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The Effect of Bima Bay Water Quality Conditions on the Sea Snot Phenomenon

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Abstract. Sea Snot is phenomenon that occurs in waters characterized by the collection of mucus or sludge on the surface of the sea which is an accumulation of various types of microorganisms such as phytoplankton and bacteria. The first occurrence in Indonesia was reported in Bima Bay on April 25, 2022. This study aims to assess the water quality of Bima Bay using Sea Surface Temperature (SST), Dissolved Oxygen (DO), and Salinity parameters derived from Landsat satellite imagery and validated through field surveys. Based on the results of determining the quality status of Bima Bay waters, shows that there is a change in quality status at each point from 2022 to 2023. From a total of 50 sample points, it shows that there are 44% of points that still have lightly polluted status and from good to lightly polluted status there are 18%. This shows that there is still lightly pollution of 62% in the waters of Bima Bay after one year of the sea snot phenomenon. The condition of Bima Bay's waters does not have the status of being moderately or heavily polluted. These findings highlight the need for increased environmental awareness among local communities to prevent further degradation of Bima Bay's waters.

Keywords: Bima Bay, dissolved oxygen, salinity, sea snot, sea surface temperature

I. INTRODUCTION

Sea Snot is phenomenon that occurs in waters characterized by the collection of slime or sludge on the surface of the sea. The slime is an accumulation of various types of microorganisms that live in waters such as phytoplankton, bacteria, and disease-causing germs. The growth of Phytoplankton and Algae is a sign of eutrophication, which can trigger a decomposition process that depletes dissolved oxygen significantly. The presence of this slime can trigger various environmental and economic problems such as damage to marine ecosystems, decreased fish populations, and decreased attractiveness of beach tourism [1].

The Sea Snot phenomenon was first discovered in the Mediterranean Sea in September-October 2007. The phenomenon that occurs in the Mediterranean Sea is closely related to sea water temperature anomalies resulting from climate change. This increase in temperature leads to a rise in the number of microbes, including pathogenic species [2]. Apart from that, Sea Snot also occurred in December 2020 in the Dardanelles Strait which leads to the Sea of Marmara, Türkiye. The identification results found that sea snot still had an effect on coral at a depth of 4-20 m. Sea snots that occur in the Dardanelles Strait are thought to occur due to temperature anomalies [3]. Furthermore, in June 2021 the Sea Snot phenomenon occurred again in the Sea of Marmara, Türkiye. Research in the Sea of Marmara focused on the effects of Sea Snot on the fishing practices of local fishermen and the health of marine organisms. This concern arises from the potential presence of pathogenic microorganisms in Sea Snot, which could create health risks and lead to a reduction in fish consumption within the community [1].

In Indonesia, the Sea Snot phenomenon first appeared in Bima Bay on April 25, 2022. When this phenomenon occurred, quantitative descriptive research was carried out using survey methods by observing sea water quality in Bima Bay based on the results of laboratory examinations of water samples taken in April 27-29, 2022. Observation results show that Bima Bay is experiencing problems with the quality of its waters which are decreasing due to the growth of harmful algae and the large number of Escherichia coli bacteria. This occurs due to elevated levels of nitrate, phosphate, and ammonia in the sea water around Bima Bay, leading to a eutrophic blooms as shown in Figure 1, that results in the formation of biomass in the form of jelly known as sea snot. The presence of excessive nitrate compounds can reduce the oxygen content in the water, causing a decline in fish populations and damage to marine biota [4].

Figure 1. Water Conditions at Amahami Beach, Bima City on April 27, 2022 [5].

Efforts can be made to determine the effect of water quality conditions on the Sea Snot phenomenon by analyzing sea water quality conditions. Water quality is a measure of the condition of water seen from its physical, chemical, and biological characteristics [6]. Based on several previous studies, the phenomenon of sea snot is closely related to the anomaly in sea air temperature and dissolved oxygen as a result of the presence of sea snot. Water temperature is one of the important factors for organism life. Temperature affects biogeochemical cycles and the quality of aquatic habitats. Higher temperatures can also trigger a faster algae growth [7]. Water temperature and depth can also affect dissolved oxygen levels. Dissolved oxygen is a parameter that indicates the amount of oxygen dissolved in water. The higher the content of organic matter in waters, the higher the need for dissolved oxygen in the decomposition process [8]. Apart from that, the water salinity parameter is essential as it is the main parameter to determine the quality of sea water. Salinity in seawater has an important role in the evolution of seawater microbial organisms, such as macroalgae, seaweed and other organisms. Abnormal salinity in waters can be an indication of pollution [9].

Based on the problems that have been described, research is needed to determine the influence of the water quality conditions in Bima Bay on the Sea Snot phenomenon which occurred in April 2022 and 1 year after the sea snot phenomenon occurred, namely in 2023. This research will make an important contribution to the development of science regarding the Sea Snot phenomenon and its influence on water quality conditions, especially Sea Surface Temperature (SST), Dissolved Oxygen (DO) and Salinity in the Bima Bay area spatially using remote sensing data, namely Landsat satellite imagery. Through Landsat image data, the water quality conditions of Bima Bay can be mapped thoroughly. This was done because previous research that had been carried out was only quantitative descriptive using survey methods so that the water quality condition data obtained was only limited to the area where water samples were taken. Next, this article will explain the case study, methods, results and analysis, as well as conclusions and policy recommendations that can be drawn.

II. METHODOLOGY

2.1 Case Study

This research was conducted in Bima Bay, which is a bay located in West Nusa Tenggara Province, Indonesia. Bima Bay is a semi-enclosed body of water on the north side of Sumbawa Island bordering Bima City and Bima Regency. Bima Bay is located at coordinates 8°28′–8°48′ South Latitude and 118°24′–119°20′ East Longitude. This bay covers an area of approximately 840 km^2 and is one of the largest bays in Indonesia. Bima Bay plays an important role for the surrounding communities, particularly in terms of economic activities and marine resources. The research location map is presented in Figure 2.

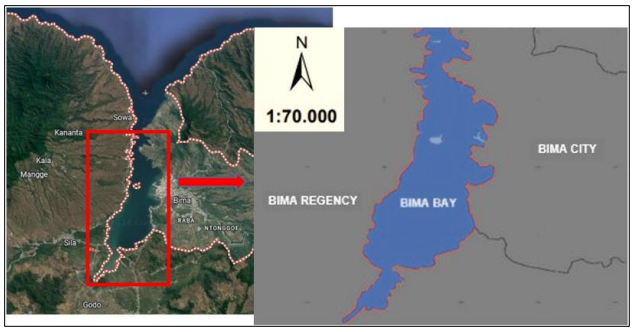

Figure 2. Case Study Location

The methodology section may be subdivided into several subsections, including study area description, tools and materials, and research design. When describing the study area, inclusion of a map or figure illustrating the location is recommended.

2.2 Data Processing and Analysis

The data processing stages carried out in this research consist of 3 stages, namely data acquisition, image processing and statistical analysis. This study follow the result flow as in Figure 3 :

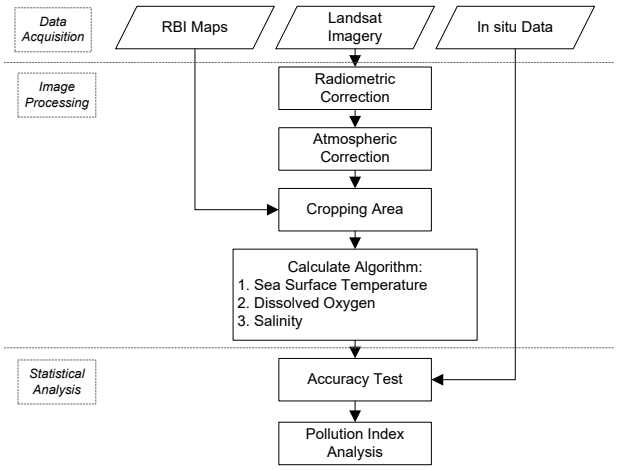

Figure 3. Research flow diagram

1. Data Acquisition

The data/materials used in the study consisted of primary and secondary data, namely:

a. Landsat-9 satellite image in April 28, 2022 taken during the sea snot phenomenon and Landsat-8 in May 25, 2023 taken 1 year after the sea snot phenomenon obtained through the website https://earthexplorer.usgs.gov/ [10].
b. Data on sea water quality parameters consisting of SST, DO and Salinity from field surveys are used to validate processed image data. Field surveys were conducted in April 2022 during the sea snot phenomenon and May 2023 1 year after the sea snot phenomenon. SST and DO parameters are taken using a DO meter which is taken directly, while salinity is done by taking water samples to be tested in the

laboratory for salinity levels. To enable the plotting of water quality parameter data onto the results from satellite image processing, coordinates are recorded for each sample point collected.

c. RBI map of Bima City and Bima Regency at a scale of 1:25,000 which was used to determine the boundaries of the case study.

2. Image Processing

The stages of this research began with the radiometric correction process of Landsat image data in the Red, Green, Blue and thermal bands (band 10 and band 11). The Red, Green, Blue band is used for the calculation of DO and salinity parameters, while the thermal band is used for the calculation of SST. The atmospheric correction are processed using the DOS (Dark Object Subtraction) method. As for the thermal band, correction is done by converting DN data to BT (Brightness Temperature) data.

After the radiometric correction process is completed, the next step is to calculate the seawater quality parameters consisting of :

a. Sea Surface Temperature (SST)

SST is often used in the marine and fisheries fields because it is one of the factors that is very important for the life of organisms for metabolic activities and breeding of organisms [7]. The SST calculation uses the Split Window algorithm which has been applied to calculate SST in Probolinggo waters [11] and Bali Serangan Island waters [12]. The following SST algorithm is used [11]:

$$SST = BT10 + (2.946 * (BT10 - BT11)) - 0.038 \quad ...(1)$$

Description, SPL = sea surface temperature (°C), BT10 = Brightness Temperature band 10 data and BT11 = Brightness Temperature band 11 data.

b. Dissolved Oxygen (DO)

DO is a parameter that shows the amount of dissolved oxygen in water which has an important role for organisms for respiration and metabolism so that DO can be used as a measure to determine water quality [8]. The DO calculation uses an algorithm that utilizes the red and blue bands in Landsat-8 and Landsat-9 images. The following is the DO algorithm used [13]:

$$DO = 5.2550 - 3.58125 \times [B2 / (B4 + 1)] \quad .....(2)$$

Description, DO = dissolved oxygen (mg/l), B2 = reflectance band 2 (blue), and B4 = reflectance band 4 (red).

c. Salinity

Salinity is the value of salt solubility in seawater which is a basic parameter for understanding ocean dynamics, various climates, energy exchange with the atmosphere and the world water cycle [14]. Salinity calculation uses an algorithm that utilizes the blue and green bands in Landsat-8 and Landsat-9 images. The following is the salinity algorithm used [15]:

$$Salinity = 10^{(-0.141 \times Cp) + 1.45} \quad .....(3)$$

The value of Cp (surface water beam attenuation coefficient) is obtained by using the following equation:

$$Cp = (0.70 \times MNDCI^3) + (0.96 \times MNDCI^2) + (1.14 \times MNDCI) - 0.2 \quad .....(4)$$

MNDCI (Maximum Normalized Difference Carbon Index) is obtained by using the following equation:

$$MNDCI = (L_{BOA\ green} - L_{BOA\ blue}) / (L_{BOA\ green} + L_{BOA\ blue}) \quad ..(5)$$

3. Statistical Analysis

Next is to test the accuracy of the value of seawater quality parameters from processed images against data taken directly in the field. The accuracy test is carried out by calculating the Normalized Mean Absolute Error (NMAE) and Root Mean Square Error (RMSE) values. Both values are used to see how much error the image processing results have on field data. The minimum requirement for the NMAE value to be used to extract water quality data from remote sensing data is an NMAE value below 30%. As for RMSE, the greater the value, the greater the error [16].

The next stage in this research is to analyze changes in the value of sea water quality parameters during and after the sea snot phenomenon to determine how much influence the sea water quality parameters have on the sea snot phenomenon that occurs in Bima Bay. The analysis was carried out by determining the status of pollution during the sea snot phenomenon and after the sea snot phenomenon using the Pollution Index in the Decree of the Minister of Environment Number 115 of 2003 concerning Guidelines for Determining Water Quality Status [17]. Here is how the Pollution Index is determined:

$$PIj = \sqrt{\frac{\left(\frac{Ci}{Lij}\right)_M^2 + \left(\frac{Ci}{Lij}\right)_R^2}{2}} \quad .....(6)$$

Description, PIj = pollution index for designation (j), Ci = concentration of surveyed water quality parameter, Lij = concentration of water quality parameter in the quality standard of designation (j), (Ci/Lij)M = maximum Ci/Lij value, and (Ci/Lij)R = average Ci/Lij value.

This method can directly relate the level of pollution for a particular use and to a particular parameter value. The criteria for seawater quality status based on the Pollution Index (PI) value are $0 \leq PIj \leq 1.0$ (meet quality standards/good condition), $1.0 \leq PIj \leq 5.0$ (lightly polluted condition), $5.0 \leq PIj \leq 10$ (medium polluted condition), and $PIj \geq 10$ (heavily polluted condition).

III. RESULT AND DISCUSSION

3.1. Processing Results of Seawater Quality Parameters

The sea water quality parameters obtained from the data processing of Landsat-9 and Landsat-8 satellite images are SST, DO and salinity. Here are the results:

1. *Sea Surface Temperature (SST)*

SST is used to determine the presence of phytoplankton because higher temperatures can trigger a faster growth of algae. The results of processing Landsat-9 satellite image data on April 28, 2022, when the sea snot phenomenon occurred in Bima Bay, obtained results as Figure 4:

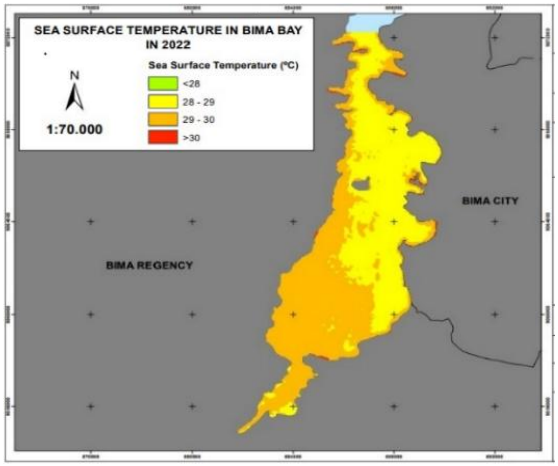

Figure 4. Sea Surface Temperature in 2022

The 2022 results show that the SST value ranges from 27.70 - 31.06 ºC. The SST value is in accordance with the characteristics of Indonesian waters which are tropical waters, namely 28 - 31 ºC [18]. Based on the Ministry of Environment's seawater quality standards in 2021, the temperature value in Bima Bay is in accordance with the quality standards, namely a good temperature for marine waters generally ranges from 28 - 32 ºC. Figure 4 shows that the central area of Bima Bay waters is dominated by the SST class of 28–30 ºC , while the coastal areas exhibit SST values greater than 30 ºC, which are indicated by red colors.

The results of 2023 (Figure 5) show that the SST value ranges from 17.52 - 33.92 ºC. The SST value does not align with the characteristics of Indonesian waters, which are tropical and typically range from 28 to 31 ºC [18]. Based on the Ministry of Environment's seawater quality standards in 2021, the temperature value in Bima Bay is also not in accordance with the quality standards, which is a good temperature for marine waters generally ranges from 28 - 32 ºC. The SST value is too low due to the influence of cloud cover at the study site. Meanwhile, SST values greater than 30 ºC, indicated by red colors, are also still observed in the coastal areas.

The results of processing Landsat-8 satellite image data on May 25, 2023, which is 1 year after the occurrence of the sea snot phenomenon in Bima Bay, obtained results as Figure 5:

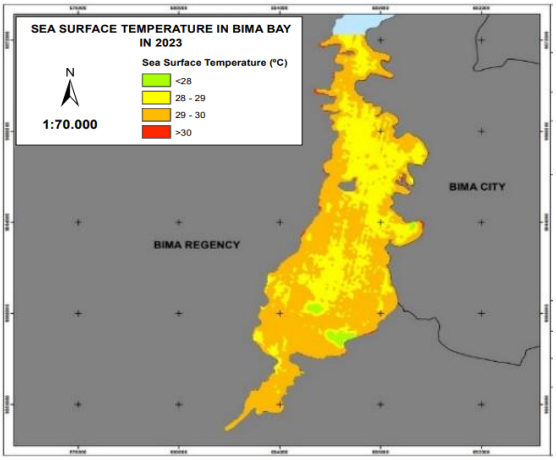

Figure 5. Sea Surface Temperature in 2023

2. *Dissolved Oxygen (DO)*

DO is used to determine eutrophication, which is a condition that indicates an increase in nutrients in the water. The increase in nutrients causes an explosion of algae growth, triggering a decomposition process that consumes dissolved oxygen in the waters. The results of processing Landsat-9 satellite image data on April 28, 2022, when the sea snot phenomenon occurred in Bima Bay, obtained results as Figure 6:

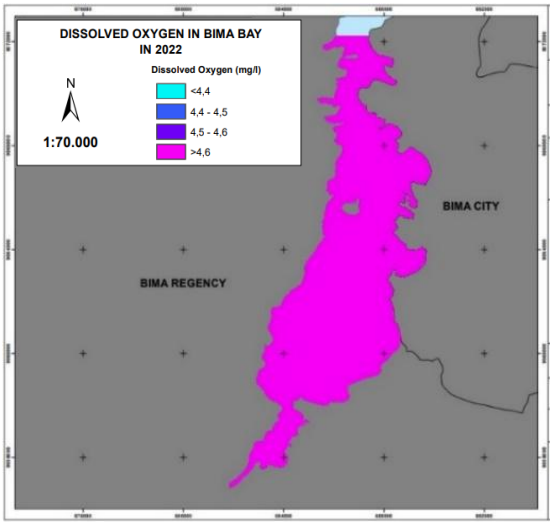

Figure 6. Dissolved Oxygen in 2022

The 2022 results show that DO values range from 4.35 - 4.96 mg/l. Visually, it can be seen that the DO value is dominated by the > 4.6 mg/l class.

The results of processing Landsat-8 satellite image data on May 25, 2023, which is 1 year after the occurrence of the sea snot phenomenon in Bima Bay, obtained results as Figure 7:

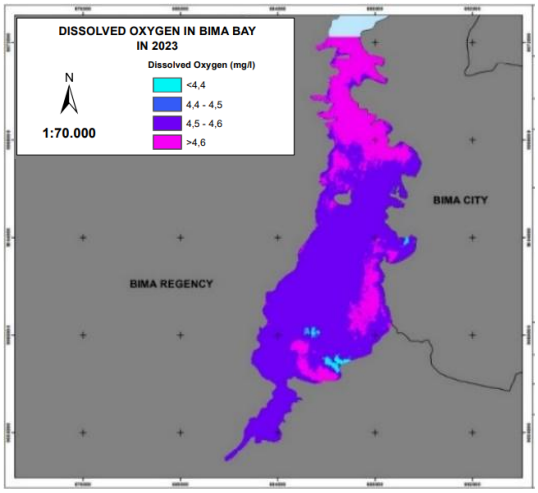

Figure 7. Dissolved Oxygen in 2023

The 2023 results show that DO values range from 4.02 - 4.62 mg/l. Visually, it can be seen that the DO value is dominated by the 4.5 - 4.6 mg/l class.

Based on the Ministry of Environment's seawater quality standards in 2021, good DO values for marine waters generally range ≥ 5 mg/l. However, the DO results for 2022 and 2023 shown in Figure 6 and Figure 7 indicate that the waters of Bima Bay contain a maximum DO value of only 4.62–4.96 mg/L. This shows that the DO results in Bima Bay are not in accordance with the sea water quality standards, as the dissolved oxygen content remains too low, indicating the potential occurrence of eutrophication in the waters of Bima Bay.

3. Salinity

Salinity in seawater has an important role in the evolution of seawater microbial organisms, such as macroalgae, seaweed and other organisms. Abnormal salinity levels in marine waters can be an indication of pollution. Increased salinity due to pollution can damage water quality, disrupting ecosystems and reducing water productivity [9]. The 2022 results show that salinity values range from 15.86 - 252.28 ppt. Visually it can be seen that the salinity value is dominated by the 22 - 32 ppt class. However, Figure 8 shows that salinity values greater than 42 exhibit characteristics and patterns located in the central waters as well as in the coastal areas. High salinity values indicate that water pollution has occurred in Bima Bay in the areas shown in blue.

The results of processing Landsat-9 satellite image data on April 28, 2022, when the sea snot phenomenon occurred in Bima Bay, obtained results as Figure 8:

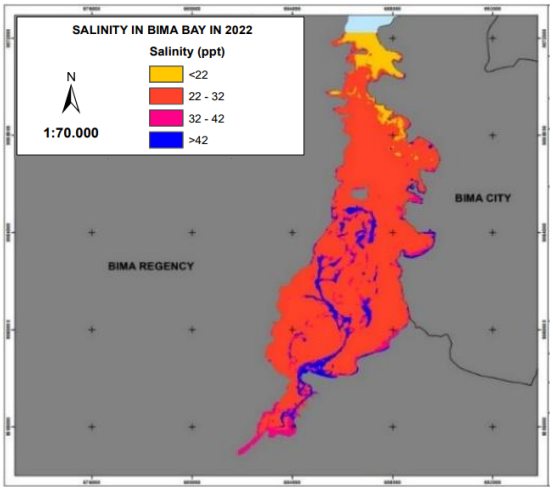

Figure 8. Salinity in 2022

The results of processing Landsat-8 satellite image data on May 25, 2023, which is 1 year after the occurrence of the sea snot phenomenon in Bima Bay, obtained results as Figure 9:

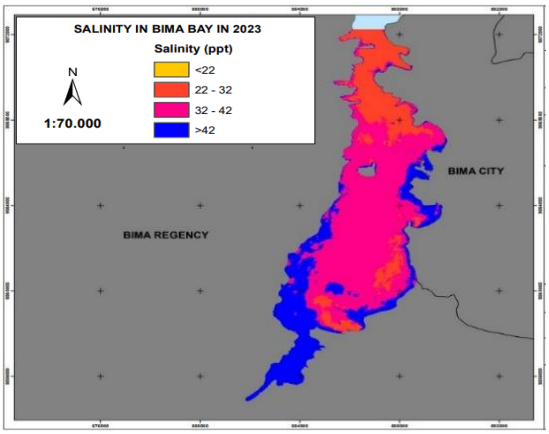

Figure 9. Salinity in 2023

The 2023 results show that salinity values range from 21.87 - 353.41 ppt. Visually it can be seen that the salinity value is dominated by the 32 - 42 ppt class. This indicates that pollution was still occurring in 2023, as shown by the dominant distribution of high salinity values marked in pink and blue across the central and coastal waters of Bima Bay.

In general, the salinity value of Indonesian waters is 28 - 33 ppt [18]. The results of 2022 show that predominantly the waters of Bima Bay are in accordance with the character of waters in Indonesia, while the results of 2023 show less suitable results. Based on the Ministry of Environment's seawater quality standards in 2021, good salinity values for marine waters generally range from ≤ 34 ppt. Visually, it can be seen in Figure 8 and Figure 9 that the salinity value in 2022 is predominantly in accordance

with seawater quality standards, while 2023 is less in accordance with seawater quality standards. However, from 2022 and 2023, it can also be seen that there are several locations that have salinity values > 42 ppt, especially in nearshore areas and several locations in the middle of the water. This indicates that there is a possibility of pollution occurring in the waters of Bima Bay.

3.2. Test of Seawater Quality Parameters Processing Results

The accuracy test is used to determine the correct value of the results of satellite image data processing against field survey data. The accuracy test was carried out twice on the results of image processing in 2022 and 2023. The number of sample points in 2022 was 3 samples taken at Amahami Beach, Bima City. The data from the field survey in 2022 was obtained from the Regional Research and Innovation Agency (BRIDA) of Bima City which was carried out when the sea snot phenomenon occurred, namely April 27-29, 2022. The number of sample points in 2023 was 14 samples taken at Amahmi Beach and the middle of Bima Bay waters. The 2023 field survey was conducted 1 year after the sea snot phenomenon occurred, on May 23, 2023.

The results of the accuracy assessment of seawater quality parameter processing, validated against field survey data from 2022 and 2023, are presented in Table 1:

Table 1. Accuracy Test Results

No.	Parameter	Year	Accuracy Test Method	
			NMAE (%)	RMSE
1	Sea Surface Temperature	2022	3.08	1.218
		2023	7.02	1.962
2	Dissolve Oxygen	2022	17.34	3.237
		2023	15.49	1.405
3	Salinity	2022	19.05	6.354
		2023	16.59	5.766

Based on the accuracy test results, it shows that all parameters have a good accuracy value. These results indicate that the algorithm used in processing satellite image data is still suitable to be applied in the waters of Bima Bay. The minimum requirement for the NMAE value to be used to extract water quality data from remote sensing data is an NMAE value below 30%. As for RMSE, the greater the value, the greater the error [16].

3.3. Analysis of Water Quality Condition of Bima Bay

Determination of water quality conditions is carried out by calculating according to Formula 6 with the determination of pollution status using the Pollution Index according to the Decree of the Minister of Environment Number 115 of 2003 concerning Guidelines for Determining Water Quality Status [17] using SST, DO and Salinity parameters. Determination of the Pollution Index status is calculated based on data from Landsat satellite image processing against the quality standards for each parameter. There are 50 sample points spread evenly in the waters of Bima Bay which are used to determine the Pollution Index status. The distribution of the 50 sample points is shown in Figure 10:

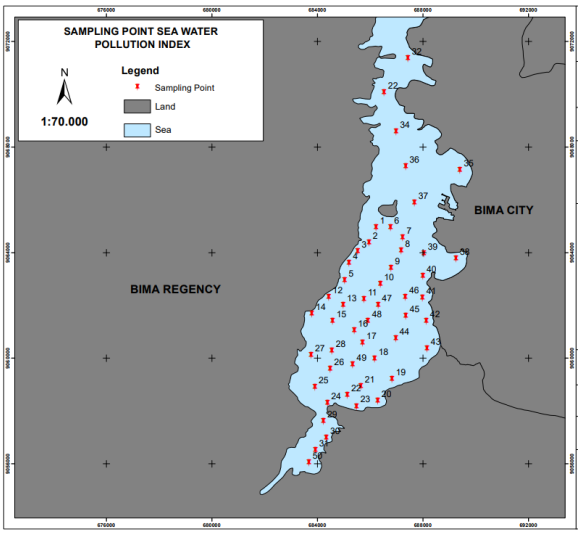

Figure 10. Sampling Point of Sea Water Pollution Index

From these 50 points, the quality status of the water quality conditions in Bima Bay waters is in accordance with quality standards and is lightly polluted. Based on the PIj calculation results for sea water quality in Bima Bay, it shows that in 2022 and 2023 the water quality is at the status of meeting quality standards and is lightly polluted with the same percentages in each year, namely 38% and 62% of the total sample of 50 points. The condition of Bima Bay's waters does not have the status of being moderately or heavily polluted. However, even though it produces the same percentage in each year, there are changes in water quality conditions at each point in each year, as shown in Table 2:

Table 2. Changes in Bima Bay Sea Water Quality Conditions from 2022 to 2023

Change in Quality Status (2022 to 2023)	Number of Points	Percentage (%)
Good to Good	10	20%
Good to Lightly Polluted	9	18%
Lightly Polluted to Lightly Polluted	22	44%
Lightly Polluted to Good	9	18%
Total	50	100%

Figure 11 is a graph of changes in PIj status from 2022 to 2023 :

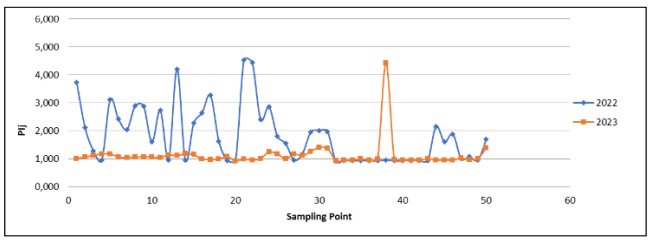

Figure 11. Changes in Sea Water Pollution Index

Based on the results of determining the quality status of Bima Bay waters, shows that there is a change in quality status at each point from 2022 to 2023. From a total of 50 sample points, it shows that there are 44% of points that still have lightly polluted status. This shows that there is still light pollution of 44% in the waters of Bima Bay after 1 year of the sea snot phenomenon.

Referring to research conducted by Asryadin [4], when the sea snot phenomenon occurred, the pollution that occurred was caused by high levels of nitrate and phosphate which were thought to have come from the use of pesticides on agricultural land around Bima Bay. In addition, the increasing concentration of waste, both from land and from activities in the ocean, is increasingly increasing changes in the physical, chemical and biological parameters of waters as a whole. High concentrations of nitrate in waters cause the growth of organisms to increase which causes the sea snot phenomenon, thereby reducing dissolved oxygen levels (Figure 6) which results in a decline in fish populations and damage to marine biota [4].

3.4. Analysis of Sea Snot Phenomenon in Bima Bay

Visual imagery is used to conduct an approach based on the recognition of spatial object characteristics. The phenomenon of sea snot that occurs in Bima Bay can be detected from the appearance contained in the Landsat-9 satellite image at the time of the incident. Figure 12 is a visual display of images on April 28, 2022:

Figure 12. Bima Bay Water Condition in 2022 [19]

Based on the visual appearance of the image, it shows that there is white froth that is quite dense along the coast and in several areas in the middle of the waters of Bima Bay. When viewed from the results of the processing of sea water quality parameters, there are characteristics and patterns that look the same as visual images on the salinity parameter (Figure 8). In areas where there is white foam, it shows a high salinity value as a sign that there has been water pollution in Bima Bay, especially in coastal areas, results in an explosion of algae growth (algae bloom).

Figure 13 is a visual display of images and processing results of sea water quality parameters on May 25, 2023, which is 1 year after the sea snot phenomenon occurred:

Figure 13. Bima Bay Water Condition in 2023

Based on the visual appearance of the image, the condition of the waters along the coast and the center of the waters in Bima Bay looks normal. When viewed from the results of the processing, the SST value shows normal results, while the DO and salinity values still show that the overall water quality 1 year after the occurrence of the sea snot phenomenon still has a value that is not in accordance with sea water quality standards (Figure 7 and Figure 9). The existence of DO and salinity values in 2023 that are not in accordance with sea water quality standards indicates that there is still pollution in the waters of Bima Bay.

IV. CONCLUSION

Based on this research, it was concluded that the water quality of Bima Bay in 2022 and 2023 met quality standards at 38% of the total 50 sampling points, while 62% were classified as lightly polluted. The waters of Bima Bay were not classified as moderately or heavily polluted. However, changes in water quality conditions occurred at each sampling point from 2022 to 2023, with 44% of the points remaining in a lightly polluted status. This indicated that light pollution persisted in the waters of Bima Bay one year after the sea snot phenomenon. In 2022, DO and salinity values that did not meet seawater quality standards, particularly in coastal areas, resulted in excessive algal growth, leading to the sea snot phenomenon. In 2023, DO and salinity values still did not comply with seawater quality standards. Through this research, it was expected that the regional government would continue to regularly monitor seawater quality conditions in Bima Bay using more diverse parameters and a greater number of water samples, as well as minimize sources contributing to increased nitrate and phosphate levels to prevent the recurrence of the sea snot phenomenon.

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