A Site Investigation of Pollution Along the Bantayan-Piapi Coastline, Dumaguete City, Philippines

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Abstract

Physico-chemical and bacteriological analyses were conducted on samples from the mouth of Mojon Creek at the north end of Silliman Beach, and sewer outfalls along the Bantayan-Piapi coastline. At each of the seven sampling stations, two samples were collected: one from the river mouth or outfall and a second from seawater located at least 20 m offshore. A supplementary underwater fish density and biomass survey was conducted in the shallow seagrass areas.

Extremely high levels of bacteria were detected in the samples, with concentrations of *E. coli* and enterococci ranging from one to five orders of magnitude exceeding the referenced standards and criteria. The concentrations of ammonia in all samples exceeded the referenced standards and criteria, thereby contributing to a toxic environment for aquatic organisms. Outfall effluent samples had non-detect to low dissolved oxygen (DO) levels, which were matched by high biochemical oxygen demand (BOD). A few outfall samples exceeded standards for oil and grease, total suspended solids (TSS), and phosphates. Based on a transect survey in the seagrass beds, the fish biomass and population density were notably low. The results of this study indicate significant pollution in the study area. This is supported by other recent data obtained by the Silliman University Angelo King Center for Research & Environmental Management (SUAKCREM). A concurrent, collaborative study on microplastics in fish gut confirmed the results of earlier studies by SUAKCREM on the occurrence of microplastics in local fish catch.

Keywords: Dumaguete pollution, Silliman beach pollution, Piapi beach pollution, Coastal pollution, Fish biomass, Microplastics in fish gut, Bacterial pollution at beaches, Mojon Creek pollution

Executive Summary

This study was conducted to determine the physico-chemical and bacteriological characteristics of water from a river mouth and sewer discharges, and the nature of pollution along the coastal areas of barangays Bantayan and Piapi, Dumaguete City. Two sampling events were completed (September 8, 2022, and June 27, 2023). The following physico-chemical parameters were measured or analyzed for flow rate, temperature, pH, conductivity, salinity, dissolved oxygen (DO), biochemical oxygen demand (BOD), oil and grease, total dissolved solids (TDS), total suspended solids (TSS), chloride, phosphate, ammonia, nitrite, and nitrate+nitrite. Enterococci and *E. coli* were quantified for bacteriological analysis. Seven sampling stations were established: one at the mouth of Mojon Creek and six at selected sewer outfalls (concrete pipes) along the coastline's seawall. At each sampling station, a second sample was collected offshore. The same parameters listed above (except for conductivity, oil and grease, TDS, and chloride) were obtained for the seawater samples at sampling points located at least 20 m directly offshore from each outfall sampling point.

The physico-chemical results indicated that high levels of ammonia and BOD, and low to non-detect levels of DO were associated with high bacteria levels at the Mojon Creek and outfall stations. At least four outfalls had ammonia levels (up to 15.017 mg NH_3-N/L) significantly exceeding the DENR's General Effluent Standard or GES (3 mg NH_3-N/L). This further indicated high levels of contamination in the effluent.

Ammonia levels in the offshore samples were as high as 0.39 mg NH3-N/L, which exceeded the DENR's Water Quality Guideline (WQG) of 0.06 mg NH_3-N/L. Two outfall samples indicated elevated oil and grease concentrations (8.6 and 8.8 mg/L), which exceeded the DENR's GES of 5 mg/L. Such elevated ammonia oil and grease levels contribute to a toxic environment for marine organisms.

The bacteriological results indicated that *E. coli* and enterococci levels exceeded their threshold limits. *E. coli* concentrations in the study area were as high as 47.2 million colony-forming units per 100 ml (CFU/100 ml) in effluent water at the outfalls and 25,500 CFU/100 ml in offshore seawater.

These were orders of magnitude higher than the DENR's General Effluent Standard or GES (200 CFU/100 ml) and Water Quality Guideline or WQG (100 CFU/100 ml). Such DENR standards and guidelines are for total coliform. Notably, the actual lab results (see Appendices A and B) for the samples reported both *E. coli* and total coliform, which were much higher than those values (i.e., for *E. coli* only) summarized in Tables 1 and 2.

Enterococci concentrations in the study area were as high as 51.6 million CFU/100 ml in effluent water at the outfalls and 28,900 CFU/100 ml in offshore seawater. These were also orders of magnitude higher than the referenced standards and criteria. Since the DENR does not specify any standards for enterococci, the sampling results were compared to existing USEPA recommended exposure limits (Recreational Water Quality Criteria, 35 CFU/100 ml), the New Jersey Surface Water Quality Standards or SWQS (30 CFU/100 ml), and the New Jersey Sanitary Code Water Quality Standards (104 CFU/100 ml, specifically for recreational beaches).

A supplementary biological investigation was conducted in the study area. Three survey transects (each one measuring 50 m x 10 m) were established offshore of Silliman and Piapi beaches. A rapid underwater survey (with photo-video documentation) was conducted to determine population density and biomass. The results were notably low. The shallow substrate's benthic composition was mainly dominated by mud and sand, with patches of seagrass and a few coral heads. A collaborative fish-gut microplastics study led by A. Bucol of SUAKCREM and biology students of the Negros Oriental State University (NORSU) was conducted in 2022 in concert with this physico-chemical study. The results indicated the occurrence of microplastics in the guts of fish collected in the study area, thereby confirming the results of previous studies conducted by SUAKCREM (A. Bucol, personal communication, February 2023).

The results of this study and other recent data provided by SUAKCREM reflect the effects of pollution in the past several decades in this coastal area. This study provides helpful information for the LGU and the country to comply with the 2030 UN Sustainable Development Summit 2015 goals. Recommendations for further studies and government action are therefore presented in the conclusion.

Introduction

This study was funded by the Silliman University Alumni Council of North America (SUACONA) and implemented by SUAKCREM to conduct a site investigation to characterize the discharges from sewer outfalls and determine the presence and nature of pollution along the coastline and beaches of barangays Bantayan and Piapi. The coastal study area runs from Mojon Creek (along the south side of the Dumaguete airport runway), southwards up to the corner of the coastal road, Flores Avenue, and the east-west trending E.J. Blanco Drive. The study area had a total length of about 1,300 meters and a width ranging from 20 to 90 m from the seawall or shoreline, and it was addressed by seven sampling stations (see Figures 1A and 1B).

Figure 1A

Location of Study Area

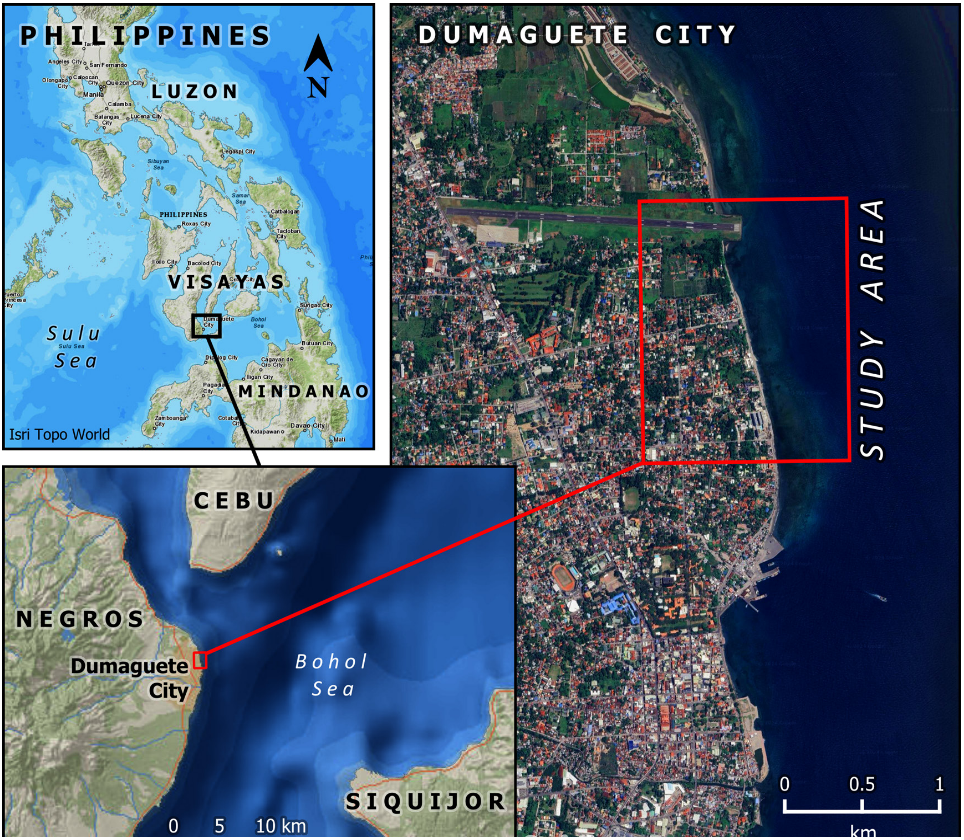

Figure 1B.

Map of the Study Area Showing the Locations of Sampling Stations (red triangles= outfalls and Mojon Creek; white triangles= offshore samples).

Silliman Beach in Bantayan is one of the few remaining free public beaches in Dumaguete City and possibly the most accessible and frequented by the public all year round. The most crowded days were noted to be those with pre-scheduled all-day power outages in the city (Figure 1B). The length of the beach is approximately 340 meters. Several decades ago, it had been longer, extending an additional 165 meters southward, but such a portion is no longer part of the beach since a seawall and a roadway (with outdoor cafes alongside) have been constructed in that area. Due to natural scouring and erosion of beach sands since the 1970s (Alcala, 2002), the width of Silliman Beach is now only about 20 to 35 meters during non-spring tide high tide. Furthermore, polluted waters from Mojon Creek have been noted to discharge into the beach waters in the past few decades. Pollution (sewage odor, bluish or dark color, frequently silty, foamy discharge, garbage debris) has been noted along the downstream stretch and at the river mouth (Station 1) at the north end, and a major (one-meter diameter concrete pipe) sewer outfall (Station 2) at the south end of the beach.

The tributaries and headwaters of Mojon Creek have not been accurately mapped, but the headwaters are estimated to be within the City's western municipal limit, somewhere between the headwaters of Amlan River and the upper part of the mainstem of Banica River. The creek's tributaries and mainstem run through a highly urbanized area characterized by numerous residential communities and commercial properties (e.g., stores, restaurants, commercial and professional office buildings), a few agricultural parcels (e.g., Silliman Farm), a university campus, a golf course, and several light-industrial facilities (e.g., vehicle repair, warehouses, gas stations, auto and motorcycle dealers).

The one-meter diameter sewer pipe at Station 2 was noted to discharge a combined wastewater-stormwater effluent from numerous residences in the adjacent coastal village and residential communities west of Silliman Beach. Similarly, all the other outfalls (Stations 3 through 7) had combined wastewater and stormwater discharge effluent. The wastewater is presumed to consist mostly of graywater since underground septic systems are required for blackwater in the city.

South of Silliman Beach is what remains of Escano Beach in Barangay Piapi. It is about 800 meters long, from East Rovira Road to E.J. Blanco Drive. The beach was already originally narrow but is now mostly covered by a coastal road (Flores Avenue) and seawall. The original beach face, berm, and backshore no longer exist. Some beachgoers still do recreational activities in front of the seawall (e.g., beachcombing during low tide, swimming, and canoeing).

There has been extensive commercial development along this coastal area of Barangay Piapi since the 1970s-mostly hotels, condominiums, and restaurants, beyond which (to the west) are numerous residential properties and commercial stores (further west, along Hibbard Avenue). For this study, five sampling stations at existing outfall pipes (with combined wastewater-stormwater effluent) were established along Escano Beach. The outfalls at Stations 2 through 7 consist of one-meter diameter concrete pipes along the seawall of the coastline. (See Fig.2 for photos of typical outfall pipes.)

Anecdotal information from some people who bathe or swim at Silliman Beach includes reports of skin irritation and rashes, eye irritation, and chronic skin disease. During sampling and several site visits in 2022 and 2023, observation of the sewer outfall areas as well as the mouth of the Mojon Creek consistently indicated the presence of contamination based on sewer odor, periodic foaming, dark or bluish-white coloration, and plastic and other garbage debris.

The study area is within the larger fishing grounds of the coastal community, which includes a delineated Marine Protected Area (MPA) in the deeper area. Thus, in addition to the physico-chemical and bacteriological study, a supplemental fish biomass and population density survey was conducted by A. Bucol of this study's research team. He also coordinated a collaborative microplastics investigation in 2022 with cooperation from biology students of NORSU.

This study aimed to document the presence and nature of pollution, with results that provided the basis for recommendations for further studies and remedial action.

Methods

Sampling Stations

The sampling stations comprised one river mouth (Mojon Creek, Station 1) and six sewer outfalls characterized by one-meter diameter concrete pipes that discharge sewage effluent and stormwater (Stations 2 through 7). These sampling stations are shown on the map in Figure 1b. Photos of the river mouth and three outfalls are shown in Figures 2A through 2F. At each station, two water samples were collected: one directly from the outfall pipe (freshwater effluent samples A1 through A7 from Stations 1 through 7) and the other from offshore seawater at a sampling point located roughly 20 m from the outfall (samples B2 through B6 from Stations 2 through 6). However, offshore samples B1 and B7 (at Stations 1 and 7) were located much farther seaward (approximately 80 to 90 m) due to the emergence of sand bars during sampling at low tide. The sampling depth for the “B” series samples was approximately 50 to 60 cm, midway between the surface and bottom of the water column.

Figure 2A. River mouth of Mojon Creek, Station 1
Note: heavily silted with plastic debris. 5-28-2023

Figure 2B. Sewer outfall south of Station 2
12-15-2023

Figure 2C. Sewer outfall, Station 3.
Note: foamy, bluish and whitish effluent. 8-26-2022

Figure 2D. South end of Silliman Beach. View of Station 2 and offshore part of study area. 12-15-2023

Figure 2E. Station 6. Note: seawall, coastal road, and ongoing construction of condominium. 9-8-2022

Figure 2F. Silliman Beach. Highly crowded on a power-outage day. 2-12-2023

For data reliability, two rounds of sampling were performed at the stations- the first on September 8, 2022, and the second on June 27, 2023. Such time of year coincided with the rainy season as well as the Habagat (southwest monsoon), which is characterized by lower energy of waves compared to the stronger Amihan (northeast monsoon) waves in this part of Negros Island. The two sampling events were scheduled during low tide and within 24 to 48 hours of a significant rainstorm (Bacteria levels are highest during and after rainstorms due to high runoff rates.) (Barboza, 2014). During the second sampling round, physico-chemical parameters for Station 2 could not be obtained since the outfall remained inaccessible throughout the day of sampling. Additionally, TDS analysis of offshore samples was not conducted since pollutant concentrations would be masked by natural salt in seawater.

Physico-chemical Parameters

At each sampling station, the following physico-chemical parameters were measured: 1) water temperature using a digital temperature meter (°C); 2) pH using a portable pH meter; 3) dissolved oxygen (DO) using the Winkler titration method; 4) salinity using a refractometer; and 5) conductivity using a conductivity meter (for outfall samples). Samples for DO were treated with $MnSO_4$ and alkaline KI in the field and further processed in the lab on the same day. A certain volume was diluted to a specified volume for samples that appeared highly contaminated. As with undiluted samples, DO levels were measured before and after a 5-day incubation period, considering the dilution factor for quantification of BOD. All bottles were covered in black plastic bags while not processed or during incubation.

Additionally, at each station, aliquots for water samples (4 liters each from outfall and seawater) were collected and immediately transported to the Silliman University Chemistry Laboratory for further lab processing and analysis of total suspended solids (TSS via gravimetric method), total dissolved solids (TDS, via a gravimetric method, for outfall samples), oil and grease (via hexane extraction and gravimetry, for outfall samples), chloride (via Mohr method, for outfall samples), phosphate (via colorimetry, USEPA Method 365.3), ammonia, nitrate+nitrite (via cadmium reduction and colorimetry, USEPA Method 353.3), and bacteria. Quantification of ammonia, NH_{-3}, was achieved using the method known as “formation of a substituted indophenol with sodium salicylate as phenolic reagent,” a specific analysis for ammonia-nitrogen (Verdouw et al., 1978) with results reported in milligrams of ammonia-nitrogen per liter (mg $NH_{\neg 3}$ -N/L).

Water Discharge Rates

At the Mojon Creek and outfalls with larger volume discharges (i.e., Stations 6 and 7), flow rates were measured using a flow meter (General Oceanics, Model 2030R Mechanical Flowmeter). Flow rates were determined at the outfalls with low discharge using the bucket and stopwatch method (volume in liters measured after 10 seconds elapsed). These methods were based on the wastewater flow measurement procedures of the USEPA (USEPA, 2020).

Bacteriological

Water sample aliquots were collected for coliform (*E. coli*) and enterococci quantification using sterile tubes prepared at the lab before the sampling events. Dilution plating and inoculation were completed on culture plates (Compact DryTM). Following the manufacturer's procedures, these were incubated for 24 hours at 35ºC at the SU Biology Laboratory. Quantification involved the use of the standard plate count method. *E. coli,* total coliform, and enterococci were originally reported as the number of colony-forming units per milliliter of sample volume (CFU/ml). The unit was later converted and tabulated as CFU/100 ml to compare with the referenced regulatory standards.

Fish Census and Biomass

The supplementary fish census and biomass study were conducted in 2022 via a rapid underwater survey, setting up three transects (50 m x 10 m) offshore between Stations 2 and 5. Using photo-video documentation, an observer (A. Bucol) identified and counted all observed fish while skin diving. The areas covered by the transects excluded the delineated Bantayan Marine Protected Area located adjacent to the study area. The fishes were identified based on taxonomic reference books (e.g., Erdmann & Allen, 2012).

The sizes and counts of each species of fish were recorded to compute fish biomass. Such data was used to estimate weight (W) in grams using the formula W=a*Lb; where a and b are constants derived from fishbase.org and L refers to the estimated total length. The fish population density of an area is expressed as individuals/500m2.

Results

Figures 3 through 12 summarize the results of the first and second rounds of sampling in plot graph format. Tables 1 to 2 are detailed summary tabulations of results for the two rounds of sampling, with referenced standards and criteria added. (Lab data sheets containing more analytical details such as standard error and mean values for each set of three trial measurements are available upon request.)

Physico-chemical Parameters

The offshore samples' water temperatures (see Fig. 3) were slightly higher (32-32.5°C at Station 2) than those of the effluent samples at the outfalls. The average value of offshore water was 30.8°C in both September 2022 and June 2023 sampling events, slightly higher than the average of 30.1°C at the outfalls.

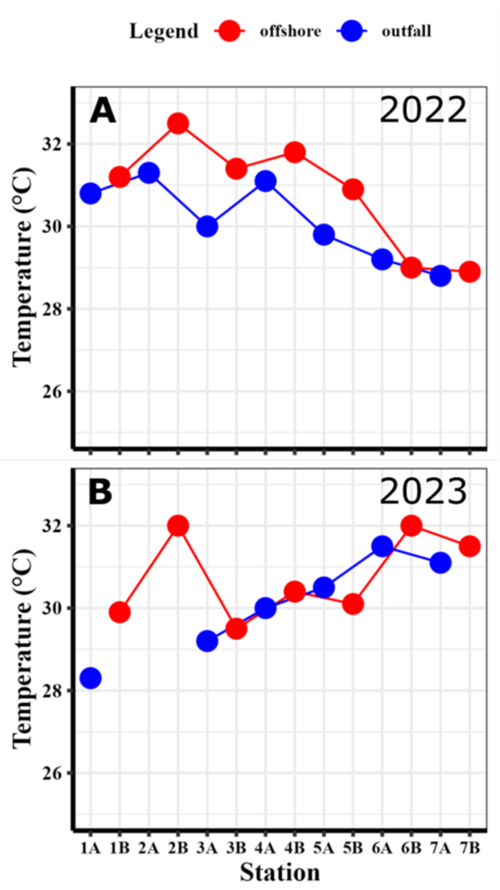

Figure 3. Water temperature readings across the sampling stations.
(blue= outfall, red= offshore sample stations).

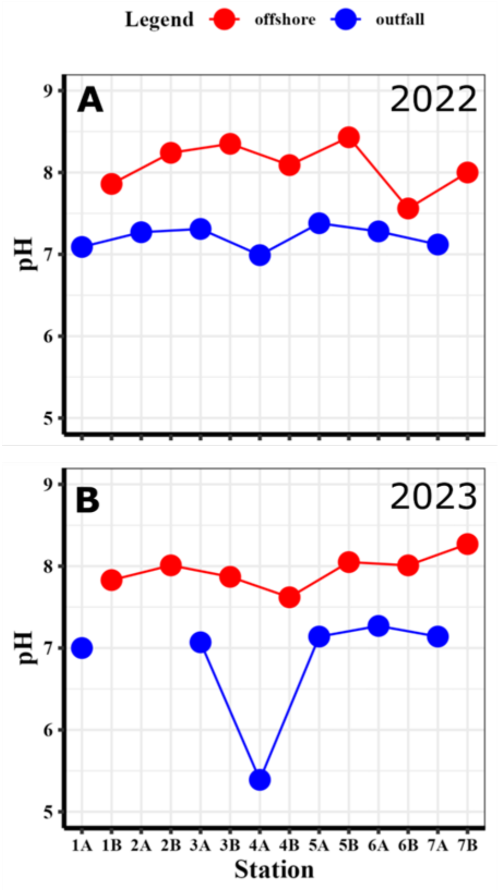

Figure 4. pH readings across the sampling stations.

The pH values (Fig. 4) of the offshore samples were typical of seawater (alkaline, with an average of 8.08 in 2022 and 7.95 in 2023, and a range of 7.56 – 8.43) while pH was lower at the outfalls (levels of 5.4 –7.4). Station 4 had the lowest pH (at 5.39), indicating acidic discharge, which in turn suggested high levels of contamination. This is supported by non-detect DO, high BOD (6.35 mg/L), high TSS (131 mg/L), high ammonia (12.6 mg NH_4-N/L), and the highest levels of bacteria (47.2 million *E. coli* colony-forming units or CFU per 100 ml, and 51.6 million enterococci CFU/100 ml).

DO concentrations (Fig. 5) were mostly lower in the outfall samples, particularly at Stations 3, 4, and 5 (≤ 0.63 mg/L), compared to that of the seawater samples (4.9 –10.16 mg/L in 2022 and 5.4 – 8.1 mg/L in 2023). Station 1 (Mojon Creek) and the outfall samples from Stations 6 and 7 had higher DO levels compared to the rest of the outfalls. This is attributable to higher flow rates and turbulence of the stream. The low DO levels at the outfall Stations 3, 4, and 5 correlate to higher levels of contamination, as indicated by the highest levels of bacteria. It should be noted that some DO results reported as "ND" indicated non-detect values, which meant that DO was not detected above the detection limit (Winkler titration method, with a detection limit of 0.06 mg O_2 per liter).

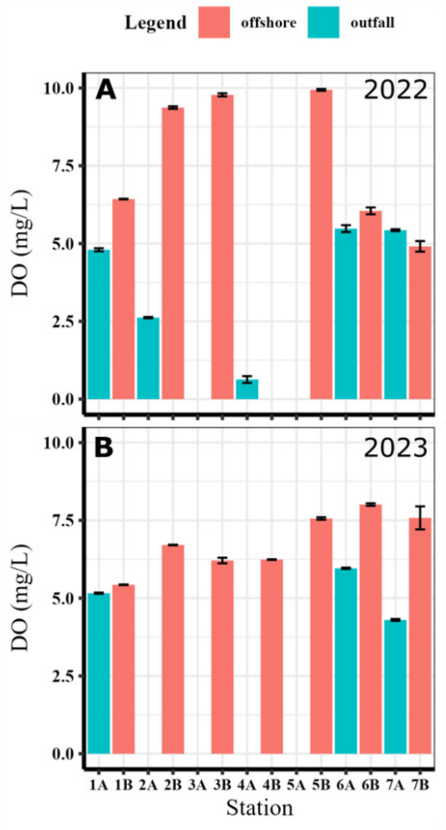

Figure 5. Dissolved oxygen readings across the sampling stations. (teal= outfall, red=offshore).

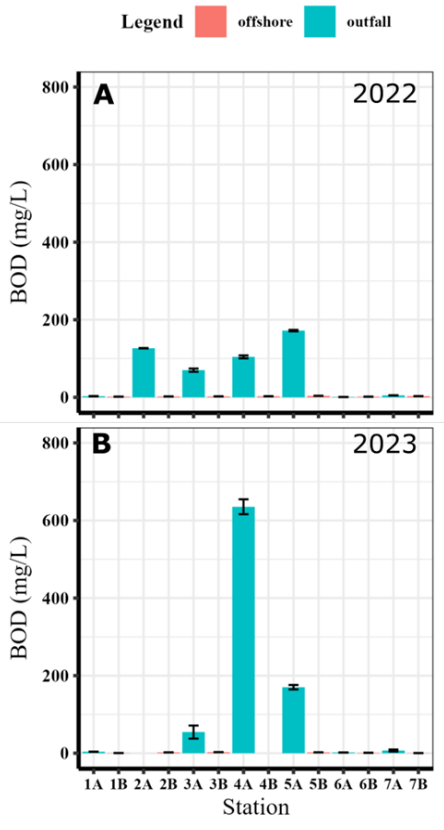

Figure 6. BOD readings across the sampling stations.

Biochemical oxygen demand (BOD) was generally higher in the outfall samples, with the highest levels detected in 2023 at Station 4 (BOD at 635.3 mg/L) and Station 5 (BOD at 170.2 mg/L). These elevated BOD levels were consistent with the low DO trends, thus indicating higher levels of contamination. The offshore samples generally had BOD below 5.0 mg/L (Fig. 6), suggesting dispersion of contamination from the outfalls.

Except for two stations (6 and 7), salinity readings (Fig. 7) at the outfalls were indicative of freshwater effluent (salinity of 0 parts per thousand, ppt). In contrast, the relatively elevated (19–20 ppt) salinity values at outfall Stations 6 and 7 (noted in both sampling rounds) may be attributable to significant saltwater intrusion into the shallow coastal groundwater and/or into the sewer lines (e.g., during the pre-sampling high tide events) at these two locations. This high salinity trend is supported by the elevated chloride (at >9,000 mg Cl/L), conductivity (≥15.93 milliSiemens per cm, mS/cm), and TDS (>16,000 mg/L) at Stations 6 and 7.

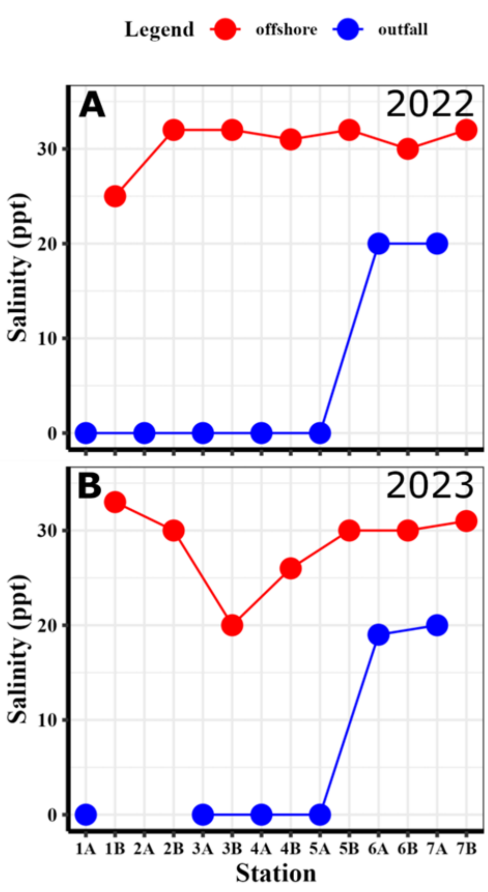

Figure 7. Salinity across the sampling stations.

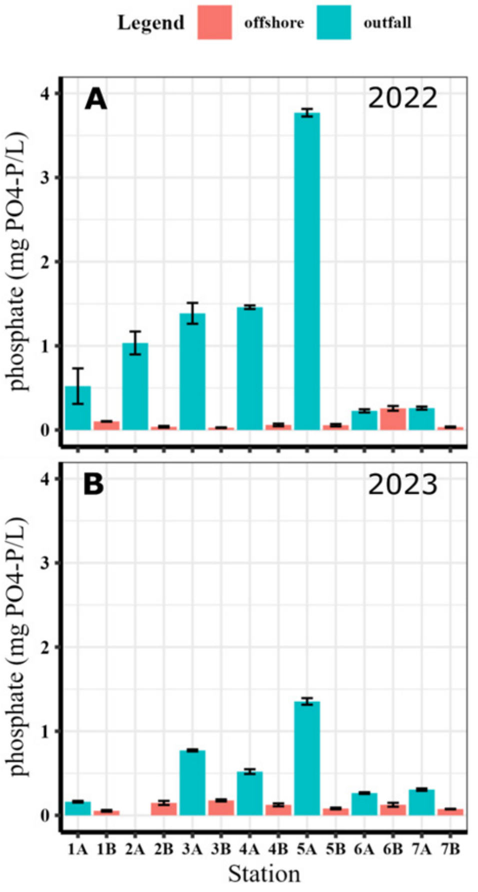

Figure 8. Phosphate concentrations across the sampling stations in 2022 (A) and 2023 (B).

Salinity readings from offshore samples were close to the typical value for seawater, 35 parts per thousand (ppt). The lower salinity values at the mouth of Mojon Creek (25 ppt at Station 1 during the 2022 sampling round) can be attributed to freshwater mixing. Stations 3 and 4 (with 20 and 26 ppt salinity values in the 2023 sampling round) also indicated significant freshwater (from the outfalls) mixing at the offshore sampling points.

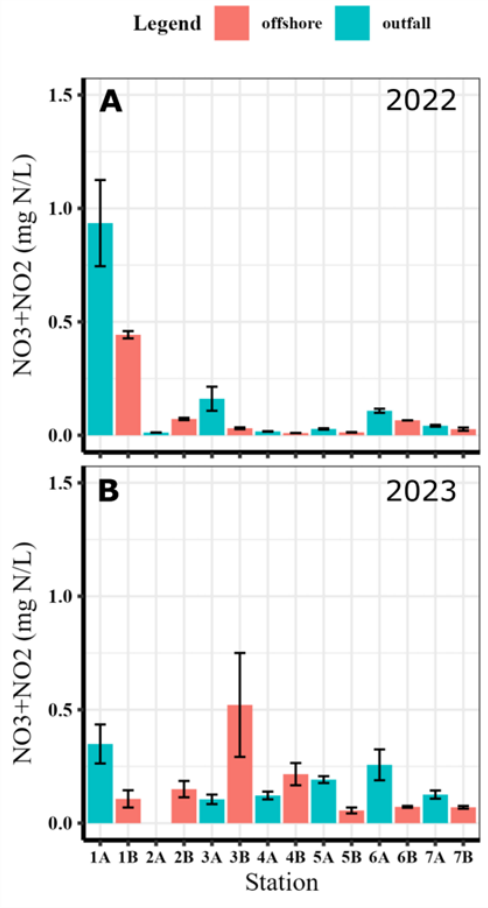

Figure 9. Total nitrogen (Nitrate+Nitrite, A-2022, B-2023) concentrations across the sampling stations.

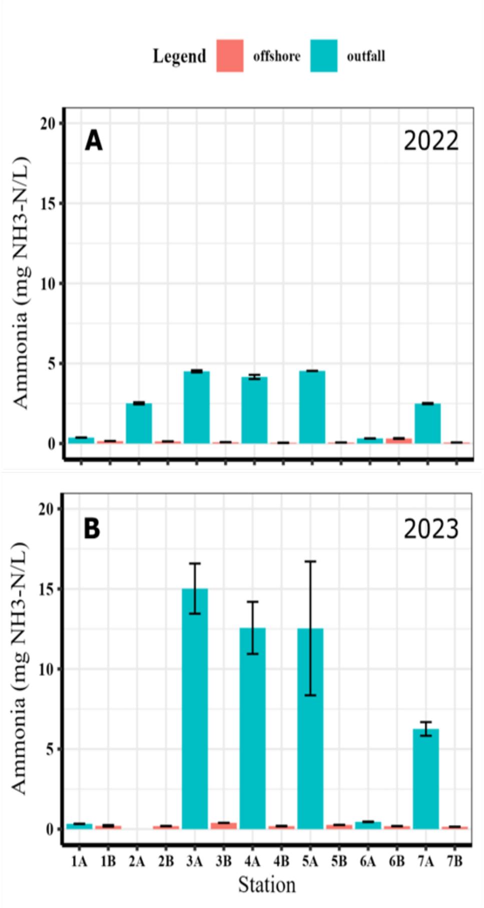

Figure 10. Ammonia (A-2022, B-2023) concentrations across the sampling stations.

The presence of phosphate (see Fig. 8) and total nitrogen (from combined nitrate and nitrite, NO_3+NO_2) (Fig. 9) in the samples suggested anthropogenic pollution due to discharge of domestic and commercial effluent, e.g., gray water or wastewater from washing and laundry activities, into the storm sewer system. (It is noted that there is no centralized municipal sewerage treatment system in the city.) During sample collection, outfall Stations 3 through 7 exhibited brownish to bluish-white and foamy discharges typical of wastewater containing sediment and detergents or soaps. All sampling results showed significant phosphate levels (ranging from 0.16 to 3.77 mg of P per liter) and total nitrate-nitrite concentrations (ranging from 0.11 to 0.94 mg of N per liter). Old and leaky septic tanks in the area may also be contributing to phosphate and nitrate-nitrite contamination of effluent. Kaczmarsky and Richardson (2011) reported the presence of elevated nitrogen and phosphorus levels in sediment and seawater samples south (from Piapi to the Dumaguete pier area) of this study area. Such contamination was correlated to coral disease infection.

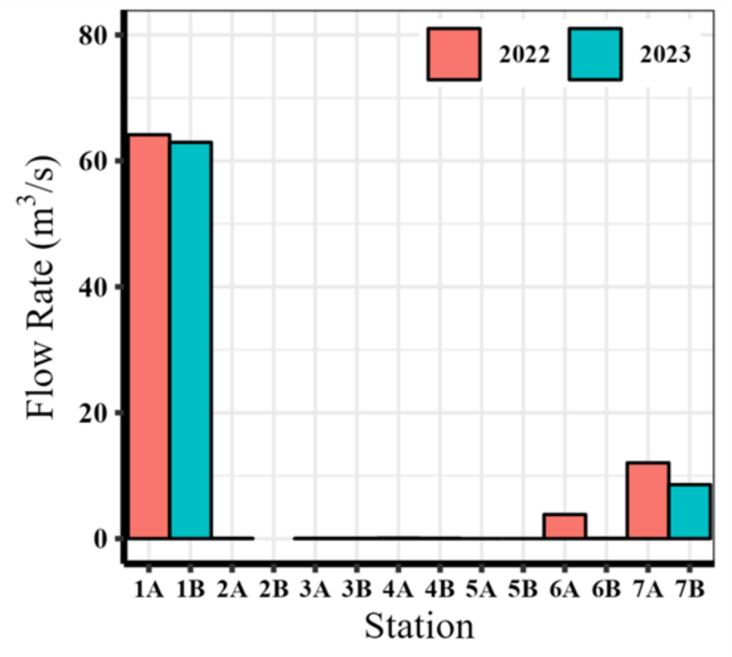

Figure 11. Water discharge rates at sewage outfalls and Mojon Creek mouth

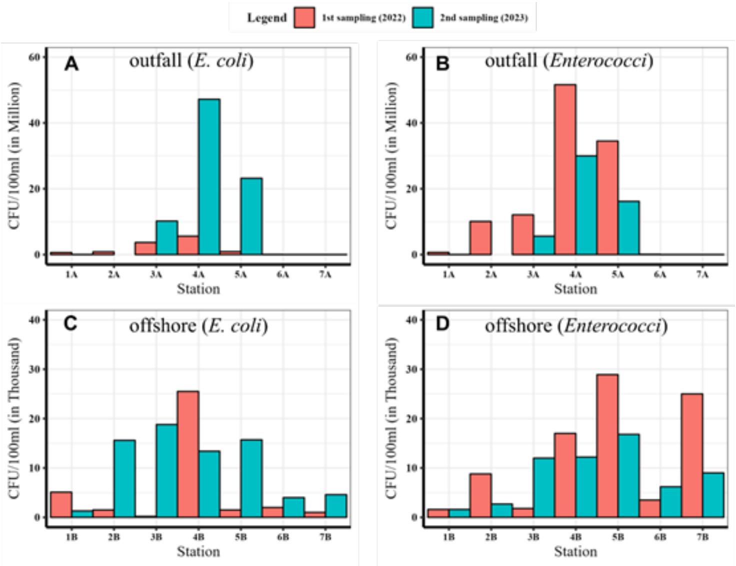

Figure 12. Bacterial colony forming units (CFU/100 ml) of *E. coli* and Enterococci from sewage outfalls (A and B) and offshore seawater samples (C and D). CFUs in outfalls in Millions/100ml and offshore sites in Thousands/100ml.

The discharges from the river mouth and outfall stations were also highly enriched in ammonia, with values (in 2022) ranging from 0.32 to 4.5 mg of ammonia-nitrogen per liter (mg NH_3-N/L). In 2023, a sharp increase was noted at outfall Stations 3, 4, and 5 (12.533 to 15.017 mg NH_3-N/L; see Fig. 10). Such difference may have been due to variability of activities responsible for ammonia discharge in this highly commercialized area, as well as the complex nature of nitrogen fixation, nitrification, and ammonia–ammonium reactions. Like phosphate contamination, such elevated ammonia levels can also be attributed to domestic and commercial wastewater discharges into the sewer system in this area.

Water discharge or flow rate (Fig. 11) was logically highest at the mouth of Mojon Creek, with a measured flow rate of 63 – 64 m^3/s. The subsequent highest flow rates (4 and 12 m^3/s) were noted at the two outfall Stations 6 and 7, respectively. Discharge at Station 6 was observed to be highly variable and occurring in pulses, as noted during the second sampling round. There appears to be an unusual correlation between high flow rates and relatively high salinity at outfall Stations 6 and 7. These conditions may be due to one or a combination of the following factors: leaky sewer pipes, high permeability of soil material, shallow water table, and saltwater intrusion (e.g., in groundwater or the sewer pipes during pre-sampling high tide). The higher flow rates at outfall Stations 6 and 7 also coincide with recent construction (including ongoing utility excavation) and the numerous restaurants, hotels, and a large condominium complex in this section of Piapi. Since the two rounds of sampling were conducted within 24 to 48 hours after a rainstorm, discharge rates are much lower during the longer periods of dry weather or between rainstorms, as noted during several random site visits in 2022 and 2023.

Bacteriological Analysis

Bacteria levels were very high across the sampling stations (Fig. 12, A–D). Mean colony forming units per 100 ml (CFU/100 ml) of *E. coli* in samples from the outfalls ranged from 30,600 to 5,600,000 in the first sampling round and 4,600 to 47,200,000 in the second sampling round, with Station 4 consistently having the highest levels. In the seawater samples, *E. coli* concentrations were notably lower than those from the outfalls, ranging from 200 to 25,500 CFU/100 ml. Such lower concentrations of *E. coli* in seawater are attributable to dispersion from the point sources (outfalls) and the typical intolerance of *E. coli* to salinity.

The enteroccoci concentrations in the outfall samples ranged from 12,000 to 51,625,000 CFU/100 ml in the first sampling round and 2,500 to 30,000,000 CFU/100 ml in the second sampling round (with highest levels at Station 4). As in the case of *E. coli*, the enteroccoci concentrations in the seawater samples were also lower than in the outfall samples, ranging from 1,600 to 28,900 CFU /100 ml and 1,600 to 16,800 CFU/100 ml in 2022 and 2023, respectively. Since enterococci are known to be salinity-tolerant bacteria (Byappanahalli et al., 2012), their significant decrease in concentration from outfall to open seawater may be attributable to dispersion and other factors that deserve further study.

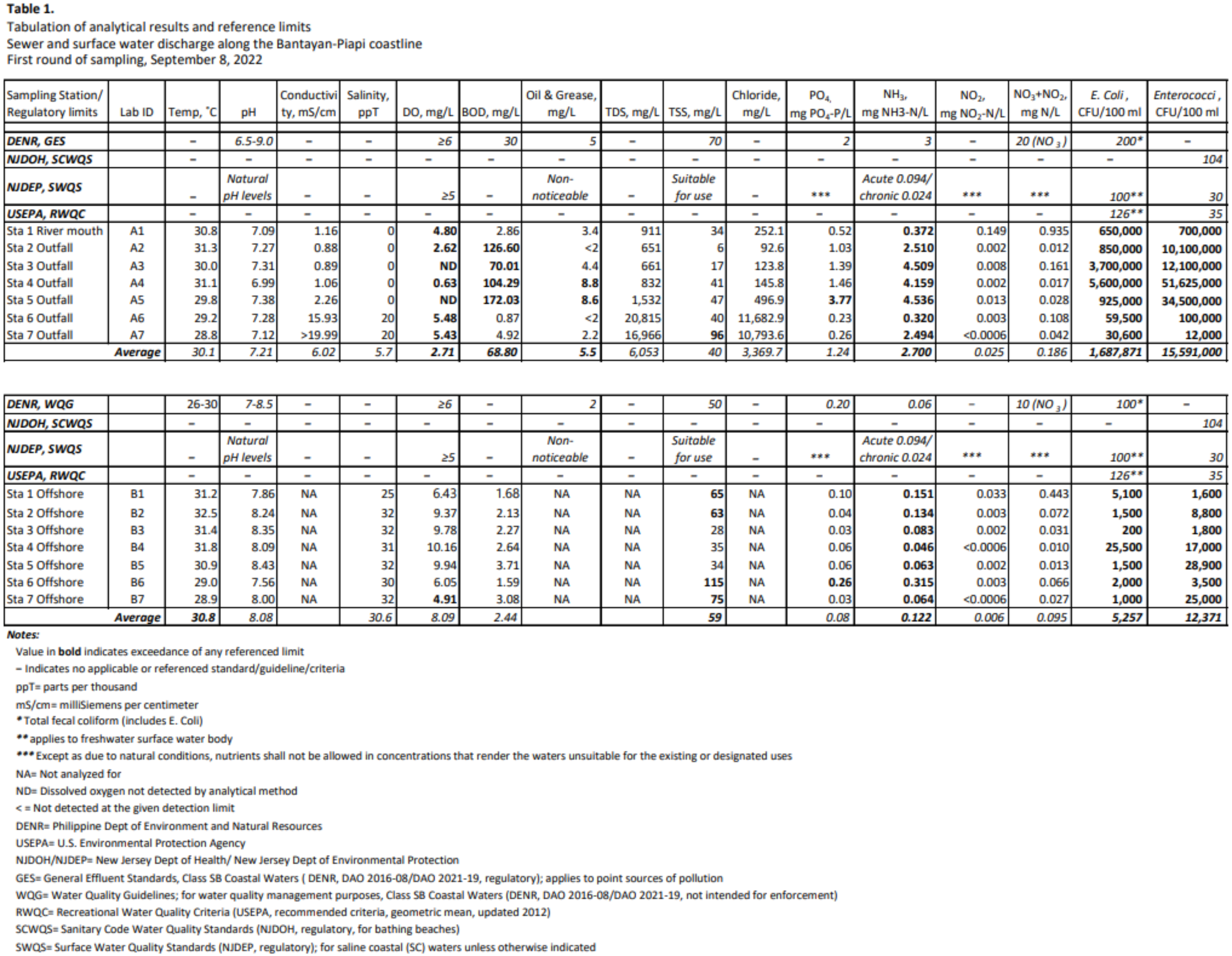

Table 1.
Tabulation of analytical results and reference limits
Sewer and surface water discharge along the Bantayan-Piapi coastline
First round of sampling, September 8, 2022

Sampling Station/ Regulatory limits	Lab ID	Temp, ˚C	pH	Conductivity, mS/cm	Salinity, ppT	DO, mg/L	BOD, mg/L	Oil & Grease, mg/L	TDS, mg/L	TSS, mg/L	Chloride, mg/L	PO_4, mg PO_4-P/L	NH_3, mg NH3-N/L	NO_2, mg NO_2-N/L	NO_3+NO_2, mg N/L	*E. Coli*, CFU/100 ml	*Enterococci*, CFU/100 ml
DENR, GES		–	*6.5-9.0*	–	–	*≥6*	*30*	*5*	–	*70*	–	*2*	*3*	–	*20 (NO_3)*	*200**	–
NJDOH, SCWQS		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	*104*
NJDEP, SWQS		–	*Natural pH levels*	–	–	*≥5*	–	*Non-noticeable*	–	*Suitable for use*	–	*****	*Acute 0.094/ chronic 0.024*	*****	*****	*100***	*30*
USEPA, RWQC		–	–	–	–	–	–	–	–	–	–	–	–	–	–	*126***	*35*
Sta 1 River mouth	A1	30.8	7.09	1.16	0	**4.80**	2.86	3.4	911	34	252.1	0.52	**0.372**	0.149	0.935	**650,000**	**700,000**
Sta 2 Outfall	A2	31.3	7.27	0.88	0	**2.62**	**126.60**	<2	651	6	92.6	1.03	**2.510**	0.002	0.012	**850,000**	**10,100,000**
Sta 3 Outfall	A3	30.0	7.31	0.89	0	**ND**	**70.01**	4.4	661	17	123.8	1.39	**4.509**	0.008	0.161	**3,700,000**	**12,100,000**
Sta 4 Outfall	A4	31.1	6.99	1.06	0	**0.63**	**104.29**	**8.8**	832	41	145.8	1.46	**4.159**	0.002	0.017	**5,600,000**	**51,625,000**
Sta 5 Outfall	A5	29.8	7.38	2.26	0	**ND**	**172.03**	**8.6**	1,532	47	496.9	**3.77**	**4.536**	0.013	0.028	**925,000**	**34,500,000**
Sta 6 Outfall	A6	29.2	7.28	15.93	20	**5.48**	0.87	<2	20,815	40	11,682.9	0.23	**0.320**	0.003	0.108	**59,500**	**100,000**
Sta 7 Outfall	A7	28.8	7.12	>19.99	20	**5.43**	4.92	2.2	16,966	**96**	10,793.6	0.26	**2.494**	<0.0006	0.042	**30,600**	**12,000**
	Average	*30.1*	*7.21*	*6.02*	*5.7*	***2.71***	***68.80***	***5.5***	*6,053*	*40*	*3,369.7*	*1.24*	***2.700***	*0.025*	*0.186*	***1,687,871***	***15,591,000***
DENR, WQG		26-30	*7-8.5*	–	–	*≥6*	–	*2*	–	*50*	–	*0.20*	*0.06*	–	*10 (NO_3)*	*100**	–
NJDOH, SCWQS		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	*104*
NJDEP, SWQS		–	*Natural pH levels*	–	–	*≥5*	–	*Non-noticeable*	–	*Suitable for use*	–	*****	*Acute 0.094/ chronic 0.024*	*****	*****	*100***	*30*
USEPA, RWQC		–	–	–	–	–	–	–	–	–	–	–	–	–	–	*126***	*35*
Sta 1 Offshore	B1	31.2	7.86	NA	25	6.43	1.68	NA	NA	**65**	NA	0.10	**0.151**	0.033	0.443	**5,100**	**1,600**
Sta 2 Offshore	B2	32.5	8.24	NA	32	9.37	2.13	NA	NA	**63**	NA	0.04	**0.134**	0.003	0.072	**1,500**	**8,800**
Sta 3 Offshore	B3	31.4	8.35	NA	32	9.78	2.27	NA	NA	28	NA	0.03	**0.083**	0.002	0.031	**200**	**1,800**
Sta 4 Offshore	B4	31.8	8.09	NA	31	10.16	2.64	NA	NA	35	NA	0.06	**0.046**	<0.0006	0.010	**25,500**	**17,000**
Sta 5 Offshore	B5	30.9	8.43	NA	32	9.94	3.71	NA	NA	34	NA	0.06	**0.063**	0.002	0.013	**1,500**	**28,900**
Sta 6 Offshore	B6	29.0	7.56	NA	30	6.05	1.59	NA	NA	**115**	NA	**0.26**	**0.315**	0.003	0.066	**2,000**	**3,500**
Sta 7 Offshore	B7	28.9	8.00	NA	32	**4.91**	3.08	NA	NA	**75**	NA	0.03	**0.064**	<0.0006	0.027	**1,000**	**25,000**
	Average	***30.8***	*8.08*		*30.6*	*8.09*	*2.44*			***59***		*0.08*	***0.122***	*0.006*	*0.095*	***5,257***	***12,371***

Notes:

Value in **bold** indicates exceedance of any referenced limit

– Indicates no applicable or referenced standard/guideline/criteria

ppT= parts per thousand

mS/cm= milliSiemens per centimeter

*Total fecal coliform (includes E. Coli)

**applies to freshwater surface water body

***Except as due to natural conditions, nutrients shall not be allowed in concentrations that render the waters unsuitable for the existing or designated uses

NA= Not analyzed for

ND= Dissolved oxygen not detected by analytical method

< = Not detected at the given detection limit

DENR= Philippine Dept of Environment and Natural Resources

USEPA= U.S. Environmental Protection Agency

NJDOH/NJDEP= New Jersey Dept of Health/ New Jersey Dept of Environmental Protection

GES= General Effluent Standards, Class SB Coastal Waters (DENR, DAO 2016-08/DAO 2021-19, regulatory); applies to point sources of pollution

WQG= Water Quality Guidelines; for water quality management purposes, Class SB Coastal Waters (DENR, DAO 2016-08/DAO 2021-19, not intended for enforcement)

RWQC= Recreational Water Quality Criteria (USEPA, recommended criteria, geometric mean, updated 2012)

SCWQS= Sanitary Code Water Quality Standards (NJDOH, regulatory, for bathing beaches)

SWQS= Surface Water Quality Standards (NJDEP, regulatory); for saline coastal (SC) waters unless otherwise indicated

Table 2.
Tabulation of analytical results and reference limits
Sewer and surface water discharge along the Bantayan-Piapi coastline
Second round sampling, June 27, 2023

Sampling Station/ Regulatory limits	Lab ID	Temp, ˚C	pH	Conductivity, mS/cm	Salinity, ppT	DO, mg/L	BOD, mg/L	Oil & Grease, mg/L	TDS, mg/L	TSS, mg/L	Chloride, mg/L	PO_4, mg PO_4-P/L	NH_3, mg NH_3-N/L	NO_2, mg NO_2-N/L	NO_3+NO_2, mg N/L	*E. Coli*, CFU/100 ml	*Enterococci*, CFU/100 ml
DENR, GES		–	*6.5-9.0*	–	–	*≥6*	*30*	*5*	–	*70*	–	*2*	*3*	–	*20 (NO_3)*	*200**	–
NJDOH, SCWQS		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	*104*
NJDEP, SWQS		–	*Natural pH levels*	–	–	*≥5*	–	*Non-noticeable*	–	*Suitable for use*	–	***	*Acute 0.094/ chronic 0.024*	***	***	*100***	*30*
USEPA, RWQC		–	–	–	–	–	–	–	–	–	–	–	–	–	–	*126***	*35*
Sta 1 River mouth	A1	28.3	7.00	0.4	0	**5.2**	3.8	NA	323	31	23.4	0.16	**0.329**	0.150	0.349	**42,600**	**22,800**
Sta 2 Outfall	A2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sta 3 Outfall	A3	29.2	7.07	0.7	0	**ND**	**54.6**	NA	423	12	78.3	0.77	**15.017**	0.023	0.105	**10,200,000**	**5,600,000**
Sta 4 Outfall	A4	30.0	**5.39**	1.1	0	**ND**	**635.3**	NA	885	**131**	163.8	0.52	**12.566**	0.042	0.122	**47,200,000**	**30,000,000**
Sta 5 Outfall	A5	30.5	7.14	1.0	0	**ND**	**170.2**	NA	443	60	75.3	1.35	**12.533**	0.028	0.192	**23,200,000**	**16,200,000**
Sta 6 Outfall	A6	31.5	7.27	>20	19	**6.0**	1.9	NA	17,933	15	9,887.1	0.27	**0.455**	0.041	0.257	**4,600**	**2,500**
Sta 7 Outfall	A7	31.1	7.14	19.9	20	**4.3**	6.9	NA	20,237	56	9,510.8	0.31	**6.256**	0.041	0.126	**41,500**	**14,000**
	Average	*30.1*	*6.84*	*7.2*	*6.5*	***2.6***	***145.4***		*6,707*	*51*	*3,289.8*	*0.56*	***7.859***	*0.054*	*0.192*	***13,448,117***	***8,639,883***
DENR, WQG		26-30	*7-8.5*	–	–	*≥6*	–	*2*	–	*50*	–	*0.20*	*0.06*	–	*10 (NO_3)*	*100**	–
NJDOH, SCWQS		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	*104*
NJDEP, SWQS		–	*Natural pH levels*	–	–	*≥5*	–	*Non-noticeable*	–	*Suitable for use*	–	***	*Acute 0.094/ chronic 0.024*	***	***	*100***	*30*
USEPA, RWQC		–	–	–	–	–	–	–	–	–	–	–	–	–	–	*126***	*35*
Sta 1 Offshore	B1	29.9	7.83	NA	33	**5.4**	0.6	NA	NA	34	NA	0.05	**0.205**	0.002	0.107	**1,300**	**1,600**
Sta 2 Offshore	B2	32.0	8.01	NA	30	6.7	2.2	NA	NA	38	NA	0.15	**0.190**	0.014	0.150	**15,600**	**2,700**
Sta 3 Offshore	B3	29.5	7.87	NA	20	6.2	2.7	NA	NA	21	NA	0.18	**0.390**	0.021	0.521	**18,800**	**12,000**
Sta 4 Offshore	B4	30.4	7.62	NA	26	6.2	No data	NA	NA	21	NA	0.13	**0.189**	0.011	0.216	**13,400**	**12,200**
Sta 5 Offshore	B5	30.1	8.05	NA	30	7.6	2.2	NA	NA	27	NA	0.08	**0.263**	0.005	0.056	**15,700**	**16,800**
Sta 6 Offshore	B6	32.0	8.01	NA	30	8.0	1.0	NA	NA	33	NA	0.13	**0.186**	0.005	0.072	**4,000**	**6,200**
Sta 7 Offshore	B7	31.5	8.27	NA	31	7.6	0.4	NA	NA	**75**	NA	0.08	**0.147**	0.003	0.070	**4,600**	**9,000**
	Average	***30.8***	*7.95*		*29*	*6.8*	*1.5*			*36*		*0.11*	***0.224***	*0.009*	*0.170*	***10,486***	***8,643***

Notes:

Value in **bold** indicates exceedance of any referenced limit
– Indicates no applicable or referenced standard/guideline/criteria
ppT= parts per thousand
mS/cm= milliSiemens per centimeter
*Total fecal coliform (includes E. Coli)
**applies to freshwater surface water
***Except as due to natural conditions, nutrients shall not be allowed in concentrations that render the waters unsuitable for the existing or designated uses
NS= No sample collected
NA= Not analyzed for
ND= Dissolved oxygen not detected by the analytical method
<= Not detected at the given detection limit
DENR= Philippine Dept of Environment and Natural Resources
USEPA= U.S. Environmental Protection Agency
NJDOH/NJDEP= New Jersey Dept of Health/ New Jersey Dept of Environmental Protection
GES= General Effluent Standards, Class SB Coastal Waters (DENR, DAO 2016-08/DAO 2021-19, regulatory); applies to point sources of pollution
WQG= Water Quality Guidelines; for water quality management purposes, Class SB Coastal Waters (DENR, DAO 2016-08/DAO 2021-19, not intended for enforcement)
RWQC= Recreational Water Quality Criteria (USEPA, recommended criteria, geometric mean, updated 2012)
SCWQS= Sanitary Code Water Quality Standards (NJDOH, regulatory, for bathing beaches)
SWQS= Surface Water Quality Standards (NJDEP, regulatory); for saline coastal (SC) waters unless otherwise indicated

Fish Abundance and Diversity

Due to poor visibility in the offshore waters during the 2023 sampling event, an underwater survey was conducted only in 2022. About 14 fish species (7 families) were documented in the adjacent (nearshore) seagrass beds and coral patches east of the Piapi Beach area. (See Appendix for photos.) Fish biomass and population density were notably low at 1.29±0.5(SE) $kg/500m^2$ and 152±82(SE) $individuals/500m^2$, respectively, based on the transects established in the seagrass beds. The most likely cause of such low biomass and fish density is pollution of the shallow marine waters, including microplastic ingestion. Similarly, in the shallow seagrass beds of the Banilad MPA, fish biomass was also very low at 1.3 $kg/500m^2$ (SUAKCREM, unpublished data). The deeper portions of the area (i.e., coral reefs) still harbor a considerable number of fish diversity and higher biomass (especially the Bantayan MPA), which in 2012 survey had an estimated total biomass of ~3.43 $kg/500m^2$ (SUAKCREM, unpublished report). Still, this figure can be considered lower than other well-protected and unpolluted seagrass beds. For example, based on a survey conducted by SUAKCREM in 2018, the shallow seagrass beds inside the unpolluted cove in Cantaan, Camiguin Island, had an estimated fish biomass of 17 $kg/500m^2$.

Another notable observation was the presence of schooling juveniles of rabbitfishes (e.g., Siganus spinus and S. fuscescens; see photos, Fig. 12K and 12R in the Appendix) in the study area. Rabbitfishes have been noted to be tolerant to changes in temperature and salinity (Seale & Ellis, 2019). Therefore, they may be adapting to pollution in the study area where elevated parameters such as temperature, TSS, ammonia, and bacteria were found.

Discussion

Tables 3 and 4 summarize the analytical results of the first (2022) and second (2023) rounds of sampling. The values were compared to various regulatory limits that include standards (enforceable) and criteria and guidelines (non-enforceable). These were obtained from the Philippine Department of Environment and Natural Resources (DENR) regulations (standards and guidelines), U.S. Environmental Protection Agency (USEPA) regulations (recommended criteria only), and standards used in the state of New Jersey (New Jersey Department of Health, DOH, and New Jersey Department of Environmental Protection, NJDEP) that apply to surface water and bathing beaches in the state. Since the USEPA only provides recommendations for criteria in recreational waters, the New Jersey standards are presented herein considering that this state hosts numerous public beaches which are visited by tens of millions (48 million in 2018) of beachgoers each summer (Petenko, 2019) and are strictly monitored by the state for bacteria levels. Daily monitoring by the State of New Jersey occasionally results in the temporary closure of beaches whenever the applicable standards are exceeded.

Only the DENR standards might be enforceable in the study area. The DENR guidelines are recommendations. The listed limits of the USEPA and the State of New Jersey are not enforceable in the study area. However, they are considered the best alternative standards and criteria to evaluate the parameters or contaminants vis-à-vis the protection of human health and aquatic organisms as scientifically established by such institutions.

The following explains the referenced limits used in this study and listed in the tabulations of sampling results (Tables 1 and 2):

- GES= General Effluent Standards; Class SB waters (DENR, DAO 2016-08/DAO 2021-19, regulatory and enforceable); applies to point sources of pollution impacting Class SB marine waters (for protection of fisheries, tourism, recreational activities)
- WQG= Water Quality Guidelines; for water quality management purposes; protection of Class SB marine waters; (DENR, DAO 2016-08/DAO 2021-19); recommendations only, not intended for enforcement
- RWQC= Recreational Water Quality Criteria (USEPA, recommended criteria, geometric mean, updated 2012); applies to human health protection in coastal and non-coastal recreational areas
- SCWQS= Sanitary Code Water Quality Standard (NJDOH, regulatory; for bathing beaches)
- SWQS= Surface Water Quality Standards (NJDEP, regulatory) for saline coastal (SC) waters; protection of shellfish, ecology, and human health in recreational activities

Temperature and pH

The NJDEP-SWQS specifies “No thermal alterations which would cause temperatures to exceed 26.7 degrees Celsius (80°F) Summer seasonal average”; however, such standard for temperate locations like much of the U.S. would not apply in tropical Philippines where natural temperatures are higher. The DENR-WQG is listed as ranging from 26 to 30°C, but further states: “The natural background temperature as determined by EMB shall prevail if the temperature is lower or higher than the WQG; provided that the maximum increase is only up to 10 percent and that it will not cause any risk to human health and the environment.” The average offshore temperature readings at the sampling stations were consistently 30.8ºC in 2022 and 2023. This slightly exceeds the maximum value of the DENR-WQG (30ºC) and suggests climate change. However, seasonal variability may also be a factor in this case; thus, a long-term study would be necessary to address such postulation.

Except for one sample, all the measured pH levels from the outfalls and the offshore seawater were within the applicable DENR-GES (pH at 6.5 to 9) and WQG (pH at 7.0 to 8.5). The exception was the sample from Outfall Station 4, which had a pH of 5.39, indicating slightly acidic conditions in June 2023. Such exceedance was associated with significant contamination, as supported by the sample’s highest BOD and bacteria levels among all the samples.

Conductivity and Salinity

No applicable standards and criteria were noted for conductivity and salinity. The elevated levels of these parameters at outfall Stations 6 and 7 were related to elevated chloride and TDS levels. Conductivity at these two stations ranged from 15.93 to more than 19.99 milliSiemens per centimeter (mS/cm), while conductivity at the other stations ranged only from 0.42 to 2.26 mS/cm. Salinity at Stations 6 and 7 was either 19 or 20 parts per thousand (ppt) in the two sampling rounds, while the other 5 stations registered zero salinity. (Typical seawater has a salinity of around 35 ppt.) The data suggests the influence of saltwater intrusion into the shallow groundwater and sewer pipes at Stations 6 and 7 (e.g., leaky pipes or entrance of salt water into the pipes and permeable soils during pre-sampling high tides).

Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD)

All DO results for the outfall samples failed the DENR standard since the measured DO values, which ranged from non-detect (ND) to 5.96 mg/L, were low during both rounds of sampling. The DENR specifies a GES (standard) of ≥ 6 mg/L (minimum), while the NJDEP has a SWQS of ≥ 5 mg/L (minimum). Such low DO values in the samples from the study area indicated significant contamination of the effluent.

On the other hand, all offshore (seawater) samples except those from two stations (Station 7, DO=4.91 mg/L in 2022 and Station 1, DO=5.43 mg/L in 2023) had acceptable values ranging from 6.21 to 8.43 mg/L. Such levels complied with the DENR standard of 6 mg/L (minimum limit). The low DO at Station 7 was likely due to the relatively high concentration of enterococci, but the possible cause for lower DO at Station 1 is unknown (bacteria and nutrient levels were relatively low); it is possible that elevated oil and grease, which were not analyzed for, may have been present in the sample and had influenced such lower DO value.

No standards or criteria were available to compare the BOD levels in the offshore (seawater) samples. Outfall samples from Stations 2, 3, 4, and 5 exhibited elevated BOD levels that failed the DENR-GES of 30 mg/L. BOD concentrations ranged from 54.55 to 635.30 mg/L. The low DO and high BOD combination further indicated the presence of contamination (i.e., consumption of oxygen by bacteria and nutrients) in the effluent.

Oil and Grease, and Total Dissolved Solids (TDS)

Only one round of sampling for oil and grease was performed for this study due to issues with the unavailability of lab materials. Analysis was performed only on the first round of samples from the outfall stations. The analytical results were compared to the DENR-GES of 5 mg/L for oil-and-grease (The NJDEP-SWQS only specifies a qualitative standard of “non-noticeable.”) The samples from Station 4 and Station 5 had concentrations of 8.8 and 8.6 mg/L, respectively, which were above the DENR-GES standard. This indicated that oil and grease contaminants were contributing to the pollution of the study area. The other five samples had concentrations that ranged from <2 to 4.4 mg/L, below the numerical standard of the DENR. Oil and grease components include waste cooking oils and petroleum oils and consist of the major types of compounds: oils, fats, and waxes. These, in turn, include many types of chemicals, including those occurring in petroleum-based waste oils or used oils. Waste or used oils may contain toxic benzene, polynuclear aromatic hydrocarbons, PCBs, and heavy metals (USEPA, 2018; Lulek,1998; CalEPA, 2021).

Only the outfall samples were analyzed for TDS during the two rounds of sampling. No standards or criteria were available for regulatory comparison of the results. However, a clear trend was noted from the results: two stations (6 and 7) had TDS concentrations (ranging from 16,966 to 20,815 mg/L) that were at least an order of magnitude higher than the rest. The results for conductivity, DO, salinity, chloride, and flow rates further differentiated the physico-chemical and hydrologic conditions at Stations 6 and 7 from the rest of the sampling stations.

Total Suspended Solids (TSS) and Chloride

The DENR-GES (applicable to point sources, e.g., the outfall sampling points in the study area) for TSS is 70 mg/L, while the WQG (applicable to the offshore samples) for TSS is 50 mg/L. The NJDEP-SWQS has a qualitative (narrative) standard for TSS in surface water: it must be suitable for various uses of the coastal waters, including tourism, recreation, ecology, and fisheries.

The results for the first sampling event (2022) showed that only one station (7) had a TSS level (96 mg/L) exceeding the DENR-GES of 70 mg/L. The offshore samples, however, indicated that four stations (1, 2, 6, and 7) had TSS (ranging from 63 to 115 mg/L) exceeding the DENR-WQG of 50 mg/L. The analytical results for the 2023 outfall sample from Station 4 indicated a TSS level of 131 mg/L, which exceeded the DENR-GES of 70 mg/L. The offshore sample from Station 7 had TSS at 75 mg/L, which exceeded the DENR-WQG by 50 mg/L. TSS was high at the offshore sampling point of Station 1 (Mojon Creek) and the offshore sampling points for Stations 2, 6, and 7. High TSS levels at the mouth of Mojon Creek are understandably due to turbidity and the suspended load carried by the creek (see photo in Fig. 2A). The TSS levels at the offshore sampling points may be due to the combination of suspended solids from sewage and from sediments associated with natural beach processes. Further study is needed to distinguish the sources of such suspended particles.

Due to the saline nature of the coastal waters in the study area, there are no applicable regulatory limits for chloride. The analytical results for the outfall samples indicated higher chloride levels (ranging from 9,510.8 to 11,682.9 mg/L) at Stations 6 and 7, with concentrations that were two orders of magnitude higher than those from the other stations (chloride levels ranging from 23.4 to 496.93 mg/L). As discussed in the previous sections above, other parameters at Stations 6 and 7, including salinity, DO, TDS, and flow rates, suggested different physico-chemical and hydrologic conditions compared to the other sampling stations. Those conditions may partly be related to saltwater intrusion (into the soils and pipes) and the high permeability of soils at those locations.

Phosphate

The DENR-GES for phosphate is 2 mg of phosphate-phosphorous per liter (mg PO_4-P/L), while the DENR-WQG is 0.20 mg PO_4-P/L. Only minor exceedance was indicated by the sampling results. In the first sampling event (2022), Station 5 had 3.77 mg PO_4-P/L in the outfall effluent, exceeding the DENR-GES. Meanwhile, Station 6 had 0.26 mg PO_4-P/L in the offshore seawater sample, slightly exceeding the DENR-WQG. All other phosphate results were below the DENR limits. No exceedances were noted in the second round of sampling (2023). Elevated phosphate levels in sewer and surface water are typically attributable to contamination from domestic and commercial wastewater (e.g., waste food, detergents, and soaps).

Ammonia, Nitrate, and Nitrite

Ammonia, nitrate, and nitrite are common nutrients in polluted waters and were all detected in the samples collected from the study area. The DENR-GES for ammonia at point sources is 3 mg of ammonia-nitrogen per liter (mg NH_3-N/L). The DENR-WQG for ammonia is a low 0.06 mg NH_3-N/L. For further comparison to international limits, the NJDEP-SWQS for ammonia consists of acute (0.094 mg NH_3-N/L) and chronic (0.024 mg NH_3-N/L) standards, which consider the protection of aquatic organisms.

The analytical results for the study area show that all outfall sampling results from the two sampling rounds exceeded the DENR-WQG and the NJDEP-SWQS for ammonia. The ammonia levels ranged from 0.32 to 15.02 mg NH_3-N/L. Furthermore, outfall Stations 3, 4, 5, and 7 had ammonia levels that exceeded the DENR-GES of 3 mg NH_3-N/L during at least one sampling event. For the offshore samples, concentrations ranged from 0.046 to 0.39 mg NH_3-N/L. All offshore samples exceeded the NJDEP-SWQS (acute/chronic effects) of 0.094/0.024 mg NH_3-N/L. And the DENR-WQG of 0.06 mg NH_3-N/L during at least one sampling event. All this data suggests that ammonia contamination in the outfall effluent and offshore waters is a concern for toxicity to marine organisms. Ammonia is a well-known and common contaminant in the environment, originating from sewage, cleaning compounds, decomposing organic matter, animal wastes, fertilizers, microbial activity, etc.

No applicable standards or criteria are available for nitrite (NO_2) concentrations. The DENR's WQG and GES for nitrate (NO_3) are 10 and 20 mg N/L, respectively. No sample from the study area exceeded these limits. Nitrite (NO_2) and nitrate (NO_3) were detected in the outfall and offshore sampling points samples. NO_2 concentrations ranged from 0.002 to 0.150 mg of nitrite-nitrogen per liter (mg NO_2-N/L). NO_3+NO_2 concentrations ranged from 0.012 to 0.935 mg of total nitrogen per liter (NO_3+NO_2 mg

N/L). It can be noted that the highest levels of nitrate and nitrite were detected at Station 1 (mouth of Mojon Creek). This is consistent with the creek's higher flow rate and length than the sewer lines associated with the other sampling stations (outfalls). Nitrogen compounds as contaminants have numerous upstream potential sources (e.g., domestic and agricultural wastewaters, leaking septic tanks and sewer pipes, gray water discharge into ditches and creeks, golf courses, and agricultural surface runoff and groundwater discharge) contributing to Mojon Creek contamination as it makes its way toward Silliman Beach.

E. coli and Enterococci Bacteria

Fecal contaminants are responsible for over 150 million cases annually of gastrointestinal and respiratory illnesses in coastal bathers and beachgoers around the world. Epidemiological studies concluded that E. coli and enterococci can be considered “indicator bacteria” for monitoring fresh and marine waters to protect human health (Halliday & Gast, 2011). When present at high levels in polluted waters, these fecal bacteria may cause illnesses. The elderly, children and those with weakened immune systems are at higher risk (Massachusetts Department of Health, 2024). The following are typical symptoms of illnesses:

- Gastrointestinal symptoms – nausea, vomiting, diarrhea, and abdominal pain
- Respiratory symptoms – sore throat, cough, runny nose, and sneezing
- Dermatological symptoms – skin rash and itching
- Eye and ear symptoms – irritation, earache, itching
- Flu-like symptoms – fever and chills

Although sandy media was not sampled for this study, beach sands under certain conditions favor the growth of enterococci bacteria (Yamahara et al., 2009) and, therefore, pose health risks for beachgoers in contact with the sand. This includes the ubiquitous pet dogs that commonly accompany human beachgoers at Silliman Beach.

For this study area in Bantayan and Piapi, the analytical results for *E. coli* and enterococci indicated extremely high pollution levels at the outfall and offshore sampling points. The DENR’s GES and WQG for total fecal coliform (including *E. coli*) are 200 colony-forming units per 100 ml (CFU/100 ml) and 100 CFU/100 ml, respectively. The USEPA recommends an RWQC for *E. coli* (126 CFU/100 ml) in freshwater, which differs from that of enterococci (35 CFU/100 ml) in either freshwater or marine water. Due to the ability of enterococci to tolerate saline water (Byappanahalli et al., 2012), New Jersey (as well as many other coastal states and other international regulatory agencies) specifies the monitoring of coastal waters and beaches for enterococci, with a Sanitary Code-Water Quality Standard of 104 CFU/100 ml and a 30-day geometric mean (GM) limit of 30 CFU/100 ml (which is also the NJDEP's Surface Water Quality Standard for saline coastal waters).

The *E. coli* results for the outfall samples in both the first and second rounds of sampling exceeded all the referenced standards and criteria and ranged from 4,600 to 47,200,000 CFU/100 ml. Compared to the regulatory (GES) and recommended (WQG) limits of the DENR, the highest *E. coli* concentrations detected in Stations 3, 4, and 5 were five orders of magnitude higher. The *E. coli* concentrations in the offshore samples were lower (ranging from 200 to 25,500 CFU/100 ml) as might be expected for this saline-intolerant bacterium, but all results of the first and second sampling rounds still exceeded the referenced standards and criteria (except for that of Station 3 which had the lowest *E. coli* concentration of 200 CFU/100 ml).

All enterococci results for the outfall samples in both the first and second rounds of sampling also exceeded the referenced standards and criteria and ranged from 2,500 to 51,625,000 CFU/100 ml, or up to five orders of magnitude higher. All the offshore samples in the first and second rounds of sampling had lower levels than those of the outfall samples, but they greatly exceeded the referenced standards and criteria (by one to twoorders of magnitude). These seawater samples had enterococci concentrations ranging from 1,600 to 28,900 CFU/100 ml. *E. coli* in the study area appears unusually tolerant to saline waters. Further studies that consider spatial and temporal variability and comparisons of the survivability of enterococci versus *E. coli* in seawater might shed light on these two types of bacteria.

Impact of Pollution on Fish Population and Biomass

This study focused on sewer-discharge pollution by bacteria and physico-chemical parameters including nutrient pollutants, and their impact on human health and marine organisms. Evaluation was based on established standards and recommended effluent and surface water criteria. The impact on fish biomass and population density was also conducted as a supplementary part of the project. This included microplastic quantification in the fish gut (discussed in the next section below).

Nitrogen contamination (e.g., from elevated ammonia levels) in the study area is most likely a significant cause of low or decreasing fish biomass; however, a long-term study would be needed to obtain data on seasonal variability. Ammonia can cause significant fish mortalities as they actively absorb the chemical through their gills (Stotton, 2023). Ammonia toxicity to fish has been documented and widely studied (Eddy, 1999). In West Hawaii, the impact of nitrogen compounds in the marine environment from sewage pollution was found to cause the most negative impact (among other impacts) on fish biomass, based on a 10-year study on pollution sources and fish biomass (Foo et al., 2021). Their study found an overall fish biomass decrease of 45% (with more than 50% for certain types of fish) in polluted waters due to nitrogen contamination. Nitrogen sources in their study included golf courses and land-based sewer discharges. It is well established that excess nitrogen and phosphorous in water bodies can lead to excessive growth of algae, which, when it dies, decays and uses up valuable oxygen. Algae also competes with seagrasses for light, which leads to the loss of seagrasses (further depleting a food source for fish) and leading to illness and death of fish (NOAA, 2024; EPA, 2024).

TSS is another parameter likely impacting fish population and biomass in the study area. The average TSS in offshore samples was 59.3 mg/L in 2022, above the DENR-WQG value of 50 mg/L. TSS is an indication of water turbidity and pollution. Such impact on water quality may result in physiological and behavioral effects, including disruptions in migrations and spawning, movement patterns, disease susceptibility, growth and development, reduced hatching success, and death. TSS impact on fish depends on other variables, including fish species, temperature, duration and frequency of exposure, and sediment type (Kjelland et al., 2015). A long-term study of TSS and turbidity and a few other parameters is recommended in the study area better to understand their impact on the fish population and biomass.

Bacteria (*E. coli* and enterococci) levels detected in the study area were extremely high at the offshore sampling stations and orders of magnitude higher at the outfalls. Such contamination is most likely a significant factor in the low fish population and biomass noted in the study area. Kumari (2020) reports on bacterial diseases caused by several bacteria types in marine fishes, including enterococci. Bacterial diseases are commonly associated with organic pollutants and reduced DO in the water. Symptoms and illnesses in fish included weakening natural resistance to environmental stress, columnaris infection, vibriosi infection, flexibacteriosis of the gills, etc. Tenacibaculosis is an ulcerative illness with symptoms of tail rot, superficial ulcerations, mouth erosion, and fin necrosis (Mabrok et al., 2023). Experiments on the effects of enterococcus infection on tilapia were reported by Zahran et al. (2019); effects included high mortality and abnormalities like anorexia, detached scales, exophthalmia, pale gills, friable liver, kidney congestion, enlarged gall bladder, etc.

Other Data (Microplastics in Fish Guts, Organic Chemical Contaminants)

A study coordinated by A. Bucol of SUAKCREM in collaboration with biology students from NORSU (sampling was conducted at the same time as the physico-chemical and bacteriological sampling event in 2022) quantified the microplastic contents in the guts of a fish species *Halichoeres scapularis* (Zigzag Wrasse) in the study area (A. Bucol, personal communication, February 2024). The results revealed a low microplastic occurrence of 14.29% (5 fish out of the 35 samples) and a density of 0.14 items per fish (Banagudos & Triplitt, 2023, unpub. thesis). Previous studies conducted in 2020 on the microplastics from the rabbitfish Siganus fuscescens samples caught by fishers in our study area (Bucol et al., 2020; Alcala et al., 2022) showed that microplastic occurrence was higher (39% out of 90 samples) with a corresponding density of 0.67–0.87 microplastic particles per fish. Bucol et al. (2020) reported an average of 12.3 particles per 150 g dry weight of intertidal sediment samples (n=15) along Silliman Beach. The difference between the microplastic occurrence and density in 2020 versus that of 2022 may be due to several factors, including seasonal variation and differences in the feeding biology of the two fish species: *Halichoeres scapularis* are invertivore while siganids are benthic herbivores.

The effects of microplastics on fish have been getting much attention from researchers in the past decade. Two significant works involving experiments on feeding fish with microplastics of varying sizes, types, or feeding frequency are Critchell and Hoogenboom (2018) and Naidoo and Glassom (2019). Results included mortality and adverse effects on physiology and growth.

A previous research collaboration between SUAKCREM and Arizona State University in 2021 involved a study of persistent organic pollutants (POPs) in fish. Their results showed that out of the 30 samples of *S. fuscescens* from the Silliman Beach area, almost all (29) were contaminated by phthalates and polyaromatic hydrocarbons (PAHs); furthermore, 15 samples were contaminated by pesticides, and 11 by PCBs (Molina et al., 2021). Such organic chemical contamination in the study area has not been previously reported.

Conclusions

- Contamination in the study area is characterized by extremely high levels of *E. coli* and enterococci bacteria originating from the Mojon Creek and outfall pipes along the seawall. They pose a risk of human health issues such as dermatological, gastrointestinal, and respiratory illnesses in beach bathers, swimmers, and people and their pets in contact with beach sand or sediments. The two sampling rounds represent worst-case levels of contamination that typically occur during and a few days of rainstorms. Bacterial contamination may also be a significant factor in low fish biomass in the shallow seagrass beds in the study area. Potential sources of fecal bacteria include domestic and commercial wastewaters, leaking septic tanks, animal waste, food preparation and disposal, and as part of natural biota in soils and surface water.
- *E. coli* concentrations were as high as 47.2 million CFU/100 ml in effluent water at the outfalls and 25,500 CFU/100 ml in offshore seawater. These were orders of magnitude higher than the DENR's General Effluent Standards or GES (200 CFU/100 ml) and Water Quality Guidelines or WQG (100 CFU/100 ml) for total coliform.
- Enterococci concentrations were as high as 51.6 million CFU/100 ml in effluent water at the outfalls and 28,900 CFU/100 ml in offshore seawater. These were also orders of magnitude higher than the referenced standards and criteria. Since the DENR does not specify any standards for enterococci, the sampling results were compared to existing USEPA recommended exposure limits (Recreational Water Quality Criteria, 35 CFU/100 ml) and the New Jersey Surface Water Quality Standards or SWQS (30 CFU/100 ml) and Sanitary Code Water Quality Standards (104 CFU/100 ml, specifically for recreational beaches).
- Bacteriological contamination was accompanied by high levels of ammonia and BOD and low levels of DO (some samples had non-detect DO). At least four outfalls had ammonia levels (up to 15.017 mg NH_3-N per liter) significantly exceeding the DENR's GES (3 mg NH_3-N per liter). This further indicated high levels of contamination in the effluent.
- Ammonia levels in the offshore samples were as high as 0.39 mg NH_3-N/L, which exceeded the DENR's WQG of 0.06 mg NH_3-N/L as well as the NJDEP's 0.09/0.024 mg NH_3-N/L for acute/chronic SWQS. Sources of ammonia and ammonium contamination typically

include effluent from domestic wastewater, agricultural activities (e.g., application of fertilizers), leaky septic tanks, and vehicular emissions. The monitoring and regulating of ammonia levels are mainly done to protect aquatic organisms. The elevated ammonia and nitrogen levels in the study area may also be a significant factor in the low fish population and biomass.

- Two outfall samples (from Stations 4 and 5) indicated elevated oil and grease concentrations (8.8 and 8.6 mg/L, respectively), which exceeded the DENR's GES of 5 mg/L. There are various potential sources of oil and grease, including vehicle maintenance and repair discharges, oil spills on roadways, and deliberate discharge of used or waste oils into the sewer system. Waste or used oils may contain individual chemicals that are toxic to humans or aquatic organisms. Such chemicals may include organic compounds (e.g., benzene, polynuclear aromatic hydrocarbons, or PCBs) and heavy metals.
- Plastics and other garbage debris were noted on the seabed offshore of Silliman Beach, discharging from the mouth of Mojon Creek and some sewer outfalls. These are all contributing to the pollution of the study area.
- Aside from physico-chemical and bacteriological contamination, microplastic contamination was documented from a collaborative investigation involving microplastics in fish guts. Microplastic ingestion by fish is likely another significant factor contributingto the study area's low population and fish biomass. Furthermore, pollution may not be limited to the contaminants addressed in this study. Based on a previous study by others on organic chemical analysis of fish specimens collected from the area, there is a possibility that other contaminants may have discharged or continue to be discharging into the marine waters of the study area, including phthalates, polynuclear aromatic hydrocarbons, pesticides, and PCBs.

Recommendations

- Higher frequency of bacteriological monitoring, e.g., daily or weekly bacteriological testing of beach waters, especially during the summer months, public holidays, scheduled electrical power outage days, and weekends during non-summer months
- Extension of the study area southwards to include other parts of the City's coastline where the public uses beaches for recreation
- Sampling of beach sands or sediments for bacteriological and

chemical analyses for selected heavy metals, PCBs, pesticides, and semi-volatile organic compounds

- Long-term studies on physico-chemical parameters, fish population, biomass, and microplastics in fish gut consider spatial and seasonal variability and variability in microplastic consumption by different fish species.
- Planning and implementation of a public warning system at the beaches and implementation of beach closure on days when dangerous bacteriological levels are detected
- Design and construction of debris (including plastics) interception or screening system at the mouth of Mojon Creek
- Design and implementation of a comprehensive environmental assessment and river basin master plan for the Mojon Creek and its tributaries
- Enforcement of existing ordinances on trash disposal at beaches and illegal discharges into the sewer system or adoption of new ordinances if existing ones do not adequately address the issues
- Requiring (or enforcing existing regulations on) sediment traps, grease traps, or oil-water separators for industrial facilities, vehicle repair stations, hotels, apartments, condominiums, restaurants, and commercial parking lots

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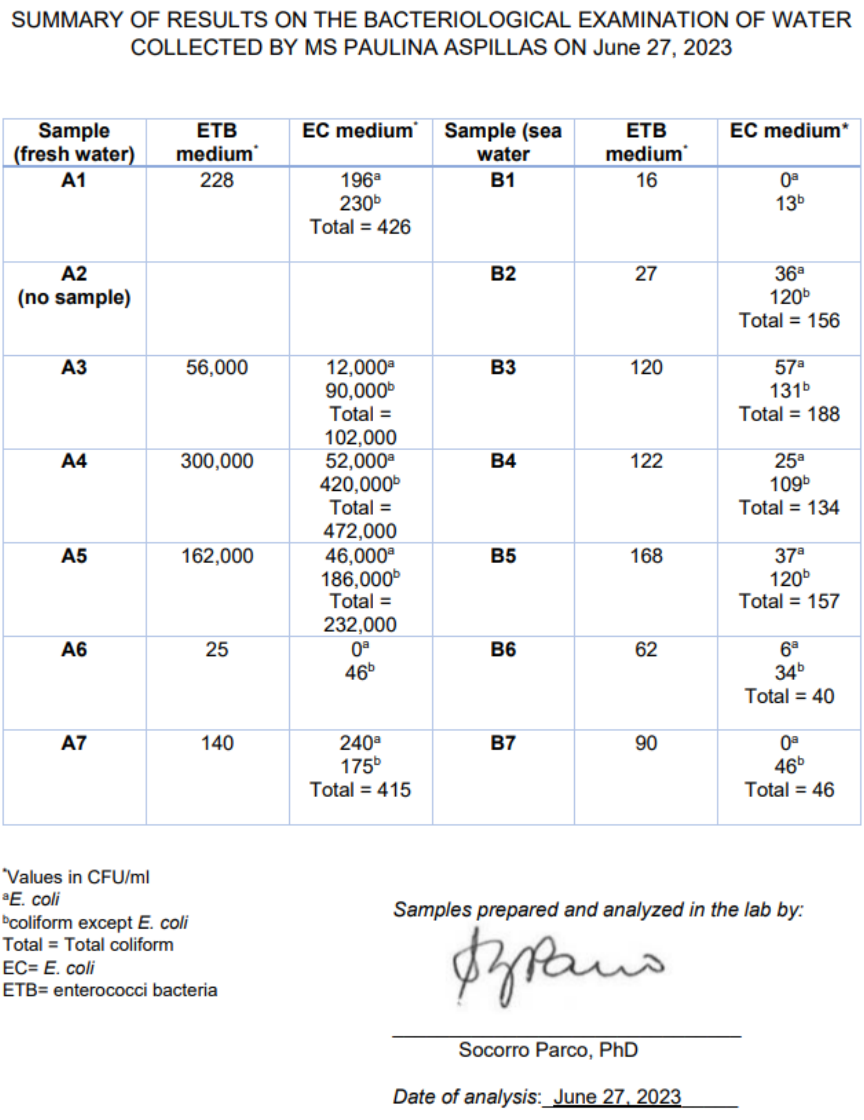
APPENDIX A



SUMMARY OF RESULTS ON THE BACTERIOLOGICAL EXAMINATION OF WATER COLLECTED BY MS PAULINA ASPILLAS ON June 27, 2023

Sample (fresh water)	ETB medium*	EC medium*	Sample (sea water	ETB medium*	EC medium*
A1	228	196[a] 230[b] Total = 426	**B1**	16	0[a] 13[b]
A2 **(no sample)**			**B2**	27	36[a] 120[b] Total = 156
A3	56,000	12,000[a] 90,000[b] Total = 102,000	**B3**	120	57[a] 131[b] Total = 188
A4	300,000	52,000[a] 420,000[b] Total = 472,000	**B4**	122	25[a] 109[b] Total = 134
A5	162,000	46,000[a] 186,000[b] Total = 232,000	**B5**	168	37[a] 120[b] Total = 157
A6	25	0[a] 46[b]	**B6**	62	6[a] 34[b] Total = 40
A7	140	240[a] 175[b] Total = 415	**B7**	90	0[a] 46[b] Total = 46

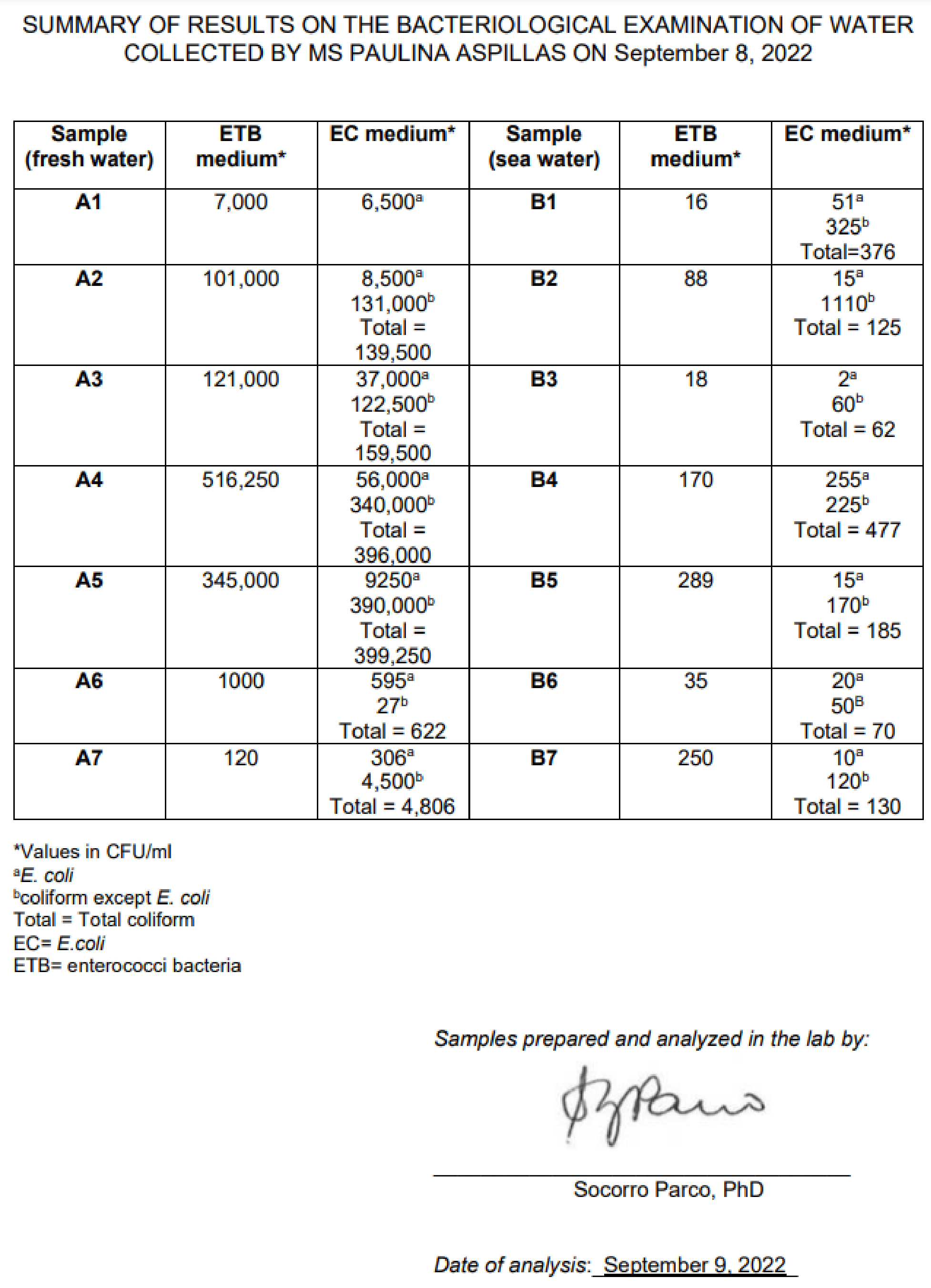
*Values in CFU/ml
[a] *E. coli*
[b] coliform except *E. coli*
Total = Total coliform
EC= *E. coli*
ETB= enterococci bacteria

Samples prepared and analyzed in the lab by:

Socorro Parco, PhD

Date of analysis: June 27, 2023

APPENDIX B



SUMMARY OF RESULTS ON THE BACTERIOLOGICAL EXAMINATION OF WATER COLLECTED BY MS PAULINA ASPILLAS ON September 8, 2022

Sample (fresh water)	ETB medium*	EC medium*	Sample (sea water)	ETB medium*	EC medium*
A1	7,000	6,500[a]	**B1**	16	51[a] 325[b] Total=376
A2	101,000	8,500[a] 131,000[b] Total = 139,500	**B2**	88	15[a] 1110[b] Total = 125
A3	121,000	37,000[a] 122,500[b] Total = 159,500	**B3**	18	2[a] 60[b] Total = 62
A4	516,250	56,000[a] 340,000[b] Total = 396,000	**B4**	170	255[a] 225[b] Total = 477
A5	345,000	9250[a] 390,000[b] Total = 399,250	**B5**	289	15[a] 170[b] Total = 185
A6	1000	595[a] 27[b] Total = 622	**B6**	35	20[a] 50[B] Total = 70
A7	120	306[a] 4,500[b] Total = 4,806	**B7**	250	10[a] 120[b] Total = 130

*Values in CFU/ml
[a]*E. coli*
[b]coliform except *E. coli*
Total = Total coliform
EC= *E.coli*
ETB= enterococci bacteria

Samples prepared and analyzed in the lab by:

Socorro Parco, PhD

Date of analysis: September 9, 2022

APPENDIX C

Photos of Fish Species Observed and Identified in the Study Area

Figure 13A. Wrasse (*Sthetojulis interrupta*)

Figure 13B. *Halichoeres argus* (TP)

Figure 13C. *Parapercis cylindrica*

Figure 13D. *Salarias fasciatus*

Figure 13E. *Siganus spinus*

Figure 13F. *Ostorhinchus hartzfieldi* (left)
Sargocentron rubrum, Red Squirrelfish (right)

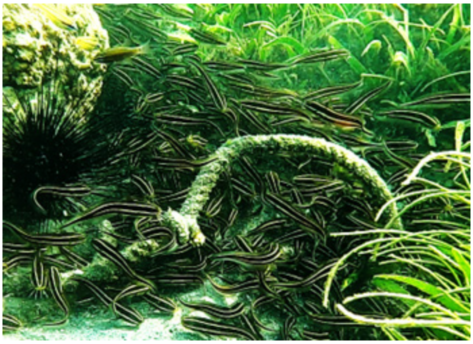


Figure 13G. *Plotosus lineatus* (shoaling)

Figure 13H. *Ostorhinchus cookii*

Figure 13I. *Pomacentrus tripunctatus* (Damselfishes, Pomacentridae)

Figure 13J. Assorted Cardinal fishes off Silliman Beach *(Ostorhinchus spp.*)

Figure 13K. *Ostorhinchus chrysopomus* (left) *Thalassoma hardwicke* (right)

Figure 13L. *Siganus fuscescens*