



A partial analysis of ocean health index based on clean waters and biodiversity goals in Ambon and Baguala bays, Maluku

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ABSTRACT

It is important to maintain a healthy marine ecosystem to support eco-friendly and sustainable fishery development. Implementation of Ocean Health Index (OHI) started globally in 2012, and it has been strongly recommended to be conducted at all levels: locally, nationally, and regionally. Indonesia has modified OHI for its national assessment, which it's called *Indeks Kesehatan Laut Indonesia* (IKLI). IKLI has been estimated since 2020 and introduction applied at the sub-national level. This study is an attempt to implement IKLI in Maluku province with the main objective is to estimate score of a partial IKLI, based on clean waters (goal no. 9) and biodiversity (goal no. 10). Samples were taken from Ambon and Baguala Bays between June and September 2022. For clean water goals, the parameters used were concentration of phosphate, nitrate, silicate, dissolved oxygen (DO), pH, and the number of ports that implemented green principles. The parameters of water quality of silicate, DO and pH in those two bays are within the range of government-mandated standards, except for nitrate and phosphate concentrations which are not. For the biodiversity goal, the parameters used are the species composition of mangrove, seagrass, fish, and coral. The IKLI biodiversity score was low due to the high level of human activity pressure at the two selected study sites. This study demonstrates the applicability of the IKLI in a partial analysis, and its usefulness in highlighting existing data and knowledge gaps. The study suggests that a comprehensive IKLI assessment should be conducted in Maluku Province. Meanwhile to improve the national-level IKLI assessment, actions should prioritize improving water quality management, expanding marine protected areas, and monitoring coastal ecosystems, especially those heavily affected by human activities.

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Introduction

The Ocean Health Index (OHI) serves as a framework to assess the health of the oceans, taking into account the benefits they provide to meet various aspects of human needs, including food provision, tourism opportunities, and coastal protection. The OHI framework can be applied to assess marine areas on global or regional scales (Daigle *et al.*, 2017). In recent years, there has been a

growing emphasis on using indicators to evaluate ecosystem status and resource management, especially in the marine environment (Halpern *et al.* 2012; Shin & Shannon, 2010). This focus on ecosystem-based management (Fulton *et al.* Pikitch *et al.*, 2004) and ecosystem level indicators (Daigle *et al.* 2017) is particularly relevant for all countries, including Indonesia.

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As part of Indonesia richest biodiversity hotspot, Maluku is an archipelago province with its own unique characteristics. These islands boast a wide array of ecosystems, including diverse coastal and aquatic features found in semi-closed or open waters, lagoon, basins, coral reefs, and estuaries. These ecosystems are not only rich in biodiversity but also play a pivotal role in the province's economy and identity. People in Maluku heavily rely on marine resources as a primary source of protein, and these resources also constitute a significant portion of the region's economic income. It is evident that future generations need to recognize the vital role played by these marine resources, especially with the increasing demand for commercial marine species. However, this reliance on marine resources brings with it the potential for considerable pressure from various human activities that could harm these resources and diminish their availability. As noted by [Helpern \(2020\)](#), there is a global trend towards engaging in 'blue economy' activities, and these activities are expected to impact coastal ecosystems at an accelerated rate compared to the past. Given these circumstances, it is of the most importance to prioritize the sustainability and adoption of eco-friendly practices when managing and utilizing marine resources. This approach is crucial for preserving the health of marine ecosystems in Maluku and ensuring that they continue to provide for the the needs of both current and future generations.

While some areas of these marine ecosystems remain in their natural, healthy state, others are under significant stress due to human activities. One such example is Ambon Island, a small yet ecologically significant part of Maluku. Ambon Island is endowed with a variety of marine natural resources, but unfortunately, its waters are currently facing challenges on multiple fronts. Human activities, including the disposal of domestic waste into the sea and the improper management of household waste on land, which eventually finds its way into the sea through rivers, have taken a toll on the fertility and water quality of Ambon and Baguala Bays. Moreover, the island's marine environment is also threatened by the traditional and extensive exploitation of marine resources. In addition to these issues, the presence of marine debris is a stark reminder of how communities may not fully grasp the importance of maintaining the cleanliness of the maritime

environment. This debris, visible in both coastal areas and the marine water column, underscores the urgent need for heightened environmental awareness and responsible stewardship of the seas. These challenges highlight the pressing need for conservation efforts and sustainable practices in Maluku, not only to preserve the province's unique ecosystems but also to secure the livelihoods and well-being of its communities.

Given the increasing impact on marine ecosystems, it is crucial to comprehend OHI. This can be produced regularly in accordance with the necessary time frame based on the ten OHI goals to investigate whether the condition of the marine ecosystem has changed. OHI is a tool that may be used to measure conditions of marine health from the global scale to the local scale ([Pacheco, 2015](#)). It is also crucial to collaborate with the worldwide community to implement and calculate the OHI in accordance with the indicators listed in the Indonesian Marine Health Index Measurement Guideline which called IKLI to ensure the sustainability of marine resources in Maluku. IKLI is measured considering several factors such as ecology, physical, socio-economy parameters to evaluate the function of the sea as a product and environment facility to the community ([Nikijuluw *et al.*, 2022](#)). As an archipelago country, Indonesia considers it essential to provide reliable IKLI. The data of IKLI for Indonesian seas is currently extremely limited and it remains a major challenge to provide this data and is not yet available for Maluku waters. It is believed that this research is important in order to be able to provide the Maluku Provincial Government with information regarding Maluku IKLI as well as a data base required to calculate Maluku IKLI on a larger scale. The results of this study can also be used as a strong justification for the local and provincial governments as the starting point for providing OHI⁺ data of Maluku waters.

The IKLI score is anticipated to increase awareness and give the government information to create policies that support a healthy ocean ([Nikijuluw, *et al.*, 2022](#)). Several approaches ([Batista *et al.*, 2014](#)) place more emphasis on ecological and environmental factors than socio-ecological factors ([Long *et al.*, 2014](#)). Therefore, the objectives of this research are to calculate and analyse the IKLI scores partially and locally in two semi-closed waters, which are Ambon and Baguala Bays. This study is the first

integrated assessment of the spatial health of Maluku's waters, based on the Ocean Health Index framework, and incorporating regional datasets of two semi-enclosed waters, Ambon and Baguala Bays. This score will be calculated based on its two goals, goal no. 9 (clean waters) and goal no. 10 (marine biodiversity). Furthermore, the knowledge gained from this first case study will be used to inform future regional applications of the IKLI of Maluku waters as well as to direct evaluations and management plans in Maluku seas. The OHI is a good reference to quantitatively assess the status of the marine environment from the perspective of couple human-ocean system (Halpern et al., 2014; Longo et al., 2017).

Materials and Methods

Location and time of research

This study was conducted from June to September 2022 in the Ambon and Baguala Bays (Figure 1). The sampling stations are indicated as red dots (●) that indicate sampling stations for taking water samples for nitrate, phosphate, and silicate analysis; blue stars (★) indicate sampling stations for mangrove and seagrass samples, and black dots (●) indicate the 8 villages where interviews took place.

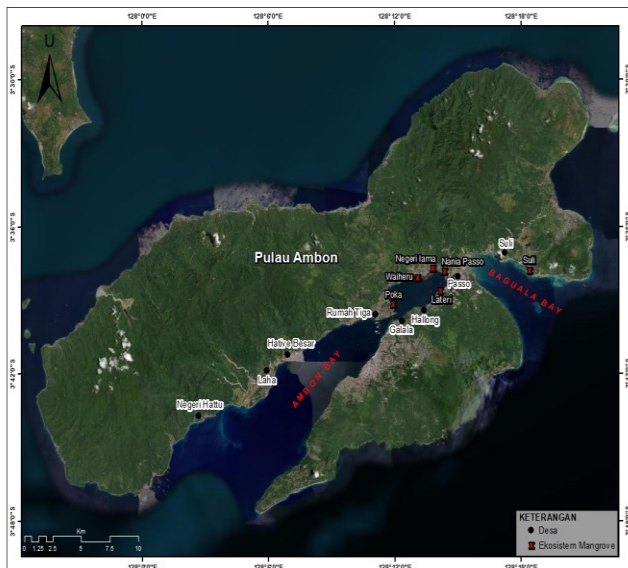


Figure 1. Research stations in Ambon Bay and Baguala bays. (★) water sampling stations; (●) station for sampling mangrove and seagrass; and black dot (●) indicate the villages for waste management.

Data analysis

IKLI calculation

Only two of the ten IKLI goals, which are clean water (goal no. 9), and biodiversity (goal no. 10) were

analysed. IKLI is about calculating the cumulative index of all 10 goals. However, IKLI can also be estimated for each goal or group of objectives (Dr. Victor Nikijulum, personal communication). Important steps that should be followed for calculating IKLI according to Panggabean et al., (2021) are:

1. Calculating the index for each indicator i.e., the present value divided by the value or reference point. The index of each of these indicators needs to be calculated also in previous years to understand its development. The goal is to predict trends in the years to come.
2. Reference points can be taken from regulations issued by the government, publication, report or other scientific paper.
3. Estimation of IKLI aggregation is obtained by giving weights to 10 goals. The basic scenario of weighting is that each goal has the same value, which is 10%. The weighing scenario may change, depending on the policies and conditions of each country or region. For example, the economic development scenario gives greater weight to socio-economic goals. Conservation scenarios give more weight to biological and ecological goals.
4. The weighting of each goal is followed by the weighting of each indicator on each goal. The total weight of all indicators in each goal must be 10%.
5. The IKLI is the sum of score from the 10 goals. In this study, only 2 goals (Clean water and Biodiversity) were calculated, as a partial analysis of OHI⁺ of Ambon and Baguala bays. Therefore, the IKLI is calculated:

$$OHI^+ = X_{PB} + X_{KH}$$

Where

X_{PB} = Destination for clean waters

X_{KH} = Diversity goal marine life, based on priority organism variables

Clean Waters

There are two variables that represent the assessment of clean waters, (a) seawater quality index (IKAL); and (b) the number of seaports that implement a green port policy and each variable has its indicators (table 1). For the seawater quality index, some chemical parameters were measured such as pH, concentration of phosphate (PO₄), nitrate (NO₂), silicate (SO₄), and dissolved oxygen (DO). *In situ* measurement of pH and dissolved oxygen (DO) used pHmeter (Lutron pH-222) and

Table 1. Indicator variable and reference point for goal number 9

No	Variable	Indicator	Reference point
9	Index of seawater quality	Concentration of PO ₄ , NO ₂ , SO ₄ , DO and pH	Concentration standard of PO ₄ , NO ₂ , SO ₄ , DO and pH based on Ministerial Decree, Ministry of Environment & Forestry No 51/2004 (IKAL)
	Number of port that implement Green Port program	Green Port program from <i>Kemenko Marves</i>	Directorate General of Sea Transportation, Ministry of Transportation, Indonesia

DO meter (Lutron DO-5510), respectively. Water samples were taken from the surface at each station by using Niskin bottle, then 1 litre of water sample was poured into the bottle (1,5 L) and kept all the bottles inside the box. After sampling, all samples were taken immediately to the Chemistry Laboratory in Deep Sea Research Centre BRIN for further analysis. Phosphate, nitrate, and silicate were analyzed according to [Strickland and Person \(1972\)](#).

For the second variable is the number of harbour that implement green port policy and also local government that implements regulation of garbage handling. The data for these parameters were obtained by interviews with the staff of the fishing port and also government in traditional villages, where the port was located. The eight villages which are all traditional villages that have their own traditional committee called *kewang* and each village has a *Raja*, who is a traditional leader in each village in Maluku. During the interview, *Raja* was accompanied by 2-3 members of *kewang*. The main objective of this interview is to find out whether or not the village have a regulation to control its community in handing their garbage and not to trough it to the coastal area.

OHI⁺ calculation in scoring goal no 9, the sea as clean waters (X_{PB}) can be calculated by using formula according to [Panggabean, et al., \(2020\)](#).

$$XPB = XIKAL + XPLGP$$

Where:

X_{PB} = Destination for clean waters

X_{IKAL} = Value of seawater quality index variable

X_{PLBP} = Variable value of seaports, that adopts the green port program

For further calculation, the index and score variables should be identified based on their importance or role in maintaining water quality to support marine organisms as well as human activities.

As this study was conducted in the Ambon and Baguala Bays, where there are many activities for supporting human live and high diversity of marine organisms are found, the score for each parameter is given based on its importance in indicating water quality. Phosphate, nitrate, and pH all had score variables of 2, but silicate and DO only have 0.5. Ambon and Baguala Bays waters have a strong anthropogenic influence and the concentration of these three parameters varies seasonally, this is a significant factor why phosphate, nitrate, and pH values of score variable is higher than silicate and DO. It is necessary to keep phosphate and nitrate concentrations at a specified level since they play a significant role in water quality and support marine life. Another factor is the pH of sea water may have changed in some parts of marine ecosystem because of ocean acidification process. This can influence the early-stage development of organisms ([Kesaulya & Vega, 2019](#)) and their growth rate ([Hinga, 2002](#)); therefore, pH is being considered as a crucial factor to be used as one of indicators in analysing OHI⁺ in Maluku waters and it is given 2 for its score variable. Silicate and DO concentrations are given a score variable 0.5 because their concentration so far is according to the regulation for water quality.

The number of ports that implement the greenhouse policy (score variable = 2) is considered one of the factors that can reduce sea debris. Besides it, those facilities belonging to the government or private sectors that can give an example to the community in managing their garbage properly. Those score variables are used to calculate the score for goal no 9 ([Table 4](#)).

Biodiversity

Biodiversity is goal no. 10 of the IKLI. This goal was chosen to provide an estimation of the level of success in maintaining and protecting the health and diversity of marine life globally and particularly in Maluku. However, because Maluku is an

archipelago province and it has a huge marine geographical area, this study focused on biodiversity that has had little attention by the government. As it is known, the sea is home to

millions of species of fish and other biodiversity. The biodiversity of species in the sea is one indicator of marine health and richness.

Table 2. Indicator variable and reference point for goal number 10

No	Variable	Indicator	Reference point
1	Fish species	Total number	Allen G.R. & Erdmann M.V. (2012). <i>Reef Fish of the East Indies</i>
2	Mangrove species	Total number	Noor dkk.(2012). <i>Panduan Pengenalan Mangrove di Indonesia</i> . Wetland International
3	Coral species	Total number	LIPI (2019). <i>Status of Indonesia Coral Reef</i>
4	Seagrass species	Total number	Status Padang Lamun Indonesia 2018 (P2O LIPI): Rustam, et al., (2019); Azkab (1999)

There are four variables to measure goal no 10 of IKLI. They are diversity of (1) fish species, (2) mangrove species, (3) coral species, and (4) seagrass species and their reference point as can be seen in table 2 (Nikijuluw et al., 2022). The reference point of those variables can also be taken from other sources such as a thesis, scientific publication, government's report, and other scientific reports. The score of each variable has decides to be the same (2.5) because each of them has given different important roles and functions in marine ecosystem.

Seagrass and mangrove sampling and analysis

Samples of seagrass and mangroves were taken at each station using line transect. Five line transects were placed perpendicular to the coastal line in each station. For seagrass sampling quadrates (50x50cm) were used, they were placed along the line transect with 25m distance between each other. The number of quadrants depends on the length of the line transect. The seagrass found inside the quadrate were taken for identification to the species level following den Hartog (1970), Azkab (1999).

Samples of mangroves was taken by using quadrate (10x10m) and each part of mangrove plant (leave, fruit, flowers, and tree diameter) that were found inside the quadrate were taken and recorded for species identification according to Dharmawan dan Pramudji (2014) and Noor, dkk (2012). Data for indicator 1 and 3 were taken from Limmon et al., (2018).

OHI⁺ calculation for score goal no. 10, The sea as a support of biodiversity (X_{KH}) by using formula according to Panggabean et al (2020):

$$X_{KH} = \sum^k e_c$$

Where:

X_{KH} = Diversity goal marine life, based on

priority organism variables
k = priority organism variable biodiversity
e = variable value
c = variable score
b = variable weight

All target-driven indicators face the challenge of explicitly setting a reference point or target. A key strength of conducting OHI assessments is the ability to tailor reference points to a region in a transparent way across all goals in the OHI. Determining reference points for all aspects of ocean health at the same time rather than setting one reference point at a time also requires confronting the inherent tradeoffs and interactions that exist in multi-objective ocean health.

Results and Discussion

Despite biochemical differences among those 2 marine ecosystems, overall, Ambon Bay and Baguala Bay scored 9.37 that comes from the score of clean waters and biodiversity.

Clean waters

Maluku waters have been facing the problem of marine debris for almost the last 15 years. This has an impact on seawater quality and on marine organisms. As an archipelago province, its community depends on natural marine resources to support family income, protein needs and a recreational place for domestic and international tourists. The sustainability of marine organism life depends on seawater quality. Therefore, water quality should be maintained and kept at a high standard. If the government introduces IKLI as a tool to monitor the quality of marine ecosystems through its ten goals and one of them is the score for clean waters as goal no. 9. The indicators which can be used for supporting goal number 9 of the IKLI score is

analyzing seawater concentration of nitrate, phosphate, silicate, dissolved oxygen (DO) and pH. The result of those parameters analysis from the two bays was compared with the required standard of clean water issued by the Government Regulation (Table 3). The results show that concentration of nitrate, phosphate and silicate of the waters of

Ambon Bay are higher than the standard values issued by the Ministry of Environment Decree no 51, 2004. On the other hand, concentration of silicate, DO and pH values all meet the regulation. The water quality in semi-enclosed waters such as in Ambon and Baguala Bays are greatly influenced from the land

Table 3. Average values of nitrate, phosphate, silicate, DO and pH of Ambon and Baguala bays in July and August 2022; the standard values for those parameters issued by the government regulation of Environment Ministry No 51, 2004 and according Tsunogai (1979)

Location	[NO ₃]	[PO ₄]	[SO ₄]	[DO] (mg/l)	pH
Ambon Bay	0.08	0.06	3.37	8.09	8.04
Baguala bay	0.01	0.05	0.68	8.76	8.1
Average values	0.045	0.055	2.03	8.425	8.07
Government regulation of Environment Ministry No 51, 2004 (KepMen LH no 51 Thn 2004)	0.008	0.015	-	> 5	> 7.8
Tsunogai (1979)			> 0.14		

through the river run-off from and other fishery activities such as fish culture in small scales that can be found in those two waters. The other aspects that may also contribute to the high concentration of nitrate and phosphate in the Ambon and Baguala bays are a high and long intensity of rainy season that has occurred lately and brought a large volume of fresh water that contains organic substance from agriculture and human domestic waste through river run off. Previous studies indicated that eutrophication has occurred in Ambon Bay, and this is supported by the low OHP score for goal no. 9. This low score also indicates that that the marine ecosystem is under pressure from depleted of dissolved inorganic carbon and raise pH. Elevated pH can have a negative impact on marine organisms, which impairs their chemosensory abilities (Turner and Chislock, 2010). Although the pH values are still meeting the regulation for sea waters issued by the government, it can be changed when concentrations of nutrients keep increasing gradually from time to time and can affect the life of marine organisms. This result indicates that the two semi-enclosed bays that have high human activities have impact on the low OHP score for goal no.9.

Biodiversity

Human activities such as coastal development, water pollution and mariculture have altered or even destroyed marine ecosystems in the Ambon and

Baguala bays. It can also threaten the biological diversity of marine environment. Biodiversity provides an understanding of how ecosystems work and how to maintain it for our benefit. Therefore, clean waters and biodiversity of marine ecosystem have been chosen as two of IKLI's goals in this study. The ocean is not as accessible, which accounts for part of the problem, only in recent years the government has paid interest in marine biodiversity.

The marine environment around Ambon and Baguala bays provides good conditions for seagrass, mangrove and coral ecosystems. They provide homes for different marine animals and support high marine diversity in those two bays. However, the disappearance of marine mammals such as dugong from the inner Ambon Bay showing signs of decline population of seagrass that have been observed in coastal area of Ambon Bay. The results show that the score of IKLI for biodiversity was low (2.02) (Table 4) because the two study sites chosen are experiencing high pressure from human activities. Humans rely on biodiversity for survival, but human activities are the primary cause of the marine biodiversity for survival, biodiversity decline, especially in semi-closed marine environment.

Declining biodiversity and the occurrence of eutrophication processes due to deterioration reduce the capacity of natural processes to reproduce a healthy marine environment. Table 4 also shows that for the diversity parameters used such as fish coral species, mangrove species, coral species and seagrass

species were far below the value used as a reference point which taken from different literature. The result from only those two semi-closed waters, Ambon and Baguala bays shows that the score of these two goals of IKLI have a correlation of low score of clean waters and biodiversity, because the poor condition of waters can influence the existing of the marine biodiversity. This condition may not be the same for the open ocean such as Seram Sea, Banda Sea, Saparua Sea, Nusalaut Sea, and other open and deep sea of the Maluku waters.

Therefore, to understand the connection between different parameters of IKLI, it must be assessed regularly in order to know the existing sea water condition or marine environment around Maluku waters. As an archipelago province, Maluku has huge marine environment. Those marine environments

exist as a semi-closed waters and open ocean, shallow and deep waters, this will have an impact for its OHI' score. Data from different waters location, neritic and open ocean should be collected to find out the current condition of IKLI in Maluku and that data could be also used to assess the IKLI of Indonesia. The government should have data from different part of Indonesia, which is helpful in improve the accuracy of the IKLI score (Baraldi and Enders, 2010).

To improve national IKLI assessment, this study suggests that future actions should focus on enhancing water quality management, expanding marine protected areas along the coastal area, and monitoring coastal ecosystem in a broad area especially in marine ecosystem that is experiencing high levels of human activity.

Table 4. Matrix calculation of IKLI score based on Panggabean et al., (2022).

No	Goal	Variable	Indicator (measurement unit)	Current status (AD)	Reference point (RP)	Variable index	Score of variable (%)	OHI' score
1	Clean waters	IKAL	[phosphate]	0,06	0,015 mg/L	4	2	1,07
			[nitrate]	0,008	0,008 mg/L	1	2	0,25
			[silicate]	2.03	> 0.14 mg/L	14.5	1	7.25
			[DO]	8,95	> 5	1,79	1	0,90
			pH	8,1	7 - 8,5	1,16	2	2,08
		Number of ports that implement greenhouse policy	Annual report	2	2	1	2	2,00
IKLI goal 9								7.35
2	Biodiversity	Species of fish coral	article	192	2057	0.09	2,5	0.23
			article	6	26	0.23	2,5	0.58
			article	15	590	0.03	2,5	0.06
			Coremap (2014)	6	13	0.46	2,5	1.15
IKLI goal 10								2.02
IKLI score								9.37

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