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Research Article

Marine Suitability Assessment for Mariculture: Combining GIS and AHP Technique in Dampier Strait Conservation Area, West Papua Province, Indonesia

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Abstract

Potential mariculture activities in the Dampier Strait Conservation Area, which are indicated by the availability of water space and local commodities, can have a multiplier effect on socio-ecological aspects. Therefore, reasonable development steps are needed to carry out environmentally friendly aquaculture. This study aims to determine the potential use of water space for the development of mariculture activities based on the level of suitability using multiple approaches. Suitability analysis was carried out with Geographic Information System (GIS) based on the Analytical Hierarchy Process (AHP) by considering the area's characteristics using several aspects seen from the geographical conditions and water quality (physical, chemical, and biological). Based on the suitability analysis results, the potential water space that can be used for mariculture development activities, namely seaweed and pearl oyster cultivation was 1,130.45 ha (0.49% of the overall space allocation 232,588.59 ha). A justification was then carried out to determine a suitable location in terms of its accessibility and environmental friendliness. The analysis has shown promising results in determining potential locations for developing mariculture activities for seaweed and pearl oyster commodities based on sustainable and environmentally friendly cultivation.

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1. Introduction

Mariculture is one of the activities that can cause a multiplier effect on the socio-ecological system in coastal and marine areas. This is evident from assumption that cultivation activities have economic benefits and help to improve social welfare in the community. However, they can pressure the environment, which indicates that a sustainable study approach with a comprehensive planning concept representing integrated and ecosystem-based management is needed (Smith *et al*., 2011). This is carried out by considering several aspects, such as production process and quality, system safety, as well as environmental and socioeconomic impacts (Perera, 2013). In developing mariculture activities, it is necessary to refer to the Ecosystem Approach to Aquaculture (EAA) (FAO, 2010).

The EAA concept can encourage sustainable and environmentally friendly mariculture activities, and this ensures that its implementation reduces the effects and impacts of ecological pressures (Soto *et al*., 2008; Silva *et al*., 2011; Byron and Costa-Pierce, 2013). In planning the stages of developing these activities, the first step is to assess the suitability based on the potential availability of existing space (Ross *et al*., 2013). The suitability study in the conservation region was carried out on a geographic scale using the EAA concept to evaluate the total area of farms that can be accommodated in the available physical space (McKindsey *et al*., 2006). It also involves several integrated cultivation clusters in a zone sharing the same water body, which requires a coordinated spatial management approach (Sanchez-Jerez *et al*., 2016). This is in line with the technical criteria for utilization by KKP (2014) that mariculture activities are carried out in a restricted–use zone integrated with other zones in the area. In determining the use of space, it is necessary to use a spatial approach to facilitate a comprehensive development pattern with the concept of ecosystem-based management (Micael *et al*., 2015).

The study of suitability with a spatial approach using Geographic Information Systems (GIS) has been widely implemented in previous studies to determine the competence of a location for mariculture development (Ross *et al*., 2011; de Sousa *et al*., 2012). However, this is still rarely carried out in conservation areas with a high level of ecosystem diversity. This indicates that it is necessary to use a spatial approach model adapted to the region's characteristics with several aspects from the geographical conditions and water quality (physical, chemical, and biological). The process can be performed by collaborating with the Multi-Criteria Evaluation (MCE) spatial approach using the Analytical Hierarchy Process (AHP) method (Mamat *et al*., 2014; Shih, 2017). AHP is often used to determine the level of importance of the aspects studied based on the need to provide comprehensive analysis results in suitability assessments tailored to the study area's specific characteristics (Teniwut *et al*., 2019; Tung and Son, 2019; Divu *et al*., 2020).

Studies on the suitability and potential of sites for mariculture in conservation areas, specifically in Indonesia, are still rare (based on the literature study in past 15 years). It is due to the understanding that if mariculture activities are carried out in water conservation areas, they can harm environmental sustainability and eliminate the function of using the area as a nature conservation location. However, if we refer to the provisions related to rules and technical implementation utilization by KKP (2014), these activities can be carried out in this area. The development process reconsiders both the concepts and approaches described above.

This indicates that a study is needed to determine these two factors as the first step in developing mariculture activities. They can also serve as the basis for anticipating negative impacts that are harmful to the sustainability of the ecosystem for current and future usage. One of the steps that can be taken is to assess the availability of space based on its characteristics as a conservation area. This study aims to determine the potential use of water bodies for the development of mariculture activities in the Dampier Strait Conservation Area based on the level of suitability using multiple approaches by implementing the GIS-based AHP method.

2. Materials and Methods

2.1 Study Area

This research was conducted in Dampier Strait Conservation Area. This area has the potential as a location for developing mariculture activities. It can be seen from the relatively extensive space allocation as well as the availability and presence of local resources included in the national aquaculture commodities. The space allocation at this location is in a restricted–use zone, with its availability reaching 232,588.59 of 353,531 ha, and it accounts for 65,79% of the total area (Loka PSPL Sorong, 2018). Cultivated commodities that are local resources include seaweed and pearl oysters (UPTD–KKPD Raja Ampat, pers. Comm).

2.2 Material

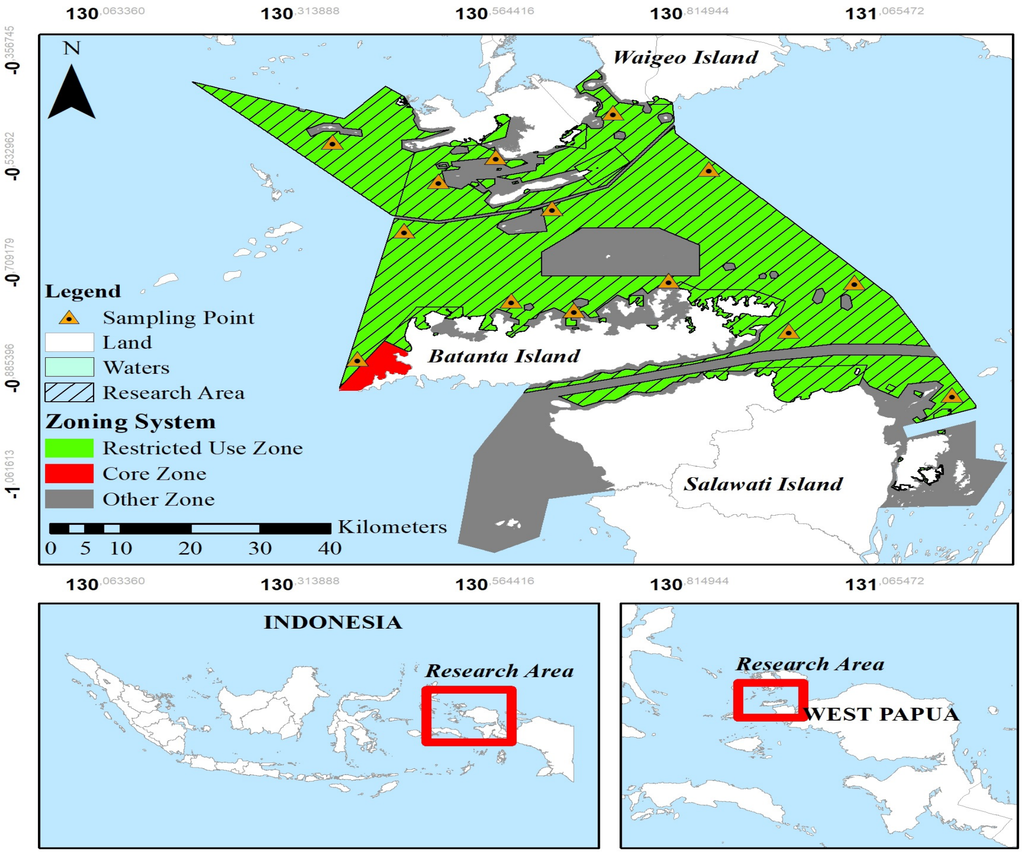


Figure 1. Research map location

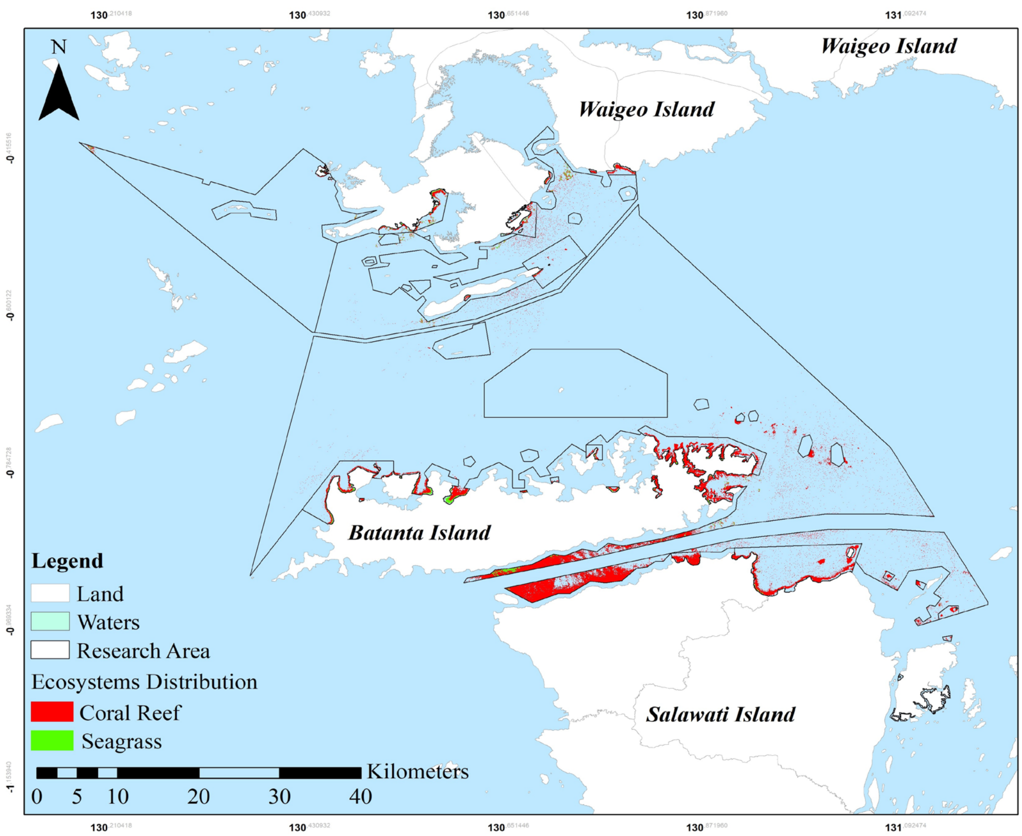


Figure 2. Distribution of coral reef and seagrass ecosystems in Dampier Strait Conservation Area

The material used in this study includes primary and secondary data on water quality parameters (physical, chemical, and biological).

2.3 Method

Data on suitability parameters were collected in September, the second transitional season (September–November).

Primary data was obtained through water quality sampling on the surface and water column through vertical stratification at 14 stations in the restricted–use zone, which was used as the boundary of the study area (Figure 1). The samples were collected with a systematic random method, which spread proportionally, and represented the availability of the data. The sampling point was determined with a spatial approach using the Geographic Information System (GIS) (Radiarta *et al.*, 2018). The technique used for the measurement, observation, collection, preservation, and analysis of water samples was based on the Standard Methods for The Examination of Water and Wastewater (APHA, 2017). Data collected through direct measurement and observation (in situ) consists of temperature, salinity, brightness, turbidity, pH, and dissolved oxygen. Meanwhile, those acquired through laboratory tests include nitrate (APHA 23rd Edition, 4500-NO3-E, 2017), phosphate (APHA 23rd Edition, 4500-P-E, 2017), ammonia (APHA 23rd Edition, 4500-NH3-F, 2017), total suspended solids (APHA 23rd Edition, 2540-D, 2017), and abundance of plankton (APHA 23rd Edition, 10200F, 2017; APHA 23rd Edition, 10200G, 2017).

Secondary data on water quality was obtained through remote sensing consisting of depth, current velocity, and wave height collected from the Indonesian Geospatial Information Agency and Aviso Satellite Altimetry. Furthermore, satellite images (Sentinel-2) from Earthexplorer were used to analyze the distribution of ecosystems. The base map used in this study was the Indonesian Earth Map obtained from the Indonesian Geospatial Information Agency. The zoning distribution data in the Dampier Strait Conservation Area was acquired from the Kupang National Marine Conservation Agency.

2.4 Analysis Data

Water suitability analysis was carried out with the weighted linear combination method, which applies the multi-criteria evaluation through a scoring process on each attribute or limiting variable (Malczewski, 2000, 2004, 2006; Nath *et al.*, 2000). Furthermore, the scores were obtained by multiplying each attribute value or limiting variable based on its level of suitability with the weight to obtain the final result in the form of a suitability class (Radiarta *et al.*, 2018). The scoring system used a range of 1 to 5 (Ross *et al.*, 2011), which was divided into three criteria, where 1 = highly unsuitable, 3 = moderate, and 5 = highly suitable (Yulianto *et al.*, 2016). A suitability matrix for seaweed and pearl oyster cultivation was compiled to obtain the suitability class for each parameter. The weight of each attribute or limiting variable was determined using AHP (Banai-Kashani, 1989; Saaty, 1987, 2008). The value obtained was the result of a combination of assessments from experts (expert judgment) based on the linkage mechanism and dependence on the study's objective. The dominant attribute has a greater weight, while a smaller value was obtained for the less dominant attribute or limiting variable (Cengiz and Akbulak, 2009; Shih, 2017). Therefore, the weight given to each of them was then arranged in a hierarchical model of suitability for seaweed and pearl oyster cultivation. The model was divided into three criteria with sub-criteria derivatives based on geographical conditions and water quality parameters.

Data analysis was carried out with an overlay technique on all the parameters to determine the percentage value of suitability based on the classes (KKP, 2014, 2016), which was calculated using the formulation below (Radiarta *et al.*, 2018). The suitability class was determined based on the percentage of absolute weight distribution using score criteria.

$$Y = (\sum Wi \; x \; Sn) \; x \; 100 \quad \text{.................................... Eq 1}$$

where:

Y = suitability class for seaweed and pearl oyster farming was categorized into three classes, namely highly suitable > 80 %; moderately suitable 40–80%; highly unsuitable < 40%.
Wi = weight factor
Sn = scoring value

In this study, the results of the suitability analysis were justified by referring to the potential cultivation areas, which were located in protected locations covered waters/bays. They also have optimal distance from the coast, with optimal depth and substrate that does not include the existence of critical marine ecosystems, including coral reefs and seagrass.

3. Results and Discussion

3.1 Result

The general characteristics of the Dampier Strait

Conservation Area as a location for the development of mariculture activities can be determined from several factors. Furthermore, it is a strait located in the restricted-use zone, which separates two large islands,

Table 1. Water quality measurements

Parameters	Unit	Average (± St. Dev)	Appendix
Temperature	ºC	29.10 ± 0.26	1
Salinity	‰	33	2
Brightness	m	> 10	3
Turbidity	NTU	0.47 ± 0.11	4
pH	mg/L	8.19 ± 0.06	5
Dissolved oxygen	mg/L	6.23 ± 0.48	6
Nitrate	mg/L	0.101 ± 0.018	7
Phosphate	mg/L	0.005 ± 0.001	8
Ammonia	mg/L	0.008 ± 0.002	9
Total suspended solids	mg/L	< 8	10
Plankton abundance	cell/L	4,175,774.36 ± 3,865,873.66	11

Table 2. Suitability matrix for seaweed farming

Parameters	Ref.	Range Value Based on Scoring		
		5	3	1
Geography				
Body of water shape	1,5,6	Closed (bay area)	–	Open water
Distance to coast (km)	Based on this study	< 3	3–5	> 5
Existence of ecosystems below the water surface	Based on this study	There are no certain types of ecosystems below the water surface	–	There are certain types of ecosystems below the water surface
Substrate	4,5,6	Sand and death coral	Muddy sand	Mud
Physical Oceanography				
Depth (m)	4,5,6	1–< 10	10–≤ 15	< 1 dan > 15
Wave height (m)	2,3	< 0.1	0.1–0.3	> 0.3
Water flow (cm/sec)	2,3	20–< 30	10–< 20 and 30–40	< 10 and > 40
Temperature (ºC)	1,7	28–< 32	32–37	< 28 and > 37
Salinity (‰)	1,7	30–34	25–< 30	< 25 and > 34
Brightness (m)	4,5,6	> 3	1–3	< 3
Turbidity (NTU)	7	< 10	10–30	> 30
Chemical Oceanography				
pH	2,3	6.5–< 8.5	8.5–10 and 4–< 6.5	< 4 and > 10
Dissolved oxygen (mg/L)	2,3	> 6	4–≤ 6	< 4
Nitrate (mg/L)	7	> 0.1	0.001–0.1	< 0.001
Phosphate (mg/L)	7	> 0.1	0.001–0.1	< 0.001
Ammonia (mg/L)	7	> 0.1	0.001–0.1	< 0.001

Source: Hasnawi *et al*., 2013[1]; KKP, 2014[2], 2016[3]; Pong–Masak *et al*., 2010[4]; Radiarta *et al*., 2004[5], 2005[6], 2018[7].

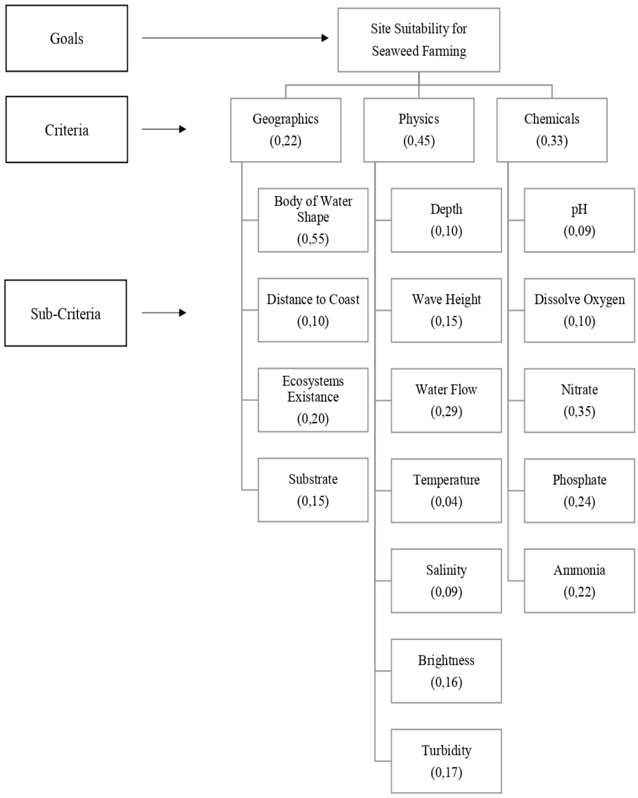


Figure 3. The hierarchical model of suitability for seaweed farming (numbers indicate the weight used)

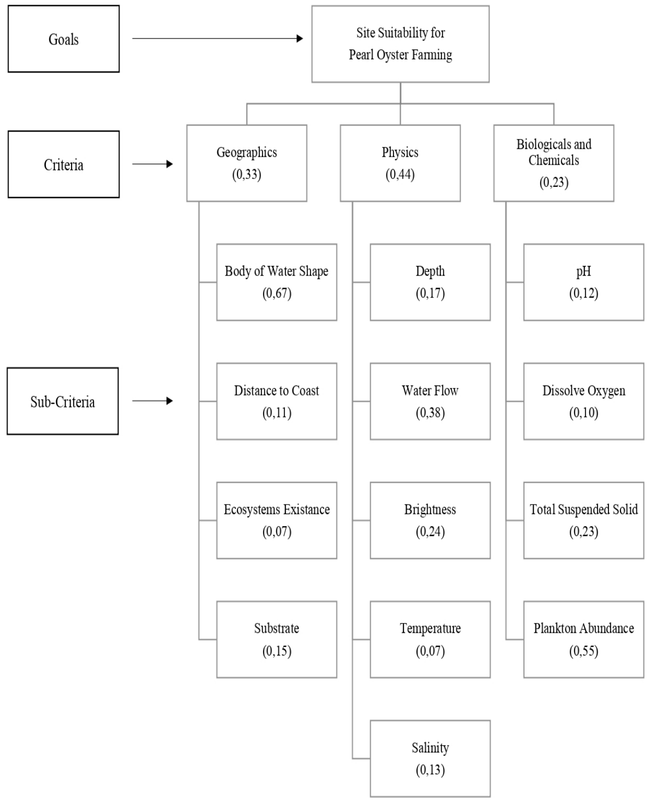


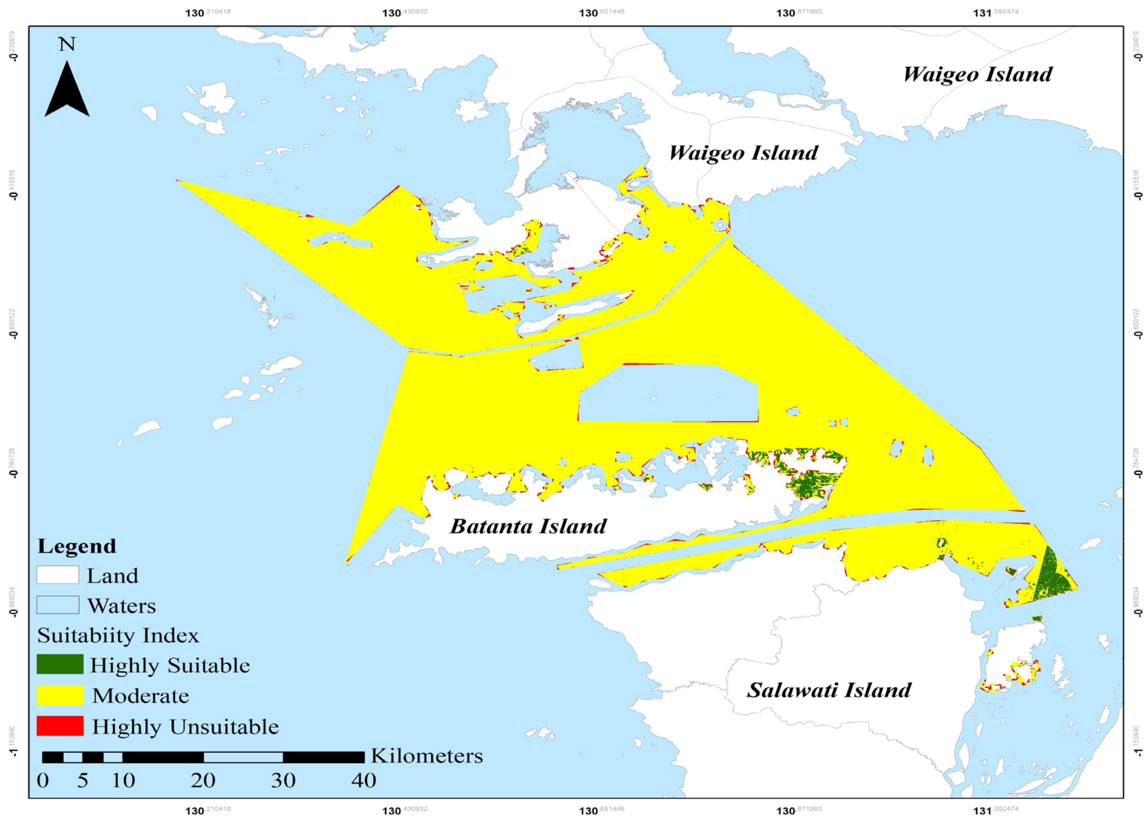
Figure 4. The hierarchical model of suitability for pearl oyster farming (numbers indicate the weight used)

namely Batanta and Waigeo. These two islands have the physical characteristics of a protected bay area. They also have ecosystem distribution in the form of coral reefs and seagrass, which is relatively extensive, and predominantly located in the bay. This was evidenced by the image analysis results carried out in this study (Figure 2). Hydro-oceanographic conditions of the waters can be obtained from water quality measurements results (Table 1) and remote sensing techniques presented as a distribution map (Appendix 12, Appendix 13, and Appendix 14). Compared with the suitability matrix that has been compiled, the results on each parameter used as attributes or limiting variables were in the good category. They also met the eligibility requirements for mariculture development activities for seaweed and pearl oyster commodities. The analysis refers to the suitability matrix (Table 2 and Table 3). This matrix is based on the criteria and sub-criteria regarding geographic conditions and hydro-oceanography parameters. It refers to the availability of the data collected to determine the level of suitability with the scoring results using the distribution of the values of each parameter at the sampling point. The parameters used are modifications from a collection of previous studies (Radiarta *et al*., 2004, 2005, 2018; Pong-Masak *et al*., 2010; Hasnawi *et al*., 2013; KKP, 2014, 2016; Sinaga *et al*., 2015; Yulianto *et al*., 2016).

The determination was based on the success of the activities carried out based on the level of biota's survival, environmental friendliness, as well as the accessibility of pre-production, production, and post-production/harvest.

The results of the weighting process based on the AHP show the scores on each criterion and sub-criteria based on their importance for the success rate of seaweed and pearl oyster cultivation (Figure 3 and Figure 4). The most influential factor is physical oceanography parameters, with values of 0.45 and 0.44, respectively. The sub-criteria results show that water current is the most influential factor among the physical oceanography parameters, with values of 0.29 and 0.38, respectively.

The data analysis results for the development of mariculture activities in the Dampier Strait Conservation Area are presented in the form of a suitability map (Figure 5). Based on the suitability class, the water area was highly suitable for developing seaweed and pearl oyster cultivation of 1,657.15 ha and 2,976.56 ha, respectively (Table 4). These results show the potential of the Dampier Strait Conservation Area as a location for mariculture activities of these two commodities. However, the analysis results cannot show a more reasonable interpretation when observed closely. It is indicated by the distribution of several locations that



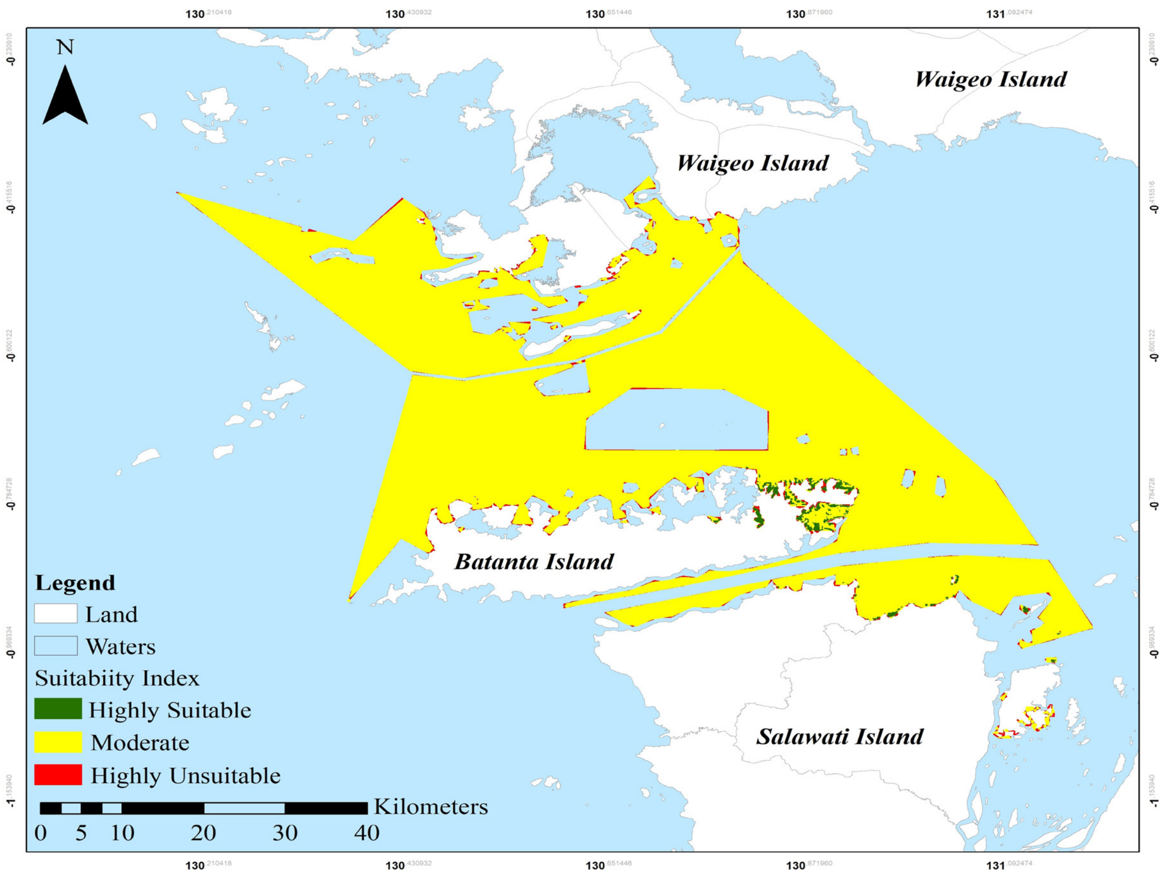


Figure 5. (a) Suitability map for pearl oyster farming before justification in Dampier Strait Conservation Area; (b) Suitability map for seaweed farming before justification in Dampier Strait Conservation Area

Table 3. Suitability matrix for pearl oyster farming

Parameters	Ref	Range Value Based on Scoring		
		5	3	1
Geography				
Body of water shape	1,3,4	Closed (bay area)	–	Open water
Distance to coast (km)	Based on this study	< 3	3–5	> 5
Existence of ecosystems below the water surface	Based on this study	There are no certain types of ecosystems below the water surface	–	There are certain types of ecosystems below the water surface
Substrate	1,3,4	Sand and death coral	Muddy sand	Mud
Physical Oceanography				
Depth (m)	1,2,3,4,5	10–< 20	20–30	< 5 and > 30
Water flow (cm/sec)	5,6	15–< 25	10–< 15 and 25–30	< 10 and > 30
Brightness (m)	5,6	4.5–< 6.5	3.5–< 4.5 and 6.5–7.7	< 3.5 and
Temperature (ºC)	1,2	25–< 32	22–< 25 and 32–35	< 22 and > 35
Salinity (‰)	1,2,6	30–35	20–< 30	< 20 and > 35
Chemical and Biological Oceanography				
pH [5]	2	7–< 8	5–< 7 and 8–9	< 5 and > 9
Dissolved oxygen (mg/L)	2,5	> 6	4–6	< 4
Total suspended solids (mg/L)	6	< 10 or 25	25–50	> 50
Plankton abundance (cell/L)	1,5,6	> 15,000	2,000–15,000	< 2,000

Source: KKP, 2014[1], 2016[2]; Radiarta *et al*., 2004[3], 2005[4]; Sinaga *et al*., 2015[5]; Yulianto *et al*., 2016[6].

Table 4. Total area based on suitability index for the development of mariculture in Dampier Strait Conservation Area

Mariculture Commodity	Total Area Based on Suitability Index (Ha)		
	Highly Suitable	Moderate	Highly Unsuitable
Before Justification			
Seaweed	1,657.15	230,112.84	818.6
Pearl Oyster	2,976.56	229,005.87	606.16
After Justification			
Seaweed	576.96	210.04	141.56
Pearl Oyster	553.49	290.5	18.66

Table 5. Potential use of space for mariculture activities in Dampier Strait Conservation Area

Mariculture Commodity	Land Use Potential (Ha)	Land Use Potential (% of overall space allocation)
Seaweed	430.84	0.19
Pearl Oyster	521.96	0.22
Seaweed and Pearl Oyster	177.66	0.08
Total	1,130.45	0.49

fall into the very suitable category in unprotected areas (open waters). Then, referring to accessibility, it is at a distance and depth that is not optimal, complicating the cultivation process. In addition, the location is in an area that overlaps with ecosystems at the bottom of the waters. Therefore, in this study, re-justification of the suitability analysis results was carried out. It was performed with the consideration that the previous parameters are the main limiting variables or attributes determining (constrain) the success rate of mariculture activities.

The results of the re-justification are presented in the form of a suitability map for the commodities (Figure 6). The area suitable for seaweed and pearl oyster cultivation activities was 576.96 ha and 553.49 ha, respectively (Table 4). The results show differences in the suitability of the location and the total area of water space that can be utilized before being justified. They have also described mariculture activities that have considered the accessibility of the pre-production, production, and post-production/harvest stages as well as the implementation of an environmentally friendly cultivation. The final result of the overall suitability analysis process can determine the potential of water space, which can be used for the development of the farming. The process was carried out by overlaying the results of the suitability analysis, which were included in the highly suitable categories from the justification results. For all locations that fall into these categories, the parameters used as attributes or limiting variables do not have a significant effect on suitability for mariculture. Utilization activities that can be carried out include seaweed commodities and pearl oysters farming (Figure 7). The total water area used was 1,130.45 ha, namely 0.49% of the overall space allocation (Table 5).

3.2 Discussion

The suitability of waters for mariculture is an integral part of spatial planning. Aquaculture spatial planning contributes to the selection of suitable sites for aquaculture activities when integrated with future planning related to regulation, management, and conservation of the environment and marine resources (McKindsey *et al*., 2006; Divu *et al*., 2020). Several cumulative factors must also be considered including geographical conditions, quality of the aquatic environment, and availability of space. The consideration is to ensure the implementation of activities based on ecosystem management (FAO, 2010). This finding is consistent with this study, which was carried out in a conservation area requiring special attention to the use of its space. Furthermore, this helps to prevent threat of ecosystem (ecological) degradation, which have an impact on the sustainability of people's lives in this location (social and economic).

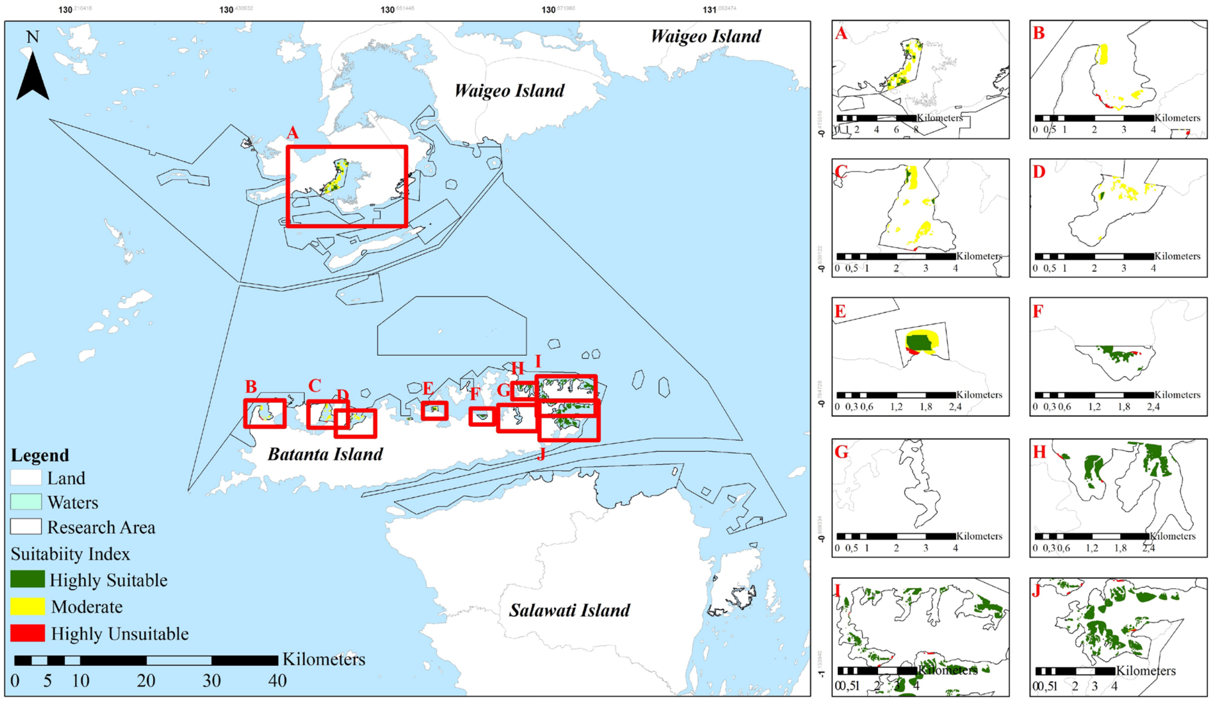
The geographical conditions of the waters significantly affected the success rate of mariculture activities. The study site is a passage, which facilitates nutrient exchange process to optimize the growth of biota (Mamat *et al*., 2014). In this area, two islands have the potential to be used for mariculture, namely Batanta and Waigeo, and they have several bays (Loka PSPL Sorong, 2018). The protected bay is a good location for aquaculture activities because it tends to have calmer currents and waves compared to open waters (Utama and Handayani, 2018). This condition can minimize damage to cultivation construction, especially during certain seasons (Tung and Son, 2019). Based on the results of image analysis, particularly in the intertidal regions, massive distribution of coral reef and seagrass ecosystems was observed. The condition needs to be considered because it is a conservation area that is rich in ecosystems.

The development of mariculture activities is environmentally friendly and does not cause negative effects on the survival of the surrounding ecosystem (Micael *et al*., 2015). Hydro–oceanographic parameters from the waters' physical, chemical, and biological characteristics significantly affected the success rate of these activities. Seasonal factors influence its distribution in water bodies on the column and surface (de Sousa *et al*., 2012). In this study, water quality measurements were carried out in September, the second transitional season (September–November). Compared with the suitability matrix, the results showed excellent value, which indicates that the Dampier Strait Conservation Area is suitable for developing mariculture activities. However, the measurements are likely to give different values when they are carried out in certain period, such as the wet season, transition I, and east, namely December-February, March-May, and June-August, respectively. It is due to differences in environmental conditions in these periods, which can affect the vertical and horizontal distribution of hydro–oceanographic parameters in the waters (Irawati *et al*., 2022). However, it is still an estimate because no previous studies at this location can describe the characteristics of these parameters in that time range.

The weight results on the attribute or limiting variable and the suitability parameter show the value influencing the objectives in each sub-criterion in the criteria studied (Figure 2). The most influential criterion in determining the success of seaweed and pearl oyster cultivation is physical oceanography, with current velocity as the sub-criterion with the highest weight.

The average current velocity in the study area ranges from 9.46 ± 5.40 cm/second, indicating good results for developing these activities. The ideal current velocity for the cultivation of the two commodities is between 10–20 cm/second for seaweed and 10–30 cm/second for pearl oyster (Radiarta *et al*., 2004, 2005).

Current is an important parameter, which plays a role in distributing nutrients to stimulate the growth of both seaweed and pearl oysters. It can also maintain water temperature stability as well as keep commodity biota from growing epiphytes (Mamat *et al*., 2014; Teniwut *et al*., 2019).



(b)

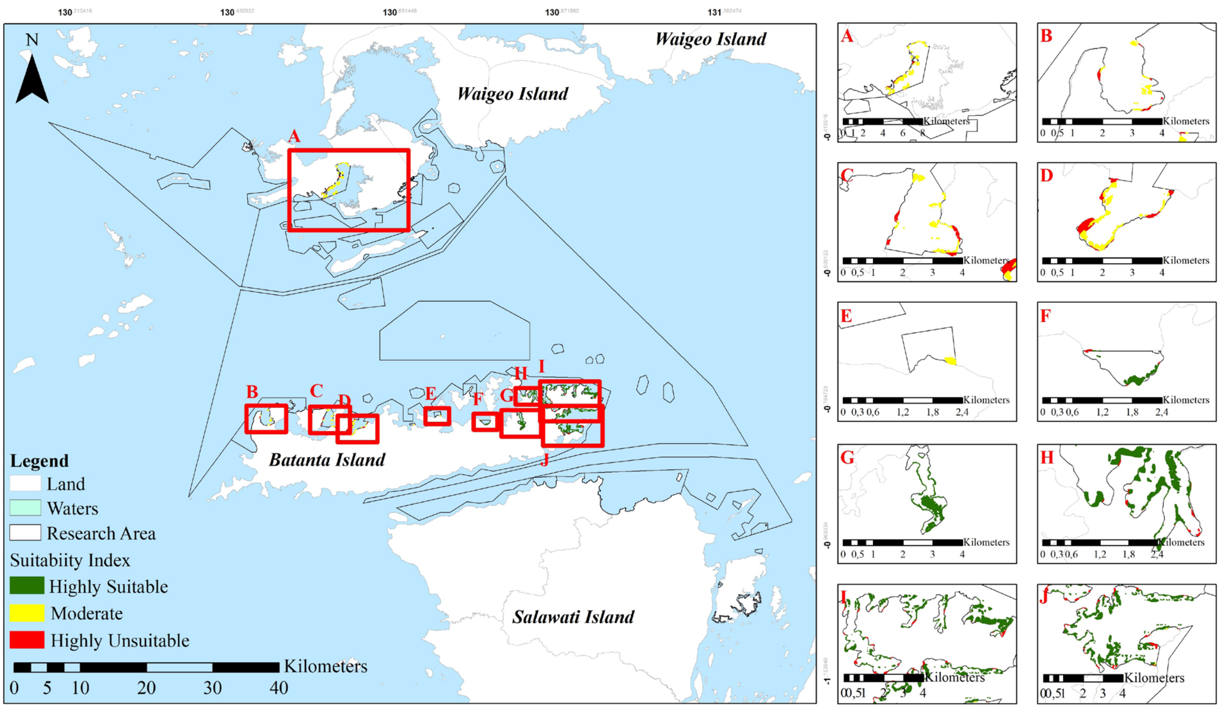


Figure 6. (a) Suitability map for pearl oyster farming after justification in Dampier Strait Conservation Area; (b) Suitability map for seaweed farming after justification in Dampier Strait Conservation Area

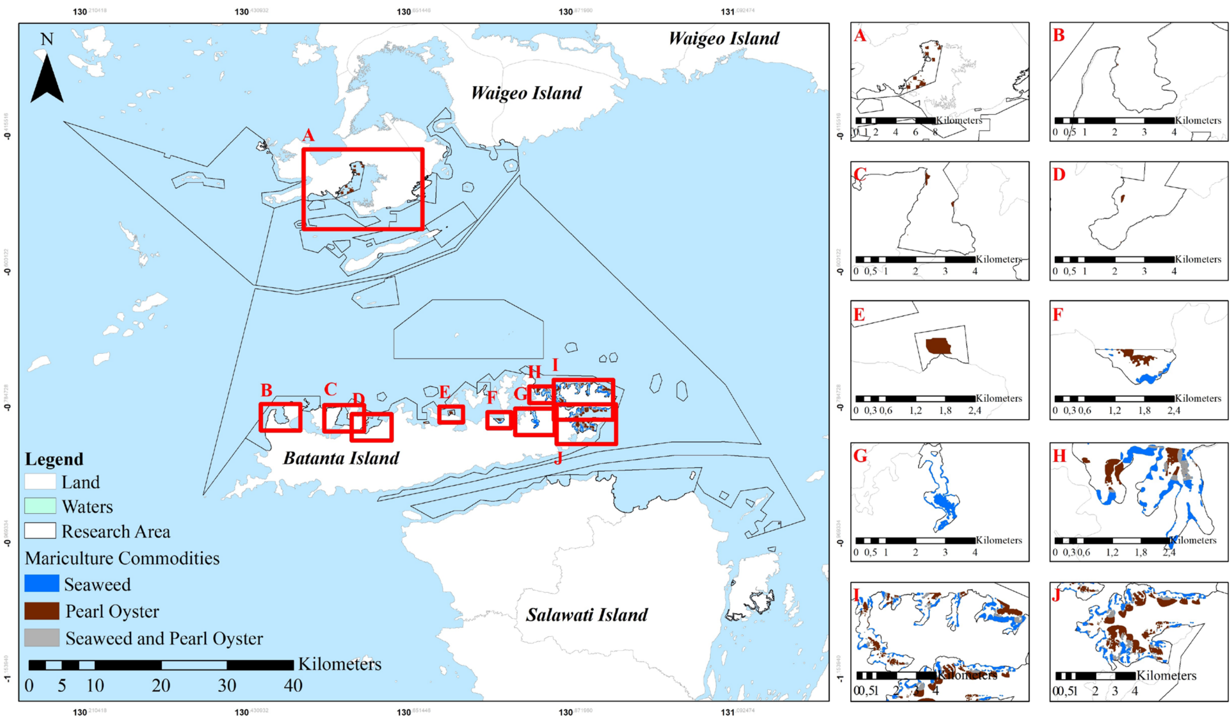


Figure 7. Potential utilization of water areas for mariculture activities in Dampier Strait Conservation Area

The suitability analysis of the waters for the development of mariculture activities in this study was carried out using the GIS-based AHP method. Furthermore, this method can show comprehensive final results tailored to the data needs and characteristics of the location (Nath *et al*., 2000). It can also accumulate the overall results of the analysis based on the level of importance of the parameters used as attributes or limiting variables (Perez *et al*., 2005). This step helps to determine the suitability of the location for mariculture development based on the allocation of available space that can be utilized (Radiarta *et al*., 2008). The GIS-based method can help the spatial planning process in coastal and marine areas based on the principle of an integrated ecosystem approach in a spatial pattern (Douvere and Ehler, 2006; Foley *et al*., 2010; Smith *et al*., 2011). In a policy-making step, the process makes it easier for stakeholders and farmers to determine the scale of the development of activities to be carried out (Cho *et al*., 2012). During AHP analysis, the weight value of criteria can change due to the different criterion scores, which were often altered subjectively by decision–makers when assigning the relative importance of alternatives on every criterion (Radiarta *et al*., 2008; Saaty, 1987, 2008). Therefore, assigning the criteria scores objectively enhances the accuracy and reliability of the analysis (Perez *et al*., 2005).

The development of aquaculture, including in marine water, must be carried out comprehensively by considering the environmental aspects of sustainable use from a social and economic perspective (Soto *et al*., 2008). Applying this concept can bring positive benefits where mariculture activities carried out are adjusted to the potential and characteristics of the area in ecosystem-based management (Sanchez-Jerez *et al*., 2016). A correlation shows the influence of cultivation on the sustainability of supporting ecosystems on the coast and the sea (Folke and Kautsky, 1992; Costa-Pierce, 2003; Brummet, 2013). This shows that mariculture development must pay attention to planning, which includes the suitability and potential of the land through a process describing the application of environmentally friendly marine aquaculture. Based on the concept, this study was carried out on the suitability with the EAA concept, which can identify suitable locations using the potential of space as well as characteristics of the aquatic environment (Ross *et al*., 2013).

4. Conclusion

The suitability index produced using multiple approaches can be used to determine potential locations for mariculture development, in this case in Dampier Strait Conservation Area, especially for seaweed and pearl oyster commodities. The approaches showed promising results because all parameters used as attributes or limiting variables cannot threaten the sustainability of the activities carried out and negatively impact the surrounding ecosystem. This is the basis for sustainable cultivation of environmentally friendly aquaculture.

Acknowledgment

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Authors' Contributions

The contribution of each author is as follows, Ichsan; conceptualized, conducted methodology, curated data, visualized, and wrote the original draft. Ali and Niken; supervised the research, curated data, wrote review, and edited the manuscript. Fery; curated data, wrote review, and edited the manuscript. Furthermore, all authors discussed the results and contributed to the final manuscript.

Conflict of Interest

The authors declare that they have no competing interests.

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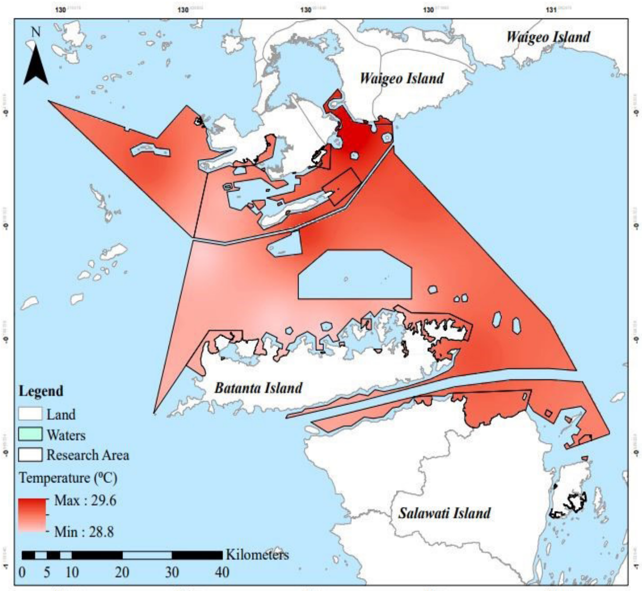
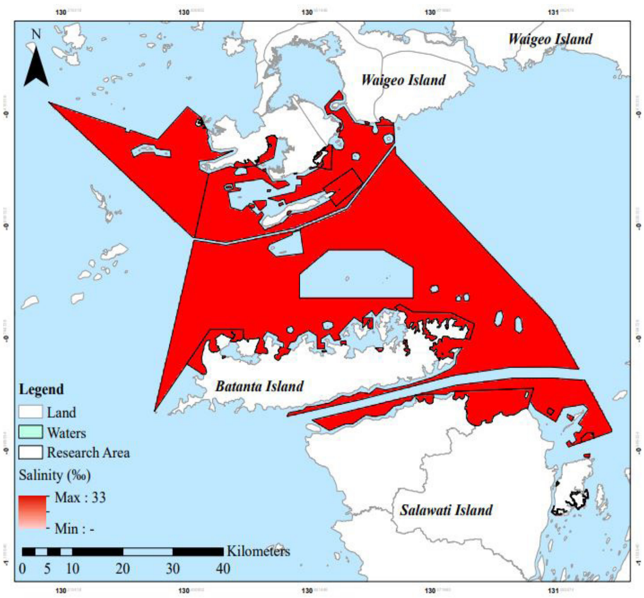
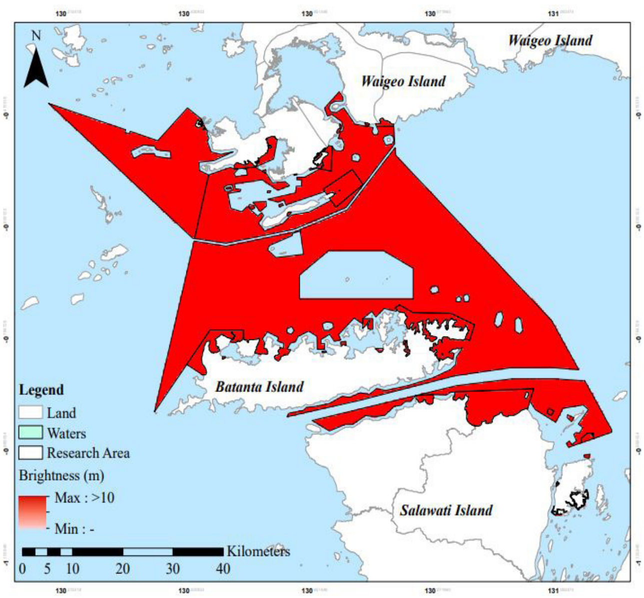


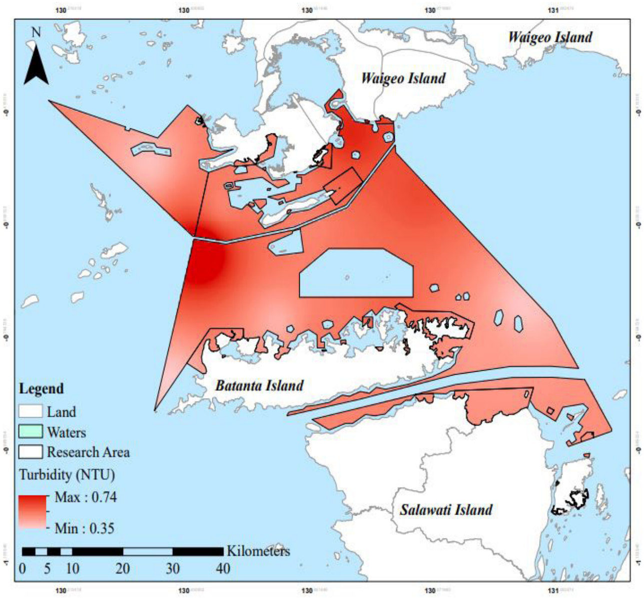
Appendix 1. Distribution of water temperature in Dampier Strait Conservation Area



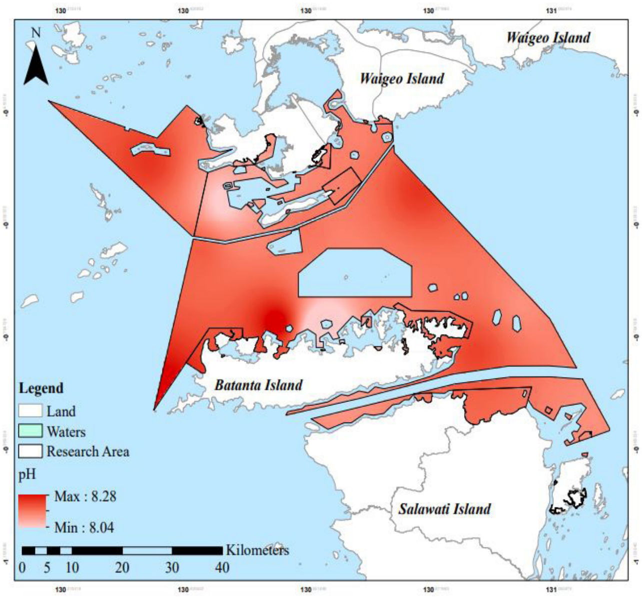
Appendix 2. Distribution of water salinity in Dampier Strait Conservation Area



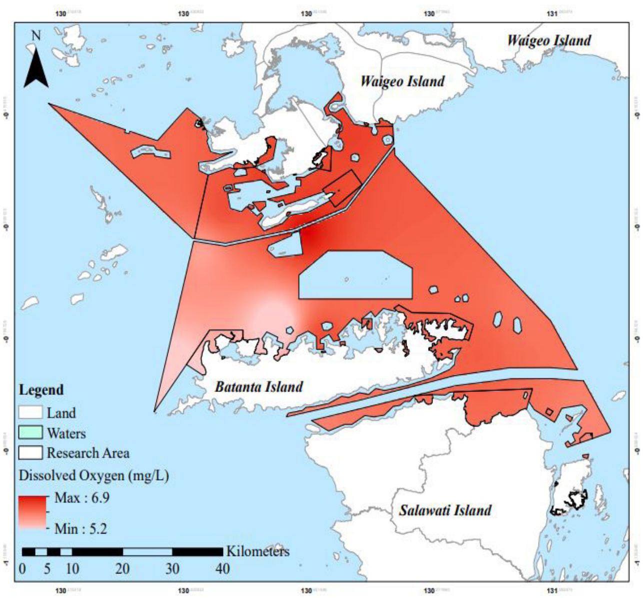
Appendix 3. Distribution of water brightness in Dampier Strait Conservation Area



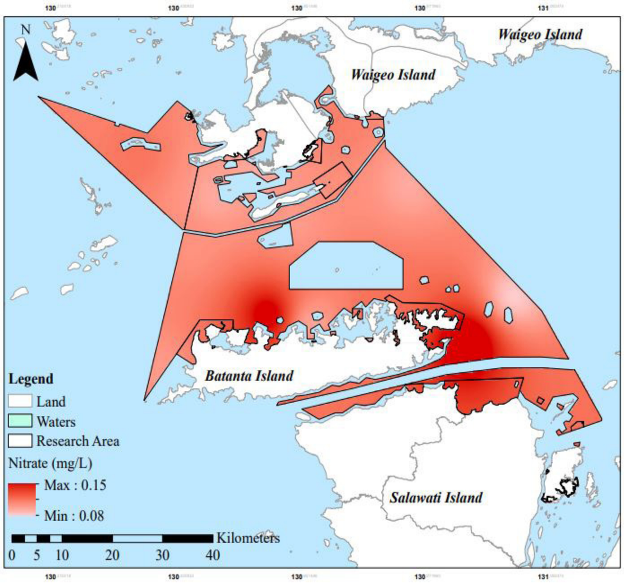
Appendix 4. Distribution of water turbidity in Dampier Strait Conservation Area



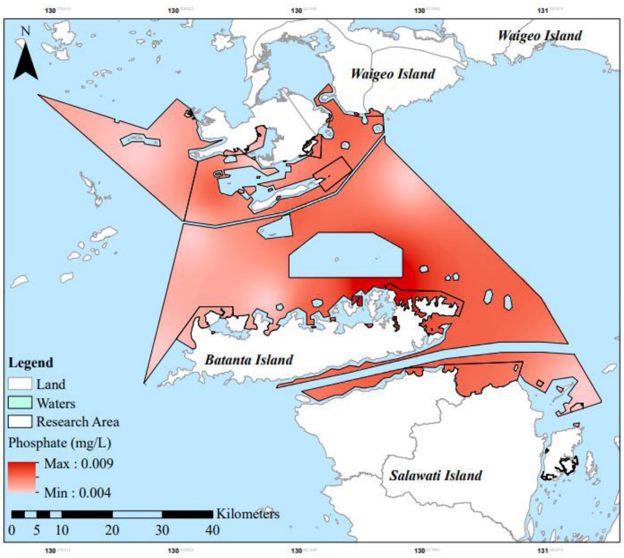
Appendix 5. Distribution of water pH in Dampier Strait Conservation Area



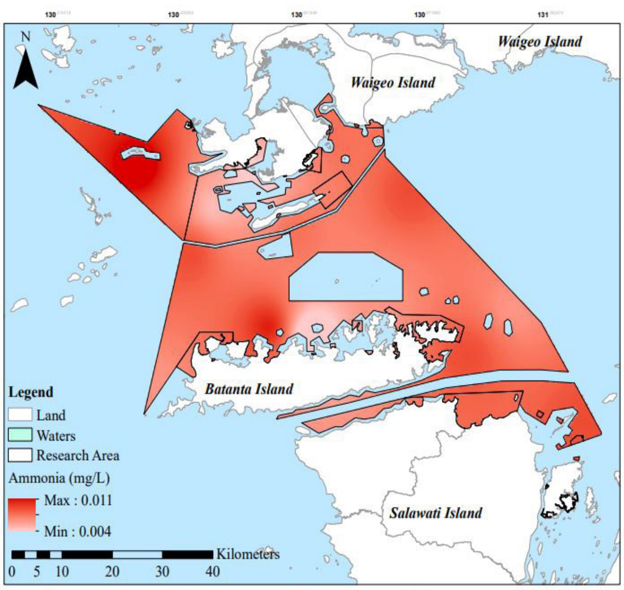
Appendix 6. Distribution of dissolved oxygen in Dampier Strait Conservation Area



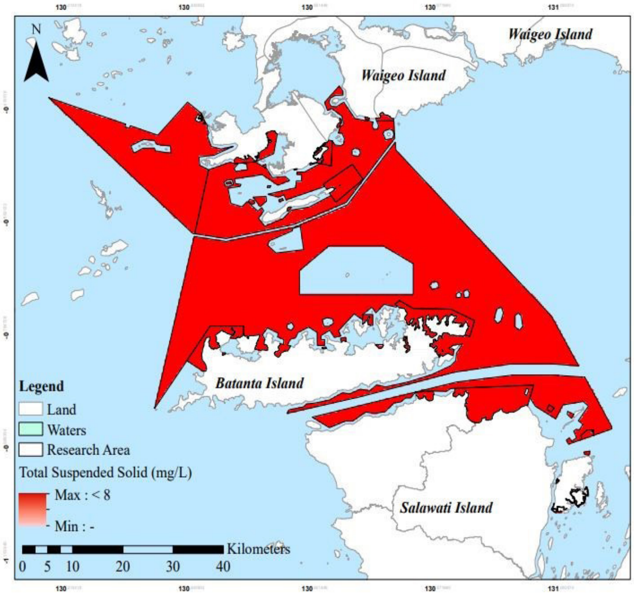
Appendix 7. Distribution of water nitrate in Dampier Strait Conservation Area



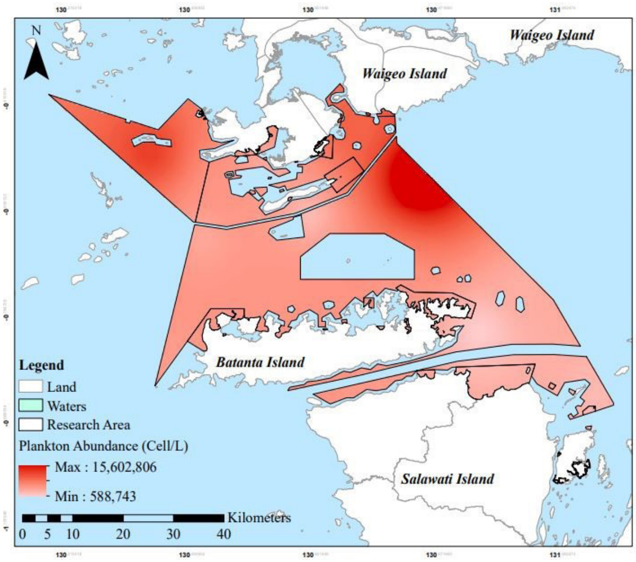
Appendix 8. Distribution of phosphate in Dampier Strait Conservation Area



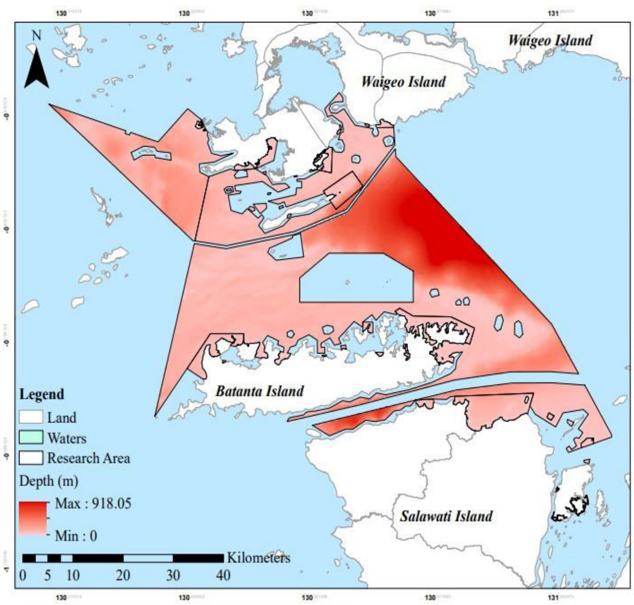
Appendix 9. Distribution of ammonia in Dampier Strait Conservation Area



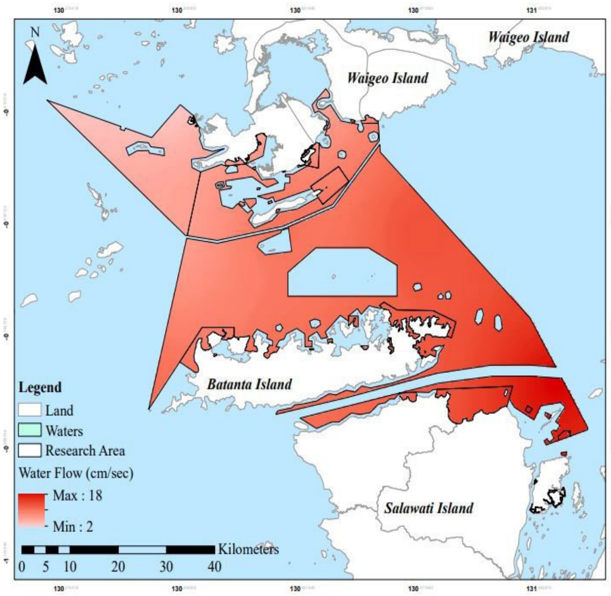
Appendix 10. Distribution of total suspended solid in Dampier Strait Conservation Area



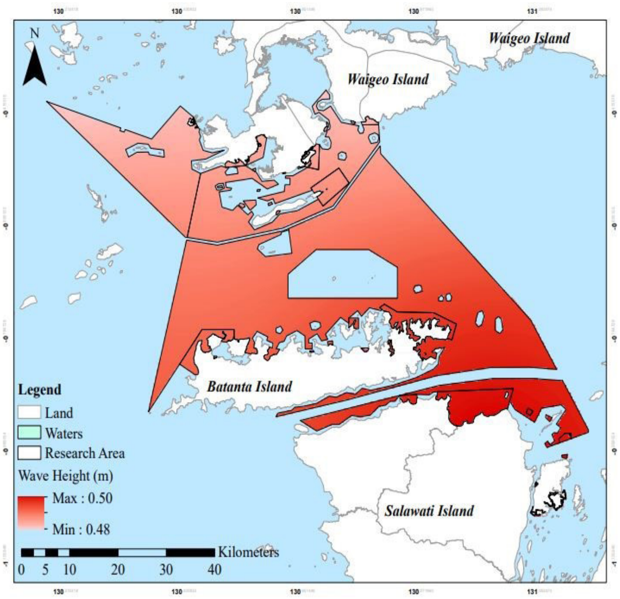
Appendix 11. Distribution of plankton abundance in Dampier Strait Conservation Area



Appendix 12. Distribution of water depth in Dampier Strait Conservation Area



Appendix 13. Distribution of water flow in Dampier Strait Conservation Area



Appendix 14. Distribution of wave height in Dampier Strait Conservation Area