International Journal of *Geo-Information*

MDPI

Article

Potential Loss of Ecosystem Service Value Due to Vessel Activity Expansion in Indonesian Marine Protected Areas

Adam Irwansyah Fauzi [1,2,3,*], Nur Azizah [1], Emi Yati [4], Aulia Try Atmojo [1,2], Arif Rohman [1], Raden Putra [5], Muhammad Ario Eko Rahadianto [1], Desi Ramadhanti [1], Nesya Hafiza Ardani [1], Balqis Falah Robbani [1], Muhammad Ulin Nuha [1,2], Agung Mahadi Putra Perdana [1,2], Anjar Dimara Sakti [3,6], Muhammad Aufaristama [7] and Ketut Wikantika [3,6]

1 Department of Geomatics Engineering, Faculty of Regional and Infrastructure Technology, Institut Teknologi Sumatera, Lampung Selatan 35365, Indonesia
2 Research and Innovation Center for Geospatial Information Science, Institut Teknologi Sumatera, Lampung Selatan 35365, Indonesia
3 Center for Remote Sensing, Institut Teknologi Bandung, Bandung 40132, Indonesia
4 Research Center for Remote Sensing, Research Organization for Aeronautics and Space, Indonesia National Research and Innovation Agency (BRIN), Cibinong 16911, Indonesia
5 Department of Environmental Engineering, Institut Teknologi Sumatera, Lampung Selatan 35365, Indonesia
6 Remote Sensing and Geographic Information Science Research Group, Faculty of Earth Sciences and Tecnology, Institut Teknologi Bandung, Bandung 40132, Indonesia
7 Department of Applied Earth Sciences, Faculty of Geo-Information Science and Earth Observation, University of Twente, Hengelosestraat 99, 7514AE Enschede, The Netherlands
* Correspondence: adam.fauzi@gt.itera.ac.id

Abstract: Sustainable Development Goal (SDG) number 14 pertains to the preservation of sustainable marine ecosystems by establishing marine protected areas (MPAs). However, studies have reported massive damage to Indonesian marine ecosystems due to shipping pollution, anchors, and fishing nets. Thus, this study estimated the potential loss of ecosystem service value due to vessel activity expansion in the MPAs of Indonesia. This study was divided into three stages. The first stage is vessel activity expansion zone modeling based on kernel density. The second stage is marine ecosystem service value modeling through semantic harmonization, reclassification, and spatial harmonization. The last stage is the overlay of the vessel expansion zone model, marine ecosystem service value model, and the MPA of Indonesia. The results of this study indicate that the marine neritic zone of Indonesia has an ecosystem service value of USD 814.23 billion, of which USD 159.87 billion (19.63%) are in the MPA. However, the increase in vessel activity that occurred in 2013–2018 could potentially lead to the loss of the ecosystem service value of USD 27.63 billion in 14 protected areas. These results can assist policymakers in determining priority conservation areas based on the threat of vessel activity and value of ecosystem services.

Keywords: ecological accounting; spatial modeling; GIS; marine threat; remote sensing; protected areas; geospatial analysis; blue carbon ecosystem

Citation: Fauzi, A.I.; Azizah, N.; Yati, E.; Atmojo, A.T.; Rohman, A.; Putra, R.; Rahadianto, M.A.E.; Ramadhanti, D.; Ardani, N.H.; Robbani, B.F.; et al. Potential Loss of Ecosystem Service Value Due to Vessel Activity Expansion in Indonesian Marine Protected Areas. *ISPRS Int. J. Geo-Inf.* **2023**, *12*, 75. https://doi.org/10.3390/ijgi12020075

Academic Editors: Wolfgang Kainz and Godwin Yeboah

Received: 9 November 2022
Revised: 7 February 2023
Accepted: 16 February 2023
Published: 18 February 2023

1. Introduction

A marine ecosystem is the central unit of ecological function in the marine environment [1]. Marine ecosystems play an important role in human well-being by providing social, economic, and environmental benefits to a growing population globally [2]. They store many ecosystem services, including provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling [3]. These ecosystem services are valuable for providing human benefits [4].

Ecosystem service value is the value or benefit received by the living from an ecosystem [2]. The assessment of ecosystem services is critical for formulating public policies for natural resource management and social policies [4–6] The greater the demand for sustainable development implementation, the greater the information needs of ecosystem service value for various policies and development planning [6–9].

Several studies have developed spatial models of ecosystem service values on land [7,10,11]. Tianhong et al. (2010) [7], Tolessa et al. (2017) [10], and Jiang et al. (2020) [11] have conducted research related to land use/land cover (LU/LC) dynamics to determine the impact of the value of changes in ecosystem services. A study by Tianhong et al. (2010) [7] identified a decrease of CNY 231.3 million from 1996 to 2004, which was mainly due to reduced forest area, wetlands, and water bodies in Shenshen City, China. A study conducted by Tolessa et al. (2017) [10] showed that changes in forest cover from 1973 to 2015 resulted in a loss in the value of ecosystem services by approximately USD 3.69 million. Further, Jiang et al. (2020) [11] showed that the total value of ecosystem services, including provision, regulation, habitat, and cultural services, increased from USD 1.77 trillion in 1990 to USD 1.81 trillion in 2015. Although many studies provide information regarding spatial modeling of ecosystem services on land, the spatial modeling of marine ecosystem service value remains limited. Notably, spatial modeling of the value of marine ecosystem services is needed, especially for marine spatial planning purposes [4,6,12].

Several studies state that the damage to marine ecosystems caused by climate change and anthropogenic activities is worsening, and is continuing to rise as an emerging concern [13–17]. Climate change and anthropogenic activities resulting in deforestation harm the long-term viability and distribution of mangroves globally [18–21]. Some studies also report that anthropogenic activities, such as land pollution and waste dumping, are significantly threatening seagrass ecosystems [22–24]. In addition, the ecological impacts of climate and chemical change on marine biodiversity are potentially severe and widespread on coral reefs [13,25]. Therefore, the existence of MPAs becomes increasingly essential.

Marine protected areas (MPAs) are one of the policy instruments to help ensure long-term conservation, maintain biodiversity and ecosystem services, and ensure the sustainable use of marine ecosystems for climate change [26–30]. The MPA is a tool for mitigating climate change, and currently, only 7% of MPAs are protected [31]. Meanwhile, based on the UN Convention on Biological Diversity, it proposes to protect at least 30% of the planet by 2030 [32]. SDG 14 is one of the solid reasons for coastal countries to establish MPAs. As an archipelagic nation, Indonesia has an MPA of 7.19% of its ocean [33]. The vast area of Indonesian marine ecosystems has resulted in the need for priority conservation, as well as effective and efficient monitoring [34,35]. The determination of priority areas for marine conservation should be supported by the existence of a spatial model of marine ecosystem service value [4,6,36].

Marine ecosystem pressures are not only caused by climate change, but are also likely to be exacerbated with the growth of the marine industry [26], as in the case of the Aru Islands, Indonesia, with an increasing number of companies and fishing fleet operations [37]. Additionally, the geographical position of Indonesia acts as the entry point for currents from the Pacific Ocean to the Indian Ocean, thus encouraging the massive exploitation of existing fishery resources [38]. Uncontrolled and destructive fishing has also damaged coral reef ecosystems [39], as in eastern Indonesia [40].

Activities from large container ships produce harmful pollutants that damage marine ecosystems [41–43]. The increased activity of ships in the water can encourage pollution in the marine environment, which can negatively impact ecosystems, habitats, and marine biota and decrease the quality of the coastal environment [44]. Ship traffic in water can also cause physical and mechanical damage to aquatic ecosystems due to the danger posed by the ship propellers [45]. Vessel navigation changes hydrodynamic forces, marine animals can be injured or killed by collisions with ships, fishing vessels deplete marine living resources, seabeds are damaged by dredging, and the ballast of the vessel sailing in the oceans can lead to the invasion of non-native species [46].

The current damage to global marine ecosystems is mainly triggered by vessel activity [47–49]. However, studies on the potential loss in ecosystem service value based on a spatial approach in MPAs are still limited. Thus, based on multi-source spatial data products, this study aimed to analyze the potential loss of marine ecosystem service value due to vessel activity in the MPA. This study conducted three primary analyses: vessel zone expansion modeling, marine ecosystem service value modeling, and marine ecosystem service value (MESV) potential loss in the MPA. The novelty of this research lies is the development of marine ecosystem service value and the estimation of its potential loss due to vessel activity in the MPA based on a geospatial approach. The results of this study will assist policymakers in determining priority areas for marine conservation based on the threat of vessel activity and value of ecosystem services.

2. Materials and Methods

2.1. Study Area

Indonesia is a mega-biodiversity archipelagic country with abundant coastal and marine biodiversity such as mangrove, seagrass, and coral reef ecosystems [50–52]. Indonesia's mangrove and seagrass ecosystems account for 25% of the world's forest area; thus, they significantly mitigate global climate change [53]. Mangrove ecosystems play an essential role in the sequestration of blue carbon, protecting against storms, and protecting marine habitats [54–56]. Seagrass ecosystems can also reduce climate change by sequestering carbon over a long period of time [57], providing food [58], and controlling erosion [59]. However, the marine ecosystem services found in Indonesian waters are inseparable from their anthropogenic use. Increasing anthropogenic and naturogenic factors threatens ecosystem sustainability [60,61]. The greater the pressure, the more likely the ecosystem will degrade, resulting in the ecosystem being unable to provide the same services as before [62]. In Indonesia, the provision of services, especially in seagrass [22,63,64] and mangrove ecosystems [65,66], is under immense pressure.

This study used five types of marine ecosystems: mangroves, seagrass, coral, coastal shelf, and intertidal. The study area was limited to the neritic zone of Indonesia as a physical boundary. In addition, the Indonesian Fisheries Management Zone (IFMZ) and the MPA were adopted as administrative boundaries. The IFMZ or WPP-RI is a fishery management area for fishing, fish cultivation, conservation, research, and fishery development, and includes inland and archipelagic waters, territorial seas, additional zones, and the exclusive economic zone of Indonesia [23]. Simultaneously, based on the WDPA data, the MPA of Indonesia is ~3.06%, or 181,865 km^2 of the total marine and coastal area (5,947,954 km^2) [67]. The research locations are shown in Figure 1.

2.2. Methodology

This research comprehensively covers three main aspects: vessel zone expansion modeling, marine ecosystem service value (MESV) modeling, and MESV potential loss in the MPAs. Figure 2 illustrates the research framework.

2.2.1. Vessels Expansion Zone (VEZ) Modeling

The vessel activity zone was processed using the VBD data [68] for the period from 2013 and 2018. The VBD data in raster format were converted into a vector data format to generate the distribution of vessel point locations in Indonesian waters. The vessel activity zone was created using the kernel density. The radius kernel density was determined based on the standard distance (Equation (1)). After obtaining the vessel activity map, we reduced the vessel activity zone in 2013 to that in 2018 to obtain the vessel expansion zone between 2013 and 2018.

$$SD = \sqrt{\frac{\sum(xi - X)^2}{N} + \frac{\sum(yi - Y)^2}{N}} \tag{1}$$

SD = standard distance
xi dan yi = coordinate of point i

N = number of data
X dan Y = mean center from the point i

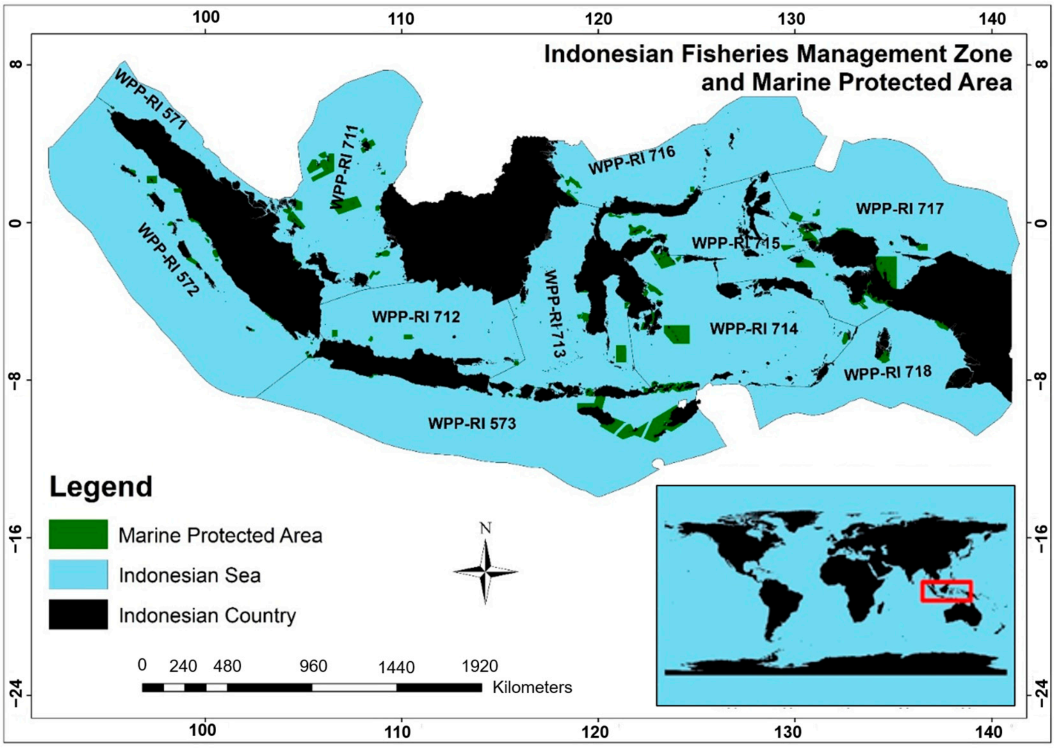

Figure 1. Map presenting the Indonesian Fisheries Management Zone (IFMZ) and Indonesian marine protected areas (MPAs).

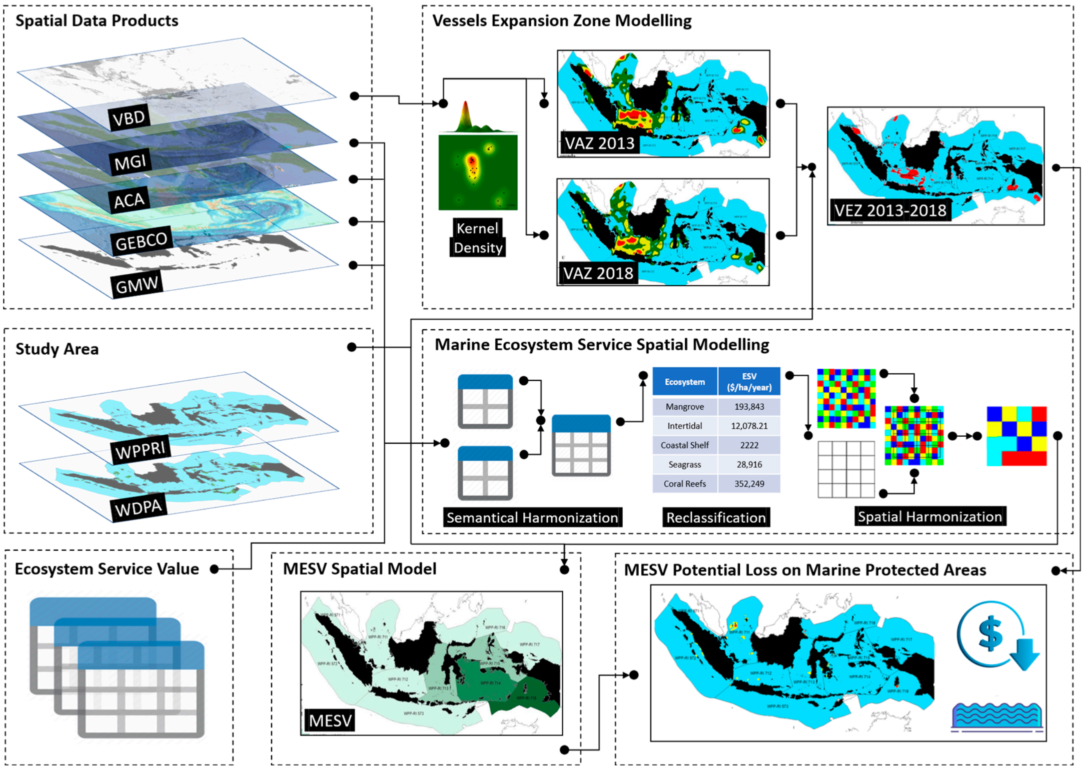

Figure 2. Schematic depicting the research framework developed in this study.

2.2.2. Marine Ecosystem Service Value (MESV) Modeling

MESV modeling was developed using multi-source spatial data products, i.e., Global Mangrove Watch (GMW), Alen Coral Atlas (ACA), Murray Global Intertidal (MGI), and General Bathymetric Chart of the Oceans (GEBCO). The ecosystem service value for each ecosystem function and type was obtained from the existing literature (Table 1) [69,70]. In this study, the unit of ecosystem service value was converted from USD/ha/year to USD/km^2/year to correlate this with the spatial resolution of the output model.

Table 1. Description of ecosystem service value for each ecosystem function and type.

No.	Ecosystem	Ecosystem Service Value USD/Ha/Year	Reference
1	Coral	352,249	[69]
2	Seagrass	28,916	[69]
3	Mangrove	193,843	[69]
4	Continental Shelf	2222	[69]
5	Intertidal	12,078.21	[70]

In the first step, semantic harmonization of the MESV was conducted to harmonize the ecosystem type in the ecosystem service value database with ecosystem type in the multi-source spatial data products. The semantically harmonized ecosystem service value was then reclassified to convert the ecosystem information into ecosystem service value.

The multi-source spatial data products used to develop the MESV have various spatial resolutions. Therefore, we conducted spatial harmonization by resampling each data product to 1 km^2. Furthermore, spatial data integration was conducted by overlaying and adding up the ecosystem service value for each marine ecosystem to produce MESV with units of USD/km^2.

2.2.3. MESV Potential Loss on Indonesian MPAs

Based on the existing literature, increased vessel activity negatively impacted the marine ecosystems. All vessel wave effects and their indirect effects led to changes in ecosystem services. This condition can also cause a loss of marine ecosystem existence [71]. Therefore, we considered a worst-case scenario by assuming that high vessel activity can cause the loss of all marine ecosystem services. The value of ecosystem services in the high-activity vessel area was 0. Technically, the potential loss of marine ecosystem service value due to vessel activity expansion in MPAs was conducted by overlaying spatial models of MESV, VEZ, and the Indonesian MPA. Further, the potential loss of MESV was estimated by identifying the total ecosystem service value in the MPA impacted by vessel activity expansion.

2.3. Data

This study explored various multi-source spatial products and protected area data to analyze the potential loss of ecosystem service value in the MPA. The specifications of the products are listed in Table 2.

2.3.1. Global Mangrove Watch (GMW)

The GMW is a global mangrove forest data product [72,73]. The GMW has a spatial resolution of 25 m with data available for 1996, 2007, 2008, 2009, 2010, 2015, 2016, 2017, 2018, 2019, and 2020. The GMW data product uses a methodology developed based on the ALOS PALSAR classification and Landsat sensor data, where mangroves are classified using the extremely randomized trees (ERTs) classifier. The overall accuracy for the mangrove area was 94.0%, with a 99% confidence level and the true value was between 93.6–94.5%, using 53,878 points of accuracy in 20 globally distributed areas [73].

Table 2. Specification of data products used in this study.

No.	Data Products	Data Information	Spatial Resolution	Data Format	Temporal Range	Reference
1.	Global Mangrove Watch (GMW)	Mangroves	25 m	Raster	1996, 2007–2010, 2015–2020	UNEP WCMC
2.	Allen Coral Atlas (ACA)	Coral Reefs and Seagrass	5 m	Raster	2018–2020	Arizona State University Center for Global Discovery and Conservation
3.	Murray Global Intertidal (MGI)	Intertidal	30 m	Raster	1984–2017	USGS/NASA
4.	General Bathymetric Chart of the Oceans (GEBCO)	Continental Shelf	500 m	Raster	2019–2022	UNESCO
5.	VIIRS Boat Detection (VBD)	Vessels	500 m	Raster	2013–2018	NOAA
6.	World Database on Protected Areas (WDPA)	Marine Protected Areas	-	Vector	2017–2030	UNEP WCMC

2.3.2. Allen Coral Atlas (ACA)

The ACA mapped the shallow-water tropical coral reefs globally using temporal composite data from PlanetScope satellite images from 2018–2020 with a 5 m spatial resolution [74,75]. The image data were processed based on the Global Discovery and Conservation Science (GDCS) algorithm to generate reflectance data on the surface, below the surface, and benthic from the emission image of the planet. Corrections were applied to the planet data to support the UQ mapping (geomorphic zone and benthic composition) and the GDCS warning monitoring components, i.e., atmospheric correction, waterbody retrieval, sun glint removal, depth calculation, and bottom reflectance estimation [76].

2.3.3. Murray Global Intertidal (MGI)

The MGI contains a global map of the tidal ecosystem generated through the supervised classification of 707,528 Landsat images. The image set consisted of a time series of 11 global tidal flat maps at a resolution of 30 m, with data available from 1984 to 2017 [77]. Each pixel was classified as tidal flat, permanent water, or otherwise, with reference to a globally distributed training dataset. The classifications were applied along the global coastlines between 60° north and 60° south [77].

2.3.4. General Bathymetric Chart of the Oceans (GEBCO)

The GEBCO is a global model for oceans and lands that provides altitude data at 15 arcsecond intervals, available for 2019–2022. The GEBCO global elevation model is generated by the assimilation of heterogeneous data types, assuming that they all refer to the mean sea level. However, in some shallow-water areas, the grid includes data from sources with a vertical datum other than the mean sea level [78].

2.3.5. VIIRS Boat Detection (VBD)

The VBD data product was developed based on an automatic ship detection algorithm using the VIIRS Day/Night Band (DNB) sensor with a spatial resolution of 15 arcseconds and data availability period of 2013–2018. The output, including csv and kmz, lists the date, time, latitude, longitude, and DNB emissions. A validation study was performed using analysis vessel detection, yielding an accuracy of 99.3% for the reference pixel set [68].

2.3.6. World Database on Protected Areas (WDPA)

The WDPA is the most comprehensive global database of marine and land protected areas, and it consists of spatial and related attribute data [79]. Each protected area in it is represented as a polygon boundary, or if not available, as a point location. The WDPA is updated monthly and contains more than 200,000 polygons and 20,000 data points, representing nearly 15% of the terrestrial land and 7.5% of the global oceans [80].

3. Results

3.1. Marine Ecosystem Service Value Model in the Indonesian Neritic Zone

This study used marine ecosystems based on the pelagic zone, but is limited to the neritic zone. The pelagic neritic zone is separated from the oceanic pelagic zone by the edge of the continental shelf and generally extends to a depth of 200 m. Here, only the ecosystems located in neritic pelagic zones up to 200 m were used. The spatial model of the MESV in the neritic zone ranges from USD 222,200 to USD 55,817,021 (Figure 3). Based on Figure 3, the samples in Figure 3A–C are located in the Aru Islands, Nusa Tenggara Islands, and Southeast Sulawesi regions, respectively. Figure 3C shows that the Aru Islands are an area with high marine ecosystem service value in Indonesia.

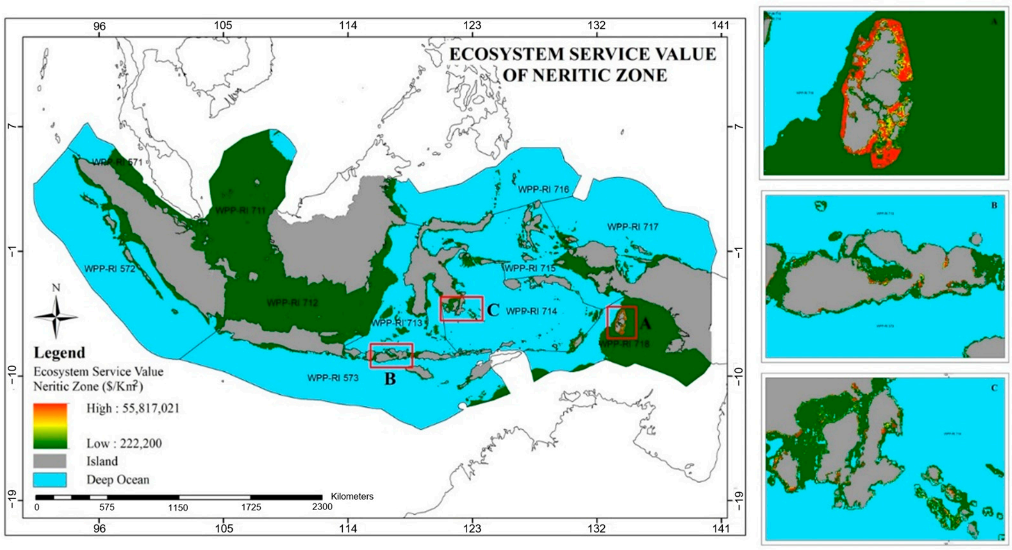

Figure 3. Map depicting the spatial model of marine ecosystem services value in the Indonesian neritic zone. (**A**) Aru Islands. (**B**) Nusa Tenggara Islands. (**C**) Southeast Sulawesi region.

The ecosystem service value for each ecosystem type was different for each IFMZ or WPP-RI (Figure 4). The MESV in Indonesia, which has the highest value, is a continental shelf ecosystem service with an estimated value of USD 422.68 billion. Comparatively, the lowest value of ecosystem services is for mangroves, with an estimated value of USD 4.45 billion. Overall, the estimated value of the marine ecosystem services of Indonesia, based on the five types of ecosystems is USD 814.23 billion. The highest marine ecosystem is in WPP-718, which is USD 207.21 billion. Contrastingly, the lowest marine ecosystem value was in WPP-717, which was USD 17.32 billion.

3.2. Vessel Expansion Zone Model in Indonesia

The vessel activity zone in Indonesian waters is based on the IFMZ or WPP-RI, where the ship activity zone was analyzed for 2013 and 2018 using the classification of low, medium, and high vessel activity (Figure 5). Figure 5A shows that in 2013, vessel activity was observed in almost every WPP-RI, except for WPP-715 and WPP-717. The highest vessel activity in Indonesia was in WPP-712 and WPP-711, which are areas with high transportation and fishing activities. WPP-712 has the highest ship activity, with low, medium, and high activity levels of 153,053 km^2, 188,775 km^2, and 50,183 km^2, respectively. The lowest ship activity zone in the Indonesian Sea is WPP-573, covering 7563 km^2.

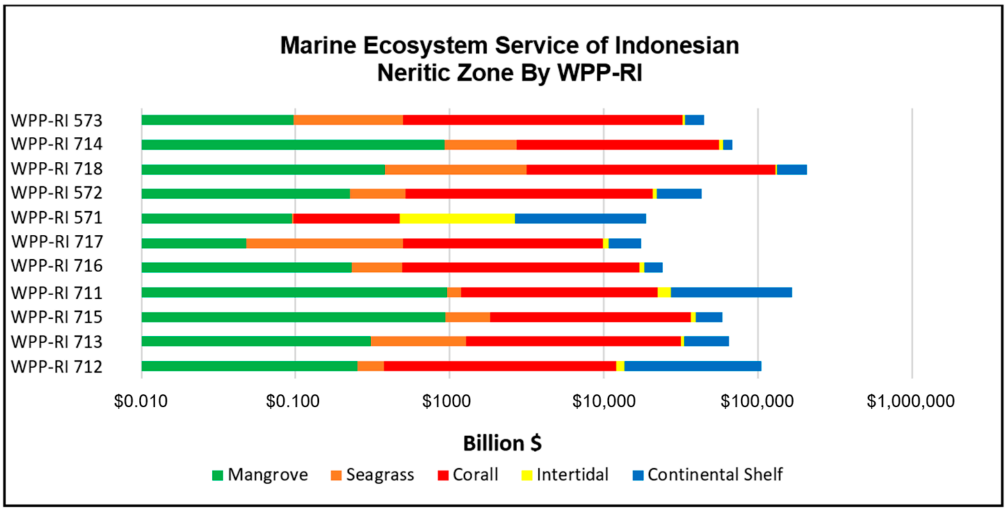

Figure 4. Plot illustrating the marine ecosystem services value in the Indonesian neritic zone by Indonesian Fisheries Management Zone (IFMZ or WPP-RI).

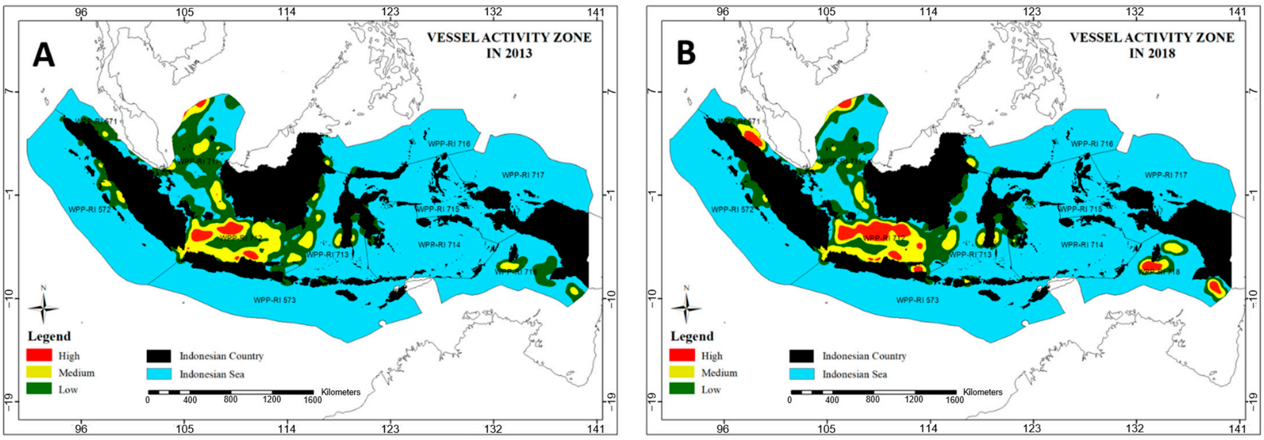

Figure 5. Maps showing the vessel activity zone in the Indonesian Fisheries Management Zone (IFMZ or WPP-RI) in 2013 and 2018. (**A**) Vessel activity zone in 2013. (**B**) Vessel activity zone in 2018.

In 2018, vessel activity was observed in almost every WPP-RI, except for WPP-717. The high vessel activity zones in 2018 included WPP-711, WPP-712, WPP-571, and WPP-718. Figure 5B shows that high vessel activity zones were found in WPP-712, WPP-711, WPP-571, and WPP-718. The highest vessel activity zone is in WPP-712, with areas of 101,140 km^2, 160,772 km^2, and 126,152 km^2 in the high, medium, and low vessel activity zones, respectively. The lowest vessel activity was observed for WPP-715, which had a low activity level of 647 km. The vessel expansion zone between 2013 and 2018 in the WPP-RI is shown in Figure 6.

Figure 6 shows that almost every WPP-RI has increased vessel activity, except for WPP-572 and WPP-717. The high-level vessel activity expansion zones are observed in WPP-712, WPP-718, WPP-571, and WPP-711. In 2013 and 2018, the vessel activity zone in WPP-712 was consistently high due to the high intensity of fishing and port transportation [81]. In WPP-712, there was also an increase in the activity of the highest active ship, which was 50,957 km^2.

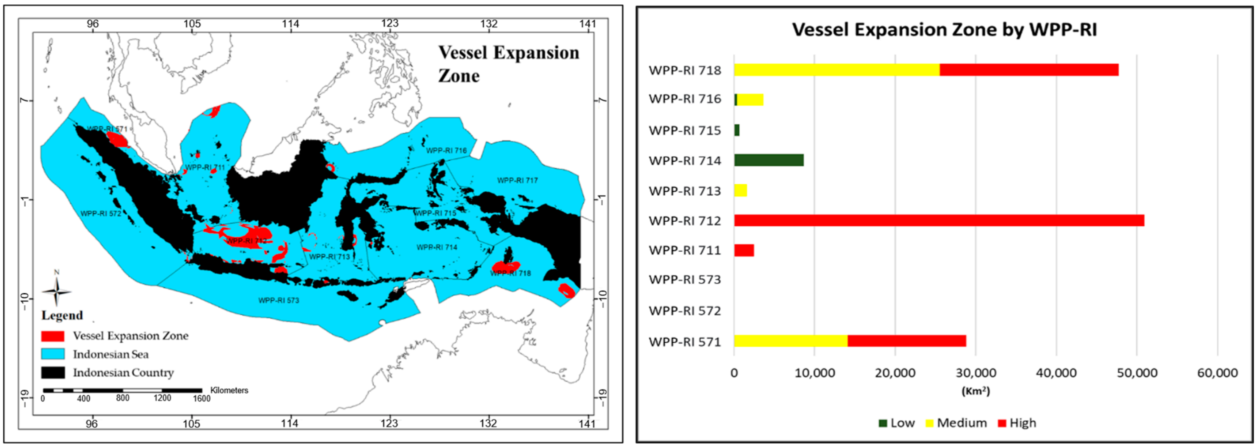

Figure 6. Map and plot depicting the vessel expansion zone in the Indonesian Fisheries Management Zone (IFMZ) between 2013 and 2018.

3.3. Potential Loss of MESV Due to Vessel Activity Expansion

The MPAs of Indonesia have a marine ecosystem service of USD 159.87 billion or 19.63% of the marine ecosystem service in the Indonesian neritic zone. The detailed ecosystem service values for each MPA are provided in Table S1. Ship activity in protected areas is a threat to the ecosystems in the MPA. Generally, 23.87% of the MPAs in Indonesia is in the vessel activity zone, and 76.13% have no vessel activity. Additionally, only 1.94% of 23.87% in the MPAs in Indonesia is in the vessel expansion zone (Figure 7).

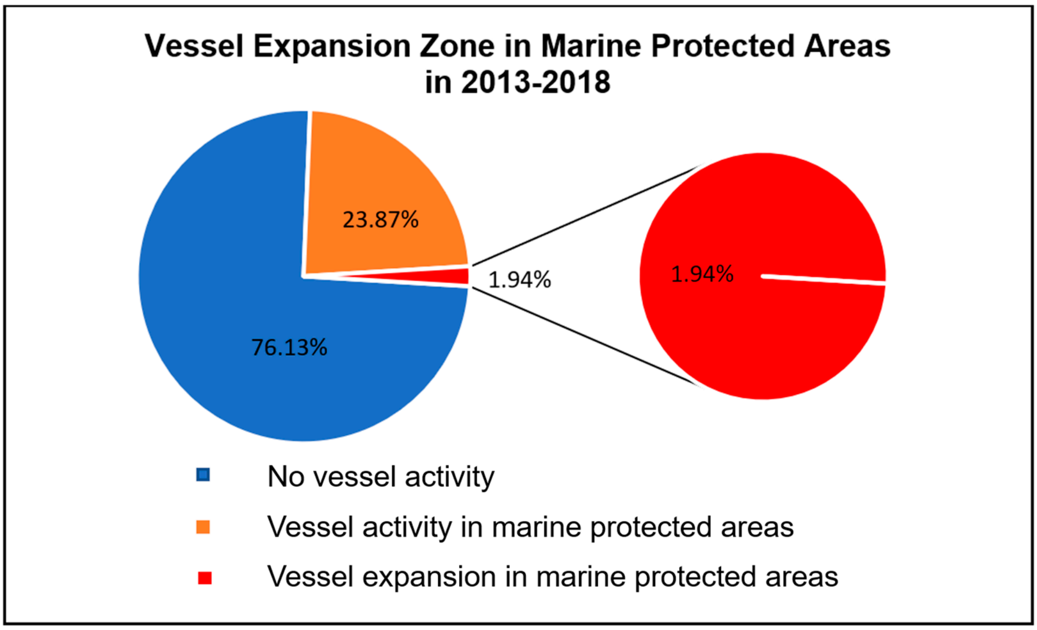

Figure 7. Pie chart illustrating the vessel expansion zone in the MPAs of Indonesia.

Figure 8 shows the distribution of 14 Indonesian MPAs potentially suffering MESV losses due to increasing vessel activity, and are identified in the vessel expansion zone with a total MESV potential loss of USD 27.63 billion. The Indonesian MPA includes: 1. KKPN Kepulauan Aru Bagian Tenggara; 2. KKPN Kepulauan Anambas; 3. KKPD Kepulauan Derawan; 4. Kabupaten Bintan; 5. Ujung Kulon National Park; 6. Tanjung Puting National Park; 7. KKPD Kabupaten Pangkajene Kepulauan; 8. Pulau Maratua-Karang Muaras; 9. Pulau Sangalaki; 10. KKPD Kabupaten Serdang Bedagai; 11. Baluran; 12. Pulau Semama; 13. Pulau Nusa; and 14. Karang Gading dan Langkat Timur Laut.

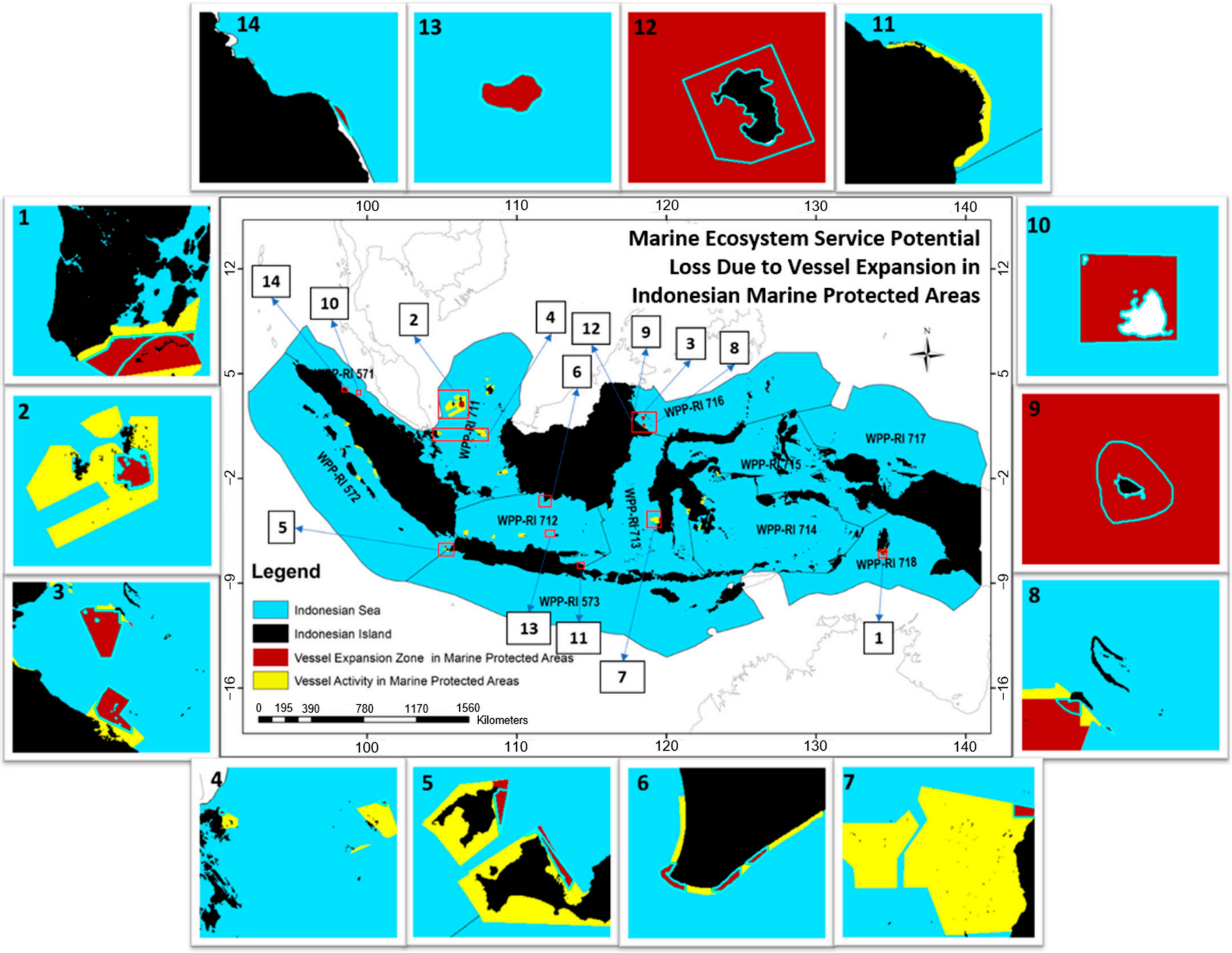

Figure 8. Map showing the vessel expansion zone in 14 Indonesian MPAs.

Table 3 shows the potential loss of marine ecosystem service values in the 14 protected areas. KKPN Kepulauan Aru Bagian Tenggara is an MPA with the highest potential loss of ecosystem service value, reaching USD 23.53 billion. Contrastingly, Pulau Nusa has the lowest potential loss of ecosystem service value with a total of USD 0.007 million.

Table 3. Potential loss of marine ecosystem service value due to vessel activity expansion in 14 Indonesian MPAs.

No.	Protected Area	Potential Loss of MESV in Millions (USD)
1	KKPN Kepulauan Aru Bagian Tenggara	23,525.729
2	KKPD Kepulauan Derawan	3,388.245
3	KKPN Kepulauan Anambas	333.773
4	Ujung Kulon National Park	306.487
5	Kabupaten Bintan	38.067
6	Tanjung Puting National Park	25.992

Table 3. *Cont.*

No.	Protected Area	Potential Loss of MESV in Millions (USD)
7	KKPD Kabupaten Pangkajene Kepulauan	8.233
8	Pulau Sangalaki	1.459
9	Pulau Semama	1.442
10	Pulau Maratua-Karang Muaras	1.439
11	KKPD Kabupaten Serdang Bedagai	0.347
12	Baluran	0.313
13	Karang Gading dan Langkat Timur Laut	0.043
14	Pulau Nusa	0.007

4. Discussion

4.1. Vessel Activity Impacts on Indonesian Marine Ecosystems

Indonesian territorial waters have potential for fisheries, marine tourism, mining, and maritime industries [82], which leads to increased ship activity. The largest vessel activity was found in the WPP-RI 711 and WPP-RI 712 zones, and these zones are located between Kalimantan Island, Sumatra Island, and Java Island. This high activity occurs because Indonesia's economic activities are centralized around Java Island [83]. Thus, many transportation ships and fishing vessels come in and out of Java. However, increased ship activity was also identified in WPP-718 and WPP-571. This suggests that the increased ship activity in other areas is caused by economic development, which elevates the need for human and freight transportation [84].

WPP-718 covers Aru waters, one of Indonesia's leading destinations for catching shrimp and fish [37,85]. Currently, these waters are the main areas for demersal fishing in Indonesia and efforts to utilize fish resources in Aru waters are rising, as indicated by the increasing number of companies and fishing fleets operating in these waters [37,86]. Meanwhile, WPP-571 includes the Malacca Strait and Andaman Sea, which have demersal fish resources that may develop rapidly [85,87]. This increases both the area's activity and number of fishing vessels [88]. Additionally, based on information from the KKP, many foreign vessels have been caught in WPP-571 [85].

Excessive fishing often occurs in areas with potential fisheries, which can be classified as illegal fishing because it only benefits fishermen and damages coral reef ecosystems [89,90]. Based on KKP data, the locations of illegal fishing captures were dominated by WPP-RI 711, with 163 vessels covering the waters of the Karimata Strait, Natuna Sea, and South China Sea [91]. WPP-RI 711 targets foreign fishermen to utilize fishery resources because it is directly adjacent to neighboring countries [92,93], and Bintan Island located in the Riau Islands is the gateway for international trade to Indonesia [94]. Thus, both reprehensive and preventive real solutions and initiatives that are supported by the government and community are needed to cope with the increasing activities that result in damage to marine ecosystems [89].

A total of 14 Indonesian MPAs can suffer losses due to increased ship activity (Table 3). The region of the Southeast Aru Islands KPPN is a protected area that could potentially experience the highest loss of ecosystem service value, which is USD 23.53 billion, and the magnitude of the potential loss is caused by the increasing number of companies and fishing fleets operating in these waters [37].

The increased ship activity at sea can increase marine pollution, which can originate from tankers and can also be generated by other types of ships, such as bulk carriers, container ships, or passenger ships [41]. Similarly, the discharge may be of several types, such as hydrocarbons, hazardous liquids, hazardous substances in bulk, solids/garbage, wastewater, or atmospheric emissions. The discharge of oil into the ocean threatens individual organisms, the surrounding resources, and entire ecosystems [41,95,96]. The increased ship activity results in ship waves, affects the physical, chemical, and biological structures, and causes indirect and tiered effects for the entire ecosystem. All of the demonstrated effects of ship waves and their indirect effects lead to changes in ecosystem services [71]. The number of negative impacts caused by increased ship activity dramatically affects the damage to the marine ecosystem; therefore, marine ecosystem services can potentially suffer losses.

4.2. Current Status of Threatened MPAs Based on Fauzi et al., 2021 [23]

Based on the analysis of the potential loss of ecosystem service value with a spatial model of fishing potential and ship activity in coastal ecosystems [23], it is stated that a high level of blue carbon risk and excessive exploitation of natural resources, especially in coastal nature reserves, can disrupt the original ecosystem service structure [97–99]. The Southeast Aru Islands KKPN and Serdang Bedagai Regency KKPN have over-exploitation and high-risk blue carbon status (Table 4), which implies that they have the potential to lose marine ecosystem service value. The Southeast Aru Islands KKPN has an ineffective conservation area management status, which is dangerous for marine ecosystems on the islands [100]. The over-exploitation of three protected areas and medium to high-risk blue carbon status, i.e., Southeast Aru Islands KKPN, Tanjung Puting National Park, and Serdang Bedagai Regency KKPD, need to be prioritized as conservation areas to prevent the loss of marine ecosystem services. Increasing conservation areas can maintain biodiversity sustainability and the value of ecosystem services [101,102]. Simultaneously, the 11 protected areas with dominant status under exploitation and sustainable blue carbon require more effective marine area management decisions, so that ship activities can be limited to reduce the risk of damage to ecosystem services and biodiversity [46].

Table 4. Status of the 14 MPAs based on Fauzi et al., 2021 [23].

No.	Protected Area	Status
1	KKPN Kepulauan Aru Bagian Tenggara	Over Exploitation and High-Risk Blue Carbon
2	KKPN Kepulauan Anambas	Low Productivity and Low-Risk Blue Carbon
3	KKPD Kepulauan Derawan	Under Exploitation and Sustainable Blue Carbon
4	Kabupaten Bintan	Under Exploitation and Low-Risk Blue Carbon
5	Tanjung Puting National Park	Over Exploitation and Medium Risk Blue Carbon
6	Ujung Kulon National Park	Under Exploitation and Sustainable Blue Carbon
7	KKPD Kabupaten Pangkajene Kepulauan	Under Exploitation and Sustainable Blue Carbon
8	Pulau Semama	Under Exploitation and Sustainable Blue Carbon
9	Pulau Sangalaki	Under Exploitation and Sustainable Blue Carbon
10	Pulau Maratua-Karang Muaras	Under Exploitation and Sustainable Blue Carbon
11	KKPD Kabupaten Serdang Bedagai	Over Exploitation and High-Risk Blue Carbon
12	Baluran	Under Exploitation and Sustainable Blue Carbon
13	Karang Gading dan Langkat Timur Laut	Sustainable Blue Carbon
14	Pulau Nusa	Under Exploitation and Low-Risk Blue Carbon

The protected area status is divided into six areas, as follows [23]:

- Over-exploitation and high blue carbon risk: These sites are overexploited and cause significant levels of harm to the blue carbon ecosystem because they have low to moderate levels of fisheries potential, but high levels of ship activity.
- Over-exploitation and medium blue carbon risk: These sites are overexploited and have moderate levels of harm to the blue carbon ecosystem because they have poor fisheries potential, but moderate levels of ship activity.
- Low productivity and low blue carbon risk: These regions have low levels of ship activity and fisheries potential, which results in low levels of fishery production yields and low levels of blue carbon ecological impacts.
- Under-exploitation and low blue carbon risk: These areas are less utilized and cause lower levels of harm to the blue carbon ecosystem because they contain a modest level of fisheries potential, but less ship activity.
- Under-exploitation and sustainable blue carbon: These places are less fished and the blue carbon ecosystem is more resilient since they contain a low to high level of fisheries potential, but little ship activity.
- Sustainable blue carbon: The potential for fishing and the degree of ship activity in these areas are quite low. Consequently, the blue carbon ecosystems are largely preserved.

4.3. Limitations

From the perspective of the study area, the ecosystem service value model developed is limited to the neritic zone, and hence does not consider the value of deep-sea ecosystem services or the pelagic zone. Generally, each ecosystem has different functional values for assessing ecosystem services. However, there are significant gaps in the studies of the broad range of marine ecosystem services valuation [103–106]. Spatial modeling of marine ecosystem services value is still underutilized due to limited validation, calibration, and quantification as a result of technical problems. This includes limited existing knowledge regarding the value of marine ecosystem services, limited practical tools and technology to assess coastal and marine ecosystem services, limited spatial data on coastal and marine ecosystems, and limited existing literature [103,107,108].

Additionally, several spatial ecosystem datasets are generally available for a certain period (mono-temporal), some of which are acquired at different timescales, although in this study, it is assumed that they are in comparable periods. The availability of these data does not allow for the analysis of changes in the value of marine ecosystem services, as can be done for terrestrial ecosystems. In particular, the data period studied was used to identify ship activities and was limited to 2013 and 2018. The ship activity analysis was conducted in this study without further classifying the type of the concerned ship.

Based on the analysis of the potential loss in the value of ecosystem services, the concerned loss is only based on the threat of increasing ship activity. Simultaneously, there are various threats to marine ecosystems that can decrease the value of ecosystem services, such as climate change, oil pollution, aquaculture waste, construction, sedimentation, and fishing [109,110].

4.4. Future Possible Directions

The unavailability of the value of ecosystem functions can result in the non-accommodation of the value of services or benefits humans obtain for survival [12,111]. Therefore, further studies are expected to comprehensively develop the value of ecosystem services for all ecosystem functions based on environmental accounting as a basis for developing spatial models [22,52,112]. Additionally, further research can integrate big Earth observation data (BEOD), cloud computing (CC), and artificial intelligence (AI) into remote sensing for marine ecosystem mapping with high resolution and extensive area coverage. Therefore, changes in the value of marine ecosystem services can be continuously monitored [113,114]. Based on the results of this study, many protected areas have several ecosystems, making it possible to develop multi-ecosystem conservation strategies, especially in the seagrass and coral ecosystems found in the Southeast Aru region [115].

Research was conducted by Mahabror and Hidayat (2018) [116] on Radarsat-2 imagery to detect the distribution of illegal fishing and commercial vessels. From the perspective of threats due to ship activities, the results of the study by Hsu et al. (2019) [117] indicate that the ship extraction methodology for VIIRS satellite imagery can be further developed to obtain information on ship types. Furthermore, ship extraction can be performed using images from various types of satellites [118,119]. A study by Heiselberg (2019) [120] showed that 13 images with different times in Sentinel-2 imagery could be used to detect and obtain ship speed values. Additionally, ships can also be detected by calculating changes in air quality in an area, as in the study by Kim et al. (2020) [121], who analyzed the CO_2 gas captured on the mid-infrared sensor of satellite imagery. This shows that there are still many alternatives for ship detection that can be re-explored to increase the accuracy and detail of information for more in-depth analysis.

From the perspective of ecosystem threats, further research can develop a multi-hazard marine ecosystem model [33,122] as a comprehensive threat map to map threats posed by anthropogenic and natural factors from the environment at the local to regional levels [109,123]. Many studies have reported successful experiments for exploiting a spatial data-driven approach for conservation issues [124–126]. Ecosystem service value and multi-threat models can then be integrated as the basis for developing a priority marine conservation area model [127]. Changes in the aquatic environment can increase the risk of storm surges, floods, delta subsidence, and geological hazards [128]. Therefore, it is necessary to develop a multi-hazard model for marine ecosystems. Disaster threat maps integrated with the value of ecosystem services can be used for environmental and natural resource management and spatial planning [12].

5. Conclusions

SDG 14, referring to life below water, encourages the establishment of MPAs to mitigate global climate change. However, much research has shown that ship activities cause damage to marine ecosystems. Thus, this study attempted to estimate the potential economic losses caused by the Indonesian MPAs due to the expansion of the ship activity zones. Based on these results, the sea around Indonesia has a potential ecosystem service value of USD 814.23 billion, of which 19.73% (USD 160.64 billion) is within an MPA, representing only 3.45% of the total territorial waters area of Indonesia. In terms of vessel activity, only 14 areas (5.15%) of the 272 MPAs in Indonesia were affected by increasing ship activity, with a potential loss of USD 27.63 billion (17.19% of the total ecosystem service value in MPAs). This potential loss indicates that several MPAs require additional attention to ensure the conservation and sustainability of the ecosystems. Thus, this study can be used as a reference for policymaking to determine conservation priority areas based on a spatial approach. Further, in this era of big geospatial data, multi-source spatial data can be intensively explored to develop a spatial decision support system for marine ecosystem management. We believe that effective conservation management strategies can be achieved by implementing spatial-based policymaking.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/ijgi12020075/s1: Table S1. Ecosystem service value of Indonesian marine protected areas.

Author Contributions: Conceptualization, Adam Irwansyah Fauzi and Emi Yati; methodology, Adam Irwansyah Fauzi and Nur Azizah; software, Aulia Try Atmojo, Nur Azizah and Balqis Falah Robbani; validation, Adam Irwansyah Fauzi, Nur Azizah, Emi Yati and Arif Rohman; formal analysis, Adam Irwansyah Fauzi, Nur Azizah, Emi Yati, Raden Putra and Aulia Try Atmojo; investigation, Adam Irwansyah Fauzi, Nur Azizah, Desi Ramadhanti, Nesya Hafiza Ardani and Muhammad Ario Eko Rahadianto; resources, Adam Irwansyah Fauzi, Nur Azizah and Emi Yati; data curation, Nur Azizah and Balqis Falah Robbani; writing—original draft preparation, Adam Irwansyah Fauzi, Nur Azizah, Desi Ramadhanti, Balqis Falah Robbani and Nesya Hafiza Ardani; writing—review and

editing, Adam Irwansyah Fauzi, Emi Yati, Aulia Try Atmojo and Raden Putra; visualization, Adam Irwansyah Fauzi, Nur Azizah, Balqis Falah Robbani and Anjar Dimara Sakti; supervision, Muhammad Aufaristama, Arif Rohman, Anjar Dimara Sakti and Ketut Wikantika; project administration, Aulia Try Atmojo, Agung Mahadi Putra Perdana and Muhammad Ulin Nuha; funding acquisition, Adam Irwansyah Fauzi, Aulia Try Atmojo, Agung Mahadi Putra Perdana, Muhammad Ulin Nuha and Raden Putra. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Institut Teknologi Sumatera through "Hibah Penelitian Kolaborasi ITERA 2022" grant number B/763z/IT9.C1/PT.01.03/2022.

Data Availability Statement: The datasets generated during and/or analyzed in the current study are available from the corresponding author on reasonable request.

Acknowledgments: The authors are grateful to acknowledge the support from Institut Teknologi Sumatera. We also thank the anonymous reviewers whose critical and constructive comments greatly helped us to prepare an improved and clearer version of this paper. All persons and institutes who kindly made their data available for this research are acknowledged.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Frederick Grassle, J. Marine Ecosystems. *Encycl. Biodivers. Second Ed.* **2013**, *5*, 45–55. [CrossRef]
2. Barbier, E.B. Marine ecosystem services. *Curr. Biol.* **2017**, *27*, R507–R510. [CrossRef]
3. Millenium Ecosystem Assessment. *Ecosystem and Human Well Being*; Island Press: Washington, DC, USA, 2005; ISBN 1597260401.
4. Austen, M.C.; Andersen, P.; Armstrong, C.; Döring, R.; Hynes, S.; Levrel, H.; Oinonen, S.; Ressurreição, A.; Coopman, J. *Valuing Marine Ecosystems – Taking into account the value of ecosystems benefits in the Blue Economy*; Future Science Brief 5 of the European Marine Board: Ostend, Belgium, 2019; ISBN 9789492043696.
5. Fisher, B.; Turner, R.K.; Morling, P. Defining and classifying ecosystem services for decision making. *Ecol. Econ.* **2009**, *68*, 643–653. [CrossRef]
6. Salcone, J.; Brander, L.; Seidl, A. *Economic Valuation of Marine and Coastal Ecosystem Services in the Pacific Guidance Manual*; Report to the MACBIO Project (GIZ, IUCN, SPREP): Suva, Fuji, 2016; Volume 46.
7. Tianhong, L.; Wenkai, L.; Zhenghan, Q. Variations in ecosystem service value in response to land use changes in Shenzhen. *Ecol. Econ.* **2010**, *69*, 1427–1435. [CrossRef]
8. Su, S.; Xiao, R.; Jiang, Z.; Zhang, Y. Characterizing landscape pattern and ecosystem service value changes for urbanization impacts at an eco-regional scale. *Appl. Geogr.* **2012**, *34*, 295–305. [CrossRef]
9. Alleway, H.K.; Gillies, C.L.; Bishop, M.J.; Gentry, R.R.; Theuerkauf, S.J.; Jones, R. The Ecosystem Services of Marine Aquaculture: Valuing Benefits to People and Nature. *Bioscience* **2019**, *69*, 59–68. [CrossRef]
10. Tolessa, T.; Senbeta, F.; Kidane, M. The impact of land use/land cover change on ecosystem services in the central highlands of Ethiopia. *Ecosyst. Serv.* **2017**, *23*, 47–54. [CrossRef]
11. Jiang, W.; Lü, Y.; Liu, Y.; Gao, W. Ecosystem service value of the Qinghai-Tibet Plateau significantly increased during 25 years. *Ecosyst. Serv.* **2020**, *44*, 101146. [CrossRef]
12. Riqqi, A.; Hendaryanto, H.; Safitri, S.; Mashita, N.; Sulistyawati, E.; Norvyani, D.A.; Afriyanie, D. Pemetaan Jasa Ekosistem. *Semin. Nas. Geomatika* **2019**, *3*, 237–246. [CrossRef]
13. Brierley, A.S.; Kingsford, M.J. Impacts of Climate Change on Marine Organisms and Ecosystems. *Curr. Biol.* **2009**, *19*, R602–R614. [CrossRef]
14. Gallardo, B.; Aldridge, D.C.; González-Moreno, P.; Pergl, J.; Pizarro, M.; Pyšek, P.; Thuiller, W.; Yesson, C.; Vilà, M. Protected areas offer refuge from invasive species spreading under climate change. *Glob. Chang. Biol.* **2017**, *23*, 5331–5343. [CrossRef] [PubMed]
15. Bates, A.E.; Cooke, R.S.C.; Duncan, M.I.; Edgar, G.J.; Bruno, J.F.; Benedetti-Cecchi, L.; Côté, I.M.; Lefcheck, J.S.; Costello, M.J.; Barrett, N.; et al. Climate resilience in marine protected areas and the 'Protection Paradox'. *Biol. Conserv.* **2019**, *236*, 305–314. [CrossRef]
16. He, Q.; Silliman, B.R. Climate Change, Human Impacts, and Coastal Ecosystems in the Anthropocene. *Curr. Biol.* **2019**, *29*, R1021–R1035. [CrossRef] [PubMed]
17. Tulloch, V.J.D.; Turschwell, M.P.; Giffin, A.L.; Halpern, B.S.; Connolly, R.; Griffiths, L.; Frazer, M.; Brown, C.J. Linking threat maps with management to guide conservation investment. *Biol. Conserv.* **2020**, *245*, 108527. [CrossRef]
18. Fauzi, A.I.; Sakti, A.D.; Yayusman, L.F.; Harto, A.B.; Prasetyo, L.B.; Irawan, B.; Wikantika, K. Evaluating mangrove forest deforestation causes in Southeast Asia by analyzing recent environment and socio-economic data products. In Proceedings of the 39th Asian Conference on Remote Sensing Remote Sensing Enabling Prosperity ACRS 2018, Kuala Lumpur, Malaysia, 15–19 October 2018; Volume 2, pp. 880–889.
19. Fauzi, A.; Sakti, A.; Yayusman, L.; Harto, A.; Prasetyo, L.; Irawan, B.; Kamal, M.; Wikantika, K. Contextualizing mangrove forest deforestation in southeast asia using environmental and socio-economic data products. *Forests* **2019**, *10*, 952. [CrossRef]

20. Goldberg, L.; Lagomasino, D.; Thomas, N.; Fatoyinbo, T. Global declines in human-driven mangrove loss. *Glob. Chang. Biol.* **2020**, *26*, 5844–5855. [CrossRef]
21. Wang, Y.S.; Gu, J.D. Ecological responses, adaptation and mechanisms of mangrove wetland ecosystem to global climate change and anthropogenic activities. *Int. Biodeterior. Biodegrad.* **2021**, *162*, 105248. [CrossRef]
22. Unsworth, R.K.F.; Ambo-Rappe, R.; Jones, B.L.; La Nafie, Y.A.; Irawan, A.; Hernawan, U.E.; Moore, A.M.; Cullen-Unsworth, L.C. Indonesia's globally significant seagrass meadows are under widespread threat. *Sci. Total Environ.* **2018**, *634*, 279–286. [CrossRef] [PubMed]
23. Fauzi, A.I.; Sakti, A.D.; Robbani, B.F.; Ristiyani, M.; Agustin, R.T.; Yati, E.; Nuha, M.U.; Anika, N.; Putra, R.; Siregar, D.I.; et al. Assessing potential climatic and human pressures in indonesian coastal ecosystems using a spatial data-driven approach. *ISPRS Int. J. Geo-Inf.* **2021**, *10*, 778. [CrossRef]
24. Brodie, G.; De Ramon N'yeurt, A. Effects of Climate Change on Seagrasses and Seagrass Habitats Relevant to the Pacific Islands. *PACIFIC Mar. Clim. Chang. Rep. CARD Sci. Rev.* **2018**, 112–131.
25. Doney, S.C.; Ruckelshaus, M.; Emmett Duffy, J.; Barry, J.P.; Chan, F.; English, C.A.; Galindo, H.M.; Grebmeier, J.M.; Hollowed, A.B.; Knowlton, N.; et al. Climate change impacts on marine ecosystems. *Ann. Rev. Mar. Sci.* **2012**, *4*, 11–37. [CrossRef] [PubMed]
26. The Organisation for Economic Co-operation and Development (OECD). Marine Protected Areas | Marine Conservation Society. *Explor. Mar. Prot. Areas UK* **2016**, *14*.
27. Wells, S.; Ray, G.C.; Gjerde, K.M.; White, A.T.; Muthiga, N.; Bezaury Creel, J.E.; Causey, B.D.; McCormick-Ray, J.; Salm, R.; Gubbay, S.; et al. Building the future of MPAs—Lessons from history. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **2016**, *26*, 101–125. [CrossRef]
28. The International Union for Conservation of Nature (IUCN). Marine Protected Areas and Climate Change. *Iucn* **2017**, 1–2.
29. Balbar, A.C.; Metaxas, A. The current application of ecological connectivity in the design of marine protected areas. *Glob. Ecol. Conserv.* **2019**, *17*, e00569. [CrossRef]
30. Cabral, R.B.; Bradley, D.; Mayorga, J.; Goodell, W.; Friedlander, A.M.; Sala, E.; Costello, C.; Gaines, S.D. A global network of marine protected areas for food. *Proc. Natl. Acad. Sci. USA* **2020**, *117*, 28134–28139. [CrossRef]
31. UNEP With 15% of Terrestrial and 7% of Marine Areas Now Protected, World on Track to Meet Conservation Targets. Available online: https://www.unep.org/news-and-stories/press-release/15-terrestrial-and-7-marine-areas-now-protected-world-track-meet (accessed on 8 July 2022).
32. The United Nations Convention on Biological Diversity (CBD). Report of the Open-Ended Working Group on the Post-2020 Global Biodiversity Framework on Its Second Meeting. *Conv. Biol. Divers.* **2020**, *5*, 248–253.
33. Rusandi, A.; Hakim, A.; Wiryawan, B.; Sarmintohadi; Yulianto, I. Pengembangan Kawasan Konservasi Untuk Mendukung Pengelolaan Perikanan yang Berkelanjutan di Indonesia. *Mar. Fish. J. Mar. Fish. Technol. Manag.* **2021**, *12*, 137–147. [CrossRef]
34. Susanto, H.A. Development and Progress of Marine Protected Area Systems in Indonesia. *Usaid* **2011**, *1*, 58.
35. Nanda Magfiroh, A.; Zairon; Fahrudin, A. Strategi Peningkatan Efektivitas Pengelolaan Kawasan Konservasi Taman Nasional Karimunjawa. *J. Ilmu dan Teknol. Kelaut. Trop.* **2020**, *12*, 369–383. [CrossRef]
36. Rees, S.E.; Mangi, S.C.; Hattam, C.; Gall, S.C.; Rodwell, L.D.; Peckett, F.J.; Attrill, M.J. The socio-economic effects of a Marine Protected Area on the ecosystem service of leisure and recreation. *Mar. Policy* **2015**, *62*, 144–152. [CrossRef]
37. Mahabror, D.; Zaky, A.R. Analisis spasial dan temporal aktivitas kapal ikan di perairan selatan aru menggunakan citra modis dan radarsat-2. *J. Kelaut. Indones. J. Mar. Sci. Technol.* **2016**, *9*, 155–163. [CrossRef]
38. Nugroho, U.A.; Budianto, F. Perspektif Eksploitasi dan Konservasi dalam Pengelolaan Sumber Daya Perikanan Indonesia. *Maj. Media Perencana* **2021**, *2*, 51–67.
39. Arkham, M.N.; Wahyudin, Y.; Pahlevi, M.R.; Hutapea, R.Y.F. Jasa Penyedia Ekosistem Terumbu Karang Di Kawasan Suaka Alam Perairan Kepulauan Raja Ampat Dari Perspektif Valuasi Ekonomi. *J. Kelaut. Indones. J. Mar. Sci. Technol.* **2020**, *13*, 239–248. [CrossRef]
40. Hadiyanto, H. Pemanasan Global, Eksploitasi Sumberdaya Perikanan, dan Pencemaran Pesisir Sebagai Penyebab Utama Perubahan Ekologi Laut di Indonesia. *OSEANA* **2018**, *42*, 1–11.
41. Longépé, N.; Mouche, A.A.; Goacolou, M.; Granier, N.; Carrere, L.; Lebras, J.Y.; Lozach, P.; Besnard, S. Polluter identi fi cation with spaceborne radar imagery, AIS and forward drift modeling. *MPB* **2015**, *101*, 4–11. [CrossRef]
42. Tichavska, M.; Tovar, B. Environmental cost and eco-efficiency from vessel emissions in Las Palmas Port. *Transp. Res. Part E Logist. Transp. Rev.* **2015**, *83*, 126–140. [CrossRef]
43. Chen, D.; Wang, X.; Nelson, P.; Li, Y.; Zhao, N.; Zhao, Y.; Lang, J.; Zhou, Y.; Guo, X. Ship emission inventory and its impact on the PM2.5 air pollution in Qingdao Port, North China. *Atmos. Environ.* **2017**, *166*, 351–361. [CrossRef]
44. Direktorat Jenderal Pengelolaan Ruang Laut KKP | Kementerian Kelautan dan Perikanan. Available online: https://kkp.go.id/djprl/artikel/23631-pencemaran-laut (accessed on 19 October 2022).
45. Fudjaja, L.; Viantika, N.M.; Rani, C.; Nurdin, N.; Priosambodo, D.; Tenriawaru, A.N. Anthropogenic activity and the destruction of coral reefs in the waters of small islands Anthropogenic activity and the destruction of coral reefs in the waters of small islands. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *575*, 12057. [CrossRef]
46. Liu, B.; Wu, X.; Liu, X.; Gong, M. Assessment of ecological stress caused by maritime vessels based on a comprehensive model using AIS data: Case study of the Bohai Sea, China. *Ecol. Indic.* **2021**, *126*, 107592. [CrossRef]
47. Robards, M.D.; Silber, G.K.; Adams, J.D.; Arroyo, J.; Lorenzini, D.; Schwehr, K.; Amos, J. Conservation science and policy applications of the marine vessel Automatic Identification System (AIS)-A review. *Bull. Mar. Sci.* **2016**, *92*, 75–103. [CrossRef]

48. Metcalfe, K.; Bréheret, N.; Chauvet, E.; Collins, T.; Curran, B.K.; Parnell, R.J.; Turner, R.A.; Witt, M.J.; Godley, B.J. Using satellite AIS to improve our understanding of shipping and fill gaps in ocean observation data to support marine spatial planning. *J. Appl. Ecol.* **2018**, *55*, 1834–1845. [CrossRef]
49. Moore, T.J.; Redfern, J.V.; Carver, M.; Hastings, S.; Adams, J.D.; Silber, G.K. Exploring ship traffic variability off California. *Ocean Coast. Manag.* **2018**, *163*, 515–527. [CrossRef]
50. Rahardi, W.; Suhardi, R.M. Keanekaragaman Hayati dan Jasa Ekosistem Mangrove di Indonesia. In Proceedings of the Prosiding Symbion (Symposium on Biology Education), Yogyakarta, Indonesia, 24 August 2016.
51. Dharmawan, I.W.E. *Pramudji Panduan Pemantauan Komunitas Mangrove*; Pusat Penelitian Oseanografi, LIPI: Jakarta, Indonesia, 2017; ISBN 978-602-6504-13-5.
52. Yudi, W.; Dadan, M.; Agus, R.; Novit, R.; Donny, S.; Arif, T.K. The Economic Value of Coastal and Marine Biodiversity in Indonesia. *J. Cendekia Ihya* **2019**, *2*, 37–51.
53. Rosyada, K.; Trismadi; Ras, A.R. Potensi Blue Carbon dalam Penanganan Perubahan Iiklim Guna Menunjang Keamanan Maritim Indonesia. *J. Marit. Indones.* **2021**, *9*, 299–311.
54. Miteva, D.A.; Murray, B.C.; Pattanayak, S.K. Do protected areas reduce blue carbon emissions? A quasi-experimental evaluation of mangroves in Indonesia. *Ecol. Econ.* **2015**, *119*, 127–135. [CrossRef]
55. Adi, N.S.; Paputungan, M.S.; Rustam, A.; Haditomo, A.H.C. Medrilzam Estimating carbon emission and baseline for blue carbon ecosystems in indonesia. In Proceedings of the IOP Conference Series: Earth and Environmental Science, Changchun, China, 21–23 August 2020; Volume 530.
56. Syahid, L.N.; Sakti, A.D.; Virtriana, R.; Windupranata, W.; Sudhana, S.A.; Wilwatikta, F.N.; Fauzi, A.I.; Wikantika, K. Land suitability analysis for global mangrove rehabilitation in Indonesia. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *500*, 012010. [CrossRef]
57. Hernawan, U.E.; Rahmawati, S.; Ambo-Rappe, R.; Sjafrie, N.D.M.; Hadiyanto, H.; Yusup, D.S.; Nugraha, A.H.; La Nafie, Y.A.; Adi, W.; Prayudha, B.; et al. The first nation-wide assessment identifies valuable blue-carbon seagrass habitat in Indonesia is in moderate condition. *Sci. Total Environ.* **2021**, *782*, 146818. [CrossRef]
58. Scott, A.L.; York, P.H.; Duncan, C.; Macreadie, P.I.; Connolly, R.M.; Ellis, M.T.; Jarvis, J.C.; Jinks, K.I.; Marsh, H.; Rasheed, M.A. The role of herbivory in structuring tropical seagrass ecosystem service delivery. *Front. Plant Sci.* **2018**, *9*, 127. [CrossRef]
59. Nordlund, L.M.; Koch, E.W.; Barbier, E.B.; Creed, J.C. Seagrass ecosystem services and their variability across genera and geographical regions. *PLoS ONE* **2016**, *11*, e0163091. [CrossRef]
60. Eddy, S.; Mulyana, A.; Ridho, M.R.; Iskandar, I. Dampak Aktivitas Antropogenik Terhadapn Degradasi Hutan Mangrove Di Indonesia. *J. Lingkung. dan Pembang.* **2015**, *1*, 292–306.
61. Sakti, A.D.; Fauzi, A.I.; Wilwatikta, F.N.; Rajagukguk, Y.S.; Sudhana, S.A.; Yayusman, L.F.; Syahid, L.N.; Sritarapipat, T.; Principe, J.A.; Quynh Trang, N.T.; et al. Multi-source remote sensing data product analysis: Investigating anthropogenic and naturogenic impacts on mangroves in southeast asia. *Remote Sens.* **2020**, *12*, 2720. [CrossRef]
62. Tahir, A. Kualitas Kesehatan Ekosistem Benua Maritim Indonesia untuk Keberlanjutan Sumber Daya Ikan. *Prosiding Simposium Nasional Kelautan Dan Perikanan.* **2018**, *4*, 1–8.
63. Dianovita, C. Jasa Ekosistem Lamun di Pulau Panjang, Serang, Banten. *IJEEM Indones. J. Environ. Educ. Manag.* **2019**, *4*, 95–106. [CrossRef]
64. Lukman, K.M.; Uchiyama, Y.; Quevedo, J.M.D.; Kohsaka, R. Local awareness as an instrument for management and conservation of seagrass ecosystem: Case of Berau Regency, Indonesia. *Ocean Coast. Manag.* **2021**, *203*, 105451. [CrossRef]
65. Onrizal Mangrove, Ekosistem Penting Langka yang Semakin Terancam. Available online: https://www.mongabay.co.id/2018/08/13/mangrove-ekosistem-penting-langka-yang-semakin-terancam/ (accessed on 19 October 2022).
66. Sofian, A.; Kusmana, C.; Fauzi, A.; Rusdiana, O. Evaluasi Kondisi Ekosistem Mangrove Angke Kapuk Teluk Jakarta Dan Konsekuensinya Terhadap Jasa Ekosistem. *J. Kelaut. Nas.* **2019**, *15*, 1–12. [CrossRef]
67. UNEP-WCMC Explore the World's Protected Areas. Available online: https://www.protectedplanet.net/country/IDN (accessed on 19 October 2022).
68. Elvidge, C.D.; Zhizhin, M.; Baugh, K.; Hsu, F.C. Automatic boat identification system for VIIRS low light imaging data. *Remote Sens.* **2015**, *7*, 3020–3036. [CrossRef]
69. Costanza, R.; de Groot, R.; Sutton, P.; van der Ploeg, S.; Anderson, S.J.; Kubiszewski, I.; Farber, S.; Turner, R.K. Changes in the global value of ecosystem services. *Glob. Environ. Change* **2014**, *26*, 152–158. [CrossRef]
70. Cao, L.; Li, J.; Ye, M.; Pu, R.; Liu, Y.; Guo, Q.; Feng, B.; Song, X. Changes of ecosystem service value in a coastal zone of Zhejiang province, China, during rapid urbanization. *Int. J. Environ. Res. Public Health* **2018**, *15*, 1301. [CrossRef]
71. Gabel, F.; Lorenz, S.; Stoll, S. Science of the Total Environment Effects of ship-induced waves on aquatic ecosystems. *Sci. Total Environ.* **2017**, *601–602*, 926–939. [CrossRef]
72. Thomas, N.; Lucas, R.; Bunting, P.; Hardy, A.; Rosenqvist, A.; Simard, M. Distribution and drivers of global mangrove forest change, 1996–2010. *PLoS ONE* **2017**, *12*, e0179302. [CrossRef]
73. Bunting, P.; Rosenqvist, A.; Lucas, R.M.; Rebelo, L.-M.; Hilarides, L.; Thomas, N.; Hardy, A.; Itoh, T.; Shimada, M.; Finlayson, C.M. The Global Mangrove Watch—A New 2010 Global Baseline of Mangrove Extent. *Remote Sens.* **2018**, *10*, 1669. [CrossRef]
74. Li, J.; Knapp, D.E.; Fabina, N.S.; Kennedy, E.V.; Larsen, K.; Lyons, M.B.; Murray, N.J.; Phinn, S.R.; Roelfsema, C.M.; Asner, G.P. A global coral reef probability map generated using convolutional neural networks. *Coral Reefs* **2020**, *39*, 1805–1815. [CrossRef]

75. Lyons, M.B.; Roelfsema, C.M.; Kennedy, E.V.; Kovacs, E.M.; Borrego-Acevedo, R.; Markey, K.; Roe, M.; Yuwono, D.M.; Harris, D.L.; Phinn, S.R.; et al. Mapping the world's coral reefs using a global multiscale earth observation framework. *Remote Sens. Ecol. Conserv.* **2020**, *6*, 557–568. [CrossRef]
76. Allen Coral Atlas Allen Coral Atlas | FAQ. Available online: https://www.allencoralatlas.org/resources/ (accessed on 19 October 2022).
77. Murray, N.J.; Phinn, S.R.; Dewitt, M.; Ferrari, R.; Johnston, R.; Lyons, M.B.; Clinton, N.; Thau, D.; Fuller, R.A. The global distribution and trajectory of tidal flats. *Nature* **2018**, *565*, 222–225. [CrossRef]
78. IHO-UNESCO GEBCO Gridded Bathymetry Data. Available online: https://www.gebco.net/data_and_products/gridded_bathymetry_data/ (accessed on 19 October 2022).
79. Juffe-Bignoli, D.; Bingham, H.; MacSharry, B.; Deguignet, M.; Lewis, E.; Milam, A.; Kingston, N. *World Database on Protected Areas User Manual 1.3*; UNEP-WCMC: Cambridge, UK, 2016; p. 70. Available online: http://wcmc.io/WDPA_Manual (accessed on 19 October 2022).
80. UNEP-WCMC World Database of Protected Areas. Available online: https://www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/zh/c/1236440/ (accessed on 19 October 2022).
81. Faizal, I.; Kristiadhi, F.; Nurrahman, Y.A.; Purba, N.P.; Prasetiya, F.S. Coral Reef Distribution around Bakauheni Sea-port, South Lampung, Indonesia. *Akuatek* **2020**, *1*, 94–103.
82. Krisnafi, Y.; Hakim, M.R.; Prayitno, M.R.E.; Maturbongs, M.W. Penentuan Prioritas Pangkalan Utama Kapal Pengawas Perikanan Untuk Pencegahan Illegal Fishing Di WPP NRI-715. *Mar. Fish.* **2021**, *12*, 59–71. [CrossRef]
83. Tri, H.M. Sahara Pengaruh Investasi terhadap Pertumbuhan Ekonomi Regional di Indonesia. *J. Ekon. dan Kebijak. Pembang. Desember* **2019**, *8*, 163–181. [CrossRef]
84. Pujiastuti, R.R. Pemanfaatan transportasi laut untuk meningkatkan pertumbuhan sektor pariwisata. *J. Saintek Marit.* **2019**, *19*, 151–164.
85. Kkp. *Laporan Tahunan Kementrian Kelautan dan Perikanan*; Kementrian Kelautan dan Perikanan: Jakarta, Indonesia, 2016; ISBN 9786025219504.
86. Umamah, M.; Wisudo, S.H.; Wahyu, R.I. Pengelolaan sumberdaya udang yang berkelanjutan di laut aru dan arafura. *ALBACORE J. Penelit. Perikan. Laut* **2018**, *1*, 245–255. [CrossRef]
87. Wahyudin, Y. Status Perikanan di Wilayah Pengelolaan Perikanan (WPP RI 571—Laut Andaman dan Selat Malaka) (Fisheries Status of Indonesian Fisheries Management Zone (WPP RI 571- Andaman Sea and Malacca Strait)). *SSRN Electron. J.* **2013**, *5*, 1–7. [CrossRef]
88. Marpaung, B.S.M.; Sitanggang, E.P.; Masengi, K.W.A.; Kaparang, F.E.; Pamikiran, R.D.C.; Sitanggang, D.F.D.; Kalalo, F.F. Pelanggaran Kapal Perikanan di Wilayah Pengelolaan Perikanan Negara Republik Indonesia 571. *J. ILMU DAN Teknol. Perikan. TANGKAP* **2022**, *7*, 141. [CrossRef]
89. Safitri, S.N.; Yustitianingtyas, L. Dampak Kerusakan Lingkungan Laut Akibat Penggunaan Jaring Trawl (Kasus: Penggunaan Jaring Trawl oleh Nelayan Jawa Timur di Perairan Lamongan dan Gresik). *J. Huk.* **2022**, *2*, 9–21.
90. Lubis, M.S.N. Pengelolaan, Model Terluar, Pulau-pulau Kecil Pada, Berbasis Sistem, Pendekatan Sosioekonomi, Sistem Sistem. *Ringkasan Desertasi* **2014**, *1*, 1–74.
91. Krisnafi, Y.; Iskandar, B.H.; Wisudo, S.H.; Haluan, J. Penentuan Prioritas Wilayah Kerja Untuk Peningkatan Pengawasan Perikanan di WPP NRI 711. *Mar. Fish.* **2017**, *8*, 211–221.
92. Hermanto, D. Maximum Economic Yield Perikanan Tangkap (Studi Manajemen Perikanan Tangkap di WPPNRI 711). *J. Fish. Mar. Res.* **2018**, *2*, 17–24.
93. Darma, A. Strategi Pengamanan ALKI-I dalam Penegakan Kedaulatan Hukum Laut Indonesia sebagai Poros Maritim Dunia. *LITIGASI* **2018**, *19*, 37–51. [CrossRef]
94. Adhityatama, S.; Sulistyarto, P.H. Bukti langsung interaksi perdagangan di kepulauan riau: Studi pada situs arkeologi bawah air di pulau natuna dan pulau bintan. *J. Segara* **2018**, *14*, 127–135. [CrossRef]
95. Fan, C.; Hsu, C.; Lin, J.; Kuan, Y.; Yang, C.; Liu, J.; Yeh, J. Taiwan's legal framework for marine pollution control and responses to marine oil spills and its implementation on T. S. Taipei cargo shipwreck salvage. *Mar. Pollut. Bull.* **2018**, *136*, 84–91. [CrossRef] [PubMed]
96. Zhang, B.; Matchinski, E.J.; Chen, B.; Ye, X.; Jing, L.; Lee, K. *Marine Oil Spills—Oil Pollution, Sources and Effects*, 2nd ed.; Elsevier Ltd.: Amsterdam, The Netherlands, 2019; ISBN 9780128050521.
97. Vina, A.; Liu, J. Hidden roles of protected areas in the conservation of biodiversity and ecosystem services. *Ecosphere* **2017**, *8*, 1–16. [CrossRef]
98. Liu, P.; Jiang, S.; Zhao, L.; Li, Y.; Zhang, P.; Zhang, L. What are the benefits of strictly protected nature reserves ? Rapid assessment of ecosystem service values in Wanglang Nature Reserve. *Ecosyst. Serv.* **2017**, *26*, 70–78. [CrossRef]
99. Sannigrahi, S.; Chakraborti, S.; Kumar, P.; Keesstra, S. Ecosystem service value assessment of a natural reserve region for strengthening protection and conservation. *J. Environ. Manag.* **2019**, *244*, 208–227. [CrossRef]
100. Dangeubun, F.D.W.; Wiryawan, B.; Mustaruddin; Purbayanto, A. Management effectiveness of southeast aru islands marine conservation area. *J. Manaj. Hutan Trop.* **2013**, *19*, 119–127. [CrossRef]
101. Xu, W.; Xiao, Y.; Zhang, J.; Yang, W.; Zhang, L.; Hull, V.; Wang, Z.; Zheng, H.; Liu, J.; Polasky, S.; et al. Strengthening protected areas for biodiversity and ecosystem services in China. *Proc. Natl. Acad. Sci. USA* **2017**, *114*, 1601–1606. [CrossRef]

102. Benetti, S.; Langemeyer, J. Ecosystem services and justice of protected areas: The case of Circeo National Park, Italy. *Ecosyst. People* **2021**, *17*, 411–431. [CrossRef] [PubMed]
103. Townsend, M.; Davies, K.; Hanley, N.; Hewitt, J.E.; Lundquist, C.J.; Lohrer, A.M. The challenge of implementing the marine ecosystem service concept. *Front. Mar. Sci.* **2018**, *5*, 1–13. [CrossRef]
104. Schuhmann, P.W.; Mahon, R. The valuation of marine ecosystem goods and services in the Caribbean: A literature review and framework for future valuation efforts. *Ecosyst. Serv.* **2015**, *11*, 56–66. [CrossRef]
105. Schaafsma, M.; Turner, R.K. Valuation of Coastal and Marine Ecosystem Services: A Literature Review. In *Coastal Zones Ecosystem Services: From Science to Values and Decision Making*; Springer: Cham, Switzerland, 2015; pp. 103–125. [CrossRef]
106. Milon, J.W.; Alvarez, S. The Elusive Quest for Valuation of Coastal and Marine Ecosystem Services. *Water* **2019**, *11*, 1518. [CrossRef]
107. Steenbeek, J.; Buszowski, J.; Chagaris, D.; Christensen, V.; Coll, M.; Fulton, E.A.; Katsanevakis, S.; Lewis, K.A.; Mazaris, A.D.; Macias, D.; et al. Making spatial-temporal marine ecosystem modelling better—A perspective. *Environ. Model. Softw.* **2021**, *145*, 105209. [CrossRef] [PubMed]
108. Carrasco De La Cruz, P.M. The Knowledge Status of Coastal and Marine Ecosystem Services—Challenges, Limitations and Lessons Learned From the Application of the Ecosystem Services Approach in Management. *Front. Mar. Sci.* **2021**, *8*, 1–28. [CrossRef]
109. Furlan, E.; Torresan, S.; Critto, A.; Marcomini, A. Spatially explicit risk approach for multi-hazard assessment and management in marine environment: The case study of the Adriatic Sea. *Sci. Total Environ.* **2018**, *618*, 1008–1023. [CrossRef]
110. Nugraha, A.H.; Tasabaramo, I.A.; Hernawan, U.E.; Rahmawati, S.; Putra, R.D.; Darus, R.F. Diversity, coverage, distribution and ecosystem services of seagrass in three small islands of northern Papua, Indonesia: Liki island, Meossu island and Befondi island. *Biodiversitas* **2021**, *22*, 5544–5549. [CrossRef]
111. Tussadiah, A.; Sujiwo, A.S.; Andesta, I.; Daeli, W. Assessment of coastal ecosystem services and its condition for policy management plan in East Nusa Tenggara, Indonesia. *Reg. Stud. Mar. Sci.* **2021**, *47*, 101941. [CrossRef]
112. Costanza, R.; D'Arge, R.; De Groot, R.; Farber, S.; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; O'Neill, R.V.; Paruelo, J.; et al. The value of the world's ecosystem services and natural capital. *Nature* **1997**, *387*, 253–260. [CrossRef]
113. Yao, X.; Li, G.; Xia, J.; Ben, J.; Cao, Q.; Zhao, L.; Ma, Y.; Zhang, L.; Zhu, D. Enabling the Big Earth Observation Data via Cloud Computing and DGGS: Opportunities and Challenges. *Remote Sens.* **2020**, *12*, 62. [CrossRef]
114. Guerry, A.D.; Ruckelshaus, M.H.; Arkema, K.K.; Bernhardt, J.R.; Guannel, G.; Kim, C.K.; Marsik, M.; Papenfus, M.; Toft, J.E.; Verutes, G.; et al. Modeling benefits from nature: Using ecosystem services to inform coastal and marine spatial planning. *Int. J. Biodivers. Sci. Ecosyst. Serv. Manag.* **2012**, *8*, 107–121. [CrossRef]
115. Kanah Arieska, P. Studi partisipasi stakeholder dalam penguatan status kawasan cagar alam pulau enu pulau karang kabupaten kepulauan aru. *J Stat. J. Ilm. Teor. dan Apl. Stat.* **2011**, *3*. [CrossRef]
116. Mahabror, D.; Hidayat, J.J. Analisis Kerugian Ekonomi Akibat Illegal Fishing Di Zona Ekonomi Eksklusif Perairan Natuna. In Proceedings of the Prosiding Seminar Nasional Kelautan dan Perikanan IV, Tunjangan, Surabaya, 5 September 2018.
117. Hsu, F.C.; Elvidge, C.D.; Baugh, K.; Zhizhin, M.; Ghosh, T.; Kroodsma, D.; Susanto, A.; Budy, W.; Riyanto, M.; Nurzeha, R.; et al. Cross-matching VIIRS boat detections with vessel monitoring system tracks in Indonesia. *Remote Sens.* **2019**, *11*, 995. [CrossRef]
118. Joshi, R. Smart Ship Detection using Transfer Learning with ResNet. *Int. Res. J. Eng. Technol.* **2019**, *6*, 1870–1874.
119. Truong, T.N.; Do Ngoc, T.; Quang, B.N.; Tran, S. Le Combining Multi-Threshold Saliency with Transfer Learning for Ship Detection and Information Extraction from Optical Satellite Images. In Proceedings of the Proceedings of IEEE 14th International Conference on Intelligent Systems and Knowledge Engineering, ISKE, Dalian, China, 14–16 November 2019.
120. Heiselberg, H. Aircraft and ship velocity determination in sentinel-2 multispectral images. *Sensors* **2019**, *19*, 2873. [CrossRef]
121. Kim, S.; Shin, J.; Ahn, J.; Kim, S. Extremely robust remote-target detection based on carbon dioxide-double spikes in midwave spectral imaging. *Sensors* **2020**, *20*, 2896. [CrossRef] [PubMed]
122. Kamiński, Ł.; Kulawiak, M.; Cizmowski, W.; Chybicki, A.; Stepnowski, A.; Orłowski, A. Web-based GIS dedicated for marine environment surveillance and monitoring. In Proceedings of the OCEANS'09 IEEE Bremen: Balancing Technology with Future Needs, Bremen, Germany, 12 May 2009.
123. Sprovieri, M.; Cucco, A.; Budillon, F.; Manta, D.S.; Trincardi, F.; Passaro, S. Large-Scale Mercury Dispersion at Sea: Modelling a Multi-Hazard Case Study from Augusta Bay (Central Mediterranean Sea). *Int. J. Environ. Res. Public Health* **2022**, *19*, 3956. [CrossRef] [PubMed]
124. Visalli, M.E.; Best, B.D.; Cabral, R.B.; Cheung, W.W.L.; Clark, N.A.; Garilao, C.; Kaschner, K.; Kesner-Reyes, K.; Lam, V.W.Y.; Maxwell, S.M.; et al. Data-driven approach for highlighting priority areas for protection in marine areas beyond national jurisdiction. *Mar. Policy* **2020**, *122*, 103927. [CrossRef]
125. Palacio, R.D.; Negret, P.J.; Velásquez-Tibatá, J.; Jacobson, A.P. A data-driven geospatial workflow to map species distributions for conservation assessments. *Divers. Distrib.* **2021**, *27*, 2559–2570. [CrossRef]
126. Sakti, A.D.; Fauzi, A.I.; Takeuchi, W.; Pradhan, B.; Yarime, M.; Vega-Garcia, C.; Agustina, E.; Wibisono, D.; Anggraini, T.S.; Theodora, M.O.; et al. Spatial Prioritization for Wildfire Mitigation by Integrating Heterogeneous Spatial Data: A New Multi-Dimensional Approach for Tropical Rainforests. *Remote Sens.* **2022**, *14*, 543. [CrossRef]

127. Estradivari; Agung, M.F.; Adhuri, D.S.; Ferse, S.C.A.; Sualia, I.; Andradi-Brown, D.A.; Campbell, S.J.; Iqbal, M.; Jonas, H.D.; Lazuardi, M.E.; et al. Marine conservation beyond MPAs: Towards the recognition of other effective area-based conservation measures (OECMs) in Indonesia. *Mar. Policy* **2022**, *137*, 104939. [CrossRef]
128. Su, Q.; Li, Z.; Li, G.; Zhu, D.; Hu, P. Application of the coastal hazard wheel for coastal multi-hazard assessment and management in the Guang-Fong-Hongkong-Macao greater bay area. *Sustainability* **2021**, *13*, 12623. [CrossRef]