Manila Journal of Science ***14*** *(2021), pp. 120–128*

Water Quality Assessment for the Management of Marine Protected Areas: The Case of Bago City, Philippines

Mary Ann T. Pandan[1] and Maria J-len J. Jonco[2,*]

[1]Department of Chemical Engineering, University of St. La Salle, Bacolod City, Negros Occidental, Philippines

[2]Department of Materials Engineering, University of St. La Salle, Bacolod City, Negros Occidental, Philippines

*Corresponding Author: m.jonco@usls.edu.ph

ABSTRACT

Industrialization coupled with accelerating human population growth has caused the deterioration of our natural resources. One evident environment issue is marine pollution, which affects the ecological balance in our coastal resources. In order to prevent the degradation of our coastal waters, there is a need to effectively manage established marine protected areas (MPAs) in our country. One challenge that is faced by managers is the lack of scientific information on the quality of our marine waters. These data will enable MPA managers to access the condition of the MPA and understand the cause and effect relationships in order to initiate appropriate interventions in the MPA. In this study, the water quality of the MPA, surrounding coastal waters, and a contributory river in Bago City, Philippines, was determined to provide an evidence-based approach in identifying pollution management strategies in the area. Four (4) sites were sampled for eight (8) parameters, namely, dissolved oxygen, temperature, pH, total suspended solids, nitrates as nitrogen, phosphates, color, and fecal coliform counts for 12 months. Results show that contamination in the MPA is evident as seen from its high color values and coliform counts. This is mainly caused by the sediment and wastewater input into the coastal waters. It is important that priority areas for MPA management are the control of anthropogenic activities in the area such as dredging and wastewater discharge. Results also showed that environmental factors such as the wind and waves are greatly affecting the water quality of the area, and thus, more studies on these factors are recommended.

Keywords: coastal pollution, color, coliform

INTRODUCTION

In recent years, the importance of addressing the deterioration of our coastal ecosystems has been the focus of various researches. Studies show that the environmental degradation of coastal areas is increasingly becoming evident as a result of accelerating human population growth and economic development (Gurney et al., 2014; Halpern et al., 2008; Reichardt et al., 2006). Coastal water degradation and marine pollution have especially been evident in Southeast Asia (SEA) and have caused major impacts such as habit destruction, biodiversity issues, and limitations in ecosystem functioning (Tiquio et al., 2017; Todd et al., 2010). Tiquio et al. (2017) also identified the degradation of the water environment as a critical issue in the SEA region and stated the need for the establishment of management interventions in the area.

An essential tool in the protection and management of our coastal resources is the establishment of marine protected areas (MPAs; Gurney et al., 2014; Tupper et al., 2015). MPAs are defined by the International Union for the Conservation of Nature as "any area of intertidal or sub tidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" (Abessa et al., 2018; Kelleher, 1999; Tupper et al., 2015). The presence of an MPA will ensure that local species and ecosystems are monitored and effective plans are developed for their conservation (Abessa et al., 2018; Kelleher, 1999).

However, one challenge in the management of MPAs is the lack of scientific information (Pomeroy et al., 2005), and water quality is often not considered. In a literature review done by Abessa et al. (2018), it was found that information on pollution in MPAs only represented 1.2% of papers in scientific databases. Also, Kamil et al. (2017) reviewed 32 papers related to MPAs in SEA and found that relatively few studies have focused on biophysical indicators and only one (1) study was connected to water quality.

As reiterated by Mishra et al. (2015), it is vital in coastal resource management that coastal water quality is known and studied. Water quality monitoring is an important factor in the development of an integrated approach leading to effective policy making in relation to MPAs (Karydis & Kitsiou, 2013). Scientific information on marine water quality will allow MPA managers to access the environmental state of the MPA as well as understand the natural and social processes in the area (Karydis & Kitsiou, 2013; Pomeroy et al., 2005).

In the assessment done by Tupper et al. (2015) of seven (7) MPA sites in the Philippines, the authors recognized that evaluation of our MPAs needs to be science based and, at the same time, grounded on the realities of the local stakeholders. With this in mind, the paper provides evidence-based information on an MPA in the Philippines to provide data for policy making and identify environmental interventions in relation to MPAs. Specifically, the study assessed the water quality of the Bago City MPA and its surrounding area in order to determine the state of the MPA and identify its possible sources of contamination, which can be the basis for pollution management strategies in the area.

MATERIALS AND METHODS

Study Area

The Bago MPA is in the city of Bago, located in the northwestern part of Negros Island, Philippines, and covers an area of 130 hectares including a 30-hectare no-take zone. Based on a 2015 census, the city has a total population of 170,981 (Philippine Statistics Authority, 2016). A study covering four (4) coastal barangays in the city showed that 50.89% of the respondents lived very close to the shore but only 11.26% are engaged in fishing (Quezon et al., 2017).

The MPA and its surrounding waters are part of the Negros Occidental Coastal Wetlands Conservation Area, which was declared a Ramsar Site (Office of the Bago City Mayor, 2017). It was also identified as one of only three known areas in the country to harbor Irrawaddy dolphins (de la Paz, 2012; Dolar et al., 2011), a species declared as endangered by the International Union for Conservation of Nature (Paing, 2017, para. 1). The abundance of migratory water birds is also evident in the area (Office of the Bago City Mayor, 2017). In order to ensure the protection and conservation of these species, the area was established as an MPA in 2017. This MPA boasts to be the first locally managed MPA for Irrawaddy dolphins in the Philippines (University of St. La Salle, 2017). Figure 1 shows the geographic coordinates and the location of the study area.

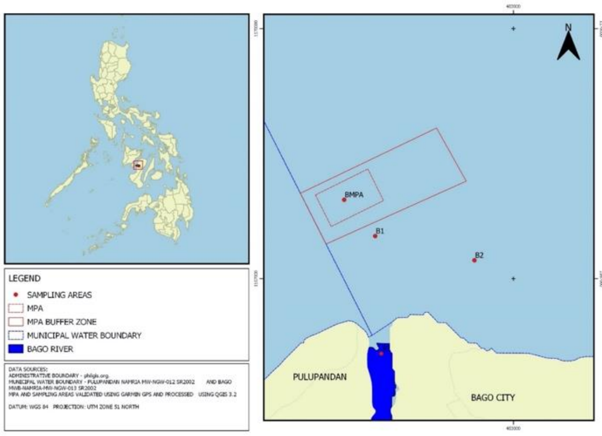

Figure 1. The location of the study area and sampling points.

Methodology

Monthly water sampling was done in the study area for twelve (12) months covering the period of April 2018 to March 2019. Samples were collected in four (4) sampling points, representing the no-take zone of the MPA (BMPA), two (2) from outside the BMPA (B1 and B2), and the mouth of the contributory river, Bago River (R1). Figure 1 shows the location of the sampling points. B1, B2, and R1 are 573, 1,724, and 1,895 meters from BMPA, respectively.

Three (3) replicate samples of 4 L of surface water were collected from each site and placed in polyethylene bottles for transport to the laboratories. For microbiological analysis, an additional 500 ml of water was placed in sterile bottles. All water samples were stored in sealed ice buckets before and during transport to the laboratory, and analysis was done within 24 h of arrival at the laboratory.

Dissolved oxygen and temperature were measured in situ using the portable meters, and additional physicochemical parameters such as pH, total suspended solids (TSS), nitrates as nitrogen (NO_3), phosphates (PO_4), color, and fecal coliform counts were determined by the Negros Prawn Producers Cooperative, Inc., the only accredited laboratory by the Department of Environment and Natural Resources (DENR) in the island. The parameters and methods of analysis used were based on DAO 2016-08 (DENR, 2016) and the standard methods for the examination of water and wastewater (Clesceri et al., 1998). These are specified in Table 1.

RESULTS AND DISCUSSION

In terms of its chemical constituents, the water of the MPA is satisfactory based on the standards set by DAO 2016-08 (DENR, 2016) for Class SA waters (protected waters) as seen from the results shown in Table 2. Nutrient content (as nitrates and phosphates) is very low throughout the year while oxygen saturation in the area is sufficient and exceeds the minimum set by DENR except for the month of April 2018. The decrease in oxygen level was observed during the summer months, and the high temperature (above the standards) caused the decreased solubility of oxygen in water (Delpla et al., 2009).

Table 1. Water Quality Parameters and Their Methods of Analysis

Parameter	Method of Analysis
Temperature	Thermometer
pH	Glass electrode method
DO	DO meter
Fecal Coliform	Multiple tube fermentation or membrane filter
Color	Visual comparison method
Total Suspended Solids	Gravimetric method
Nitrates as nitrogen	Specific ion electrode method
Phosphate as phosphorus	Stannous chloride method

Additionally, some physical parameters failed the standard in some months: pH for the months of August 2018, December 2018, and March 2019 and TSS for the months of September to November 2018. The increase in TSS levels may be attributed to the transition of the winds from Habagat (southwest monsoon) to Amihan (northeast monsoon). This time is characterized by strong turbulence in coastal waters and may cause sediments to be resuspended into the water column from the sea floor. Abdul azis et al. (2018) stated that waves influence the presence, transport, and distribution of contaminants through increased diffusivity and material mixing. On the other hand, pH results show that the waters in Bago MPA are alkaline, which becomes more pronounced during the Amihan season.

Two (2) parameters that showed remarkable results are color and coliform. High color values were also observed in the MPA for the majority of the months in the area, covering the months of June–November 2018 and January–March 2019. Color in coastal waters indicates the possible contamination of the water, and this may be due to the presence of dissolved organic matter or minerals in the water. Highly colored water limits the penetration of light, which is critical for the growth of aquatic plants and organisms (California State Water Resources Control Board, n.d.). Another notable result that can be seen is that the fecal coliform count in the area exceeded standards in all the months surveyed. This indicates the presence of disease-causing microorganisms in the MPA and signifies the contamination of water by human and/or animal fecal matter (Jamieson et al., 2002; Wahyuni, 2015). This contamination may diminish the potential use of the area for recreational purposes and can contribute to the outbreak of waterborne diseases, skin infections, ear inflammations, and respiratory illnesses (Abdul azis et al., 2018). Details on color and coliform are further discussed in the succeeding sections.

Table 2. Physicochemical and Biological Characteristics of the Bago MPA During April 2018–March 2019

	DO (ppm)	Temp (°C)	TSS (ppm)	pH	Color (TCU)	NO_3 (ppm)	PO_4 (ppm)	Fecal Coli (MPN/100 ml)
Standards	5	26–30	25	7–8.5	5	10	0.1	<1.1
Apr-18	3.72	30.67	18.33	7.67	4.33	0.17	0.01	2.00
May-18	—	31.40	18.33	7.67	4.83	0.02	0.01	2.83
Jun-18	12.26	—	16.33	7.60	15.67	0.04	0.02	24.33
Jul-18	8.78	—	17.00	7.47	15.00	0.02	0.02	14.00
Aug-18	9.41	29.53	20.33	8.71	14.67	0.27	0.00	12.40
Sep-18	11.23	28.57	25.00	7.47	12.67	0.17	0.04	37.00
Oct-18	7.34	34.13	27.67	8.45	11.00	0.17	0.03	116.67
Nov-18	8.77	29.77	30.00	8.24	12.67	0.01	0.03	66.00
Dec-18	11.08	27.87	6.67	8.64	5.00	0.15	0.03	29.00
Jan-19	11.52	26.43	8.33	8.42	7.67	0.06	0.03	104.67
Feb-19	12.98	25.57	10.00	8.40	20.33	0.01	0.02	91.00
Mar-19	9.17	27.70	9.67	8.67	20.00	0.04	0.03	126.67

Note. Values in red are values that failed the standards set by the Department of Environment and Natural Resources; missing data were brought about by equipment malfunction in the field survey. DO = dissolved oxygen; TSS = total suspended solids; Fecal Coli = fecal coliform; TCU = true color unit; MPN = most probable number.

Color

Figure 2 shows the color values of the no-take zone of the MPA and its surrounding area. Results show that all coastal sampling points failed to meet the standards set for protected waters for most of the year (June 2018–March 2019) while the contributory river exhibited good quality for 12 months. The color of the coastal waters showed numerically near results, with B1 and B2 having higher values than BMPA during the dry season and BMPA showing higher values during the wet season. This shows that the sampling points are influencing each other with BMPA as a driver during the Habagat (southwest monsoon) season. However, the values for the contributory river are higher than that of the BMPA in most months of the year. This indicates that the river is a source of color and that sediment transport is influencing the quality of the BMPA. Upon visual assessment, the water was brownish in color, which could be attributed to the presence of minerals coming from the sediments and dissolved organic matter brought about by the decay of vegetative matter and soil runoff. It is also important to note that these waters are very low in nutrient content, so this negates the presence of phytoplankton and algae as the source of color.

Extreme values for color was seen in Bago River for the month of September 2018. This is consistent with the increase in TSS in the river during the same month. High suspended solids may be caused by input of sediments to the sea due to human activities such as dredging and mining. Sediments increase the turbidity in water, which reduces visibility in water and hinders photosynthetic processes in the water (Todd et al., 2010). Todd et al. (2010) further added that increased sediment loads may negatively affect fish spawning and other ecological processes.

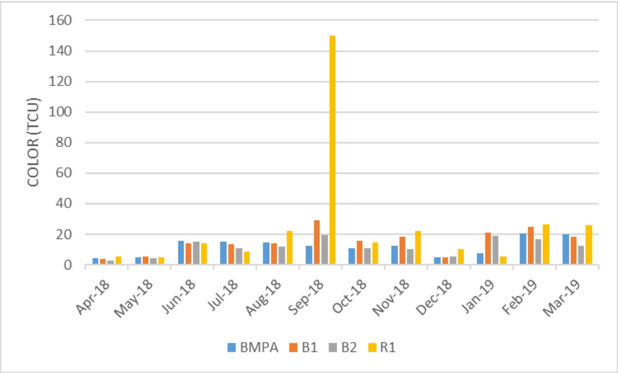

Figure 2. Comparison of color values in the marine protected areas and surrounding areas. BMPA = no-take zone of the marine protected area; B1 and B2 = two sampling points outside the BMPA; R1 = Bago River.

Fecal Coliform

Analysis of the fecal coliform counts of the sampling points in the vicinity of the MPA is shown in Figure 3. It shows that all sampling points in the MPA are affected by coliform contamination for all the months of sampling. This is not in accordance with standards set for protected waters. Also, it can be seen that the coliform counts increased in all sampling sites during the dry season (October 2018–March 2019). Mishra et al. (2015) also found a similar trend of increasing pathogenic bacteria in the coastal waters off Chennai City during the dry season. However, this is contrary to the study of Zimmer-Faust et al. (2018), which showed that coliform counts in estuaries are higher during wet season due to the increased runoff coming from domestic sources. The opposite trend in our study shows that coliform counts in the area are not due to wastes coming from the community, which is also shown by the lack of correlation of values between Bago River (R1) and the coastal waters (BMPA, B1, B2). A possible reason is the alkalinity (pH values > 7) in the study area. The survival rate of fecal coliforms is higher in alkaline water compared to acidic waters (Wahyuni, 2015), and this is consistent with the trends between pH and coliform counts in the sampling sites. Another possible cause is the high temperature, which is characteristic of coastal waters in the tropics. Reichardt et al. (2006) state that at temperatures approaching 30 °C, waters will select for "mesophilic" bacteria and the abundance of opportunistic pathogens is expected to peak. Another reason is that fecal bacteria may accumulate within the sediment and can be suspended by environmental factors such as temperature and water currents (Kacar & Omuzbuken, 2017; Stephenson & Rychert, 1982).

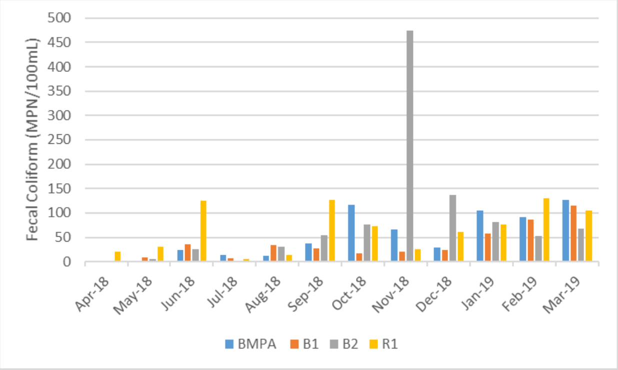

Figure 3. Comparison of fecal coliform counts in the BMPA and surrounding area. BMPA = no-take zone of the marine protected area; B1 and B2 = two sampling points outside the BMPA; R1 = Bago River.

CONCLUSION

The water quality of the MPA is poor due to high color values and coliform counts. However, its oxygen saturation and nutrient content are good and indicate that the MPA is still able to provide ecological services in support of biological communities in the area. Possible causes of contamination were identified as the sediment and wastewater transport into the sea and environmental factors such as temperature and seasonal changes in the winds.

Priority areas that should be considered in the management of the MPA are control of anthropogenic stressors such as dredging activities in the area. Even though the high coliform level in the waters may be attributed to natural processes, it is still crucial to control the release of domestic wastewater into the water as not to aggravate the condition. Also, it is important for health programs in relation to waterborne diseases to be established in the coastal barangays in order to prepare the communities in case of an outbreak.

It was observed that the water quality in the MPAs is greatly influenced by environmental factors, and further investigations on the influence of these factors are needed. The coastal environment is highly dynamic, complex, and site specific (Cai et al., 2016), and this poses a challenge for researchers and MPA managers in developing interventions in the MPAs. Thus, comprehensive and multidisciplinary approaches are needed. Further, in relation to the main contaminants found by this paper, studies on color specifically on chlorophyll a distribution and an epidemiological study for waterborne diseases in the coastal barangays are encouraged.

REFERENCES

Abdul azis, P., Mancera-Pineda, J. E., & Gavio, B. (2018). Rapid assessment of coastal water quality for recreational purposes: Methodological proposal. *Ocean and Coastal Management*, *151*, 118–126.

Abessa, D. M. S., Albuquerque, H. C., Morais, L. G., Araujo, G. S., Fonseca, T. G., Cruz, A. C. F., Campos, B. G., Camargo, J. B. D. A., Gusso-Choueri, P. K., Perina, F. C., Choueri, R. B., & Buruaem, L. M. (2018). Pollution status of marine protected areas worldwide and the consequent toxic effects are unknown. *Environmental Pollution*, *243*, 1450–1459.

Cai, M., Liu, Y., Chen, K., Huang, D., & Yang, S. (2016). Quantitative analysis of anthropogenic influences on coastal water—A new perspective. *Ecological Indicators*, *67*, 673–683.

California State Water Resources Control Board. (n.d.). *Color of water fact sheet.* Retrieved April 24, 2019, from https://www.waterboards.ca.gov/water_issues/programs/swamp/docs/cwt/guidance/3159.pdf

Clesceri, L. S., Greenberg, A. E., & Eaton, A. D. (1998). *Standard methods for the examination of water and wastewater* (20th ed.). Washington, DC: American Public Health Association.

De la Paz, M. E. L. (2012). *Behavior and area use of Irrawaddy dolphins (*Orcaella brevirostris*, Gray 1886) in the coastal waters of Bago and Pulupandan, Negros Occidental, Philippines* [Unpublished master's thesis]. Silliman University, Philippines.

Delpla, I., Jung A. V., Baures, E., Clement, M., & Thomas, O. (2009). Impacts of climate change on surface water quality in relation to drinking water production. *Environment International*, *35*, 1225–1233.

Department of Environment and Natural Resources. (2016). *DAO 2016-08: Water quality guidelines and general effluent standards of 2016*. Retrieved January 20, 2018, from https://server2.denr.gov.ph/uploads/rmdd/dao-2016-08.pdf

Dolar, M. M. L., Sabater, E. R., de la Paz, M. E. L., Villegas, J., & Perrrin, W. F. (2011, November). Irrawaddy dolphins of the Visayas and Mindanao, Philippines [Poster presentation]. 19th Biennial Conference on the Biology of Marine Mammals, Tampa, Florida, USA.

Gurney, G. G., Cinner, J., Ban, N. C., Pressey, R. L., Pollnac, R., Campbell, S. J., Tasidjawa, S., & Setiawan, F. (2014). Poverty and protected areas: An evaluation of a marine integrated conservation and development project in Indonesia. *Global Environmental Change*, *26*, 98–107.

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., Bruno, J. F., Casey, K. S., Ebert, C., Fox, H. E., Fujita, R., Heinemann, D., Lenihan, H. S., Madin, E. M. P., Perry, M. T., Selig, E. R., Spalding, M., Steneck, R., & Watson, R. (2008). A global map of human impact on marine ecosystems. *Science*, *319*, 948–952.

Jamieson, R. C., Sharples, K. E., Stratton, G. W., & Madani, A. (2002). Movement and persistence of fecal bacteria in agricultural soils and subsurface drainage water: A review. *Canadian Biosystems Engineering*, *44*, 1.1–1.9.

Kacar, A., & Omuzbuken, B. (2017). Assessing the seawater quality of a coastal city using fecal indicators and environmental variable (Eastern Aegean Sea). *Marine Pollution Bulletin*, *123*, 400–403.

Kamil, K. A., Hailu, A., Rogers, A., & Pandit, R. (2017). An assessment of marine protected areas as a marine management strategy in Southeast Asia: A literature review. *Ocean and Coastal Management*, *145*, 72–81.

Karydis, M., & Kitsiou, D. (2013). Marine water quality monitoring: A review. *Marine Pollution Bulletin*, *77*, 23–36.

Kelleher, G. (1999). *Guidelines for marine protected areas*. Gland, Switzerland, and Cambridge, UK: International Union for the Conservation of Nature.

Mishra, P., Panda, U. S., Pradhan, U., Kumar, C. S., Naik, S., Begum, M., & Ishwarya, J. (2015). Coastal water quality monitoring and modelling off Chennai City. *Procedia Engineering*, *116*, 955–962.

Office of the Bago City Mayor. (2017). *Bago City Marine Protected Area Management Plan 2017–2022*. Bago City.

Paing, T. H. (2017). Status of Irrawaddy dolphin raised to "Endangered." *The Irrawaddy*. Retrieved March 18, 2019, from https://www.irrawaddy.com/news/status-irrawaddy-dolphin-raised-endangered.html

Philippine Statistics Authority. (2016). *Population of Negros Island Region (Based on the 2015 Census of Population)*. Retrieved November 5, 2018, from https://psa.gov.ph/content/population-negros-island-region-based-2015-census-population

Pomeroy, R. S., Watson, L. M., Parks, J. E., & Cid, G. A. (2005). How is your MPA doing? A methodology for evaluating the management effectiveness for marine protected areas. *Ocean and Coastal Management*, *48*, 485–502.

Quezon, M. S., Alova, A. A., & Parreňo, E. A. (2017). *Socio-economic profile of coastal communities in Bago City* (Protected Areas Management Enhancement PAME Program Report). Bacolod City: USLS University Press.

Reichardt, W., McGlone, M. L. S. D., & Jacinto, G. S. (2006). Organic pollution and its impacts on the microbiology of coastal marine environments; A Philippine perspective. *Asian Journal of Water, Environment and Pollution*, *4*(1), 1–9.

Stephenson, G. R., & Rychert, R. C. (1982). Bottom sediment: A reservoir of *Escherichia coli* in range land streams. *Journal of Range Management*, *35*, 119–123.

Tiquio, M. G. J. P., Marmier, N., & Francour, P. (2017). Management frameworks for coastal and marine pollution in the European and South East Asian regions. *Ocean and Coastal Management*, *135*, 65–78.

Todd, P. A., Ong, X., & Chou, L. M. (2010). Impacts of pollution on marine life in

Southeast Asia. *Biodiversity and Conservation*, *19*(4), 1063–1082.

Tupper, M., Asif, F., Garces, L. R., & Pido, M. D. (2015). Evaluating the management effectiveness of marine protected areas at seven selected sites in the Philippines. *Marine Policy*, *56*, 33–42.

University of St. La Salle. (2017). *Conservation and management enhancement of Irrawaddy dolphin habitats in Negros Occidental* (Terminal Report). Bacolod City: GIZ.

Wahyuni, E. A. (2015). The influence of pH characteristics on the occurance of coliform bacteria in Madura strait. *Procedia Environmental Science*, *23*, 130–135.

Zimmer-Faust, A. G., Brown, C. A., & Manderson, A. (2018). Statistical models of fecal coliform levels in Pacific Northwest estuaries for improved shellfish harvest area closure decision making. *Marine Pollution Bulletin*, *137*, 360–369.