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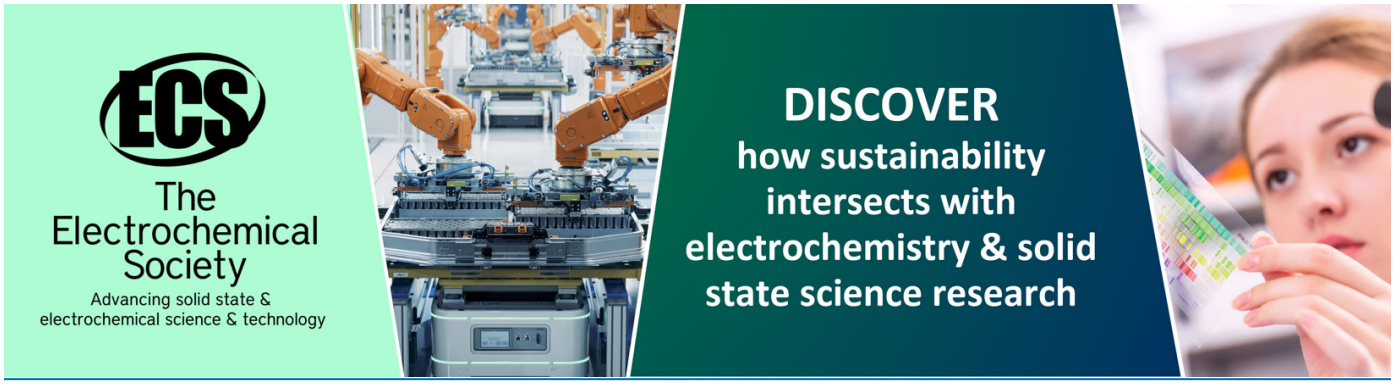

Lesson learned on coral reef ecosystem services valuation damage due to vessel grounded in Indonesia

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Abstract: Vessel grounded on coral reef ecosystem still one of the most significant damage by the incident to corals ecosystem services. Many cases had been handled, but not all of them are completely solved. The settled cases showed the willingness of the vessel owners to paid the claimed environmental loss. This research paper is aimed to compare cases of a vessel grounded during the year 2017 and 2018. This paper concluded the summary of all the works of experts hired by the Directorate General of Law Enforcement on corals ecosystem; ecosystem services valuation, and national regulation. The final calculation shows a varied amount of value claimed, due to the quality of corals before damages, its location and its technical approaches. The calculation of the claimed cost was based on the principles of ecosystem services valuation approaches which includes provisioning, regulating, cultural and supporting services. From all cases, the value of coral ecosystem per squares meter per year of corals damage ranges from IDR 0.12 to 0.83 million. This value was related significantly with the year damaged coral, the quality of the coral ecosystem before damaged, and the distance from the nearest coastline.

Keywords: coral reef; ecosystem services; economic valuation; vessel grounded.

1. Introduction

Indonesia is a country located on the world trade route and logistics system by using the sea as media as the world's sea transportation [1]. More than 80% of the trade distribution in goods and services uses sea transportation, and 40% goes through the territory of the country which extends from Sabang to Merauke and crosses from Miangas to Rote Island [2]. Indonesia's marine potential opens big business opportunities that can be a source of foreign exchange for the Indonesian state [3].

After establishing the United Nation Convention on the Law of the Sea (UNCLOS) 1982, Indonesia has known as the largest archipelagic country in the world, where the ocean area of 5.9 million square kilometers (2/3 of the total area of the sea waters of Indonesia) became the territorial adhesive of 17,504 islands and united the 81,000 kilometers of Indonesia's coastline (the second-longest after Canada). Also, the location of Indonesia, which is on the equator and the tropics, has

consequences for the magnitude of the rich biodiversity, even Indonesia is known as a mega-biodiversity country [2, 4].

Indonesia's strategic location makes Indonesia potentially a world maritime axis [3]. Indonesia's sea area is one of the most densely populated sea traffic media in the world [2]. Indonesia has three Indonesian archipelagic sea lanes (ALKI) which provide access to ships from other countries through the Indonesian sea area in peace. Of course, this has become one of the significant marine potentials to be captured as a source of foreign exchange for national development if Indonesian marine personnel can take a better role in capturing that existing opportunity [5].

Sea traffic through these three ALKIs does not cause consequences for Indonesia. The density of ships going back and forth through Indonesian sea waters has the potential to impact the occurrence of sea accidents which can result in pollution and/or environmental damage, such as ship collisions, ship aground on coral reefs, sinking ships and so on [3]. Of course, it has negative impacts that can harm the people Indonesia, because the Indonesian people should be able to utilize the existence of coastal and marine resources to the greatest of their welfare [6].

Three important ecosystems in coastal areas that have the potential to face negative impacts (damage) of sea transportation activities are coral reef ecosystems, seagrass beds and mangroves [7]. Cases of environmental damage in coastal areas occurred a long time ago. Several cases of a vessel grounded and/or pollution based damage have had a major impact on the environment in Indonesia's coastal areas. However, these cases have not been handled well. Several cases of pollution and/or environmental damage that occurred from 2017 to 2018 have shown a significant impact that affects the condition of coral reef in Indonesia. Some cases have been resolved and are just waiting for continued execution in the context of ecosystem recovery. This article is intended illustrate how the legal substance and assessment of coral reef ecosystem losses are applied in Indonesia.

This research focused on the lesson learned of valuing coral reef ecosystem services in Indonesia, primary based on how the Ministry of Environment and Forestry Number 7 the Year 2014 implemented to solve the environmental dispute resolution raised in Indonesia during 2017-2018. In addition, the other focus of this research was measuring the correlation between all the settle claimed on coral reef ecosystem services loss with the several status of coral condition, such as the year of damaged, the quality of coral coverage before damaged, the distance of coral damage to the nearest coastline and the conservation status of the damaged coral reefs. The limitation of this research was because of the limited number of settled environmental dispute resolution in the period of 2017-2018 in Indonesia.

2. Materials and methods

The research on coral reef ecosystem services valuation has been conducted based on several cases during 2017-2018 that handled by the directorate general of law enforcement for the Ministry of Environment and Forestry as an institution authorized to make efforts to resolve environmental disputes in Indonesia. The method used by this research is a comparative analysis between all cases of a vessel grounded on coral reef ecosystem in Indonesia, and descriptive analysis would be followed used to describe a lesson learned on this valuation damage of coral reef ecosystem service due to vessel grounded in Indonesia.

This comparative method used because all the techniques for valuing the ecosystem services loss were similar in every case. The coral reef illustrates the existence of ecosystem services that are beneficial to the welfare of the community. Coral reef ecosystem services can be assessed those related to the function of ecosystems, such as provisioning services, regulating services, cultural services, and supporting services (Figure 1).

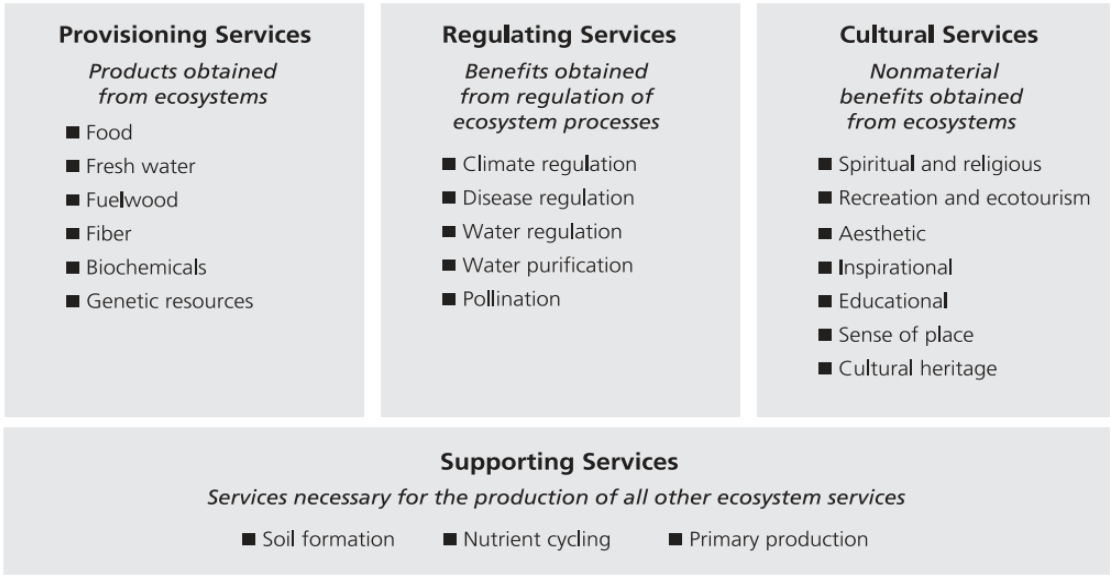

Figure 1. The potency of coral reef ecosystem services [8-14].

Valuing the ecosystem service valuation carried out using several valuation techniques that are common and widely used by resource economic valuators. Economic valuation techniques that can be used in valuing loss of coral reef ecosystem services on the cases include travel cost methods (TCM), contingent valuation methods (CVM), effects on production (EOP), and benefits transfer method (BTM) [6-9, 12-19].

3. Result

3.1. Regulation

The handling of a vessel grounded cases on coral reef ecosystems in Indonesia is settled by referring to several laws and regulations in force in Indonesia. The vessel grounded on the coral reef ecosystem is included in the category of environmental cases, so that the handling is adjusted to the laws and regulations relating to the environmental case.

Handling of environmental cases in Indonesia is based on the mandate of Law Number 32 of 2009 concerning Management and Protection of the Environment. The procedure for handling environmental disputes is carried out based on the Minister of Environment Regulation Number 4 of 2013 concerning Procedures for Settling Environmental Disputes. The procedure for calculation of environmental losses is regulated in the Regulation of the Minister of Environment Number 7 of 2014 concerning Assessment of Environmental Damage.

3.2. Assessment of environmental damage

Damage loss assessment is carried out in the form of compensation claim calculation. Claims for compensation for environmental damage in Indonesia are regulated based on Minister of the Environment Regulation Number 7 the Year 2014 concerning Calculation of Compensation due to Pollution and/or Environmental Damage. The settlement of environmental disputes regarding vessel grounded cases can be done outside or through a court that must be accompanied by evidence of environmental damage (coral reefs). This data or evidence must be the result of research, field observations, or other data in the form of expert opinions which can be scientifically justified.

Some things that need to be analyzed in order to resolve the case of a vessel grounded on a coral reef include: (i) is it true that coral reefs have been damaged; (ii) who caused damage to the coral reefs; (iii) who suffered losses due to damage to coral reefs; (iv) what is the status of ownership of damaged coral reef ecosystems; (v) what type of loss (direct or indirect); (vi) how much is the loss;

(vii) how long did the coral reef damage occur; (viii) what types of coral reef ecosystem services are affected; (ix) the value of ecosystems, both those which can and cannot be valued economically, and others [2].

Minister of Environment Regulation Number.7 Year 2014 also explains that pollution and/or environmental damage will cause various types of losses which can be classified as (i) losses due to exceeding Environmental Quality Standards; (ii) losses for reimbursing the costs of carrying out environmental dispute resolution; (iii) losses to cover costs for overcoming pollution and/or environmental damage and environmental restoration; (iv) ecosystem losses; and (v) community losses due to pollution and/or environmental damage [2, 20].

However, for cases of ship wreckage on coral reefs, more is approached by counting only four losses, namely: (i) losses for reimbursement of costs for carrying out environmental dispute resolution (coral reefs); (ii) losses for the costs of replacing damaged and recovery coral reef ecosystems; (iii) ecosystem losses; and (iv) community losses due to damage to coral reefs.

Determination of coral reef loss claims is carried out using the following steps: (i) determination of the exposed area; (ii) determination of the type of affected coral reef ecosystem; (iii) measurement determination of the extent of coral reef ecosystem damage that can be compensated; (iv) assessment of loss of economic value of damaged coral reef ecosystem services; (v) analysis of the cost of restoration damaged coral reef ecosystems; (vi) analysis of operating costs and verification in the context of resolving environmental disputes; and (vii) determination of the total value of compensation for coral reef ecosystem damage [2].

3.3. Measuring the compensated area of coral reef damage

The survey is promptly conducted to observe the reef profile of the target location and identify the boundaries of the affected and non-affected areas. Once the boundary of the two regions is identified from the water surface, the affected point is indicated by the marker buoy. Coordinates recording by GPS is done in one corner of the affected area. This marker is also a benchmark for determining the collection of corals cover data and the diversity of coral species between areas in detail. Figure 2 shows the 'Fishbone' survey technique with transect meter is used to identify, observe and measure the general extent of damage to coral reefs [21]. Marking at the initial stage is enough to describe the topographic map of reef damage where the meter line is placed. By following a line of transect lines on either side of the line, patch damage, the kind and type of damage (directly or indirectly) is directly identified. The distance between points of damage (patch damage) is measured by the Nearest to Neighbor technique. Meanwhile, damage illustration site could be shown in Figure 3.

The total of the coverage area of affected coral damage (massive damage) is obtained based on two measurement techniques, namely GPS-tracking from the Aerial Imagery Drone above the water level and the distance measurement between points directly underwater [23]. This is the calculation formula based on the coverage measurement of irregular polygons:

$$A_p = \frac{\left(Y_1Y_2 - X_2Y_1\right) + \left(Y_2Y_3 - X_3Y_2\right) + \left(Y_3Y_4 - X_4Y_3\right) + .. + \left(Y_{n-1}Y_n - X_nY_{n-1}\right)}{2}$$

(A_P = polygon area, while X and Y are coordinates of a point if viewed from the X or Y-axis), these two measurement techniques are analyzed with the help of a computer program. While the size of the distance between points underwater is plotted and analyzed using a combination of CPCe program software.

After the area of damage to the affected coral reef is known, then to find out the area of damaged coral reef that can be compensated for is done using the following formulation:

$$CAD = DA * CCA * PM$$

Note: CAD = compensated area of damage (sq. m); DA = damage areas (sq. m); CCA = coral coverage area (%); and PM = probability of mortality (%).

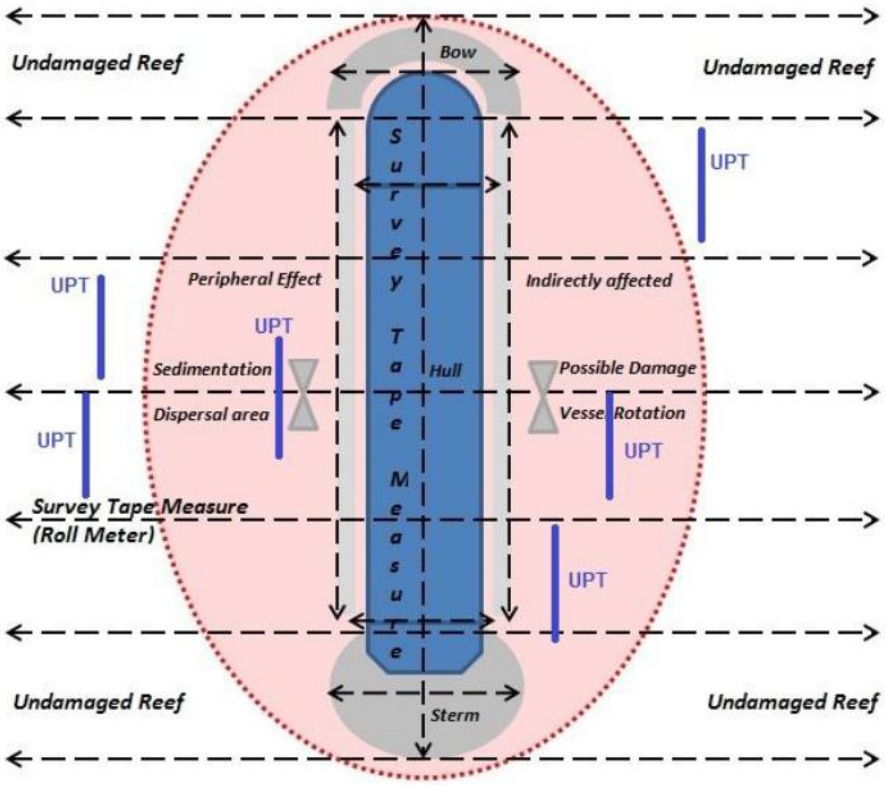

Figure 2. "Fishbone" Method [21].

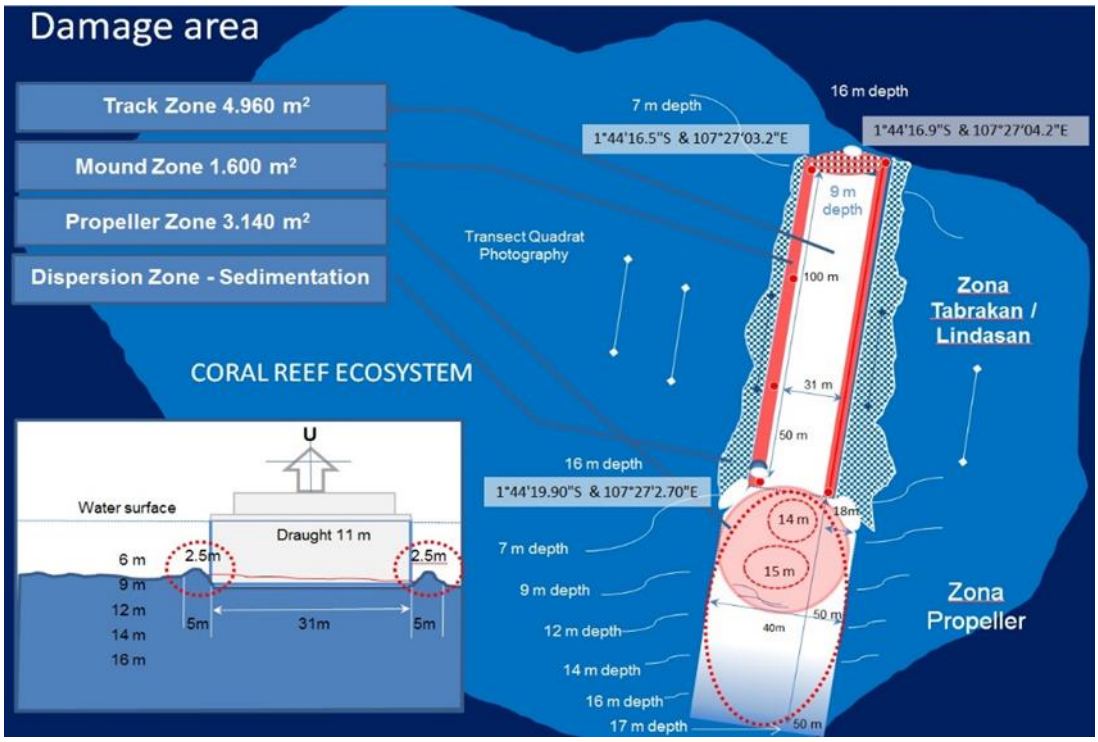

Figure 3. Damage Site Illustration [22].

3.4. Valuing ecosystem loss

Assessment of coastal and marine ecosystems is one of the references for evaluating the loss of coral reef ecosystem services that occur due to environmental damage caused by an activity [2]. The economic valuation of ecosystem services is approached using the total economic value approach to ecosystem services based on the approach of de Groot et al [9] which states that the total value of ecosystem services consists of: (i) ecological value (EV); (ii) socio-cultural values (SV); and (iii) economic value (economic value, EcV). Mathematically can be denoted as follows:

$$TEV = EV + SV + EcV$$

Some analytical techniques used in the economic valuation of ecosystem services include: (i) effect on productivity – EOP; (ii) contingent valuation method – CVM; (iii) travel cost method – TCM; (iv) replacement cost method – RCM; and (v) benefit transfer method – BTM [7-9, 12-19].

3.5. The value of coral reef ecosystem services loss

Based on several cases of a vessel grounded on coral reef ecosystem handled by Directorate General of Law Enforcement Ministry of Environment and Forestry in the year 2017-2018 and have been decided as the arranged claim for compensated loss, the average value of coral reef ecosystem services loss calculated IDR 0.35 million per meter squares per year. The range value loss of coral reef ecosystem services per meter squares per year calculated IDR 0.12 million to IDR 0.83 million (Table 1). The number value of ecosystem services loss IDR 0.83 million per meter square per year seems to be different with other values, although the valuation technique was similar because the owner of the grounded vessel was willing to pay the cost directly without any challenges from them.

There are more than twenty cases of a vessel grounded on a coral reef ecosystem that happened in Indonesia in the year 2017-2018. In this year 2019, there are already 8 cases of coral reef damage happened due to vessel grounded and/or pollution in Indonesia. However, all the cases are still ongoing and still need to be clarified, challenged and negotiated by all the parties involved in each case, then could not include being calculated in this research.

Table 1. Several values of coral reef ecosystem services loss in the year 2017-2018.

Year of Cases	Region	Quality of Coral	Coral Location (km)	Value (million IDR/m^2/year)
2017	Belitung Timur (Gosong Panjang)	Moderate	122	0.12
2017	Bangka (Karang Pesawat)	Moderate	82	0.15
2017	Jepara (Cilik, Karimunjawa)	Good	12	0.31
2017	Jepara (Kemujan, Karimunjawa)	Good	8	0.37
2017	Jepara (Tengah, Karimunjawa)	Good	10	0.57
2018	Jepara (Seloka, Karimunjawa)	Bad	12	0.14
2018	Jepara (Ujung Gelam, Karimunjawa)	Good	8	0.83
2018	Kep. Seribu (Pari)	Bad	3	0.17
2018	Aceh Besar (Lampuuk)	Bad	1	0.30
2018	Probolinggo (Karang)	Good	8	0.47
2018	Bima (Lawa Darat)	Moderate	34	0.40
2018	Raja Ampat (Kapissawar)	Bad	4	0.46
	Average Value			0.36

Source: Directorate General Law Enforcement Ministry of Environment and Forestry [24].

4. Discussion

The average value of IDR 0.36 million per meter squares per year, as mentioned in Table 1 was calculated based 12 settled cases of a vessel grounded on coral reef ecosystem that happened in in the year 2017-2018. The range of value loss IDR 0.12-0.83 million per meter squares per year estimated

based on four functions of coral reef as ecosystem services. This value is still in minimum value and could be higher when the techniques and approaches to measure other ecosystem services could be developed. Costanza et al. [8] stated that because of the nature of the uncertainties, they must be considered a minimum estimate and that is the way in the year 2014 Costanza et al. [13] give another opinion on his research and gave a higher value of the ecosystem than in the year 1997.

There are four ecosystem services as mentioned by Costanza et al [8], de Groot et al [9], MEA [10], UNEP [11], de Groot et al [12], Costanza et al [13], Wahyudin et al [6], Wahyudin et al [19], i.e. provisioning services (production services), regulating services, cultural services (information services), and supporting services (habitat services). All the services calculated as well as the approaches of EOP, CVM, TCM, RCM and BTM.

The average value loss of coral reef ecosystem are still higher than several studies related with ecosystem services in Indonesia as well as mentioned in Lombok Strait IDR 0.03 million per meter squares per year [17], in Bontang IDR 0.01 million per meter squares per year [7, 25], in Wakatobi IDR 0.02 million per meter squares per year [26]. The differences value of coral reef ecosystem services were caused by the detail ecosystem services calculated, the technique valuation, location, quality of coral reef, the population involved in valuation, and other differences social-ecological system of each calculated coral reef ecosystem services.

Based on those issues, we try to deliver the idea to simply rapid valuation of coral reef ecosystem services loss, in order to have a rapid calculation of loss. Those models include the year (t), quality of coral reef ecosystem (Q, %) and the distance of coral reef from the nearest coastline (D, km) as variables influenced the value of coral reef ecosystem services value and/or loss (V, million IDR). There are two models defined, i.e. linear model and non-linear model by using formulas below.

$$V = \beta_0 + \beta_1 t + \beta_2 Q + \beta_3 D \text{ (linear model)}$$

$$V = \beta_0 t^{\beta_1} Q^{\beta_2} D^{\beta_3} \text{ (non-linear model)}$$

Table 2. Regression analysis of the linear model and non-linear model for rapid coral reef ecosystem services value and/or loss

Parameters	Linear Model	Non-Linear Model
R-square	0.6586	0.7296
Significance F	0.0285	0.0116
Intercept	-437.8932*	-8171.2724*
	(241.3437)	*(4454.4499)*
Coefficient of t	0.2170*	1073.1471*
	(0.1196)	*(585.2942)*
Coefficient of Q	0.0076**	1.1313***
	(0.0024)	*(0.2751)*
Coefficient of D	-0.0011*	-0.2323**
	(0.0014)	*(0.1009)*

Note: * not significant (p-value > 0.05), ** significant (0.05 > p-value > 0.00), *** very significant (p-value < 0.00).

The result of regression analysis (ANOVA) based on all the required variables could be shown in Table 2. Table 2 shows that the non-linear model more significant than the linear model. Shown that R-square (0.7296) and Significance F (0.0116) of the non-linear model more significant than R-square (0.6586) and Significance F (0.0285) of the linear model. The variable of Q for both models shows more significant than others. In the linear model shows only variable of Q more significant than others, meanwhile in the non-linear model shows variable of Q and variable of D more significant than others. Based on this result, we recommend the non-linear model as a chosen model to rapid estimate the value of coral reef ecosystem services and/or loss. The model as the following formula:

$$\ln V = -8171.2724 + 1073.1471 \ln t + 1.1313 \ln Q - 0.2323 \ln D$$

With the formula above, we could rapidly estimate the value of coral reef ecosystem services loss by introducing the year of cases to variable t, the quality of coral reef ecosystem before being damaged by vessel grounded (percentage life form, %) to variable Q, and the distance of damaged coral reef from the nearest coastline (kilometers) to variable D.

The formula mentioned still need to be developed by introduced the general socioeconomic conditions into the models. The socio-economics condition may include the conditions of human resource development which are demonstrated by three characteristics, namely (i) individual capacity and capability characteristics of the level of formal education undertaken, (ii) characteristic of socio-ecological system of society in the form of relationship between social system with the existence of coastal and marine resources and (iii) local institutional characteristics in the management of natural resources and the surrounding environment [27-29].

5. Conclusions

The vessel grounded on a coral reef in Indonesia often happened due to too many vessels from over the world and domestic using international sea lane and domestic sea lane as their transportation media. There are more than twenty cases of a vessel grounded in Indonesia, but only 12 cases have been settled by Directorate Law Enforcement Ministry of Environment and Forestry. The average value of loss IDR 0.36 million per meter squares per year and the range value of loss IDR 0.12-.83 million per meter squares per year. Those value range estimated based four classification of coral reef ecosystem services and still higher than a few of references due to the differences of the calculating method, the quality of coral reef, the distances from the nearest coastline, the year, and other differences coral reef social-ecological system.

The rapid value of coral reef ecosystem services loss could be estimated by using a formulated model based on this research. The value in this research reminds still in minimum value and could be higher and higher when the techniques and approaches to measure other ecosystem services could be developed.

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