Analysis of ecological dimensions on the sustainability of port management of PT Pelindo Dumai branch

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Abstract. Coral reefs are highly valuable ecosystems and play crucial roles in marine ecosystem dynamics by providing food and shelter for many organisms. Unfortunately, coral reefs around the globe are declining. Thus, apart from marine protected areas, active conservation and restoration efforts are extremely important. In this study, *Acropora formosa* nubbins were transplanted and their performance was monitored, with the main aim to evaluate their survival and growth in comparison with natural reef. The extension growth, proto-branch generation, mortality and survival were assessed for one year in Tioman Island, Malaysia. The *A. formosa* growth rates ranged from 0.59±0.07 to 1.20±0.03 cm mth^{-1} in the nursery and from 0.55±0.13 to 0.72±0.11 cm mth^{-1} in the natural reef. The transplanted corals exhibited higher growth rates, particularly during the early period of transplant, and, moreover, had higher proto-branch generation rates compared with the natural colony. However, their survival was low, mostly due to predation by fish and other corallivores. Seasonal variations in coral growth were observed, with faster rates during the inter-monsoon period (March-April and October-November). This study documented the success of *A. formosa* transplantation and its application in coral nurseries in Malaysian waters. Coral transplantation is highly beneficial for active coral reef restoration and conservation. Nevertheless, continuous long term systematic monitoring is needed to have greater understanding of *A. formosa* growth and dynamics in the tropical coral reef ecosystems.
Key Words: *Acropora formosa*, coral growth rates, coral nursery, coral transplant, reef restoration.

Introduction. Indonesia is an archipelagic country with 17508 islands. As a maritime country, its water area reaches 3.54 million km^2. This makes Indonesia's position important for the world's marine product trade (Mbay et al 2014), as well as for sea transportation that connects one island to another. Infrastructure is important for maritime activities, especially ports, which are important factors in the economy (Gunarse et al 2019).

The increase in economic activity that occurs at the port does not have just a positive effect on the economy, but also has a negative effect in the form of environmental damage. Increased greenhouse gas emissions, water pollution, destruction of marine life are various negative effects that arise due to high port activity (Moura & Andrade 2018). To overcome these negative effects, the concept of ecoport or greenport was introduced. The ecoport is a concept that offers a balance between environmental impact and increasing economic value (Perawati et al 2017). Through this ecoport concept, economic and ecological interests are balanced, so that economic development does not exceed the capacity of nature. Various efforts are made in the implementation of the ecoport, for example using environmentally friendly methods in various operational activities and port management. Muninggar et al (2019) describes an environmentally friendly port (ecoport) as a port that is managed using the principles of sustainable development. The goal of an ecoport is the harmonization of economic and environmental aspects in sustainable management efforts (Zebblon et al 2016). The harmonization of the principles of sustainable development must include all dimensions, namely social, economic and ecological dimensions.

Currently, Dumai Port is growing rapidly, becoming an international port, especially for crude palm oil (CPO) export activities because it is supported by geographical conditions that stretch almost all over the mainland of Riau Province to the borders of North Sumatra, West Sumatra and Jambi Provinces. These various provinces are growing with oil palm, rubber and other plantations as well as with the tourism industry, which demands the Dumai Port to become the main gate of the Riau regional economy.

Port activities have a significant impact on the environment. These impacts mainly arise from the use of energy, and from waste of ships anchored and docked in the port. The disposal of solid waste from docked ships is made by scavengers and is not organized. Water use, landscape changes, garbage, waste and changes in ambient air quality are results of loading, unloading and other activities in the area. These can develop into environmental problems such as pollution (water, air and soil). In PT Pelindo Dumai Branch, in addition to loading and unloading activities, there are CPO processing industries, and if not handles properly, may develop into environmental problems.

The important role played by the Port of PT Pelindo Dumai Branch demands efficiency, effectiveness and sustainability through good and environmentally sound port management. The purpose of this study is to analyze the ecological dimensions for the sustainable management of the Port of PT Pelindo Dumai Branch.

Material and Method

Description of the study sites. The research was conducted in the port area of PT Pelindo Dumai Branch, Riau Province, from July 2020 to June 2021 The port of PT Pelindo Dumai Branch is located in the province of Riau, and is an area affected by the economic cooperation between Indonesia, Malaysia, Singapore and Thailand, resulting in growth in the industrial sector. Dumai Port is also one of the main ports in Riau Province. It has a favorable geographical location because it is a natural port protected by several islands including Rupat Island, Payung Island and Rampang Island, so that it has deep and calm waters and a pleasant climate.

The decline in seawater quality based on port activities was analyzed at 11 monitoring stations. The water quality parameters measured were brightness, total suspended solids, temperature, pH and salinity. Water quality was determined at 11 stations over 2 months, using standard tools and techniques. Brightness was measured using a Secchi disk, total suspended solids were measured using the gravimetric method, temperature was determined with a thermometer, pH with a pH meter and salinity with a refractometer. Brightness is a measure of the transparency of water, determined visually, using the Secchi disk. The brightness value is expressed in meters. This value is strongly influenced by weather conditions, time of measurement, suspended solids, and turbidity as well as the accuracy of the person taking the measurement. Air quality parameters were determined with measurements of SO_2, CO, NO_2, Dust, NH_3 and H_2S. Noise measurement were carried out using a sound level meter. To determine dissolved metals in the seawaters of Dumai Port, dissolved metal measurements were conducted on sediments based on PPRI No. 1010 of 2014.

Ecological factors. Types and sources of data consist of primary and secondary data. The biophysical data collected in this research are soil conditions around the port, water quality data, noise maps and action plans. In addition, efforts to handle waste at the port of PT Pelindo Dumai Branch were also documented. Cleanliness conditions, reforestation efforts to sedimentation are collected for later analysis. The following dimensions and attributes to be analyzed are presented in Table 1.

Table 1

Attributes of the ecological dimension

Data type	*Data source*	*Data collection method*
Water quality	Secondary (Report and environmental document from management)	Literature review
Air quality	Secondary (Report and environmental document from management)	Literature Review
Noise	Secondary (Report and environmental document from management)	Literature review
Reforestation effort	Primary and secondary sources	Survey and literature review
Dissolved metals in sedimentation	Secondary (Report and environmental document from management)	Literature review
Solid waste management	Primary and secondary	Survey and literature review
Sedimentation	Secondary (Report and environmental document from management)	Literature review
Hazardous waste management	Secondary (Report and environmental document from management)	Literature review
Liquid waste management	Secondary (Report and environmental document from management)	Literature review
Water availability	Secondary (Report and environmental document from management)	Literature review

Results and Discussion. At the initial stage, data was collected on the latest conditions of the ecological aspect. This data collection was carried out not only within the port area, but also outside the area that is expected to be affected by port operations.

Water quality. The results of the seawater quality analysis at Dumai Port are presented in Table 2.

Table 2

Parameters of seawater quality in Dumai Port

Stations	*Brightness (m)*	*Total Suspended Solids (mg L^{-1})*	*Temperature (°C)*	*pH*	*Salinity (%)*
I	1.75	52.75	29.40	7.72	27.20
II	1.79	39.50	29.08	7.79	27.52
III	2.12	36.75	29.08	7.80	29.43
IV	2.17	27.00	29.58	7.88	28.53
V	1.67	32.75	29.45	7.84	28.70
VI	3.73	26.50	29.53	7.85	28.43
VII	1.85	25.00	29.58	7.87	29.15
VIII	2.00	33.25	29.63	7.49	25.40
IX	0.95	40.00	28.75	7.70	31.00
X	0.95	33.00	28.75	7.35	31.00
Standard[a]	0.45	20	28-32	7-8.5	34

Note: a - standards of the Decree of the Minister of the Environment No. 51 of 2004.

Water is clear if it meets the standards of the Decree of the Minister of the Environment No. 51 of 2004, which is 3 m. The brightness value ranges from 0.95 to 3.75 m. At Station VI (passenger dock), the brightness was 3.73 m, above the quality standard. This is due to the movement of ships when compared to other stations. The movement of ships causes stirring, affecting the water brightness. The ability of sunlight to penetrate to the bottom of the water is influenced by the turbidity of the water. Therefore, the level of brightness and turbidity of seawater affects the growth of marine life. The level of brightness of seawater greatly determines the level of photosynthesis of biota in marine waters (Hamuna et al 2018).

TSS had the value of 26.5-40 mg L^{-1}. The standard for TSS is 20 mg L^{-1}. The increase in TSS will increase the level of turbidity, which further inhibits the penetration of sunlight into the water column. The lack of sunlight intensity is due to the high TSS values and will inhibit the growth of phytoplankton. These suspended solids can also have a negative impact on aquatic ecosystems, fish catches, and others, such as aquaculture activities. If a water has a high turbidity value, the productivity is low. This is closely related to the process of photosynthesis and respiration of aquatic organisms.

The temperature in the Dumai harbor waters ranges from 28.75 to 29.58^{o}C. Temperature is an important factor supporting the metabolic and reproductive activities of organisms. The optimum temperature for marine organisms ranges from 28–30^{o}C (Kepmen LH No. 51 of 2004). The temperature in the waters of Dumai port is within the quality standard value. Temperature is strongly influenced by the intensity of the sun, water circulation, water mass, surrounding environmental conditions, water depth and others (Mutmainah & Adnan 2018). Temperature is an important factor in supporting the metabolic activities of organisms.

In general the pH is slightly in the alkaline range. However, the pH is within the range of 7.35-8.5, which is a limiting factor for organisms living in the waters. A too high pH will cause low survival of organisms (Sudirman et al 2013).

Salinity is a physical oceanographic parameter of waters that determines the feasibility of an aquatic environment. Salinity is influenced by the movement of water masses that occur continuously due to natural factors or human activities. Various kinds of human activities can directly cause changes in salinity. Salinity describes the total ion concentration of a water with the main ion constituents, namely sodium, potassium, magnesium, chloride, sulfate, and bicarbonate. The salinity value for Dumai port waters is below the quality standard for all stations, namely 25.4–31%.

Air quality. The results of the research on air quality parameters in Dumai port are presented in Table 3.

Table 3

Parameter of air quality in Dumai Port

Stations	*SO_2*	*CO*	*No_2*	*Dust*	*NH_3*	*H_2S*
I	41.07	630.25	33.38	48.63	0.0203	0.0035
II	40.45	454.75	30.64	47.78	0.0176	0.0035
III	37.47	602.75	34.18	56.80	0.0176	0.0035
IV	50.38	771.25	42.80	42.25	0.0228	0.0035
V	39.77	540.75	29.26	49.43	0.0176	0.0035
VI	44.75	770.50	40.94	65.58	0.0153	0.0035
VII	51.52	778.00	48.78	65.15	0.0128	0.0035
VIII	53.75	767.00	44.66	65.25	0.0153	0.0035
IX	52.02	1969.00	34.67	63.75	0.0203	0.0035
X	73.30	629.00	38.00	44.00	0.0128	0.0035

The SO_2 value is strongly influenced by the exhaust gases of motorized vehicles operating in the port area. Vehicle activities in this port support transporting goods from ships to passenger fields or vice versa. For SO_2, the quality standard is 900 ug Nm^{-3} in accordance with PP. No. 41 of 1999. The SO_2 parameter around the port area is in the value range of 39–77 ug Nm^{-3}, below the quality standard.

The value of carbon monoxide (CO) is strongly influenced by exhaust gas from motor vehicles operating in the Dumai Port area. The most important characteristic of CO is its ability to bind to hemoglobin. The value of CO in the port area ranges from 454.75–1969 ug Nm^{-3}. When compared to the quality standard of Dumai Port waters, it is below the standard of 3000 ug Nm^{-3} (PPRI No. 41 of 1999 concerning Air Pollution Quality Standards).

Alchamddani (2019) stated that although nitrogen dioxide (NO_2) gas is not very dangerous, it is an irritant that causes chronic respiratory problems. Alchamdai (2019) stated that NO_2 has a characteristic sharp smell, brown and reddish color below 21.1°C. It has an impact on health such as decreased lung function, shortness of breath and even death. NO_2 is produced from the rest of the combustion of gasoline, burning waste and the coal industry. Alchamdi (2019) added that the increase in NO^2 levels in the air is in line with the increase in the number of motorized vehicles. Air quality for NO_2 at Dumai Port meets the quality standards in accordance with PP. 41 of 1999, which is 400 ug Nm^{-3}. The value of NO_2 in all stations is in the range of 29.26–48.78 ug Nm^{-3}.

The dust parameter (TSP) at Dumai Port is in the range of 40-65.58 ug Nm^{-3}, below the quality standard of 900 ug Nm^{-3} as stated in PPRI No. 41 of 1999 concerning Air Pollution Quality Standards.

The presence of ammonia in the Dumai Port area comes from the decomposition process of waste found around Dumai Port. The air quality for the NH_3 parameter at the Dumai Port location in all monitoring stations was in the range of 0.0128-0.0228 ppm. The value is below the quality standard of 2000 ppm according to Kepmen LH no. 50 of 1996 concerning odor level standards.

The air quality regarding H_2S at Dumai Port had a value of 0.0035 ppm, lower than the quality standard of 0.02 ppm in accordance with Kepmen LH No. 50 of 1996. Organoleptically, the smell of air was felt in the ambience around the port area when conducting field surveys. Based on the analysis of ambient air quality, it can be said that the parameters for the Dumai port area do not exceed the quality standard.

Noise. The results of the research on noise parameters in Dumai port can be seen in figure 1.

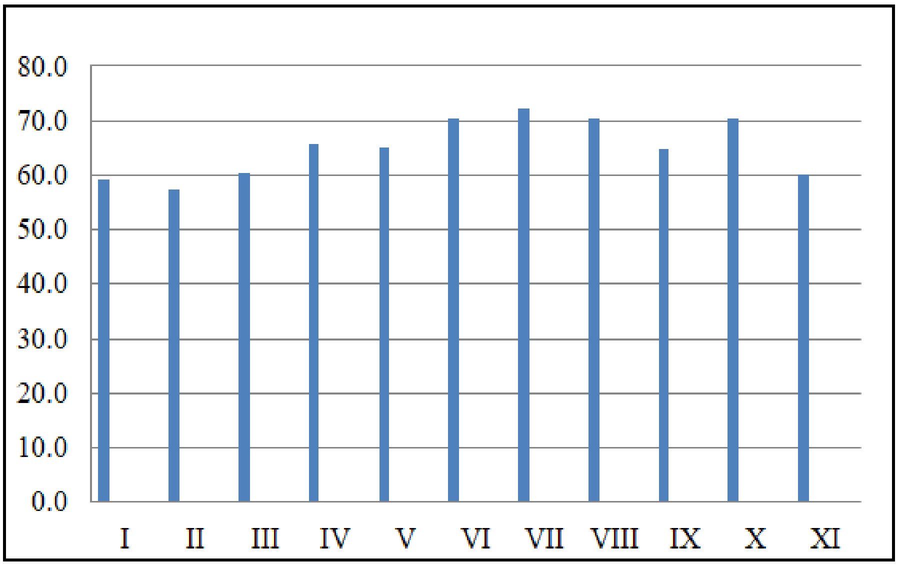

Figure 4. Noise level recorded in Dumai Port (dB).

Based on the monitoring results, the noise level at the Port of PT Pelindo Dumai Branch is below the quality standard of 70 dB. The results of the research by Harianto & Pratomo (2013) show that port workers who are exposed to noise increase their chances of developing hypertension by 21.88%.

Reforestation effort. Dumai Port has a green open space zone of 6.59 ha of the total land area of 114.44 ha. Noise-canceling plants have been planted on both sides of the road. After the implementation of the reforestation program, there was an increase in the number and abundance of flora and fauna around Dumai Harbor. Based on Law Number

26 of 2007 concerning Spatial Planning, the condition of reforestation in the form of green open space on the mainland of the port can be compared with the standard reforestation plan of the area. If the area of green open space reaches 20-30%, then it is included in the category of very good reforestation; moderate reforestation conditions exist if the area of green open space reaches 10-20%; and the reforestation condition is low if the area reaches only 0-10%. Based on these categories, the reforestation condition in the port area needs to be improved, because it is in the low reforestation category.

Sedimentation. Sedimentation or siltation must be minimized, especially in port pools and shipping lanes in order to secure and improve shipping flows. The problem of siltation will be even greater and more complex if the port is located at the mouth of a river. Geographically, Dumai Port is located at the mouth of the Dumai River and the sedimentation process is not only influenced by tides, but also by the river's discharge. In this regard, dredging shipping lanes and harbor ponds may reduce siltation caused by sedimentation. During the operation of the Dumai Port, no dredging of the port channel has been carried out. However, the port pool was dredged (Table 4).

Table 4

Dredging of the water pond of PT Pelindo Dumai Branch

Dredging year	*Volume (m^3)*
2010	100000
2015	86500
2018-2020	95000

From 2018 to 2020, yearly dredging was performed, removing each year a volume of 95000 m^3 from the area. The amount of sediment dredged is in accordance with the environmental assessment document that has been prepared by PT Pelindo Dumai Branch. Dumai Port sediment dredging is carried out periodically every 3 years and the maximum volume of sediment dredging is 100000 m^3 by dredging the dumping area as stipulated in Indonesian Law Government No 125 of 2018 concerning dredging and reclamation.

Dissolved metals. The results of the metal analysis that has been carried out in June 2020 are presented in Table 5.

Table 5

Dissolved metals in the water

Station	*Metals in water*				
	Cadmium ($mg\ L^{-1}$)	*Copper ($mg\ L^{-1}$)*	*Lead ($mg\ L^{-1}$)*	*Mercury ($mg\ L^{-1}$)*	*Zinc ($mg\ L^{-1}$)*
I	0.00300	0.01775	0.00575	0.00028	0.0065
II	0.00225	0.01825	0.01175	0.00028	0.01075
III	0.00225	0.01775	0.00575	0.00028	0.01324
IV	0.00225	0.01800	0.00575	0.00028	0.0215
V	0.00225	0.01725	0.00575	0.00028	0.0215
VI	0.00225	0.01775	0.00550	0.00028	0.02400
VII	0.00225	0.01775	0.00575	0.00028	0.01325
VIII	0.00225	0.01725	0.01175	0.00028	0.0115
IX	0.00100	0.0020	0.02300	0.00010	0.02500
X	0.00100	0.0020	0.02300	0.00010	0.05000

Sedimentation is the process of depositing material carried by water or wind. This process occurs through 2 stages. The first stage, at the time of erosion, water will bring material flowing into rivers, lakes and finally into the sea. The next stage occurs when water transport power is reduced and material is deposited in the watershed (Hutari et al 2018).

Solid waste management. Marine waste needs to be handled in an integrated manner, because it is negatively impacting the tourism sector, the environment, and human health. Loading and unloading activities, dock and warehouse operations, shipping traffic and others cause the emergence of solid waste. Based on the results of monitoring, there are several waste disposal facilities in the port area of PT Pelindo Dumai Branch. There are 20 units of waste containers scattered in the area of PT Pelindo Dumai Branch, spread within the port area and port support facilities. An increase in the number of containers in the port area can reduce the incidence of waste entering the water.

Hazardous waste management. Hazardous waste is estimated to reach an average 3 kg per month. Management is carried out by placing solid waste into plastic bags and in solid waste storage facilities. Liquid hazardous waste in the form of used oil is estimated to reach 3.5 L per day. The management is carried out by placing used the oil into a drum of 200 L, which will later be transported to a hazardous waste storage facility.

Liquid waste management. Liquid waste can affect the quality of water bodies. Liquid waste originates from restrooms, pantry and operational activities in the terminal. PT. Pelindo Dumai Branch has a waste treatment plant under construction, being in the installation stage. There are 2 point of treatment, in the office and passenger terminal. There has been no issuance of permission from relevant agencies for the disposal of liquid waste in the sea.

Conclusions. Ecological existing conditions in Dumai Port indicate that water quality, noise, dissolved metals, waste management, hazardous waste management, and ambient air quality meet the quality standards. Groundwater conditions, greening, sedimentation (dredging) and liquid waste management need attention from the perspective of port management sustainability.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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