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Exploring ecosystem health through physico-chemical parameters and bioindicators in Miagao, Iloilo, Philippines: A preliminary study

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Abstract

Ecological health surveys are crucial for evaluating the well-being of ecosystems, as they provide essential insights through surrogate indicators, enabling informed decision-making for sustainable environmental management and conservation. This study conducted an ecosystem health survey in Miagao, Iloilo, Philippines, with specific objectives including the evaluation of physico-chemical parameters, identification of plankton at the family level, microbiological analysis, and detection of photosynthetic bacteria in selected sites. Four sites were chosen, and physico-chemical parameters in sites 1 and 4 were almost identical. Plankton presence was observed, but quantification was not conducted. Microbiological analysis in Site 1 indicated that the total plate count was 10^5 CFU mL^{-1}. Growth of photosynthetic bacteria was observed in samples with sediment after 14 days. Despite limitations in site coverage and real-time insight, the study highlights the presence of bioindicators, offering valuable groundwork for future research and the need for comprehensive analysis across all sites.

Keywords: Ecosystem, Ecosystem health survey, Microbiological analysis, PSB

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1. Introduction

Ecological health can be viewed in terms of ecosystems, where structural and functional characteristics are maintained (Manickavasagam et al., 2019). As ecosystem health cannot be measured or observed directly, surrogate measures (indicators) must be applied to assess it (Burkhard et al., 2008). Each organic entity inside a biological system provides an indication of the health of its surroundings (Parmar et al., 2016). One functional way to assess the health of ecosystems is to measure or model indicators that represent important processes in the ecosystem, from which conclusions for the–whole system can be drawn (Burkhard et al., 2008).

For instance, organisms known as bioindicators–living entities such as plants, plankton, animals, and microbes–are utilized to monitor the health of the natural ecosystem (Parmar et al., 2016). Bioindicators indicate altered environmental conditions and can be used to identify and/or quantify the impact of pollutants on the environment. Assessing the status of bioindicators indirectly provides an estimate of the natural state or the level/degree of contamination present in that particular ecosystem. It can be used as an index of measures or a model that characterizes ecosystem health (Manickavasagam et al., 2019). Bioindication and biomonitoring have become promising methods for studying the impacts of external factors on an ecosystem, its development, and for differentiating polluted and unpolluted areas. The environment's condition is effectively monitored by using bioindicator species due to their resistance to ecological variability (Parmar et al., 2016).

The Municipality of Miagao, a province in the Philippines, is a coastal area located forty kilometers from Iloilo City, along the southwestern part of the province of Iloilo, Panay Island. It has 22 coastal barangays out of the 119 barangays, with a 16 km coastline covering 24,000 hectares of municipal waters with rich fishery resources. A significant portion of its populace relies on coastal and marine resources for subsistence and livelihood. In fact, the 21,896 coastal population, comprising 34% of the 64,545 total population (NSO, 2010; Pilapil-Añasco et al., 2016), directly and indirectly depends on fishing as their source of livelihood. As of 2015, the Municipal Fisherfolk Registration (FishR) Program of BFAR 6 and LGU Miagao has a total of 2,360 registered fisherfolks, about four percent (4%) of the total population. According to the study of Chen et al. (2019a), the utilization of water resources has increased, and aquatic ecosystems have been seriously degraded or destroyed in recent years. The heights of dependability of the locals on its coastal resources made this survey information crucial to the locality. The study will serve as a preliminary report on the current status of the ecosystem's health in the area. Hence, this study aims to assess the ecosystem health status of selected sites in Miagao, Iloilo, Philippines. Specifically, this study aims to: (1) evaluate the physico-chemical parameters of the sampling areas; (2) identify, to the family level, the presence of plankton in two selected sites; (3) determine the bacterial count of a selected site; and (4) determine the presence of photosynthetic bacteria in selected sites using different improvised culture media.

2. Material and Methods

2.1. Study site

The study was conducted in Miagao, Iloilo, Philippines. Four specific sites were chosen for this study, namely: Site 1 – coast near the University of the Philippines (UPV) hatchery; Site 2 – coast near the UPV Ocean Weather Laboratory (OWL) building; Site 3 – waters near Sulu Restaurant; and Site 4 – coast near Barangay Sapa (Figure 1). The choosing of the sites was based on the available potential domestic wastes that could possibly alter the ecosystem's health. Site 1 is closer to hatchery site where wastes were directly discharged into the water. Site 2 and 3 are near residential areas while Site 4 is along a commercial restaurant. In addition, the sites chosen were close to each other due to some logistical constraints such as time and availability of materials in the laboratory. However, through the collection of water parameters of the chosen sites, these may have a group of organisms that establish bioindicators that can indicate the health of the ecosystem and have an impact on the community that relies on fisheries. Furthermore, each experiment only pertains to specific sites and does not necessarily cover all four mentioned areas. All analyses were conducted at the UPV laboratory.

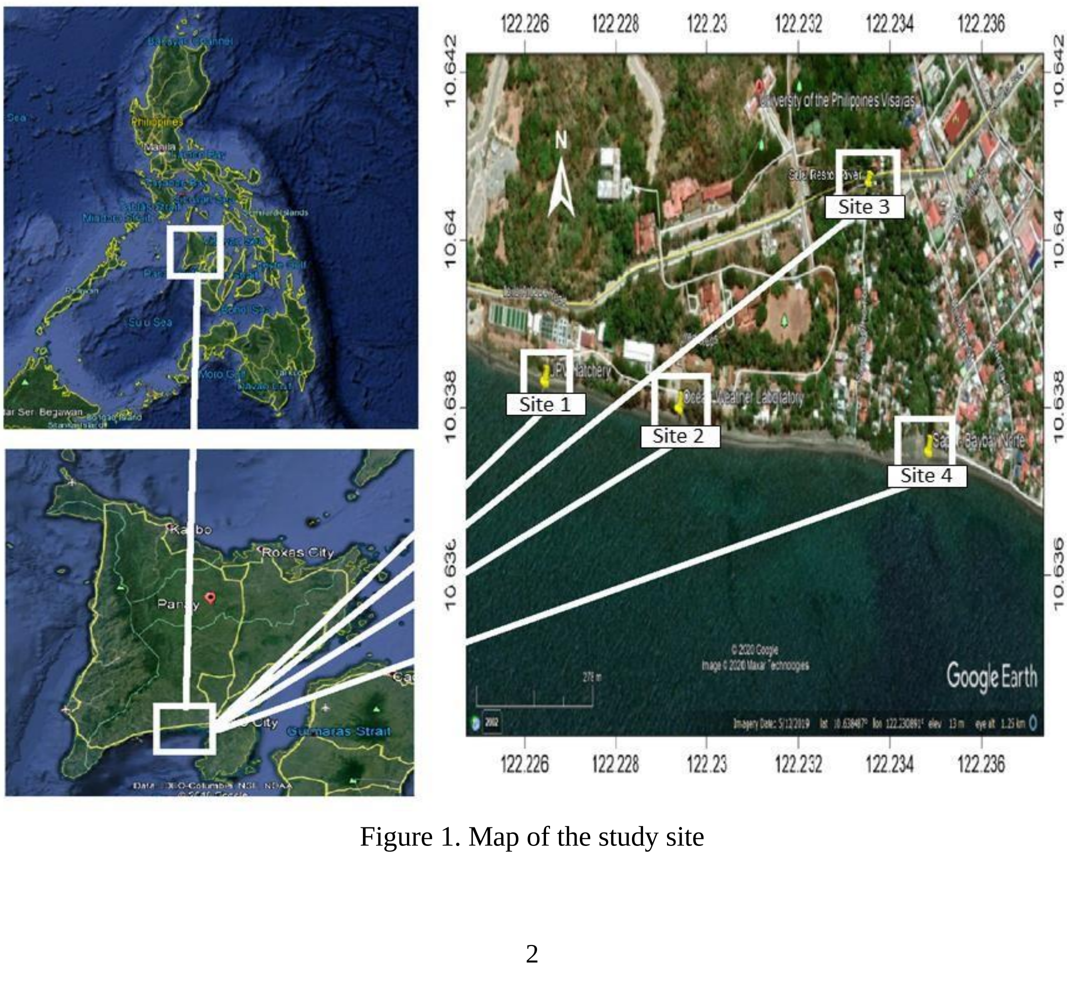

Figure 1. Map of the study site

2.2. Evaluation of physico-chemical parameters and plankton identification

Physico-chemical parameters such as salinity, temperature, and total dissolved solids (TDS) were recorded using a YSI Pro Plus multi-parameter water quality meter. Due to time constraints and laboratory resource limitations, only two sites were sampled: the coast near the UPV hatchery (Site 1) where hatchery discharges are located and Barangay Sapa (Site 4), situated closer to coastal residences. These sites were chosen to assess bioindicators indicative of ecosystem health. Additionally, the type of substrate and weather conditions at each sampling location were noted for plankton identification. A plankton tow net with a 50 µm mesh size, 12.0 cm diameter, and 30 cm length was used to collect water samples. The net was manually dragged along the coast, and the collected samples were then transferred to separate, properly labeled plastic containers for each site. These containers were transported to the IMFO-UPV laboratory for identification using a compound microscope. Samples were identified up to the family level using the identification manual (Verlecar & Desai, 2004) and subsequently photographed for documentation and analysis purposes. A one-time sampling event was conducted as this study aims solely to provide a preliminary assessment of the chosen sites' ecosystem health.

2.3. Glasswares, equipment and media preparation

All glassware, including test tubes, petri dishes, L-rods, pipettes, pipette tips, etc., were thoroughly washed and sterilized to prevent any contamination. The sterilization process took place at the IMFO-UPV Laboratory. On the other hand, media preparation was conducted at the Institute of Aquaculture (IA), UPV. The media used are listed in Table 1. These media were accurately weighed with their corresponding concentrations and then autoclaved. Subsequently, they were poured into petri dishes and properly labeled.

Table 1. Media used in bacterial counting in this study

Treatment No.	Media Used
1	nutrient agar (NA) + filtered seawater (FSW)
2	tryptone + yeast extract + agar-agar + FSW
3	NA + 2% NaCl + distilled water

2.4. Microbiological analysis

A water sample from one site, specifically the coast near UPV hatchery, was taken to the Microbiology Laboratory of IA-UPV for the total plate count (TPC) of bacteria present. Only one site was processed instead of two due to time constraints and the availability of materials in the laboratory. Five-fold dilutions were prepared with sterile saline solution. An aliquot (100 µL) of each sample dilution was spread onto plates with prepared media using an L-rod. The plates were then inverted, placed inside transparent plastic cellophane, and stored in the laboratory at room temperature for 72 hours. Only the first, third, and fifth dilutions were used in this study. Two replicates per sample were prepared and executed. All plates were monitored every 24 hours, and the number of colonies present was counted. For the calculation of bacteria colonies using the TPC method, the following procedure was employed:

$$\text{TPC} = \frac{\text{Number of colonies}}{\text{Dilution Factor x Volume Plated}}$$

2.5. Determination of the Presence of Photosynthetic Bacteria (PSB)

Media preparation

An egg solution was served as fertilizer and used to aid the growth of PSB in this experiment. The ingredients used were 2 eggs, 2 tablespoons of monosodium glutamate (MSG), and 1 tablespoon of soy sauce. These were mixed thoroughly and added to each water sample collected from each study site.

Culture method and monitoring of PSB growth

Collected water and sediment samples from all four sites were used in this experiment. Transparent plastic bottles with a volume of 200 mL were used, and a total of ten treatments were prepared (Table 2). The media, i.e., the fertilizer aiding in bacterial growth, was then added to each bottle. Each site had two treatments: water samples only and water together with its sediments. The sediment for the control treatment was gathered from terrestrial soil nearby. Ten bottles were prepared, appropriately labeled, and stored at the Faculty Center Building of UPV, where sufficient sunlight is available (Figure 2). Monitoring was conducted once a week for 21 days. Each bottle was thoroughly observed for any progress, and observations were noted. Samples were also photographed during each visit for documentation and analysis purposes.

Table 2. Treatments used in PSB culture in this study

Treatment No.	Samples Used
1	coast near hatchery of UPV; water only
2	coast near hatchery of UPV; water + sediment
3	coast near OWL building of UPV; water only
4	coast near OWL building of UPV; water + sediment
5	waters near Sulu Restaurant; water only
6	waters near Sulu Restaurant; water + sediment
7	coast near Barangay Sapa; water only
8	coast near Barangay Sapa; water + sediment
9	distilled water (control)
10	distilled water + soil (control)

Figure 2. Experimental samples used in PSB culture

3. Results and Discussion

3.1. Physico-chemical parameters

Physico-chemical and biological characteristics dictate the aquatic ecosystem's health (Venkatesharaju et al., 2010). According to Pal and Chakraborty (2014), good quality of water resources depends on a large number of physico-chemical parameters and biological characteristics. Water quality is an important component of a water ecosystem health assessment (Chen et al., 2019a). In this study, only two sites, namely sites 1 and 4, were considered in this part of the experiment, as these two sites were initially planned for microbiological analysis. The selection of sites was limited due to the availability of materials in the laboratory. The water sample in site 1 was collected from an area near hatchery discharges, while the water sample in site 4 was collected from an area near coastal community residences. Physico-chemical parameters for the two sites did not show any significant differences since the two locations are less than a kilometer away (Table 3). The only distinction between the two is the type of substrate each area has, i.e., sandy for site 1 and rocky for site 4. Water parameters were measured during a sunny day; hence, the temperature is quite high, coinciding with its salinity.

Table 3. Physico-chemical parameters

Sampling Site	Type of substrate	Salinity (ppt)	Temperature (°C)	Total dissolved solids (TDS)
1	Sandy	32.7	27	32.06
4	Rocky	33.0	27	32.27

The first bioindicators identified in this study are plankton. In many water bodies, such as seas, lakes, streams, and swamps, significant biological production is carried out by plankton. These organisms consist of communities that float along currents and tides, yet they fuse and cycle important quantities of energy that are then passed on to higher trophic levels (Walsh, 1978). The presence of plankton is key to marine organisms, serving as both an indicator of water quality and the main food source for many fish (Thakur et al., 2013). The changes that occur within the communities of plankton provide the platform to determine the trophic state of water bodies (Pradhan et al., 2008). These organisms respond rapidly to changes taking place in the surrounding environment and serve as important biomarkers for assessing the quality of water as well as indicators of water pollution (Parmar et al., 2016).

Plankton includes both plants, referred to as phytoplankton, and animals referred to as zooplankton. As shown in Table 4, both sites have the presence of diatoms and dinoflagellates, which are phytoplankton. Phytoplankton have been used for the successful observation of water contamination and are a useful indicator of water quality (Wu, 1984). Changes in the diversity of phytoplankton species may indicate pollution of the marine ecosystem (Walsh, 1978; Hosmani, 2014). However, this study only focuses on the identification of plankton present at the family level. Counting was not done in this study due to some unexpected circumstances (i.e., time due to the COVID-19 pandemic) where prohibitions were enforced and all samples left in the laboratory were left out and damaged; hence, conclusions about the status of the ecosystem in the locality are not possible. In the context of altering nutrient charges in aquatic systems, the ratio of the major phytoplankton groups, diatoms versus flagellates (diatoms–nondiatoms ratio), can be used as an indicator. For example, regarding eutrophication, nutrient reductions can be observed in a decrease in flagellate abundance (Burkhard et al., 2008). Diatoms are powerful indicators of environmental change and have emerged as preferred indicators in monitoring studies (Dixit et al., 1992). In the study of Yusuf (2020), the presence of organic pollution indicators *Closterium* sp., *Navicula* sp., *Nitzschia* sp., *Synedra* sp., *Chlamydomonas* sp., *Cyclotella* sp,. and *Anacystis* sp. is a warning sign of the deteriorating condition of the water quality in the reservoir. Therefore, quantifying the presence of plankton and identifying it at the species level will give more weight to overseeing the real state of the ecosystem.

For the zooplankton identified in the study, both sites exhibited the same presence of copepods. Identification of the zooplankton plays a vital role and forms the intermediate trophic status between phytoplankton communities and fish groups which serves as a necessary component of the aquatic ecosystem (Pal & Chakraborty, 2014). The organism plays a vital role in the food chain, nutrient recycling, and energy flow in the aquatic ecosystem (Park et al., 2007). According to Aslam et al. (2012), copepods (cyclops & phyllodiaptomus) indicate the health of the marine body. These organisms are microscopic animals living near the surface of the water body. They are poor swimmers, instead relying on tides and currents as a transport mechanism. Zooplankton also play an important role as bioindicators and help to evaluate the level of water pollution (Parmar et al., 2016). These types of organisms play a pivotal role in aquatic food webs by transferring carbon to higher trophic levels, consuming microorganisms (bacteria, protists), and serving as prey for fish and invertebrates (Drira et al., 2018). The presence or absence of certain zooplankton species may indicate the relative influence of different water types on ecosystem structures and may serve as an early indication of a biological response to environmental and climatic changes (Hays et al., 2005; Ziadi et al., 2015). They are identified as excellent bioindicators to evaluate the contamination of any coastal and oceanic bodies (Zannatul & Muktadir, 2009; Parmar et al., 2016). Quantification of these organisms is of great importance as well to have an overview of the area's ecosystem health. However, determination of their abundance was not done in this experiment.

Table 4. Plankton identified in two study sites

Sampling Site	Phytoplankton	Family	Zooplankton
1	Diatoms	Rhizosoleniaceae	Copepods
		Coscinodiscaceae	
		Thallasionemataceae	
		Leptocylindraceae	
		Naviculaceae	
		Chaetocerotacea	
		Bacillariophyceae	
	Dinoflagellate	Pyrocyctis	
		Ceratium	
		Gymodinium	
2	Diatoms	Bacillariophyceae	Copepods
		Rhizosoleniaceae	
		Coscinodiscaceae	
		Lithodesmiaceae	
		Chaetocerotacea	
		Eupodiscacea	
	Dinoflagellate	Ceratium	Fish
			Larvae
			Copepods
			Zoea

3.2. Microbiological analysis

Microorganisms play a crucial role in maintaining and sustaining any ecosystem, as they are more capable of rapid adjustment toward environmental changes and deterioration (Sorokin, 1981; Dash et al., 2012). Marine microbial communities form the basis of the ocean food web and, therefore, produce food for all life in the ocean (Glöckner et al., 2012). They can also serve as indicators of aquatic or terrestrial ecosystem health. Due to their abundance, they are easy to test and readily available (Parmar et al., 2016). One such marine microorganism is bacteria (Glöckner et al., 2012), which is used in this study to evaluate the ecosystem's health status of a selected site in Miagao, Iloilo. The site near UPV hatchery was chosen due to its location where discharges from the said facility are the focus of water sampling. Results revealed that in almost all of the tested media, abundances were consistently at almost the same level, approximately 10^5 CFU mL^{-1}, indicating a higher bacterial presence at the sampling site, likely due to its proximity to the hatchery system where effluents are discharged. Bioindicators are evidently present in this area, suggesting a lack of bioremediation. Although the bacteria are not identified, it can be inferred that the sampling area is considered biologically polluted. Microbial pollution of coastal areas can harm aquatic wildlife, i.e., potentially detrimental to coral reef community health, as well as human health, leading to many skin and intestinal diseases, thus reducing the benefits that coastal environments provide to the community (Basili et al., 2021; Ochsenkühn et al., 2021).

Table 5. Total plate count (TPC, CFU mL^{-1}) of bacteria from UPV hatchery water sample

Treatment	Incubation period (h)		
	24	48	72
1 (NA+FSW)	3.0×10^5	2.0×10^5	2.0×10^5
2 (tryptone+yeast+ NaCl+agar-agar+FSW)	3.0×10^3	2.0×10^5	5.0×10^5
3 (NA+2%Nacl+ distilled water)	2.6×10^6	4.0×10^5	8.5×10^5

3.3. Growth of photosynthetic bacteria

Bacteria have long been known to play a part in marine ecosystems (Sorokin, 1981). A particular strain of these microorganisms is known as photosynthetic bacteria (PSB). PSB are the earliest prokaryotes with a primitive photo energy synthesis system on earth (Chen et al., 2020) and are widely distributed in oceans, lakes, soil, and activated sludge (Zhou et al., 2015), possessing light-absorbing pigments (Talaiekhozani & Rezania, 2017). This means that this type of bacteria harvests light energy using specialized pigments (the 'photo' part) and can convert CO_2 into organic carbon (the 'synthesis' part), although with differing efficiencies (Karl, 2002). There are four families of PSB: Rhodospirillaceae (purple non-sulfur bacteria, PNSB), Chromatiaceae (purple sulfur bacteria), Chlorobiaceae (green sulfur bacteria), and Chloroflexaceae (gliding filamentous green sulfur bacteria) (Blankenship et al., 1995). These bacteria have versatile metabolic pathways (Madukasi & Zhang, 2010). Under light conditions, their metabolic pathways are photoautotrophic or photoheterotrophic; whereas under dark conditions, the metabolic pathway is chemo-heterotrophic (Larimer et al., 2004) hence enabling them to survive under light-anaerobic or dark-aerobic conditions (Talaiekhozani & Rezania, 2017). Such flexibility enables PSB to utilize various types of substrates, including organics, N, P, and S (He et al., 2010).

PSB cells are rich in high-valued substances, in which the protein content is usually 45%–65% (Yang et al., 2018). These high-value substances can be utilized as animal feed, fertilizer, agents of disease prevention, food and cosmetic supplements, and soil conditioners (Chen et al., 2019b). The photosynthetic bacteria also offer numerous advantages for the bioremediation process due to their capacity to utilize various types of organic compounds. They have the ability to remove COD, nitrogen, phosphorous, and different types of heavy metals from wastewater (Talaiekhozani & Rezania, 2017). Moreover, in the study of Chen et al. (2019b), PSB are used in wastewater treatment, i.e., a new technology that can simultaneously remove pollutants from wastewater and produce high-value substances. Numerous studies conducted by different authors (e.g., Kaewsuk et al., 2010, Chitapornpan et al., 2013, Prachanurak et al., 2014, Zhou et al., 2014) showed and noted that PSB have been utilized for the treatment of different wastewaters from sugar industries, food processing, chicken abattoirs, dairy, and fermented starch. This type of bacteria is resistant to salty environments; therefore, they have good potential for treating different high-organics-load wastewaters (Qin et al., 2017). Furthermore, PSB are not only applicable for wastewater treatment but are also used to generate quality-added products such as biodiesel and hydrogen (Talaiekhozani & Rezania, 2017). Hence, PSB serve a significant purpose in the marine environment.

In this study, the culturing of PSB utilizing an egg solution as fertilizer in water samples gathered from each selected site was used to determine the presence of these organisms. Observed growth of PSB, as shown in Figure 3, was noticed after 14 days of culture. The areas where these PSB grow are water samples gathered from the coast near the UPV hatchery, UPV-OWL building, and Barangay Sapa. In addition to that, samples with sediments are the ones where PSB successfully grow. The purple colors in each bottle designate the presence of this type of bacteria. According to Kolber et al. (2000), PSB has several independent lines of purple pigments which this experiment is based on. The presence of purple carotenoids such as spirilloxanthin gives these bacteria their distinct color (Jagannathan & Golbeck, 2009). The rest of the water samples do not exhibit any growth of PSB after 21 days of culture. Fleischman (2011) stated that PSB plays many important roles in the environment, as much as a third of the earth's photosynthesis is performed by microorganisms in the oceans. The areas where PSB were being observed are all water samples gathered from a coast hence coinciding with the studies that these organisms can be found in marine waters. In the study of Orel et al. (2022), these types of bacteria have a high ability to remove heavy metals, dyes, and macro-pollutants from wastewater and a promising technology to treat different types of wastewater effectively and economically. As for the control sample, it showed no signs of growth, and the other site, i.e., near Sulu Restaurant, is subjected to some domestic discharges which may have affected the salinity of the area. However, further investigation must be done since water parameters were not being gathered during the experiment.

The results of the study would provide the local government and community with an overview of the ecosystem health status of the locality. Without clear definitions of ecosystem health, it is not possible to set targets and assess whether management actions have been effective. Bioindicators have remarkable potential in forecasting disasters, preventing pollution, and exploring and conserving natural resources, all aiming at sustainable development with minimum destruction of the biosphere (Manickavasagam et al., 2019). The findings of this study will serve as baseline information for future coastal resource management planning by responsible agencies and will also serve as a trial experiment. It can be applied to predict the impact of anthropogenic activities, particularly pollutants, and predict environmental changes in a timely manner. Informing the public about the real-time status of their coastal water is of high importance. Even though the concept of ecosystem health has been criticized for being too fuzzy and not concrete enough for practical application, Burkhard et al. (2008) stress that it still found entry into different management strategies and definitions of political targets. Furthermore, O'Brien et al. (2016) emphasize that assessing ecosystem health is an ongoing priority for governments, scientists, and managers worldwide.

4. Conclusion

In conclusion, with the preliminary data gathered, ecosystem health surveys in coastal areas, particularly in regions like Miagao, Iloilo, Philippines, are crucial for communities heavily dependent on fisheries. Additionally, time constraints and limited equipment in the laboratory are likely to mean that not all potential variables can be monitored. Hence, this paper highly recommends evaluating the sites thoroughly again for comprehensive data. Ecosystem health, indicative of sustainability and minimal external support, is intertwined with the well-being of both the environment and its human inhabitants. The assessment's results offer real-time insights into the coastal ecosystem, enabling informed decision-making for the benefit of both humans and the environment. Moreover, the preliminary data can help the policymakers/managers to make appropriate decisions to gather a more comprehensive scientific record for the better management of the coastal ecosystems studied.

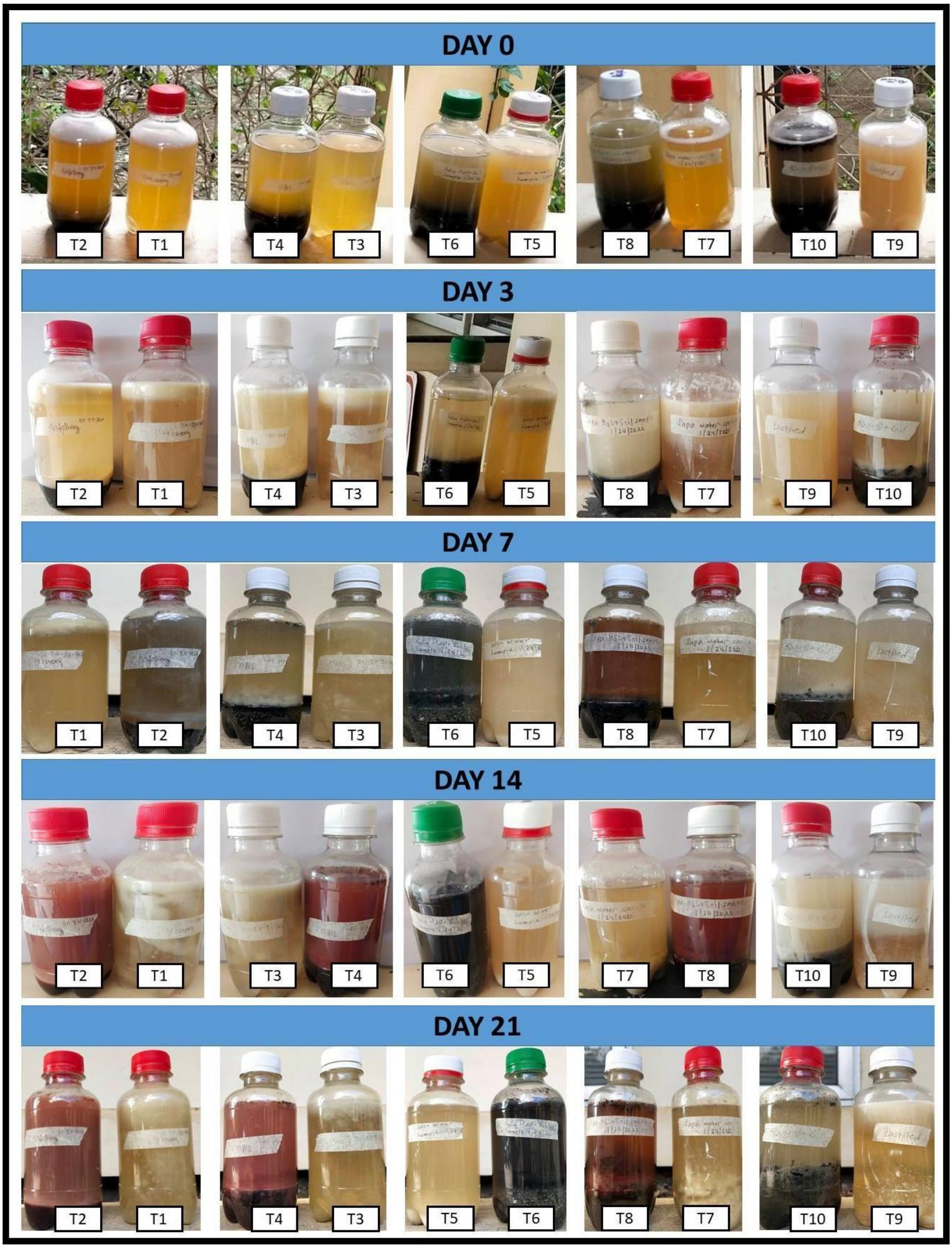

Figure 3. Monitoring of PSB growth for 21 days in this study

Conflict of interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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