Social-ecological system in Depapre Bay Area of Jayapura Papua Indonesia

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Abstract. A Socio-Ecological Systems (SESs) are systems that connect human systems and natural systems by emphasizing that humans must be seen as part of, and cannot be separated from nature. Understanding SESs is very important as the main capital in planning the management of coastal and marine resources. The purpose of this study was to study SESs in Depapre Bay, Jayapura, Papua Province using the Drivers-Pressure-Impact-State-Responses (DPSIR) approach. Based on the research results, it was found that the issues and problems of SESs in Depapre Bay were related to the utilization of coastal and marine resources that were not environmentally friendly, such as the use of blast fishing and tuba root poisoning and development that did not consider the sustainability of coastal and marine resources. In addition, the response of the government and stakeholders has not focused on overcoming the damage to ecosystems and coastal and marine biological resources in an integrated manner. This can be seen from the programs carried out that are still partial, especially in the prevention of destructive fishing and the rehabilitation of coastal and marine ecosystems that have been damaged.

1. Introduction
A socio-ecological systems (SESs) is a system that connects human and natural systems, by emphasizing that humans must be seen as part of, and inseparable from, nature [1] [2] [3] [4] [5] [6], or an ecological system that is closely related and influenced by one or more social systems [7], are interconnected and dynamic [8]. SESs relationship is defined as the functional interdependence between social change and ecological change [7] [8]. SESs is very important in management because as a complex adaptive system, it has emergent properties [9] [10] [11], and the resilience or ability of the system to continue to function when intrinsic or extrinsic disturbances occur [12].

The dynamics and complexity of social and ecological systems, both naturally and anthropogenically, have become major challenges in managing areas and natural resources [13]. This
not only provides the uncertainty of the system but also concepts, such as feedback cycles, tipping points, and regime shifts, which trigger fears of unintended consequences of management actions [14] [15]. Therefore, understanding the dynamic relationship between social, environmental and climate phenomena is now considered the key to making sound management decisions [16] [17], so that an integrated study of the combined SESs is seen as dominant in the ecosystem management framework [18]. The complexity of the dynamics of humans and nature is best conceptualized within the SESs framework [19].

Understanding the issues and problems of SESs is the main asset in developing a better management strategy for sustainable development of coastal areas and communities on the coast of Depapre Bay. Therefore, policy makers are challenged to accurately define the actual situation of the issues and problems in the Depapre Bay area to make appropriate coastal and marine resource management policies.

2. Method

2.1. Time and location of research
This research was conducted from November 2019 to February 2020 in Depapre Bay, Jayapura Regency, namely in the villages of Tablanusu, Tablasufa, and Waiya (Figure 1).

![Figure 1. Research Site at Depapre Bay](image)

2.2. Sources, types and data collection
The data used in this research are primary and secondary data. The primary data were obtained through direct field surveys by means of observation and interviews with 10 respondents in each selected village. The respondents were selected by purposive sampling with the criteria of understanding and being able to convey opinions and / or ideas well regarding the problems being studied, representing their characteristics and background (position, education and gender) and being willing to be respondents. The secondary data were obtained through literature studies from various journals, research reports and other sources of scientific data relevant to the study. The data that had been collected was discussed descriptively and based on a triangulation technique.
2.3. Data analysis
The DPSIR approach was used to determine the relationship between the factors causing pressure on the ecosystem since it could be used to assess the intensity of human resource use and activities in coastal areas. The DPSIR conceptual model is one of the frameworks showing the causal relationship between environmental systems and humans. The DPSIR conceptual model has been widely used as a model for analyzing and assessing SESs problems [8].

The DPSIR approach was developed by the European Environment Agency [20] based on the Pressure-State-Response (PSR) framework previously developed by the Organization for Economic Co-operation and Development (OECD) in 1993 [21]. DPSIR is generally used in the fields of ecology, environment, and management of socio-economic activities because this approach can analyze the complex causality between environmental and socio-economic systems. Within the DPSIR framework, socio-economic development is the driving force (D) which creates pressure (P) on the environment. In response to these pressures, environmental conditions (S) change and have an impact (I) on human health, ecosystems, and others. Whereas Response (R) is feedback for D, S, and I in the form of adaptation and prevention policies [22]. The framework of the analysis method using the DPSIR approach can be seen in Figure 2.

![Figure 2. DPSIR Conceptual Model](image)

3. Results and discussion

3.1. Overview of the social system for coastal communities in Depapre Bay
The Tabla tribe or also known as the Tefraa tribe is one of the indigenous tribes who inhabit the coastal area of Depapre Bay in Jayapura Regency [23] [24]. The livelihoods of the people of Depapre Bay are quite diverse, including fishermen, farmers, entrepreneurs, private employees, village officials, State Civil Servants, and retirees. However, in general, most of the people in the community work as fishermen. This is supported by natural conditions with coastal topography. In addition, the low education, only completing elementary school (no special skills), is another reason why most of the heads of families choose to work as fishermen [25]. Generally, the fishermen in Depapre Bay can be categorized as subsistence with fairly simple fishing tools such as fishing rods, spears, arrows, but some have already used nets. The income of the fishermen depends on the amount of fish caught which is very influenced by weather conditions at sea. If the weather is good, they can go to sea. The quantities of catches really depend on the season. In the shady season, the number of fish catches is likely to be higher than the wave season. Farmers generally manage land belonging to tribes because in the Depapre area there is still a very strong system of land distribution based on their customary rights, so the size of the land they own depends on the division from the Ondoafi (tribal head).
However, only a small portion of the communal land has been processed as productive lands, such as gardens or agricultural land, the rest is still forest.

The facilities and infrastructure of health and education in Depare Bay are still very limited, especially in the three study villages, where there is only 1 community health center (puskesmas) in Waiya Village, 1 village polyclinic (polindes) in Tablanusu and Tablasufa villages, 4 units of mobile water community health centers (puskesmas air keliling) and 2 units of mobile land health community centers (puskesmas darat keliling). Meanwhile, educational facilities include 1 elementary school in Tablausu, Tablasufa and Waiya villages, 2 state junior high schools, and 1 State Vocational High School [26]. Land transportation facilities can only be found in Waiya Village, Tablanusu Village and Tabasupa. Depapre District can be reached in about 2 hours from Jayapura City using cars and motorbikes. People's wharf as a means of public transportation between villages in each village is available. The Ministry of Maritime Affairs and Fisheries built a fish landing and auction site on the east coast of Kampung Waiya as a means for fishermen to market their catch, but it has not been running optimally. Electricity in Depapre District is supplied from Sentani City which is managed by PLN, while telecommunications can be reached by cellular telecommunications with one BTS from PT. Telkomsel.

As with village communities in other parts of Papua, the cultural system adopted is based on the local cultural system [27] [23]. One of the basic cultures in the community structure in Depapre Bay is the customary authority system which is still very strong, namely the Ondoafi system (Figure 3).

![Figure 3. Customary Leadership Structure in Tablasufa and Tablanusu Villages](image)

Knowledge of the sea has long been recognized by people in Depapre Bay areas, such as Tablanusu, Tablasufa and Waiya [27] [23]. Furthermore, states that the sea (Nau in the language of Tefraa / Tabla tribe) for the people of Depapre Bay has a high value associated with land or soil, as is the relationship with the land of class one, which has a high selling price. On this basis, the various marine resources in it will be managed and protected by applying customary norms. It is further explained that the sea and all the potential in it are recognized as God's creation to be managed and preserved [27].

The people in Depapre Bay, especially in the villages of Tablanusu, Waiya and Tablasufa, have a very close relationship with the surrounding nature. The coast and sea as well as the resources contained therein for the people of Depapre Bay is a very valuable asset [27] [23], which is likened to mother or in the Tefra / Tabla language called Kalume. Therefore, the treatment must be carried out in a careful and wise manner. This view is reflected in management practices that have been passed
down from generation to generation in the form of Tiaitiki local wisdom, which is an open-close system of a certain area and at certain times to protect certain marine biota such as sea cucumbers, fish, lola, etc., including various plants and forests on land areas.

For communities in Depapre Bay [27] [23], the sea is divided into 4 zones based on certain depths and characteristics, namely:

a. Akadame, a shallow part of the sea, starting from the highest tide limit to a depth of 12 meters, and is usually a stretch of coral reefs and seagrass beds, which at low tide partially emerges and looks dry.

b. Kia-kia, a part of the sea with a depth of 12-25 meters. The eye can still see the seabed and at the lowest tide it is still water. Some still consist of coral.

c. Nou Koti, a part of the sea that has a depth of 25-100 meters, and the seabed is no longer visible from the surface with a bluish sea color.

d. Beta nau, a part of the sea that has a depth of more than 100 meters to the open sea towards the Pacific Ocean, is generally already outside Depapre Bay.

When referring to the division of the sea, in the social system of the people of Depapre Bay, the use of the area above also refers to the customary rights system, where the marine area which is included in the customary ulayat (sea tribe) is the area of akadame, kia-kia and nou koti. The three areas being controlled by adat (custom) are considered strategic areas that affect the reproductive system of marine biota as a place for spawning, raising, and growing. Meanwhile, beta nau is not included in the area of customary ulayat rights because it is a free sea zone and is not violated by custom.

In the customary law system called Tiaitiki, the areas where Tiaitiki is implemented are the akadame and kia-kia areas. These areas are ecologically necessary to be protected because they are places to find food for marine biota. While the water currents in these areas are generally not fast, lots of nutrients and shelters for marine biota have made the areas ideal for reproduction.

Depapre Bay is a quite complex socio-ecological system. Various uses of its resources have existed, influencing each other, either the influence of the social system on ecology or vice versa. The forms of land use in Depapre Bay waters by the surrounding community include: the marine cultivation area in Tablanusu Village, the port area that is being built (in the process) in Tablanusu Village, residential settlements over the sea in Tablasupa Village and land settlements in Tablanusu Village, Waiya Village and Tablasupa Village, an area for the development of education, trade, government and economic activities centered in Waiya Village as well as aquatic ecosystem services as a medium of transportation or recreation. Beach tourism activities are carried out in Tanjung Harlem, Tanjung Tanah Merah, Tanjung Pistol, Amay beach, Tablanusu Village, and Tablasufa Village.

3.2. Overview of the ecological system of coastal and marine resources in Depapre Bay

Geographically, Depapre Bay is at coordinates 140° 15’ 00” - 140° 22’ 00” East Longitude and 2° 28’ 00” - 2° 24’ 00” South Latitude. Depapre Bay is one of the bays directly facing the Pacific Ocean and has a very varied topography, ranging from flat, wavy, and steep morphology. Depapre Bay bathymetry forms an immediate topography that is steep (slope). The distance to the deep sea is very short from the outer boundary of the average coral reef and on certain beaches the topography of the coast is immediately steep reaching a depth of > 100 m [28]. The difference between the rainy season and the dry season is almost non-existent due to the influence of the wind. In general, wind patterns in the Depapre Bay area and its surroundings [24] [29] can be divided into 4 patterns based on the existing seasons, namely the western season (December-February), the transitional season I (March-May), the eastern season (June-August) and the transitional season II (September-November). The conditions of the aquatic environment based on several parameters are presented in Table 1 [30] [31] [32].
Table 1. The Condition of the aquatic environment in Depapre Bay

| Parameters                  | Range Values |
|-----------------------------|--------------|
| Sea Surface Temperature     | 27.00-31.82 °C |
| Salinity                    | 32.27-33.61 ppt |
| Flow Velocity               | 0.20-0.28 m/S |
| Wave Height                 | 0.67-1.26 m   |
| Tidal Height                | ±1.76 m       |
| Dissolved Oxygen            | 5.24-5.25 mg/L|
| pH                          | 7.3-8.5       |

The coastal land cover in the Depapre Bay area consists of secondary forest, shrubs and reeds, fields / moor, mixed gardens, vacant land / barren land and settlements. Vegetation types in narrow forest clusters generally occupy areas around the bay with flat topography [31] [25]. The coastal forest vegetation formation consists of 2 main types, namely the coastal yam formation (*Ipomea pescaprae*) and the Barringtonia formation (25-50 m) on a sloping coastal area, decreasing if the coast is steep and rocky. The Pescaprae Formation consists of low-growing plants, mostly herbaceous species, some of which grow creeper. The most common types are beach sweet potato (*Ipomea pescaprae*) and running grass (*Spinifex squarosus*). The Barringtonia Formation consists of keben (*Barringtonia asiatica*), nyamplung (*Calophyllum inophyllum*), ketapang (*Terminalia catappa*), pandanus (*Pandanus tectorius*), coconut (*Cocos nucifera*) and others [31].

The mangrove ecosystem in Depapre Bay is not extensive with sparse vegetation. The presence of mangroves in Entiyebo Village can be found behind the village, namely in the lake which consists of *Rhizophora apiculata*, *Sonneratia alba* and *Nypa fruticans* while Waiya Village is on the right side of the village. Kampung Kendate can be found in front of the village consisting of *Rhizophora apiculata*, *Sonneratia alba* and *Nypa fruticans* [25] [32]. Seagrass ecosystems are found along the coast of the Depapre Bay area, mainly such types as *Cymodocea rotundata*, *Thalassia hemprichii*, *Enhalus acoroides*, *Halodule uninervis*, and *Halophila ovalis*. Seagrass vegetation is quite extensive in the waters of Tablasufa Village, but the highest cover percentage is found in Waiya and Tablanusu Villages [31].

The Depapre Bay waters are relatively calm during certain seasons so that it is very potential to become a good spawning ground, nursery ground and feeding ground for fisheries resources, especially pelagic fish and demersal fish and other economic biota. This can be seen from the discovery of small pelagic fish resources, namely puri (*Stolephorus spp*), sako / cendro (*Thylosurus spp*), momar (*Decapterus spp*), mackerel (*Rastrelliger spp*), and kawalinya (*selar spp*) and large pelagic fish such as tuna (*Thunnus spp*), skipjack (*Katsuwonus pelamis*), and mackerel (*Scomberomorus sp*). Apart from small pelagic fish, demersal fish are also found such as geropa / grouper fish (*Chelopholis sp*), snapper (*Lutjanus sp*), napoleon (*Cheilinus undulatus*), baronang (*Siganus spp*), and lobster (*Panulirus sp*), and others. Apart from fish, there are also economic biota such as crustaceans, molluscs and sea turtles [32] [24].

The season for small pelagic fish (puri, momar, mackerel, and kawalinya) is in March-May and in August and November. Large pelagic fish (tuna and skipjack) are predominantly caught in August-November. Pelagic fish resources, bubara and sako, are types of pelagic fish that are often caught throughout the year with their distribution patterns not far from coastal waters. Meanwhile, demersal fisheries resources such as red snapper, grouper and lobster are caught most of the year [24].

In the 2015 Jayapura Regency Marine and Fisheries Service Report, there are three types of sea turtles in the Depapre Bay area, namely the hawksbill turtle (*Eretmochelys imbricata*), green turtle (*Chelonia mydas*) and leatherback turtle (*Dermochelys coriacea*) which are protected marine reptiles, because their population in nature has declined dramatically due to being hunted by humans to fulfill various necessities of life and traditional rituals. The nesting areas for turtles include the northern part of Tanjung Tanah Merah. In the meantime, at least 7 types of whales pass through the waters of the
Depapre Bay area, namely humpback whale (*Megaptera novaeangliae*), sei whale (*Balaenoptera borealis*), blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalis*), sperm whale (*Physeter catodon*), Physeter sp., and killer whale (*Orcinus Orca*). The presence of *Balaenoptera musculus*, *Physeter catodon* and *Orcinus Orca* in these waters is classified as specific and it is suspected that the migration route from the Pacific Ocean to the Indian Ocean and/or vice versa crosses the coastal and marine waters of the Depapre Bay area. Meanwhile, five dolphin species are found in the coastal and marine waters of the Depapre Bay area, namely: shortfin pilot whale (*Globicephala macrocephalus* Gray, 1846), false killer whale (*Pseudorca crassidens* Owen, 1846), snout dolphin short (*Delphinus delphis*), long snout dolphin (*Delphinus capensis* Gray, 1828), and bottlenose dolphin (*Tursiops truncatus* Montagu, 1821). This type of dolphin is a protected marine mammal. One important marine mammal that generally present in the relatively shallow coastal waters of the Depapre Bay area is the dugong (*Dugong dugon*).

### 3.3. Issues and problems of SESs based on the DPSIR conceptual model

Like coastal areas in general, the Depapre Bay area has issues and problems related to the use of coastal and marine resources, where ecosystems and resources are degraded due to destructive or environmentally unfriendly uses and due to development that does not consider the sustainability of coastal and marine resources (Figure 4).

![Figure 4. DPSIR analysis on the coast of Depapre Bay](image)

As shown in Figure 4, destructive fishing, transportation and marine tourism activities as well as road infrastructure development and port construction are the driving force factors. Destructive fishing using explosives in Depapre Bay is quite common. This practice, based on community interviews, began around the 1990s, and it was introduced by fishermen from outside. The raw material for the bombs is gunpowder from the remains of World War II which are still often found by the people. In addition, the use of tuba roots in catching fish is still frequently done. Ironically, some people are of the view that the use of tuba roots is not harmful because it only causes the fish to become unconscious and the fish are not dangerous to consume. Apart from destructive fishing, there is also damage to coastal and marine ecosystems, especially coral reef ecosystems due to anchoring of fishing boats around coral reefs. Destructive fishing practices have resulted in decreased live coral cover in almost all areas in Depapre Bay [32] [28]. Meanwhile, there has been a change in the coastline, especially in Waiya Village due to the widening of the road to support the port infrastructure. Apart from sedimentation, backfilling was also carried out (stockpiling of parts of the sea) as the location for
the port construction in Kampung Tua Tablanusu. As a result of sedimentation from the upland and partially filling of the coastal area, the surrounding area becomes cloudy and shallow. This condition has resulted in the loss of one of the fishing ground areas, especially in an area that has been degraded for the construction of a port in Tua Tablanusu village.

The impact of the utilization and development as mentioned above has indirectly caused a decrease in fishermen's catch due to the loss of the fishing ground area. In addition, the effect of port development has triggered conflicts among communities due to claims of customary rights in marine areas and triggered a change in people's views on coastal and marine ecosystem resources, where people have begun to tend to be apathetic to conservation programs because they are deemed unsuccessful.

As responses to the issues and problems in the Depapre Bay area, the government and various other stakeholders have partially carried out various counseling and training related to the management and utilization of coastal and marine resources. Meanwhile, in the management and utilization of coastal and marine resources, the communities are re-applying the Tiaitiki local wisdom system, whose implementation authority is based on customary rights ownership. In addition, the central and regional government responses are through the relevant Regional Government Organizations, namely by distributing aid in the form of fishing gear, such as FADs, nets, coolboxes, and others.

4. Conclusion
Issues and problems of SESs with the contextual model of DPSIR in Depapre Bay are related to the use of coastal and marine resources that are not environmentally friendly as well as the development that considers the sustainability of coastal and marine resources. In addition, the responses of the government and stakeholders have not focused on overcoming the damage to ecosystems and coastal and marine biological resources in an integrated manner. This can be seen from the program that is still partial. Therefore, the strategy for managing coastal and marine resources in the future must focus on programs to combat destructive fishing and rehabilitate damaged coastal and marine ecosystems.

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