Identification of potential water pollution in coastal areas from anthropogenic activities in Karimunjawa National Park

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Abstract. Water quality is one of the important factors that support the growth of coastal ecosystems. The existence of anthropogenic activities makes water conditions uncertain if there is no monitoring. Karimunjawa National Park has a variety of land uses that are thought to have the potential to cause disturbed water conditions along the coast. Therefore, this study aims to identify the potential for pollution from anthropogenic activities and to see the status of water quality from the calculation of the pollution index which is adjusted to the standard value of sea water quality. There are 7 water parameters measured. The method used is direct measurement in the field and laboratory analysis. The research stations are spread over 9 points, which are located on Kemujan Island, Karimunjawa Island, and Menjangan Besar Island. Based on the results of research conducted in August 2021, there are 5 stations with low polluted status and 4 stations that are suitable with quality standards. Land use affects the spatial variation of the calculation of the pollution index value. Anthropogenic activities in the Karimunjawa National Park area must continue to be monitored and managed properly so that the ecosystem can continue to be sustainable.
Key Words: anthropogenic, coastal pollution index, water quality.

Introduction. One of the islands in the north of Java Island is the Karimunjawa National Park area. It is about 45 nautical miles from the city of Jepara and is part of the Karimunjawa District in the Dati II Jepara Regency. Based on Decree of the Minister of Forestry No. 161/Menhut/1988, the Karimun Jawa Islands were made into a national park. The park covers an area of about 111.500 ha, with about 1.500 ha of land and about 110.000 ha of water. The Karimunjawa region has a location profile as a marine tourism area, fishing village, aquaculture and shipbuilding industry. Observations directly in the field indicate that in the Karimunjawa National Park area there are many anthropogenic activities, such as fishing, agriculture, and densely populated settlements. These anthropogenic activities can affect water quality on the coast (Bernatchez et al 2011). Water quality on the coast of Karimunjawa is also influenced by material input from the river flow that empties into the coast. There are several small rivers that empties into the Karimunjawa coast, namely the Kapuran River, Jati Kerep River, and the Legon Lele River. There are many tourism activities, settlements, agriculture, and aquaculture industries along those three rivers. These activities produce waste that can pollute the waters. Several studies on water quality show that waste from domestic, agricultural and industrial activities along the river has an impact on water pollution (Parimala et al 2007; Sakinah et al 2018; Santucci et al 2018). This pollution causes the concentration of several water quality parameters to show values that tend to increase (biological oxygen demand - BOD, total suspended solid - TSS, nitrate, phosphate, total coli) and decrease (brightness and dissolved oxygen - DO) from upstream to downstream, even exceeding the quality standard (Schleppi et al 2012; Liu et al 2020).

Water quality parameters that are not in accordance with quality standards due to waste input can affect the quality status of these waters (Alves et al 2018). Coastal conditions are closely related to river systems, estuaries, and the sea. Changes in the nature of rivers that occur due to human activities will result in a decrease in water quality (Liu et al 2011). In recent years, the growth in population activity in terms of settlements, agriculture, tourism, and industry has led to an increase in waste disposal, and rivers and oceans have been the primary locations for this waste disposal (Neyestani et al 2016). Therefore, it is certain that there has been a decline in the quality of the waters from rivers, estuaries, to the sea. Marine pollution according to US EPA (2002) is the introduction by humans, either directly or indirectly, of compounds and energy into the marine environment (including estuaries) that can cause negative impacts on biological resources, public health, disruption of maritime activities including marine activities, fishing, decreasing water quality according to its designation and decreasing recreational interest. Marine pollution includes threats from land sources, oil spills, untreated waste, water turbidity, nutrient enrichment, invasive species, persistent organic pollution, heavy metals, acidification of waters, radioactive compounds, garbage, overfishing and destruction of coastal habitats (Sarma et al 2020).

The sea has homeostatic power, namely the ability to maintain balance and is an aquatic ecosystem that has the carrying capacity to purify itself from all disturbances that enter water bodies (Krishna et al 2016). In fact, coastal waters are the final reservoir of all types of waste generated by human activities. The ocean receives water-borne materials from agricultural areas, household waste, garbage, ship discharges, and offshore oil spills (Conley et al 2009). If the load received by the waters has exceeded the carrying capacity, then the water quality will decrease. The aquatic environment is no longer in accordance with the established quality standard criteria, the waters have been polluted physically, chemically, and microbiologically (McClelland et al 1997). Mangroves are one of the most biodiverse ecosystems in the world, rich in organic matter and nutrients and support a very large biomass of flora and fauna (Guhathakurta & Kaviraj 2005). Qiu et al (2014) have reported that mangrove forests can be used as an additional natural system to increase the efficiency of an artificial wastewater treatment system. Mangrove ecosystems create a suitable environment by removing and converting pollutants in wastewater through processes of sedimentation, filtration, microbial activity, plant absorption, etc. when water passes through mangroves (Stoner & Acevedo 1990; Shin et al 2008; Ren et al 2011; Qiu et al 2014).

Research by Gomes et al (2014) shows that pollution that occurs in rivers will reduce the quality of sea water into which the river empties. Waste from domestic, agricultural, tourism and industrial activities along the river has an impact on reducing water quality, so that water cannot be used according to its designation (Bandyopadhyay et al 2017). The WQI (Water Quality Index) method is widely used to assess water quality and the results are very useful for the community and policy makers (Boix et al 2005). The WQI method is a simple mathematical instrument that integrates several parameters into one number, so that the results can be understood, provide a comprehensive picture of the status of water quality and are inexpensive (Boix et al 2005; Chaturvedi & Bassin 2010; Song & Kim 2009; Nikoo et al 2011). WQI methods have been developed in many countries to assess surface water, such as WQI min used in Taihu lake (Wu et al 2018), NSFWQI in Luanhe river (Tian et al 2019), and Weighted Arithmetic Index method in Kolong river (Bora & Goswami 2017). The Ministry of Environment in Indonesia has adopted and used two water quality indices, namely the Storet Index and the Pollution Index. This pollution index is widely used in Indonesia, as in research (Effendi 2016; Susanti & Miardini 2017).

Determining the status of water quality according to Dash et al (2015) is one of the first steps in the process of monitoring and preventing the decline in the quality of waters. Determining the status of water quality is the first step in order to know the condition of the waters, so that water management can be carried out according to the level of pollution that occurs. Therefore, it is necessary to study the quality of the waters in the Karimunjawa National Park area to determine the level of pollution that occurs, and can be considered in the management of coastal areas.

Material and Method

Description of the study sites. This research was conducted in August 2021 on Karimunjawa Island, Kemujan Island and Menjangan Besar Island which are located in the Karimunjawa National Park area, Jepara Regency, Central Java Province. Karimunjawa National Park consists of 27 islands with a total area of 111,625 ha. Administratively, there are four villages included in this area, namely Karimunjawa village, Kemujan village, Nyamuk village, and Parang village. Its management consists of a core zone, a protection zone and a utilization zone. In accordance with the Decree of the Directorate General of KSDAE No. SK.28/IV-SET/2012, the Karimunjawa zoning consists of a core zone, jungle zone, marine protection zone, land use zone, marine tourism utilization zone, marine cultivation zone, religious zone, culture, history, rehabilitation zone, traditional fishing zone. Based on research by Latifah et al (2018), 84.5 ha of mangrove land have been changed over the past 25 years, from 1992 to 2017. The main factors causing the decline in mangrove area include illegal logging, natural factors, changes in land function into ponds and hotels. This massive anthropogenic activity will contribute to changes in coastal water quality. The research area can be seen in Figure 1.

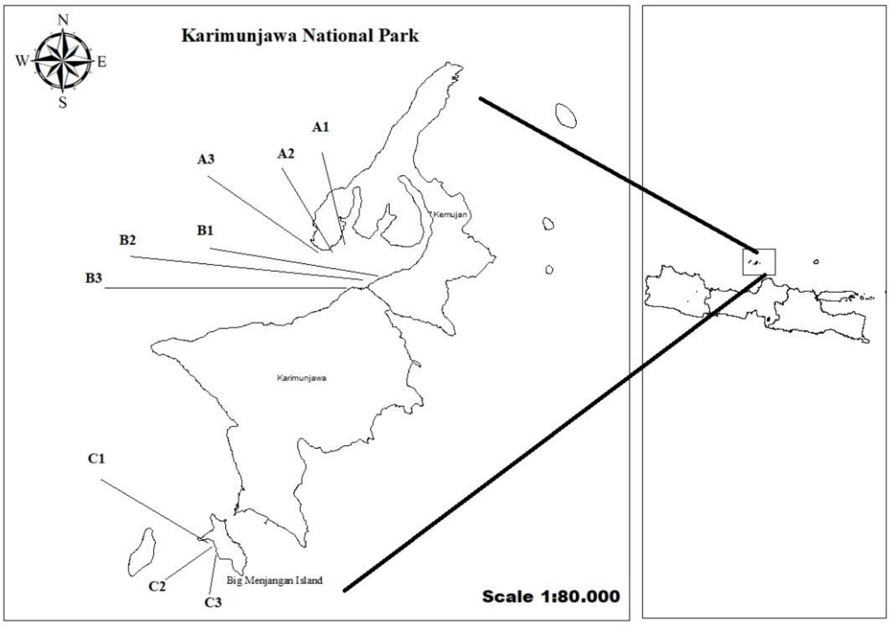

Figure 1. Research location points.

Sampling. Water samples were taken based on purposive sampling in August 2021 at nine points located on Karimunjawa Island, Kemujan Island and Menjangan Besar Island (Table 1). The sampling points are in the estuary area bordering the sea. Determination of sample points was based on small watersheds located on Karimunjawa Island, Kemujan Island and Menjangan Besar Island. Land use from upstream to downstream of the river sequentially is in the form of mixed plantations, ponds, and mangrove forests.

The method of water sampling is based on INS 6989.57:2008 concerning Surface Water Sampling Methods. The parameters that were measured directly in the field were pH, dissolved oxygen, and salinity, while the parameters for Total Suspended Solids, Nitrate, Phosphate, Biochemical Oxygen Demand were analyzed in a laboratory accredited by the National Accreditation Committee (Table 2).

Table 1

Research location coordinates

Code	Coordinates		Location
	Longitude	Latitude	
A1	110°27'24.1452'' E	5°48'47.2716'' S	Kemujan Island
A2	110°27'14.094'' E	5°48'54.126'' S	Kemujan Island
A3	110°27'1.7568'' E	5°48'54.5832'' S	Kemujan Island
B1	110°27'52.4736'' E	5°49'14.4588'' S	Karimunjawa Island
B2	110°27'39.6792'' E	5°49'17.6592'' S	Karimunjawa Island
B3	110°27'25.5168'' E	5°49'24.7404'' S	Karimunjawa Island
C1	110°25'28.794'' E	5°53'0.3912'' S	Menjangan besar Island
C2	110°25'31.9332'' E	5°53'4.1028'' S	Menjangan besar Island
C3	110°25'35.6448'' E	5°53'10.6728'' S	Menjangan besar Island

Table 2

Method for analyzing the parameters of water quality

Parameter	*Unit*	*Method*
TSS	mg L^{-1}	SNI 06-6989.3-2004
Nitrate	mg L^{-1}	SNI-6989-79-2011
Phosphate	mg L^{-1}	SNI 06-6989.31-2005
Salinity	ppm	WQC
BOD	mg L^{-1}	SNI 6989.72:2009
DO	mg L^{-1}	WQC
pH	-	WQC

Data analysis. Water quality data were analyzed using the pollution index method which refers to the Decree of the Minister of Environment No. 115 of 2003 concerning guidelines for determining the status of water quality using class 2 water quality standards for water recreation infrastructure/facilities, pond cultivation, animal husbandry and for irrigating crops. The status of water quality is calculated using the pollution index method with the following equation:

$$Plj = \sqrt{\frac{(\frac{Ci}{Lij})^2 max + (\frac{Ci}{Lij})^2 avg}{2}} \quad (1)$$

where: Plj = pollution index for designation (j);
Ci = concentration of measured water quality parameters;
Lij = concentration of water quality parameters according to quality standards;
(Ci/Lij) max = maximum Ci/Lij value;
(Ci/Lij) avg = average Ci/Lij value.

Evaluation of water quality status values based on the Pollution Index method is classified into four classes (Table 3). Meanwhile, the criteria for determining seawater quality standards are based on PP No.22 of 2021 concerning the implementation of environmental protection and management.

Table 3

Quality status assesment

Pollution index	*Status*
$0 \leq Plj \leq 1$	Suitable
$1 \leq Plj \leq 5$	Low polluted
$5 \leq Plj \leq 10$	Medium polluted
$Plj \geq 10$	Heavily polluted

Source: Ministry of Environment Decree No. 115 Year 2003.

Results and Discussion

Water quality parameters*.* The results of the measurement of water quality samples in the waters of the Karimunjawa National Park are presented in the form of a graph contained in Figure 2 and spatially presented in Figure 3.

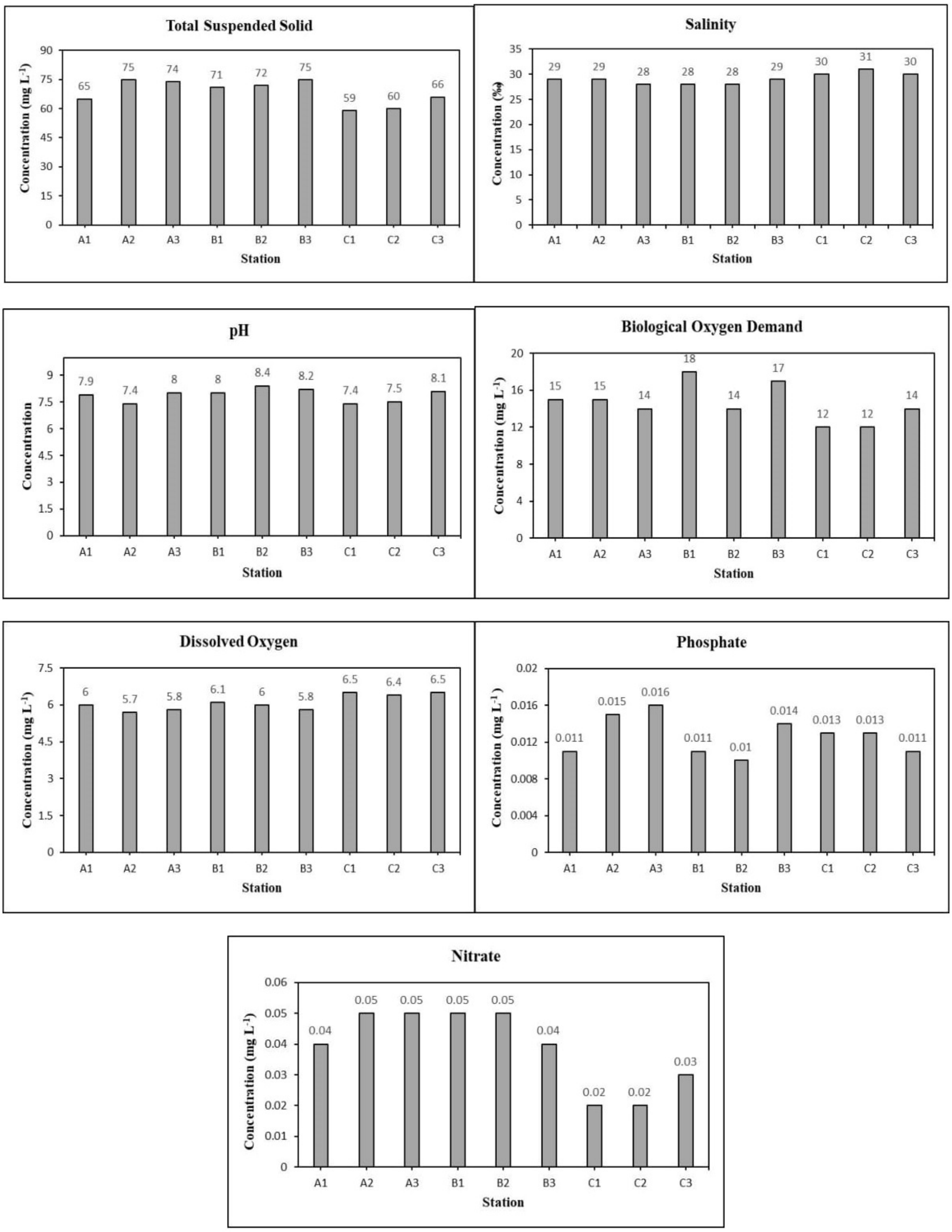

Figure 2. Water parameter values.

The parameter values of seawater samples taken are below the quality standard, and some are close to the quality standard. The pH value shows a range of 7.4-8.4. Seawater generally has a pH value above 7 which means it is alkaline, but under certain conditions the value can be lower than 7 so that it becomes acidic (Adrian-Martinez et al 2012). Most of the aquatic biota are sensitive to changes in pH value, the ideal value for marine life according to Government Regulation No. 22 of 2021 is between 7 and 8.5. Most of the pH values at all stations were still within the standard range of seawater quality, but at stations A2 and C1 the lowest pH value was 7.4. Station A2 is located in the south of Kemujan Island and C1 is on the south coast of the western part of Menjangan Besar Island, where the area is a plantation, agriculture and tourism area that can cause pollution. It is suspected that there was liquid fertilizer waste from plantations, fuel/oil, and organic and inorganic waste from ships that flowed into the sea. This needs to be watched out for because these waters have a low pH value compared to other water areas. Because it has a low pH value and tends to be acidic, it makes it hard for biota to grow and makes them vulnerable to bacteria and parasites (Karbassi et al 2013). Due to the flow of waste that flows directly into the waters, it causes a decrease in the pH value which will adversely affect aquatic organisms. Differences in pH values are also influenced by the oceanographic and geomorphological characteristics of an area (Mandal et al 2017). Open waters tend to have a higher pH value than closed waters, small islands have a pH value that tends to be alkaline and large islands with lots of river flows tend to lower the pH value to acid (Goodkin et al 2015).

DO measurements generally show normal values and are above the sea water quality standard. The trend of ups and downs in DO values in waters is strongly influenced by the increase in organic matter entering the waters in addition to other factors including temperature increases, salinity, respiration, the presence of a layer above the water surface, easily oxidized compounds and atmospheric pressure (Abe et al 2010). The more organic wastes there are in the water, the less oxygen content is dissolved in it. According to Ning et al (2011) that the source of DO levels in a water can also come from the photosynthesis of organisms, the higher the DO level, the higher the concentration of phytoplankton in the area. Phytoplankton itself is an indicator of fertility in an area.

The spatial value of water quality is depicted in Figure 3. The BOD concentration in the waters of Karimunjawa National Park ranges between 12 to 18 mg L^{-1} (Figure 2). The locations in stations B1, B2, and B3 which are in the core zone of the national park have the highest average BOD value compared to other stations. This is presumably due to the influence of the amount of mangrove litter which is organic material to be decomposed by microorganisms. The waters high organic matter content raises BOD. This is in accordance with the statement of Reader et al (2014) which states that the biological oxygen demand value will be higher with the increase in organic matter in the waters. On the other hand, the lower the amount of organic matter in the water, the lower the biological oxygen demand value.

The TSS value indicates the resistance of sunlight into the water so that it affects the photosynthesis process. The higher the TSS value, the smaller the percentage of sunlight entering the waters. Factors that affect the TSS value consist of silt, dissolved sand, and detritus dissolved in water (Ping et al 2016). The highest TSS value was found at stations A2 and B3 (75 mg L^{-1}), this was because the measurement location was close to the mangrove ecosystem. High levels of TSS in waters can reduce DO levels in waters. This opinion is in accordance with what was found at the research location, where stations A2 and B3 had lower DO content compared to other stations even though the value was still in accordance with the quality standard. If DO levels decrease for a long time, the water can become anaerobic, which is bad for the organisms that live in it. It should be noted that the waters around the mangrove ecosystem contain a lot of sediment, because mangrove roots can bind large amounts of sediment.

The level of salinity in a water is influenced by several factors. Conditions at the research location are heavily influenced by river run-off. Based on the measurement results at all stations, the salinity values are still in accordance with the quality standard, within the range of 29-31 ‰. Furthermore, water conditions with salinity values like this are very suitable for the growth of mangroves and biota in the area.

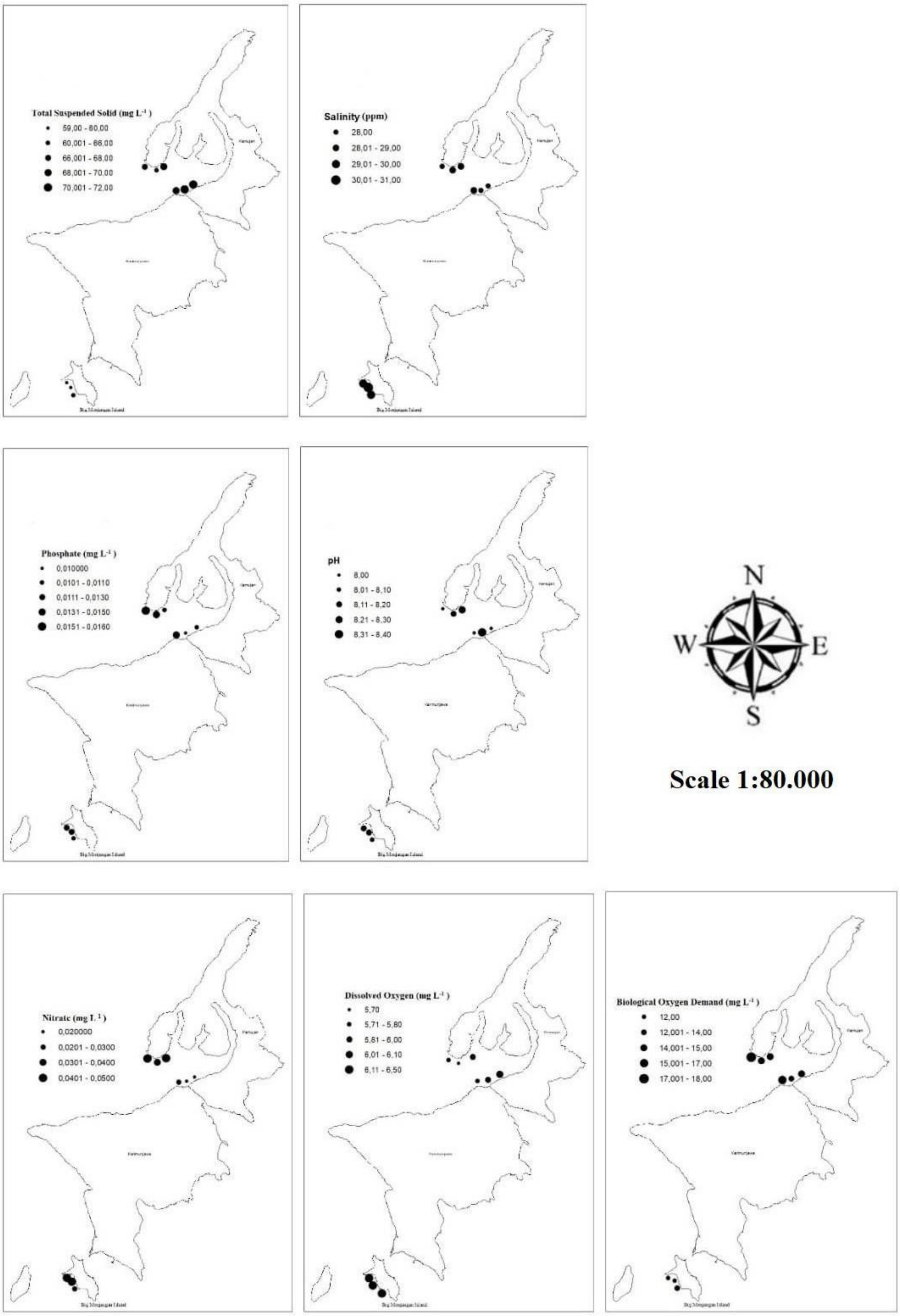

Figure 3. Water parameters spatial distribution.

The highest nitrate concentration was found at stations A2, A3, B1, and B2 with a value of 0.05 mg L^{-1}. Meanwhile, the highest phosphate concentration was at station A3. The land use of Kemujan Island and Karimunjawa Island is dominated by mixed plantations, ponds, and agriculture, so it is possible that the nitrate and phosphate content comes from the disposal of fertilizer/feed waste, this is what causes the station to have the highest concentration value of the nitrate and phosphate parameters. This value is below the quality standard, so water is safe. Because tourism dominates Menjangan Besar Island, nitrate and phosphate values are low. The amount of nitrate and phosphate also affects the fertility level of the waters. Nitrate is the main form of nitrogen in natural waters and is a major nutrient for plant and algal growth. Nitrogen is very soluble in water and is stable. This compound is produced from the complete oxidation process of nitrogen compounds in the waters (Cai and Jiao 2008). Phosphate is a form of phosphorus that can be utilized by plants and is an essential element for higher plants and algae, so that this element becomes a limiting factor for phytoplankton and algae and greatly affects water productivity. The differences in the values of nitrate and phosphate are strongly influenced by the ecological conditions of the island, especially input from the mainland and currents (Nedashkovskii et al 2006).

Determination of water quality status. Water quality evaluation is very important to do for pollution control and water resource management. The use of the pollution index can turn a complex assessment into a single value that makes it easier for stakeholders to formulate pollution control strategies, especially in the waters of the Karimunjawa National Park. The results of the pollution index analysis state that there are several observation stations that have a lightly polluted status (Table 4). Kemujan Island has 2 stations (A1 and A2), Karimunjawa Island has 1 station (B2) and Menjangan Besar Island has 2 stations (C1 and C2).

Table 4

Status of water quality at the research site

St	*Ci/Lij Max*	*Ci/Lij Avg*	*Ci/Lij max²*	*Ci/Lij avg²*	*(Ci/Lij max)²+ (Ci/Lij avg)²/2*	$\frac{\sqrt{(\mathrm{Ci/Lij}\,max)^2 - (\frac{\mathrm{Ci}}{\mathrm{Lij}}\,avg)^2}}{2}$	*Status*
A1	2.75	0.96	7.56	0.92	8.48	4.24	Low polluted
A2	1.5	0.86	2.25	0.75	3.00	1.50	Low polluted
A3	1.06	0.72	1.12	0.52	1.65	0.82	Suitable
B1	0.91	0.69	0.83	0.48	1.31	0.66	Suitable
B2	0.91	1.52	0.83	2.30	3.13	1.56	Low polluted
B3	0.93	0.70	0.86	0.49	1.36	0.68	Suitable
C1	1.5	0.71	2.25	0.50	2.75	1.38	Low polluted
C2	1.5	0.71	2.25	0.50	2.75	1.37	Low polluted
C3	0.88	0.65	0.77	0.42	1.19	0.59	Suitable

According to the spatial distribution of water quality status (Figure 4), the locations indicated to be lightly polluted did indeed have anthropogenic activities, namely tropical plantations, agriculture, and settlements. The index value at station A1 (4.24) is the highest among all stations. The results of this study are the same as the research conducted by Harianja et al (2018), where the pollutant load on Bengkalis Island has a value of 4.33 which is caused by agricultural activities. Station 2, which is located on Karimunjawa Island, which is close to the national park, has a lightly polluted status at one point (B2). This can happen because near station B2 there are milkfish and shrimp pond activities which have the potential to cause pollution to water bodies. At station B2, which is in the core zone of the national park, the pollution index shows a value of 1.56. The Environment Minister's Decree No. 115/2003 classifies this value as low polluted.

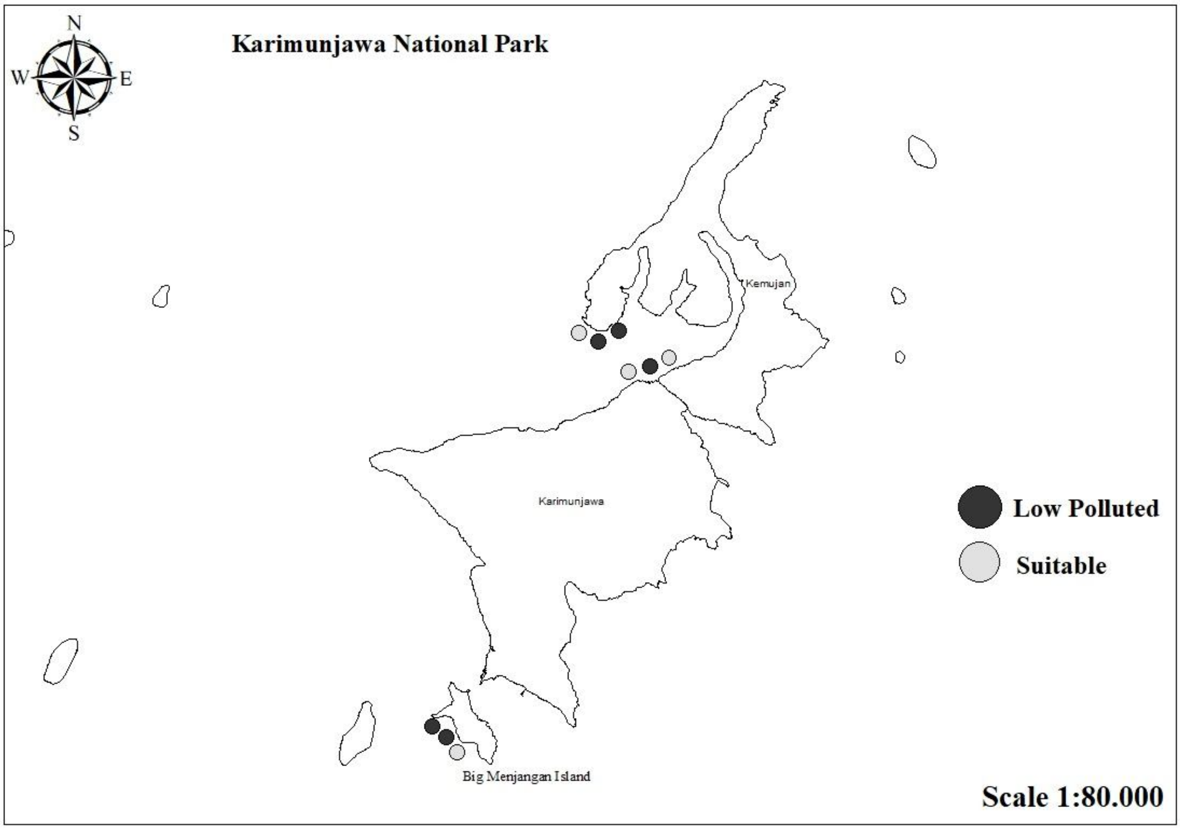

Figure 4. Spatial distribution of water quality status.

The aquatic ecosystem will get most of its waste organic matter and nutrients from fertilizer and fish feed. This waste can cause nitrification followed by changes in phytoplankton ecology, increased sedimentation, siltation, hypoxia, changes in productivity (Kaster et al 2007). If left unchecked, the aquatic ecosystem will be damaged. The damage to the aquatic ecosystem will also have an impact on the life of aquatic biota such as benthic organisms which live on the bottom of the water, where a decrease in the abundance and composition of these organisms is usually an indicator of ecological disturbances that occur in a water. Meanwhile, the stations located on Menjangan Besar Island have a lightly polluted status of 2 stations (C1 and C2). Activities that occur around Menjangan Besar Island are tourism. Many tourist boats pass every day and it is suspected that there is liquid waste from those boats such as oil, ship fuel and solid waste that spill around the observation station, which cause the surrounding waters to become polluted. Oil and ship fuel are included in hazardous and toxic waste. This is indicated by a low pH value (stations C1 and C2). According to research from Irawan (2015) there are 79.44 kg^{-1} $month^{-1}$ organic and inorganic waste from fishing vessels around the water PPN Pelabuhanratu. Furthermore, according to Sulistyono (2014) coastal and marine ecosystems have ecological functions as breeding areas that provide habitat and food for adult organisms and support food networks for ecosystems or other habitats around them. The pressure from the entry of hazardous and toxic waste will affect the designation of these systems, plus the vulnerability of these ecosystems is very high against hazardous and toxic materials.

Conclusions. The Decree of the Minister of the Environment Number 115 of 2003 explains that the water quality in the Karimunjawa National Park on Kemujan Island, Karimunjawa Island, and Menjangan Besar Island ranges from 0.66 to 4.24 on a scale of 1 to 10. When sampling in August 2021, there were 5 stations with mildly polluted status and 4 stations whose status was in accordance with quality standards. Land use affects the spatial variation of the pollution index values. This research is expected to support sustainable management of water and land resources in the Karimunjawa National Park area.

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

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