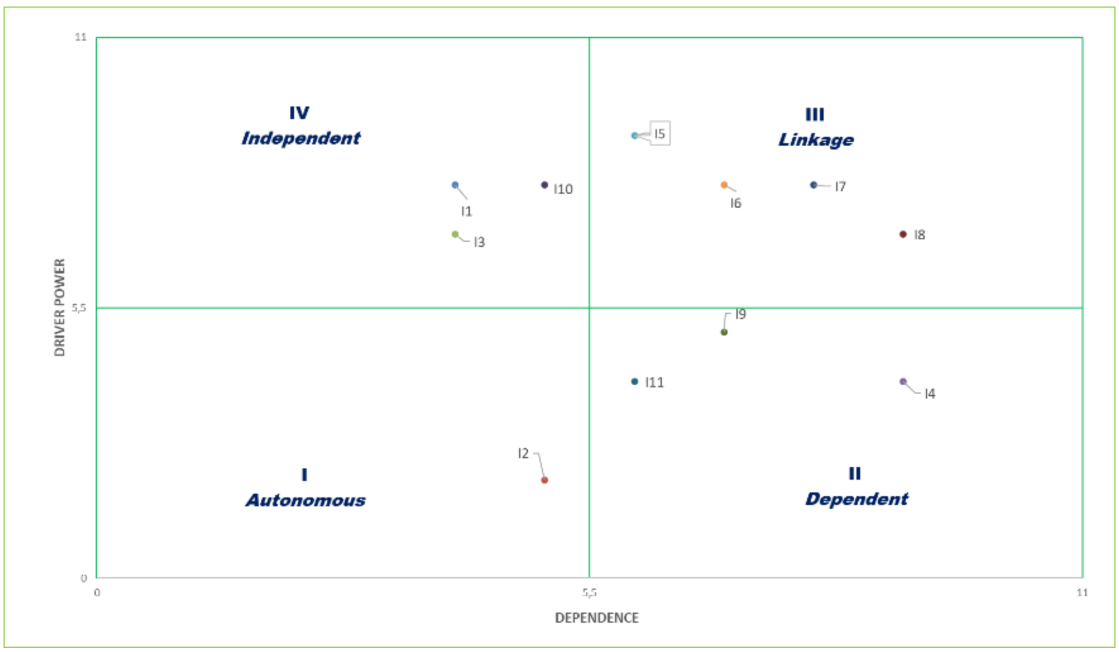

Fig. 13. Matrix of issues and problems power-dependence drivers

Description: [I1] Increase in population [I2] Climate change (uncertain weather), [I3] Limited alternative livelihoods and low community income, [I4] Limited community knowledge in managing mangrove ecosystems, [I5] Increased water pollution (solid waste and liquid waste), [I6] Massive conversion of mangrove land (opening of roads and bridges, ponds and settlements), [I7] Transfer of ownership rights (buying and selling land) by the community, [I8] Abrasion on Cibery Beach, [I9] Increased conflicts over use and ownership of areas, [I10] Decrease in fishermen's catches, and [I11] Sea water intrusion.

CONCLUSION

Based on the results of research by combining the understanding of social and ecological systems in sustainable mangrove management which contributes to ecosystem damage and loss of biodiversity in Yotefa Bay, several issues and problems were found. The DPSIR analysis reveals that the damage and loss of biodiversity in Yotefa Bay are primarily driven by factors such as population growth, undervaluation of the mangrove ecosystem's economic benefits, limited community livelihoods and low incomes, and inadequate knowledge of sustainable mangrove management. These issues have led to several negative outcomes, including decreased water quality, reduced mangrove area, diminished biodiversity (affecting mangroves, fish resources, and other economically important biota), increased conflicts over land use, and a decline in the overall carrying capacity of the mangrove ecosystem. The main management strategy based on issues and problems, namely increasing water pollution (waste: solid and liquid), massive conversion of mangrove land (opening of roads and bridges, ponds and settlements), transfer of ownership rights (buying and selling land) by the community, abrasion on Cibery Beach.

RECOMENDATION

To address these challenges, the following recommendations are proposed: 1) Reducing the rate of pollution by increasing environmental education for communities in pollution source areas; 2) rehabilitating and restoring damaged or lost mangrove areas; 3) educating the community on the benefits and importance of mangrove ecosystems and sustainable management practices by environmental education; and 4) developing a collaborative management model for better resource governance. In addition, it is recommended to 5) promote and develop ecotourism as a means to enhance economic benefits while supporting conservation efforts; 6) ensure consistent implementation of the applicable rules and regulations; and 7) construction a wave damper in front of Cibery Beach.

ACKNOWLEDGMENT

This research was funded by KEMDIKBUDRISTEK for the 2024 Fiscal Year, under Contract Number 046/E5/PG.02.00.PL/2024, dated June 11, 2024, and Derivative Contract Number 541/UN.20.2.1/PG/2024, dated June 19, 2024. The author would like to express gratitude to the following individuals and institutions for their support: the Rector of Cenderawasih University, the Rector of Bangka Belitung University, the Head of the

Institute for Research and Community Service at Cenderawasih University, the Head of the Department of Marine Science and Fisheries Science at UNCEN, the Head of the Center for Marine and Fisheries Resources Studies at Cenderawasih University, and the Heads of Enggros Village, Tobati Village, and Nafri Village. Special thanks also go to all others who contributed to the success of this research.

REFERENCES

Adrianto, L. and Aziz, N. (2006). *Valuing The Social-Ecological Interactions in Coastal Zone Management: A Lesson Learned from The Case of Economic Valuation of Mangrove Ecosystem in Barru Sub-District, South Sulawesi Province*. Seminar in Social-Ecological System Analysis. ZMT, Bremen University.

Anderies, J.M.; Janssen, M.A. and Ostrom, E. (2004). A framework to analyze the robustness of social-ecological systems from an institutional perspective. *Ecology and Society, 9*(1), 18.

Antoh, A. (2015). Peranan Hutan Mangrove pada Ekosistem Pesisir yang Terabaikan (Kerusakan Hutan Mangrove di Taman Wisata Alam Teluk Youtefa, Kota Jayapura, Prov. Papua). *Warta Konservasi Lahan Basah, 23*(1), 12–13.

Arikunto, S. (2010). *Prosedur Penelitian Suatu Pendekatan Praktik*. Rineka Cipta.

Aritonang, L.; Septyani, E. and Maria, L. (2022). Mapping of Changes in Mangrove Area Through Analysis of Landsat Satellite Imagery in Tangkokak Barat, Karawang, West Java. *Jurnal Geosains dan Remote Sensing (JGRS), 3*(1), 30–35.

Auliansyah; Kusumastanto, T.; Sadelie, A.; Aprianti, Y.; Sulindrina, A. and Nurfadillah. (2020). Valuasi Ekonomi dan Penilaian Kerusakan Kawasan Ekosistem Mangrove di Pulau Tanakeke, Kabupaten Takalar. *Inovasi, 16*(1), 72–83. https://doi.org/10.29264/jinv.v16i1.7331

Badan Standar Nasional. (2008). *SNI 6989.57:2008. Metode Pengambilan Contoh Air Permukaan*.

Baldwin, C.; Lewison, R.L.; Lieske, S.N.; Beger, M.; Hines, E.; Dearden, P.; Rudd, M.A.; Jones, C.; Satumantapan, S. and Junchompo, C. (2016). Using the DPSIR framework for transdisciplinary training and knowledge elicitation in the Gulf of Thailand. *Ocean and Coastal Management, 134,* 163–172. https://doi.org/10.1016/j.ocecoaman.2016.09.005

Berkes, F. and Folke, C. (1998). *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. Cambridge University Press.

Berkes, F.; Folke, C. and Colding, J. (2000). Linking social and ecological systems for resilience and sustainability. *Beijer Discussion Paper Series, 52*, 18–27.

Berkes, F.; Folke, C. and Colding, J. (2003). *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. Cambridge University Press.

Botero, L. and Salzwedel, H. (1999). Rehabilitation of the Cienaga Grande de Santa Marta, a mangrove-estuarine system in the Caribbean coast of Colombia. *Ocean & Coastal Management, 42*(4), 243–256. https://doi.org/10.1016/S0964-5691(98)00056-8

Bouhayene, S. and Djebar, J. (2014). Evaluation of the microbiological quality of the seawater of the main beaches of Skikda (East-Algerian). *Annals of Biological Research, 5*(12), 34–40.

Bradley, P. and Yee, S. (2015). *Using the DPSIR Framework to Develop a Conceptual Model: Technical Support Document*. US Environmental Protection Agency. EPA/600/R-15/154.

Carrasquilla-Henao, M.; Ban, N.; Rueda, M. and Juanes, F. (2019). The mangrove-fishery relationship: A local ecological knowledge perspective. *Marine Policy, 108,* 103656. https://doi.org/10.1016/j.marpol.2019.103656

Costanza, R. (1999). The ecological economics and social importance of the oceans. *Ecological Economics, 31*(2), 199–213. https://doi.org/10.1016/S0921-8009(99)00079-8

Costanza, R.; Low, B.S.; Ostrom, E. and Wilson, J. (2000). *Institutions Ecosystems and Sustainability*. Lewis Publisher.

De Vos, A.; Biggs, R. and Preiser, R. (2019). Methods for understanding social-ecological systems: a review of place-based studies. *Ecology and Society, 24*(4), 16. https://doi.org/10.5751/ES-11236-240416

Duke, N.C.; Ball, M.C. and Ellison, J.C. (1998). Factors influencing biodiversity and distributional gradients in mangroves. *Global Ecology and Biogeography Letters, 7*(1), 27–47. https://doi.org/10.2307/2997695

Elisabeth, A. (2019). Nasib Hutan Perempuan Kampung Enggros. *Mongabay.co.id*.

Folke, C.; Biggs, R.; Norström, A.V.; Reyers, B. and Rockström, J. (2016). Social-ecological resilience and biosphere-based sustainability science. *Ecology and Society, 21*(3), 41. https://doi.org/10.5751/ES-08748-210341

Gillson, L. and Marchant, R. (2014). From myopia to clarity: Sharpening the focus of ecosystem management through the lens of palaeoecology. *Trends in Ecology and Evolution, 29*(6), 317–325. https://doi.org/10.1016/j.tree.2014.03.010

Gilman, E.L.; Ellison, J.; Duke, N.C. and Field, C. (2008). Threats to mangroves from climate change and adaptation options: A review. *Aquatic Botany, 89*(2), 237–250. https://doi.org/10.1016/j.aquabot.2007.12.009

Glaser, M. and Glaeser, B. (2010). Global change and coastal marine threats: The Indonesian case. An attempt in multilevel social ecological research. *Human Ecology Review, 17*(2), 135–147.

Hamuna, B.; Sari, A.N. and Megawati, R. (2018). Kondisi Hutan Mangrove di Kawasan Taman Wisata Alam Teluk Youtefa, Kota Jayapura. *Majalah Ilmiah Biologi Biosfera: A Scientific Journal, 35*(2), 75–83.

Hamuna, B. and Tanjung, R.H.R. (2018). Deteksi Perubahan Luasan Mangrove Teluk Youtefa Kota Jayapura Menggunakan Citra Landsat Multitemporal. *Majalah Geografi Indonesia, 32*(2), 115–122. https://doi.org/10.22146/mgi.33755

Handono, N.; Tanjung, R.H.R. and Zebua, L.I. (2018). Struktur Vegetasi dan Nilai Ekonomi Hutan Mangrove Teluk Youtefa, Kota Jayapura, Papua. *Jurnal Biologi Papua, 6*(1), 1–11. https://doi.org/10.31957/jbp.445

He, B.; Lai, T.; Fan, H.; Wang, W. and Zheng, H. (2007). Comparison of flooding-tolerance in four mangrove species in a diurnal tidal zone in the Beibu Gulf. *Estuarine, Coastal and Shelf Science, 74*(1-2), 254–262. https://doi.org/10.1016/j.ecss.2007.04.018

Indrawan, M.; Primack, R.B. and Supriatna, J. (2007). *Biologi Konservasi*. Yayasan Obor Indonesia.

Ismail; Sulistiono; Hariyadi, S. and Madduppa, H. (2019). Correlation Between Mangrove Degradation in Segara Anakan and Production of Crab (*Scylla* sp.) in Cilacap Regency, Central Java Province. *Jurnal Ilmu Pertanian Indonesia (JIPI), 24*(3), 179–187. https://doi.org/10.18343/jipi.24.3.179

Kalor, J.D. and Paiki, K. (2021). Dampak Kerusakan Ekosistem Mangrove terhadap Keanekaragaman dan Populasi Perikanan di Teluk Youtefa Kota Jayapura Provinsi Papua. *Majalah Ilmiah Biologi Biosfera: A Scientific Journal, 38*(1), 39–46. https://doi.org/10.20884/1.mib.2021.38.1.1349

Kanwar, P. (2018). Ecological risk in the anthropocene: an evaluation of theory, values, and social construct. In: *Encyclopedia of the Anthropocene;* Dellasala, D.A. and Goldstein, M.I., Eds.; Elsevier, pp. 367–372.

Kartikasari, S.N.; Marshall, A.J. and Beehler, B.M. (2012). *Ekologi Papua: Seri Ekologi Indonesia Jilid VI*. Yayasan Pustaka Obor Indonesia.

Kritiyasari, D.; Purnomo, P. and Suryanti, S. (2021). Pertumbuhan Zooxanthellae Berdasarkan Tiga Spesies Karang Berbeda dari Perairan Pulau Panjang, Jepara. *Maspari Journal, 13*(1), 11–24. https://doi.org/10.56064/maspari.v13i1.13443

Kumar, A. and Singh, V. (2019). Overview Of Interpretive Structural Modeling. *International Journal of Engineering Applied Sciences and Technology, 4*(5), 536–540.

Levin, S.; Xepapadeas, T.; Crépin, A.S.; Norberg, J.; De Zeeuw, A.; Folke, C.; Hughes, T.; Arrow, K.; Barrett, S. and Daily, G. (2013). Social-ecological systems as complex adaptive systems: Modeling and policy implications. *Environment and Development Economics, 18*(2), 111–132. https://doi.org/10.1017/S1355770X12000460

Lewaherilla, N.E. (2007). Pemanfaatan Wilayah Pesisir Teluk Youtefa-Jayapura Secara Partisipatif. *Akselerasi Inovasi Teknologi Pertanian Spesifik Lokasi Mendukung Ketahanan Pangan di Wilayah Kepulauan*, 705–715.

Liu, J.; Dietz, T.; Carpenter, S.R.; Alberti, M.; Folke, C.; Moran, E.; Pell, A.N.; Deadman, P.; Kratz, T.; Lubchenco, J.; Ostrom, E.; Ouyang, Z.; Provencher, W.; Redman, C.L.; Schneider, S.H. and Taylor, W.W. (2007). Complexity of coupled human and natural systems. *Science*, *317*(5844), 1513–1516. https://doi.org/10.1126/science.1144004

Manalu, J.; Nurjaya, I.W. and Kholil, K. (2011). Analisis Tingkat Pencemaran Air dengan Metode Indeks Pencemaran di Teluk Youtefa, Jayapura, Provinsi Papua. *Berita Biologi*, *10*(6), 749–761.

Mandey, V.K. (2019). Kajian Kondisi Ekosistem Terumbu Karang Di Teluk Youtefa, Kota Jayapura, Provinsi Papua. *Acropora: Jurnal Ilmu Kelautan dan Perikanan Papua*, *2*(2), 50–54. https://doi.org/10.31957/acr.v2i2.1065

Mudjiyanto, B. (2018). Tipe Penelitian Eksploratif Komunikasi. *Jurnal Studi Komunikasi dan Media*, *22*(1), 65–74.

Murdjoko, A.; Jitmau, M.M.; Djitmau, D.A.; Suburian, R.A.S.; Ungirwalu, A.; Wanma, A.O.; Mardiyadi, Z. and Saragih, A.S.B. (2020). Heterospecific and conspecific associations of trees in lowland tropical forest of New Guinea. *Biodiversitas*, *21*(9), 4405–4418. https://doi.org/10.13057/biodiv/d210960

Murdjoko, A.; Djitmau, D.A.; Ungirwalu, A.; Sinery, A.S.; Herlina, R.; Siburian; Mardiyadi, Z. and Lekitoo, K. (2021). Pattern of tree diversity in lowland tropical forest in Nikiwar, West Papua, Indonesia. *Dendrobiology*, *85*, 78–91. https://doi.org/10.12657/denbio.085.008

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, *325*(5939), 419–422. https://doi.org/10.1126/science.1172133

Paembonan, R.E.; Naipon, Y.D.; Baddu, S.; Baksir, A.; Marus, I.; Ramili, Y. and Akbar, N. (2022). Penilaian ikan karang pada daerah transplantasi karang di perairan laut Kastela Ternate. *Jurnal Ilmu Kelautan Kepulauan*, *5*(1), 562–570. https://doi.org/10.33387/jikk.v5i1.4755

Pangaribuan, T.H.; Soedarsono, P. and Ain, C. (2013). Hubungan Kandungan Nitrat Dan Fosfat dengan Densitas Zooxanthellae pada Polip Karang *Acropora* sp. di Perairan Terumbu Karang Pulau Menjangan Kecil, Karimun Jawa. *Management of Aquatic Resources Journal (MAQUARES)*, *2*(4), 136–145. https://doi.org/10.14710/marj.v2i4.4277

Paulangan, Y.P. (2007). Analisis kondisi mangrove di taman wisata Teluk Youtefa Kota Jayapura Provinsi Papua. *Jurnal Sains Mipa Universitas Cenderawasih*, *1*(1), 32–45.

Paulangan, Y.P. (2014). Potensi Ekosistem Mangrove di Taman Wisata Teluk Youtefa. *Jurnal Kelautan*, *7*(2), 60–68.

Paulangan, Y.P.; Barapadang, B.; Al Amin, M.A. and Tangkelayuk, H. (2021). Social-ecological system in Depapre Bay Area of Jayapura Papua Indonesia. *IOP Conference Series: Earth and Environmental Science*, *890*, 012070. https://doi.org/10.1088/1755-1315/890/1/012070

Paulangan, Y.P.; Sombo, H.; Silaen, P. and Fofied, J.V. (2022). Analisis Kelembagaan Lokal Pengelolaan Calon Kawasan Konservasi Taman Pulau Kolepom Kabupaten Merauke Provinsi Papua. *Jurnal Kebijakan Perikanan Indonesia*, *14*(1), 25–33. https://doi.org/10.15578/jkpi.14.1.2022.25-33

Petrosillo, I.; Aretano, R. and Zurlini, G. (2015). Socioecological Systems. In: *Reference Module in Earth Systems and Environmental Sciences;* Elsevier.

Piragnolo, M.; Pirotti, F.; Guarnieri, A.; Vettore, A. and Salogni, G. (2014). Geo-spatial support for assessment of anthropic impact on biodiversity. *ISPRS International Journal of Geo-Information, 3*(2), 599–618. https://doi.org/10.3390/ijgi3020599

Ranasinghe, R.; Duong, T.; Uhlenbrook, S.; Roelvink, D. and Stive, M. (2013). Climate-change impact assessment for inlet-interrupted coastlines. *Nature Climate Change*, *3*, 83–87. https://doi.org/10.1038/nclimate1664

Randongkir, H.; Ohee, H.L. and Kalor, J.D. (2019). Komposisi Vegetasi dan Pemanfaatan Ekosistem Mangrove di Kawasan Wisata Alam Teluk Youtefa Kota Jayapura. *Acropora: Jurnal Ilmu Kelautan dan Perikanan Papua*, *2*(1), 21–29. https://doi.org/10.31957/acr.v2i1.982

Rencana Tata Ruang Wilayah (RTRW) Kota Jayapura 2013-2033. (2013). Pemerintah Daerah Kota Jayapura.

Rockström, J.; Steffen, W.; Noone, K.; Persson, A.; Chapin, F.S.; Lambin, E.F.; Lenton, T.M.; Scheffer, M.; Folke, C.; Schellnhuber, H.J.; Nykvist, B.; de Wit, C.A.; Hughes, T.; van der Leeuw, S.; Rodhe, H.; Sörlin, S.; Snyder, P.K.; Costanza, R.; Svedin, U.; Falkenmark, M.; Karlberg, L.; Corell, R.W.; Fabry, V.J.; Hansen, J.; Walker, B.; Liverman, D.; Richardson, K.; Crutzen, P. and Foley, J. (2009). A safe operating space for humanity. *Nature*, *461*(7263), 472–475. https://doi.org/10.1038/461472a

Rosalina, D.; Hawati; Rombe, K.H.; Surachmat, A.; Awaluddin; Amiluddin, M.; Leilani, A. and Asriyanti. (2023). Application of remote sensing and GIS for mapping changes in land area and mangrove density in the Kuri Caddi Mangrove tourism, South Sulawesi Province, Indonesia. *Biodiversitas*, *24*(2), 1049–1056.

Rumahorbo, B.T.; Hamuna, B. and Keiluhu, H.J. (2020). An assessment of the coastal ecosystem services of Jayapura City, Papua Province, Indonesia. *Environmental & Socio-economic Studies, 8*(2), 45–53. https://doi.org/10.2478/environ-2020-0011

Sari, A.; Tuwo, A.; Saru, A. and Rani, C. (2022). Diversity of fauna species in the mangrove ecosystem of Youtefa Bay Tourism Park, Papua, Indonesia. *Biodiversitas*, *23*(9), 4490–4500. https://doi.org/10.13057/biodiv/d230915

Sidle, R.C.; Benson, W.H.; Carriger, J.F. and Kamai, T. (2013). Broader perspective on ecosystem sustainability: Consequence for decision making. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(23), 9201–9208. https://doi.org/10.1073/pnas.1302328110

Suripto, B.A. (2000). Keanekaragaman Hayati di Pulau-Pulau Kecil di Indonesia: Asal-Usul Mereka, Statusnya Kini dan Nasibnya yang akan Datang. In: *Prosiding Seminar Nasional Pengelolaan Ekosistem Pantai dan Pulau-Pulau Kecil dalam Konteks Negara Kepulauan;* Fakultas Geografi UGM, Yogyakarta.

Tebay, S.; Yulianda, F.; Fahrudin, A. and Muchsin, I. (2014). Struktur Komunitas Ikan pada Habitat Lamun di Teluk Youtefa Jayapura Papua. *Jurnal Iktiologi Indonesia*, *14*(1), 49–65. https://doi.org/10.32491/jii.v14i1.95

Tijjani, S.; Mizuno, K. and Herdiansyah, H. (2021). The Loss of Ecosystem Services in Women's Forest at Youtefa Bay, Jayapura, Papua, Indonesia. *IOP Conference Series: Earth and Environmental Science, 940,* 012061. https://doi.org/10.1088/1755-1315/940/1/012061

Tomascik, T.; Mah, A.J.; Nontji, A. and Moosa, M.K. (1997). *The Ecology of the Indonesian Seas. Part II*. Periplus Editions.

Virapongse, A. and Alessa, L. (2016). A social–ecological systems approach for environmental management. *Journal of Environmental Management*, *178*, 83–91. https://doi.org/10.1016/j.jenvman.2016.02.028

Wankhade, N. and Kundu, G.K. (2020). Interpretive Structural Modelling (ISM) Methodology and its application in Supply Chain Research. *International Journal of Innovative Technology and Exploring Engineering (IJITEE), 9*(4), 1101–1109.