

EVALUATION OF WATER QUALITY OF MAJOR RIVERS IN PALAWAN, PHILIPPINES USING PHYSICO-CHEMICAL PARAMETERS AND WATER QUALITY INDEX

by

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ABSTRACT

The rivers in Palawan have fundamental roles in local society as source of water for recreation; domestic use; irrigation; as well as sink for agricultural and domestic wastes. Beneficial usage of water is thus depends on its water quality. This study attempts to characterize the water quality of major rivers in the province using water quality index (WQI) developed by Canadian Council of Ministers of the Environment (CCME). WQI was calculated for thirty six (36) river monitoring stations based on physico-chemical and microbiological parameters vis-à-vis freshwater quality standards stipulated in the DENR Administrative Order 34, series of 1990. Results show that all river monitoring stations have description of good to excellent water quality if utilized for agriculture, irrigation, and other purposes (Class D). Only five (5) river monitoring stations have good to excellent rating as sources of drinking water after a complete treatment (Class A). The water quality index is potentially useful as a decision tool in environmental planning and decision-making activities related to water resource protection, improvement and utilization towards a sustainable water resource management in the province of Palawan.

Keywords: *water quality, DAO standards, physico-chemical parameters, river monitoring, Palawan*

1. Introduction

Rivers are the most important natural resources for human consumption and development. They provides ecosystem services such as fresh water sources for domestic and agriculture consumption, water regulation, primary production as well as transportation and recreation purposes. However, human activities gradually alter the inland water ecosystem and its catchments through land conversion, sand and gravel extraction, and indiscriminate disposal of sewage, agricultural and industrial wastes to water bodies. It is therefore necessary to determine the water quality and evaluate its impacts and provide measures to mitigate the problems (Mishra et al., 2009).

Water quality monitoring is essential to determine the physical, chemical and biological characteristics of water. These characteristics provide basis as to how and for what water can be used and the species and ecosystem processes it can support. Monitoring is also the foundation on which water quality management is based. It provides the information that permits the rational decision to be made on describing water resources, identifying actual and emerging problems of water pollution, use and abstraction of water, and land use; formulating plans; and in evaluating the effectiveness of management actions (UNEP/WHO, 1996). At the same time, water quality monitoring data can be used to track response to management regimes aimed at improving water quality.

To assess whether the water body is fit for various human activities and could support aquatic species and ecosystem processes, various physical, chemical and microbiological parameters are

determined through laboratory analyses. With hundreds of parameters available to assess the water quality, the challenge remains on providing a single statement that would sum up several water quality parameters into one holistic description. Like any other environmental monitoring program, there is a problem on the reporting of water quality monitoring results to both managers and the general public because of the complexity associated with analyzing a large number of measured variables.

In response to this, numerous water quality indices have been formulated all over the world. These indices are based on the comparison of the water quality parameters to the standards and give a single value for the water quality of a certain source (Bharti and Katyal, 2011). The scatterscore index was used to assess changes in water quality of mining sites in USA (Kim and Cardone, 2005); index of river water quality was developed and used in Taiwan (Liou et al., 2004); overall index of pollution was used in India (Sargaonkr and Deshpande, 2003); and Chemical Water Quality Index used in USA (Tsegaye et al., 2006) are some of the numerous attempts to simplify complex water quality data and monitoring. The Water Quality Index (WQI) developed by Canadian Council of Ministers of the Environment (CCME) in 2001 assesses the quality of water against the water quality standard set forth by the government agency or site specific background concentration (CCME, 2001). It is among the well-accepted and widely applicable model for evaluating the water quality index (Sharma and Kansal, 2011; Damo and Icka, 2013). Because of its versatility, this method was utilized by UNEP GEMS/Water programme as the model that can be followed in developing a global water quality index (UNEP, 2007).

While some countries and regions have developed and are using water quality indices that assess water quality either on a national or global level, these rely mostly on normalizing or standardizing data parameter according to expected concentrations (Carr and Rickwood, 2008). The CCME WQI, on the other hand, provides a mathematical framework for assessing ambient water quality conditions relative to water quality standards, thus, reflects the overall and current condition of the water bodies. There is no formulated and developed guidelines on water quality indices in the Philippines, although there are water quality standards used as basis for acceptable values of physico-chemical and microbiological parameters. The Department of Environment and Natural Resources issued the Administrative Order 34 series of 1990 stipulating the water quality criteria or standards based on the beneficial usage of the body of water or classification of freshwaters and marine waters, providing basis to determine the suitability of water bodies for specific use.

This study focuses in the province of Palawan, known as the Philippines' last frontier, one of the major tourist destinations in the country and lauded as the World's Best Island from 2013 to 2016 by the Conde Nast Traveler and Travel+Leisure Magazine. The growing socio-economic activities and demands of increasing population for food and space have impacted the province's water resources. The province experiences water shortage especially during summer season. The Palawan Council for Sustainable Development Staff (PCSDS) conducts river water quality assessment. It has thus, established river monitoring stations in the province to continuously monitor the impacts of socio-economic activities in the water resources in the province. However, the accumulated water quality data have limited usage in terms of policy formulation in the province. The brief and simple descriptions should be developed in order for these technical data of water quality to be translated into simple and understandable to the end user, whether from academe, civil society, to policy makers.

This study evaluates the water quality of major rivers in the province of Palawan vis-à-vis water quality standards as stipulated in DAO 34, S. 1990. By utilizing the Canadian Water Quality Index model, this study attempts to verify its applicability in evaluation of water quality of rivers in Palawan. This study aims to come up with description of river systems with different beneficial

usage. The empirical data derived in this study could be utilized for the evaluation or formulation of policy towards the sustainable water resource management in the province.

2. Methodology

Sample Collection and Analysis

The data used in this study is based on the results of water quality monitoring conducted by the Palawan Council for Sustainable Development Staff as part of its activities under the Environmental Monitoring and Evaluation System. The river monitoring stations located in 9 mainland municipalities in Palawan are situated either adjacent to paddy farms, rural communities, or mining activities. For purposes of monitoring, some major rivers are divided into upstream (dams), midstream and downstream sections of the river.

Grab water samples were collected from 36 river monitoring stations located in 28 river bodies in Palawan. Water containers differ on the parameters to be analyzed; 1-Liter wide-mouthed glass with screw cap containers were used for oil and grease; sterilized glass bottles were used for total coliform analysis; and 3-Liter plastic bottles were used for other analyses. The water samples were stored in an ice chest, packed with ice and delivered as soon as possible in the PCSD Environmental Laboratory for analyses. Sample collections were done twice a year since 2014.

Analyses of water samples were performed at the PCSD Environmental Laboratory following the APHA-AWWA (2005) methods of analysis (Table 1). Nine (9) parameters were analyzed from water samples namely: pH, dissolved oxygen, total suspended solids, total dissolved solids, oil and grease, biochemical oxygen demand, phosphates, nitrates and total coliform. The results were compared on the water quality standards for fresh surface waters such as lakes, rivers, reservoirs, etc. based on the DENR Administrative Order No. 34 s.1990.

Table 1. List of parameters and methods of analysis.

Parameter	Method of Analysis
pH	
Dissolved oxygen	Hach Portable multi-parameter meter ^a
Biological oxygen demand	Azide Modification Dilution Technique
Total suspended solids	Gravimetric method (dried at 103 – 105 ⁰ C)
Total dissolved solids	Gravimetric method at 180 ⁰ C
Nitrates	Hach DR3900 Benchtop VIS Spectrophotometer
Phosphates	
Oil and grease	Gravimetric method (Petroleum Ether Extraction)
Total Coliform	Multiple Tube Fermentation Technique

Note: ^aMeasured in-situ; Methods are based on Standards Methods of Analysis for Water and Wastewater, 21st Edition, APHA AWWA (2010) except for nitrates and phosphates analyses

Calculation of Water Quality Index (WQI)

The WQI equation is calculated based on the mathematical framework provided by Canadian water quality guidelines for the protection of aquatic life: CCME Water Quality Index 1.0 (CCME 2001) for assessing ambient water quality conditions relative to water quality objectives (Table of DAO 34 S. 1990), using three factors as follows:

$$WQI = 100 - (\sqrt{F_1^2 + F_2^2 + F_3^2}/1.732) \quad (\text{Eq. 1})$$

where:

Factor 1: Scope

This represents the extent of water quality guideline non-compliance over the time period of interest and is calculated as follows:

$$F_1 = \frac{\text{number of failed variables}}{\text{total number of variables}} \times 100 \quad (\text{Eq. 2})$$

Factor 2: Frequency

This refers to the percentage of individual tests that do not meet the standards (failed tests):

$$F_2 = \frac{\text{number of failed tests}}{\text{total number of tests}} \times 100 \quad (\text{Eq. 3})$$

Factor 3: Amplitude

This represents the amount by which failed test values do not meet their objectives. It is calculated in three steps:

1) Excursion or the number of times by which an individual concentration is greater than (or less than, when the objective is a minimum)

$$\text{excursion}_i = \frac{\text{failed test value}_i}{\text{standard}_i} - 1 \quad (\text{Eq. 4})$$

2) The normalized sum of excursions, or nse, is calculated as

$$\text{nse} = \frac{\sum_{i=1}^n \text{excursion}_i}{\text{number of tests}} \quad (\text{Eq. 5})$$

3) Amplitude, F3 is then calculated as follows:

$$F_3 = \left(\frac{\text{nse}}{0.01\text{nse} + 0.01} \right) \quad (\text{Eq. 6})$$

Data Interpretation

The calculated WQI are then compared to the water quality rank that provides a convenient description of summarizing complex water quality data. Table 2 shows the general description based on the calculated water quality.

Table 2. General description of the calculated water quality rank adapted from the Canadian Council of Ministers of the Environment (2001).

Rank	WQI Range	Ecological Condition
Excellent	95–100	No water uses that fall under certain water classification ever interrupted Conditions very close to natural or pristine under certain water classification
Good	80–94	Water quality is protected but occasionally threatened or impaired Under certain water classification rarely depart from natural or desirable quality
Fair	65–79	A single water use under certain water classification may be temporarily interrupted Conditions sometimes depart from desirable quality as required under certain water classification
Marginal	45–64	Water quality under certain water classification is frequently threatened or impaired Conditions often depart from desirable quality as required under certain water classification
Poor	0–44	Water quality under certain water classification is almost always threatened or impaired Conditions usually depart from desirable quality as required under certain water classification

3. Results and Discussion

Physico-Chemical Analysis

The color and total suspended solids in the river water provide the visual quality of the water; the higher concentration signifies highly turbid water. Color concentration of 50 mg/L and beyond signals a turbid water which can be caused by natural disturbance such as increased sedimentation during rainy season or anthropogenic disturbance such as quarry activities upstream of the river monitoring stations (Figure 1). Some of the river monitoring stations were observed to be turbid all the time such as Panitian river, Magara river, Guineratan and Magara downstream. Panitian river is close to farm lots where the water flows from the rice paddies directly draining to the river. The sampling stations of Magara, Guineratan and Magara downstream are all located along Magara River. This river is one of the locations of gold panning activity in Roxas, Palawan. Aside from cultivation of soil from farming and natural scouring, the gold panning activities that has been taking place for decades resulted to the siltation of Magara river. The concentration started to decrease from Magara midstream to Magara downstream as the suspended solids eventually settle to the

river bed as it is transported along the river.

Total suspended solids are water insoluble materials, including organic and inorganic, that are suspended in water such as silt, plankton and industrial wastes (Kumar et al., 2010). The Environmental Management Bureau (2008) stated that the higher the TSS value, the lower is the ability of the water to support aquatic life due to reduced light penetration affecting plant photosynthesis.

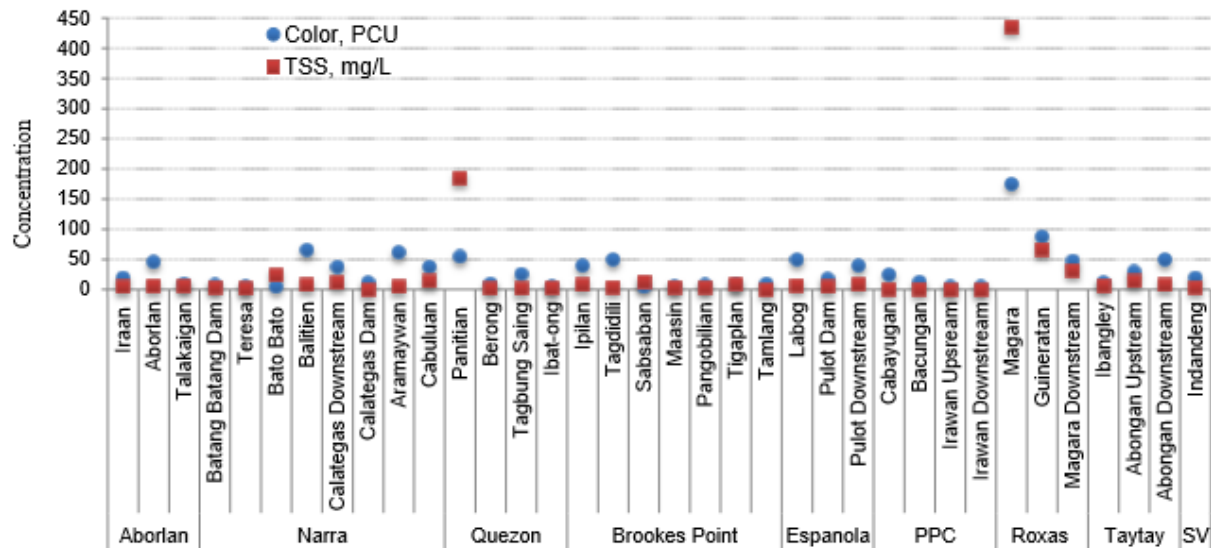


Figure 1. Average concentration of color and total suspended solids of river monitoring stations in 2014.

The high concentration of dissolved oxygen, which is observed from all monitoring stations signifies a condition favorable for the aquatic organisms to thrive in the water bodies (Figure 2). The dissolved oxygen concentration is a general indicator to assess organic pollution, and is commonly used in the environmental monitoring. High concentration of dissolved oxygen is favorable to aquatic organisms, while concentration lower than 2 mg/L in a prolong period could be detrimental leading to asphyxiation of fishes (Behar, 1997; Kutty, 1987).

On the other hand, biochemical oxygen demand refers to the amount of oxygen used by microorganisms to oxidize organic matter in water. Decaying plants and fallen leaves can be a natural source of organic matter in the river, thus, high BOD concentration is directly related to the high amount of organic matter in water, signalling pollution of water bodies. The biodegradation of these organic matter as BOD and oil and grease occurs in water unless its concentration exceed the capacity of fresh water to assimilate such pollutants naturally.

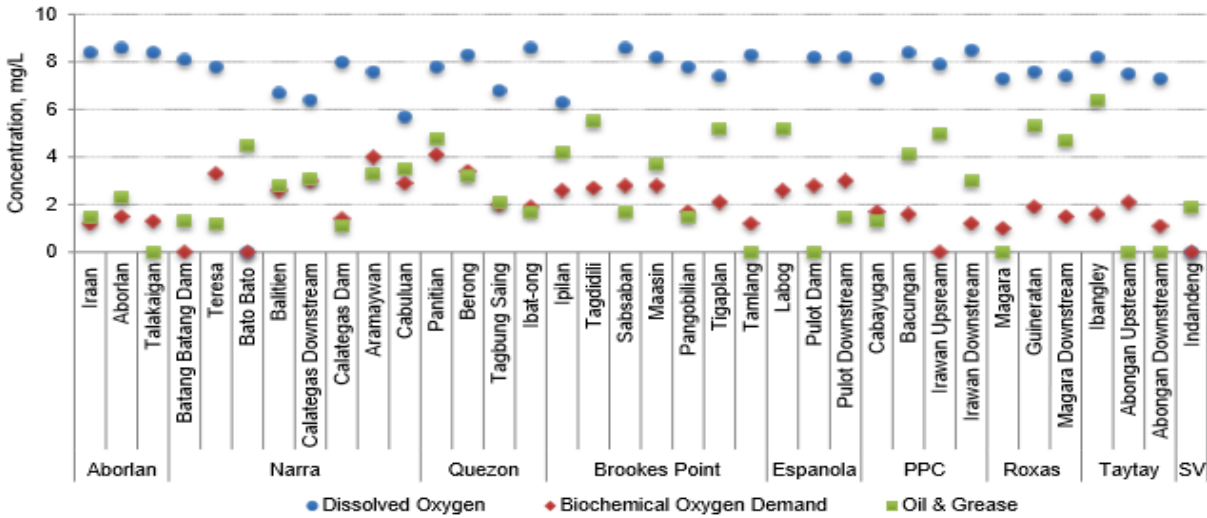


Figure 2. Average concentration of dissolved oxygen, BOD and oil and grease from river monitoring stations in 2014.

Nutrients such as nitrates and phosphates are essential for the growth of bacteria, algae and other tiny organisms in the water, however, the excessive amount fuels excessive growth of algae. This results to increased die-off and decomposition of algae blooms, reduced dissolved oxygen in water that would suffocate larger fishes. Concentration of phosphates from the river monitoring stations range from 0.1 mg/L (Tamlang, Maasin, Tagbung-saing and Berong) to 1.5 mg/L (Panitian), while nitrates range from 0.4 mg/L (Tamlang) to 11 mg/L (Magara) (Figure 3). These nutrients drain to the rivers from farm lots, agricultural fertilizer, residential and garbage dumps.

These physico-chemical parameters are used as indicators of ecosystem health and can be potentially linked directly to socio-economic indicators such as access to safe water, environmental or watershed protection expenditures, withdrawal of surface water, and domestic consumption of water per capita. These indicators and discussions could further be reinforced by providing a general description of prevailing water quality of the rivers and the monitoring stations, and can be done through the calculation of water quality index.

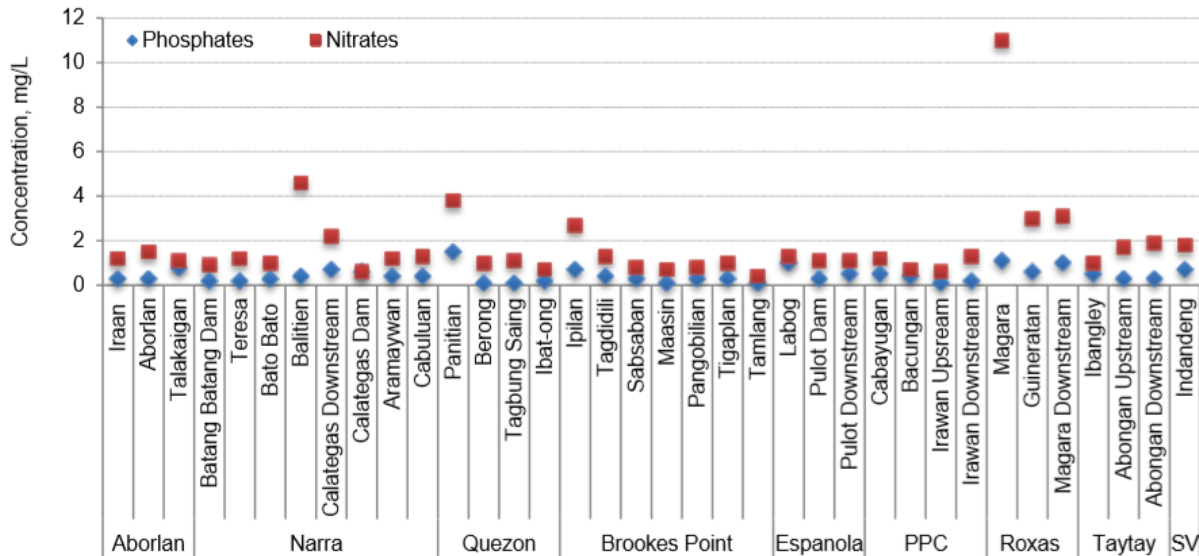


Figure 3. Average concentration of nutrients such as nitrates and phosphates from river monitoring stations in 2014.





Water Quality Index and Water Quality Rank

The water quality index (WQI) is used to provide information on water quality of Palawan’s river waters. It incorporates the information on water usage and classification of fresh water bodies based on the DENR Administrative Order No. 34, Series 1990. Table 3 shows the general water quality description of river stations with respect to four water classification or beneficial usage. Figure 4 also shows the general water quality description or rank vis-à-vis Class A (DAO 34, s. 1990) of river monitoring stations in Palawan in 2014.

The water quality in river monitoring stations located in Pulot Dam in Española, Sabsaban and Tamlang Dam in Brooke’s Point, and Cabayugan and Irawan Upstream in Puerto Princesa City were in good condition suitable for Public Water Supply Class II or fit as sources of water supply that would require complete treatment (coagulation, sedimentation, filtration and disinfection) in order to meet the National Standards for Drinking Water (NSDW) – Class A. On the other hand, Magara upstream was assessed to be poor or with water quality almost always threatened or impaired and conditions usually depart from desirable quality as required under Class A. All of the river monitoring stations had good to excellent condition/status if utilized for agriculture, irrigation, and others (Class D of DAO 34, s. 1990).

Generally, the monitoring stations located in the upstream of the river systems such as dams had better water quality than those stations in the midstream and downstream of the rivers. This was observed particularly in Calategas Dam and Calategas River in Narra, and in Pulot Dam and Pulot downstream in Española; and Irawan upstream and downstream in Puerto Princesa City. The reverse was observed in the Magara upstream in Roxas, Palawan with poor water quality while stations located at midstream and downstream have marginal or having water quality that if compared to Class A is frequently threatened or impaired. This is due to the higher concentration of total suspended solids recorded in Magara upstream than in the midstream and downstream of rivers. This can be attributed to the small scale gold panning activities located nearby the Magara upstream station. As the water flows, the solids settle down resulting to the lower concentration of suspended solids.

Table 3. General Water Quality Description/Rank vis-a-vis River Classification, 2014.

Municipality	River Stations				
		Class A	Class B	Class C	Class D
1. Aborlan	Aborlan	Fair	Fair	Good	Excellent
	Iraan	Fair	Fair	Good	Excellent
	Talakaigan Dam	Fair	Fair	Good	Excellent
2. Narra	Batang-batang Dam	Fair	Good	Good	Excellent
	Batang-batang	Fair	Good	Good	Excellent
	Calategas Dam	Fair	Good	Good	Excellent
	Calategas	Marginal	Fair	Fair	Excellent
	Aramaywan	Marginal	Fair	Good	Excellent
	Balitien	Marginal	Marginal	Fair	Excellent
	Bato-bato	Fair	Fair	Good	Excellent
	Cabuluan	Fair	Fair	Fair	Good
Tagdidili	Fair	Fair	Good	Good	
3. Espanola	Pulot Dam	Good	Good	Excellent	Excellent
	Pulot downstream	Fair	Fair	Good	Excellent
	Labog	Marginal	Marginal	Fair	Excellent
4. Brooke's Point	Sabsaban	Good	Good	Excellent	Excellent
	Tamlang Dam	Good	Good	Excellent	Excellent
	Pangobilian	Fair	Fair	Good	Excellent
	Tigaplan	Marginal	Marginal	Good	Excellent
	Ipilan	Fair	Fair	Fair	Excellent
	Maasin	Fair	Fair	Good	Good
5. Quezon	Panitian	Marginal	Marginal	Fair	Good
	Ibat-ong	Fair	Fair	Excellent	Excellent
	Tagbung-saing Lake	Fair	Fair	Good	Excellent
	Berong	Fair	Fair	Good	Excellent
6. Puerto Princesa City	Bacungan	Fair	Fair	Good	Excellent
	Cabayugan	Good	Excellent	Excellent	Excellent
	Irawan upstream	Good	Good	Excellent	Excellent
	Irawan downstream	Fair	Fair	Good	Excellent
7. Roxas	Magara upstream	Poor	Marginal	Good	Good
	Magara Midstream/ Guineratan	Marginal	Marginal	Fair	Excellent
	Magara downstream	Marginal	Fair	Good	Excellent
8. San Vicente	Inandeng	Marginal	Marginal	Good	Excellent
9. Taytay	Ibangley	Fair	Fair	Good	Excellent
	Abongan downstream	Fair	Fair	Excellent	Excellent
	Abongan upstream	Fair	Fair	Excellent	Excellent

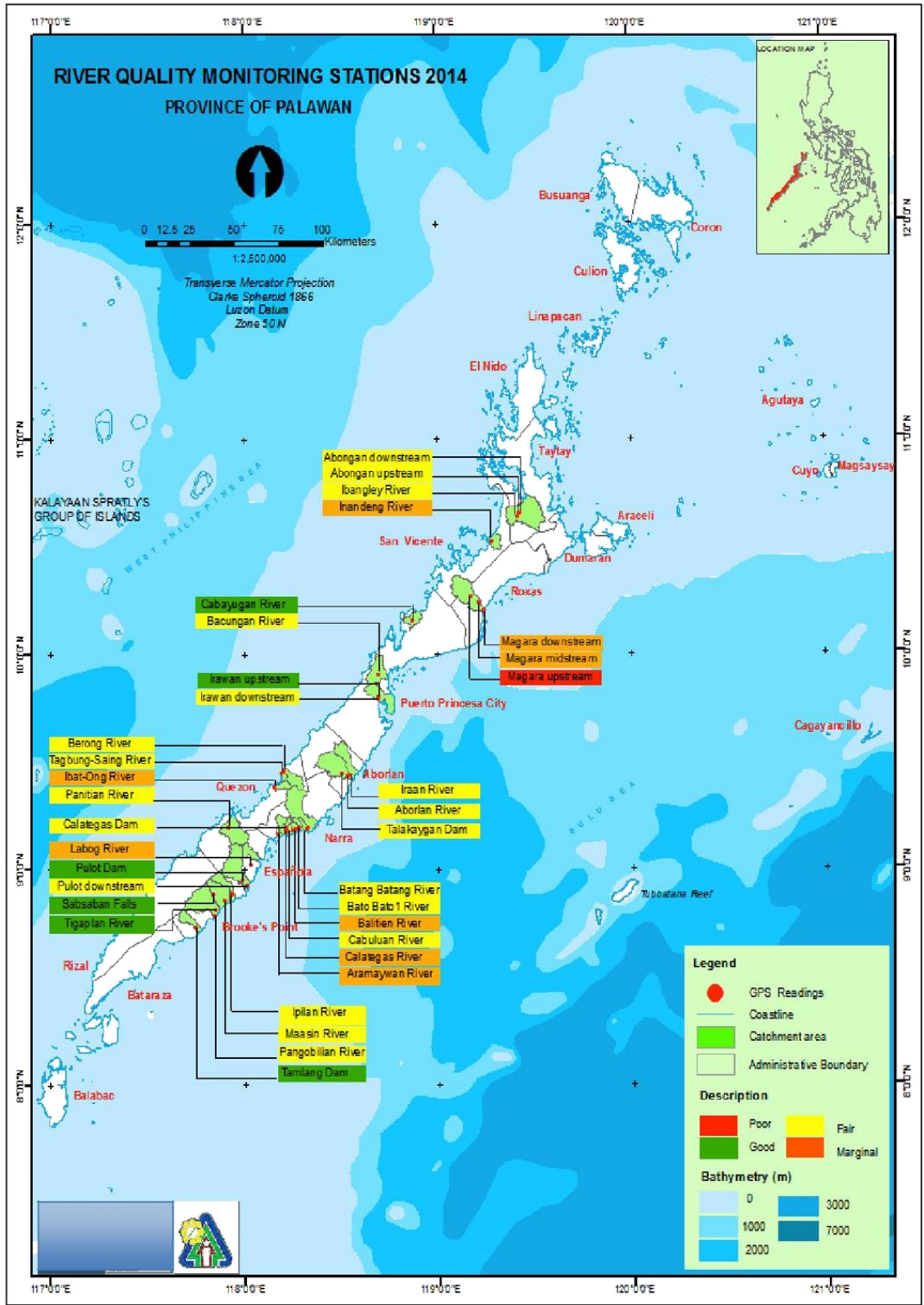


Figure 4. General water quality description of river monitoring stations in Palawan in 2014 vis-à-vis Class A water quality standards (per DAO 34, s. 1990).

Based on the parameters assessed in the study, phosphates, total coliform, oil and grease, and total suspended solids were often observed to exceed the standards. Among the common sources of phosphates and nitrates in waters are wastewater and septic effluents, detergents, fertilizers, soil run-off, industrial discharges, and synthetic materials which contain organophosphates, such as insecticides. It is a limiting nutrient needed for the growth of all plants- aquatic plants and algae alike, if too much nutrients are present in the water the algae and weeds will grow rapidly, may choke the waterway, and use up large amounts of precious oxygen and it could result to the death of fishes and other aquatic organisms (Muller and Helsel, 1999).

Bacteriological communities can be used as bio-indicators of aquatic ecosystem dynamics and determination of their occurrence may help to assess the water quality of rivers (Kumar et al., 2010). Total bacterial count can be a reliable indicator of organic pollution, because they are unable to survive in clean water beyond limited time and the number of bacteria present depends upon the degree of contamination (EMB, 2008). Thus, stations with high total coliform concentration failed to meet the standards for Classes AA, A and B and were considered unsuitable for drinking even for recreational or bathing purposes.

4. Conclusion and Policy Implication

The CCME WQI is an effective tool to evaluate water quality with respect to beneficial usage of rivers in the province of Palawan. Results showed that 5 of the 36 river monitoring stations are of good water quality with respect to Class A standards, and thus, can be possible sources of water supply for domestic usage. All of the tested rivers had good to excellent quality when utilized for livestock or irrigation purposes. Overall, the indices are reflective of the real data obtained from water quality monitoring of PCSDS.

The variety of water uses such as for recreation, agriculture and domestic purposes rely on the water quality and quantity. The water quality standards have been established to protect both users from adverse consequences of poor water quality, and for the ecosystem to be able to maintain its healthy state. Higher concentrations of indicators of water quality when compared with water quality standards can restrict the water use and development. When left neglected, it would impair the ecosystem health and necessitate expensive treatment. Thus, monitoring of water quality is fundamental to identify areas that would pose potential threat to health, identify the sources of contamination and provide reliable information for decision making to enhance water sustainability.

Anthropogenic disturbances such as sand and gravel quarry, mining operations, and gold panning activities, domestic wastewater and drains from farm lots pose threats to water quality that could result to irreversible pollution and damage to river ecosystem. The information provided by the WQI is a useful tool for describing the state and trends of the river water quality on temporal and spatial scale. The water quality index is useful as decision tool in environmental planning and decision-making related to water resource protection, improvement and utilization towards a sustainable water resource management in the province of Palawan. This study also recommends a continuous monitoring of water quality of freshwater bodies in the province of Palawan.

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