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Bio-physical and chemical assessment of Mangrove waters in Gonzaga, Cagayan

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Abstract

The present study was carried out to determine the seasonal variations on the biological, physical and chemical characteristics of mangrove waters in Gonzaga, Cagayan, Philippines specifically in Barangays Caroan, San Jose and Tapel based on six water quality parameters such as pH, alkalinity, nitrite, ammonia, salinity and temperature. Five sampling stations were monitored along the mangrove ecosystems once a month for twelve months from June 2018 to May 2019. Results showed that mean values of different water quality parameters were as follows: pH (7.65 to 7.79), alkalinity (92mg/L to 118mg/L), nitrite (0.04 to 0.05mg/L), ammonia (0.04-0.18mg/L), salinity (31 ppt to 34 ppt) and water temperature (28°C-29°C). Significant seasonal variations ($P<0.05$) were observed in nitrite and temperature values. while no seasonal variations ($P>0.05$) were observed in pH, alkalinity, ammonia and salinity values. Meanwhile, the recorded values of water parameters are within the ideal range appropriate for marine environment specifically mangrove species which are presence in the sampling stations. Based on the data gathered, there were significant seasonal variations in biological, physical and chemical characteristics specifically on nitrite level and temperature of mangrove waters in all five sampling stations. All parameters obtained low values during wet season, while high values during dry season in all stations. Therefore, the present study revealed that season (wet and dry season) is the main factor in the variations of biological, physical and chemical characteristics of mangrove waters in Barangays Caroan, San Jose and Tapel of Gonzaga, Cagayan. Implications of the study will serve reference for the conservation, management and sustainable development of the mangrove ecosystem, it is necessary to perform annual monitoring of biological, physical and chemical characteristics of mangrove waters should be done.

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Introduction

Mangrove forests are considered as a highly productive ecosystem which provides important ecological and economic services. They play a vital role in providing appropriate habitats for fauna, safe breeding and chick rearing grounds, nurseries for a diversity of fishes and shellfishes, also as ideal forage grounds for animals like fishes, birds and aquatic invertebrates and refuge from predators (Zakaria and Rajpar, 2015).

The stability of the mangrove is influenced by salinity, soil type and chemistry, nutrient content and dynamics, physiological tolerance, predation and competition at local level (Smith *et al.*, (2003). Moreover, Cuenca *et al.*, (2015) affirmed that mangrove distribution is influenced by climatic, environmental, and physiochemical factors, propagule properties, and biotic interactions. Hence, it is very crucial to assess the biological, physical and chemical characteristics of mangrove waters. According to Lewis (2009), successful mangrove forest restoration requires careful analyses of number of factors in advance of attempting actual restoration. A wide variety of restoration techniques have been developed, but the most critical point is to fit restoration efforts with the local physical and biological settings, selecting the right species and right locations (Van Lavieren *et al.*, 2012). Recently, testing water quality data for trend over period of time has received considerable attention. The interest in methods of water quality trend arises because of the question of changing water quality arising out of the environmental concern and activity (Antonopoulos *et al.*, 2001).

This study is a preliminary attempt to reveal the bio-physical and chemical characteristics of mangrove waters in Gonzaga, Cagayan, Philippines which will be of great help in order to use as baseline data to address local issues. The conservation, management and sustainable development of the mangroves depend on the maintenance of hydrogeochemical characteristics of the system. Specifically, understanding the water quality information on the variations during wet and dry seasons supports the management activities since in this study area has had limited research conducted about its water quality.

The purposively assessed the biological, physical and chemical characteristics of the mangrove areas. Specifically, the study assessed the water quality variations during dry and wet seasons based on six bio-physical and chemical parameters such as pH, alkalinity, nitrite, ammonia, salinity and temperature.

Materials and methods

Sampling area

Bio-physical and chemical assessment of mangrove water was conducted in Gonzaga, Cagayan. According to PHILATLAS, Gonzaga is a coastal municipality in the province of Cagayan. The municipality has a land area of 567.43 km^2 which constitutes 6.10% of Cagayan's total area. The municipal center of Gonzaga is situated at approximately 18°16' N, 121°60' E, in the island of Luzon. Five sampling stations were selected: Station 1 (mangrove ecosystem in Brgy. Caroan fringed with dense growth of Avicennia species), Station 2 (mangrove ecosystem in Brgy. Caroan fringed with dense growth of Avicennia species), Station 3 (mangrove ecosystem in Brgy. Caroan fringed with dense growth of Avicennia and Rhizopora species), Station 4 (mangrove ecosystem in Brgy. San Jose fringed with dense growth of Avicennia and Sonneratia species) and Station 5 (mangrove ecosystem in Brgy. Tapel fringed with dense growth of Avicennia and Rhizophora species) (Fig. 1). These three barangays were selected because of the large tracts of mangroves in the areas.

Fig. 1. Location of five sampling stations around Gonzaga.

Water analysis

The bio-physical and chemical assessment of water was done at monthly intervals for a period of one year from June 2018 to May 2019 for the estimation of various bio-physical and chemical parameters. Six water quality parameters were used in the study. Water parameters such as pH, salinity and temperature were determined *in situ* using pH meter, salinometer and thermometer, respectively, while alkalinity, nitrite, ammonia, were analyzed by Bureau of Fisheries and Aquatic Resources Region 02.

Fig. 2. On-field analysis of water quality parameters.

Data analysis

Data were statistically analyzed using descriptive statistics. Comparison of means of two seasons was carried out using T-test at significant level of $P<0.05$. Statistical analyses were done using SPSS software version 16. Based on the cycle of meteorological events in the Philippines, two seasons can be recognized: dry season (starts in November and ends in May) and wet season (starts in June and lasts till October).

Results and discussion

Water parameters such as pH, alkalinity, nitrite, ammonia, salinity and temperature were used to estimate various bio-physical and chemical characteristics of mangrove waters in Gonzaga, Cagayan. Monthly sampling of waters was done for a period of one year.

There is no data obtained in the month of September due to occurrence of typhoon in this month. Graphical monthly variations of pH are represented in Fig. 3. It shows almost similar monthly and seasonal changes of pH levels at the five sampling stations. The recorded pH levels ranged between minimum of 7.50 at Station 1 and maximum of 7.83 at Station 3 during wet season, meanwhile, during dry season, it ranged between minimum of 7.65 at Station 4 and maximum of 7.80 at Station 1. Table 1 shows the statistics of water pH during wet and dry seasons in all sampling stations.

The recorded pH values for wet and dry seasons varied between 7.67 and 7.73, respectively. Based from the pH values obtained, there is no significant seasonal variation ($P>0.05$). Meanwhile, the pH values of 7.67 and 7.73 are mainly appropriate for aquatic marine life. This is evidenced by having mangrove stands in all sampling stations in the present study. According to Mariappan *et al.* (2015), pH is one of the vital environmental variables that determines the survival, metabolism, physiology and growth of aquatic organisms.

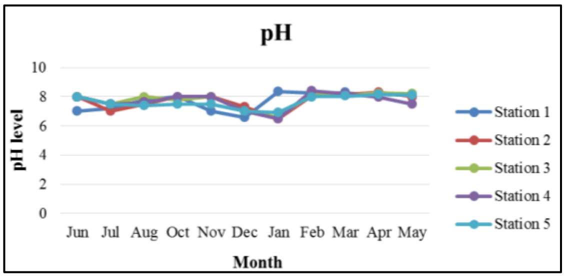

Fig. 3. Monthly trend of pH levels for all sampling stations.

Table 1. Statistics of the analyzed water quality for dry and wet season.

Parameter	Wet Season	Dry Season	P-value	Acceptable Range/Value
pH	7.67±0.34	7.73±0.62	0.60	6.5-8.5
Alkalinity	102±16.94	109±12.44	0.11	≥20
Ammonia	0.14±0.15	0.09±0.08	0.23	0.055
Nitrite	0.03±0.02	0.05±0.00	0.00*	<1.0
Salinity	34±2.35	32±3.27	0.08	30-35
Temperature	27±0.67	29±1.47	0.00*	≥18

*Significant at 0.05 level

Fig. 4 illustrates that there were conspicuous monthly and seasonal variations in alkalinity at the five stations. It can be seen that alkalinity levels of water sample ranged between minimum of 80mg/L at Station 5 and maximum of 116mg/L at Station 3 during wet season, whereas, in dry season, it ranged between minimum of 98mg/L at Station 5 and maximum of 120mg/L at Station 3. It shows in Table 1 that the recorded alkalinity level of water during wet and dry seasons varied between 102 and 109mg/L, respectively. Higher alkalinity value was observed in dry season compared to wet season. The same observation was obtained in the study of Manju *et al.*, (2012) on the Assessment of Water Quality Parameters in Mangrove Ecosystems Along Kerala Coast. However, there is no displayed significant difference between the two seasons. Generally, the recorded alkalinity values are within the level appropriate for aquatic marine life.

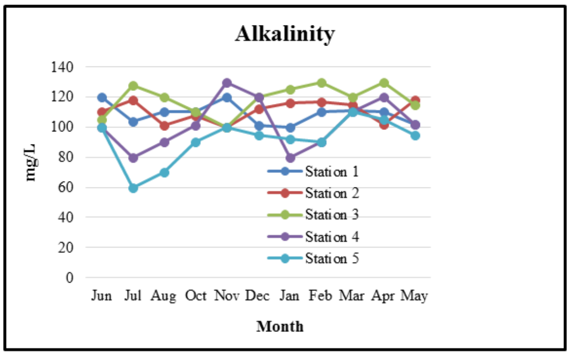

Fig. 4. Monthly trend of alkalinity levels for all sampling stations.

Fig. 5 illustrates that there is fluctuating pattern of ammonia values at the five sampling stations. The highest value of ammonia in the wet season was recorded in Station 1 with 0.21mg/L, while the lowest was recorded at Station 2 with 0.01mg/L. On the other hand, the highest value of ammonia during dry season was recorded at Station 1 with 0.17mg/L, while the lowest was recorded at Station 2 with 0.03mg/L (Table 4). Table 1 displays the ammonia level of water during wet season is high (0.14mg/L) and low during dry season (0.09mg/L). The high ammonia level during wet season might be due to terrestrial runoff which contributes more of particulate matter to the mangrove environment. Similar observation was found in the study of Kumar *et al.* and stated that the detrital particles brought down by the rivers and litter production by the aquatic macrophytes and mangroves are the causes for the enrichment of particulate organic matter in the mangrove environment. Statistically, there is no variation in ammonia value between wet season and dry season. Generally, ammonia values of 0.14 and 0.09mg/L are still within the standard for marine environment.

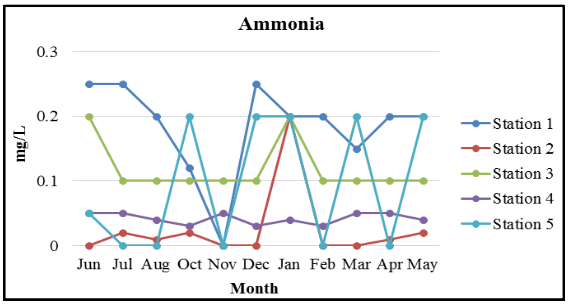

Fig. 5. Monthly trend of ammonia levels for all sampling stations.

It can be seen in Fig. 6 that all stations showed almost similar monthly and seasonal changes in nitrite values. During dry season, all five stations obtained the same nitrite value of 0.05mg/L. Meanwhile, during wet season, observed nitrite values ranged between minimum of 0.01 at Station 2 and maximum of 0.05 at Station 5. During the whole study period, the recorded seasonal nitrite values in all stations were found to be significantly higher during dry season (0.05mg/L) than during wet season (0.03mg/L) (Table 1). The observed variations among stations during wet season could be due to biological causes like the activity of "nitrogen cycle" bacteria, excretion of nitrogenous compounds by plankton and decay of vegetation. Generally, the recorded nitrite values are within the acceptable levels for marine environment.

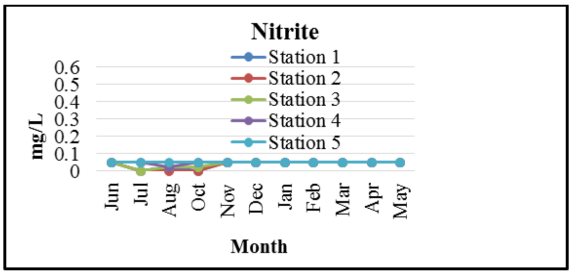

Fig. 6. Monthly trend of nitrite levels for all sampling stations.

All stations have almost similar monthly and seasonal changes in salinity as shown in Fig. 7. During wet season, the highest salinity level recorded was 33 ppt at Stations 3 and 4, and the lowest level recorded was 31 ppt at Station 1. Whereas, during dry season, the highest salinity level recorded was 35 ppt at Stations 2 and 3 and the lowest level recorded was 31 ppt at Station 1. Mangroves are distributed horizontally and vertically in estuarine and intertidal zones, respectively as influenced by several factors including salinity (Giesen *et al.*, 2007 and Primavera *et al.*, 2012). In the present study, all the five sampling stations have mangrove stands specifically Avicennia and Rhizophora species with salinity ranges from 31 ppt to 34 ppt. This obtained data support the statement of Jayatiss *et al*, 2008 that salinity is vital importance in determining mangrove growth and shows that salinity tolerance is a species-specific. It can be seen in Table 1, the recorded salinity level for wet and dry seasons varied between 32 ppt and 33 ppt, respectively. The salinity levels of water during wet season are lower than during dry season. The observed low level of salinity during wet season might be due to lesser evaporation rate and higher degree of dilution by inflow of freshwater caused by rains. The same observation was obtained from the study of Manju *et al.*, (2012) in which salinity exhibited minimum value during monsoon season due to freshwater runoff. In addition, Jayatiss *et al*, 2008 states that in a mangrove habitat, the salinity is not constant but fluctuates depending mainly on the freshwater inflow. Statistically, there is no significant difference between the recorded salinity value of wet season and dry season.

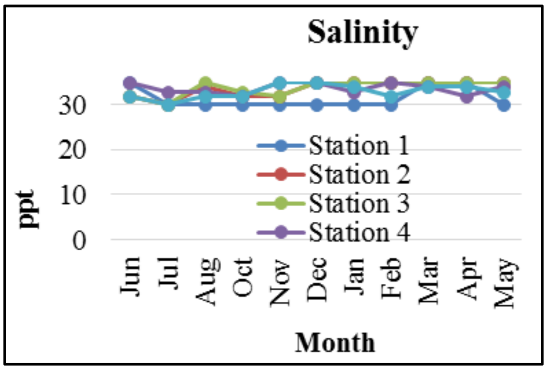

Fig. 7. Monthly trend of salinity levels for all sampling stations.

All stations have almost similar monthly and seasonal changes in water temperature as illustrated in Fig. 8. The highest water temperature during wet season was observed at Stations 1,2,3 and 4 with 27 °C, while the lowest was observed at Station 5 with 26°C. On the other hand, during dry season, the highest water temperature (30°C) was recorded at Stations 2 and 5, while the lowest value (27°C) was recorded at Station 2. During the whole study period, Table 1 shows that the water temperature during dry season is always warmer (29°C) than during wet season (27°C).

The recorded water temperature was significantly different between dry season and wet season ($P<0.05$). The observed variations in temperature during dry and wet seasons could be due to solar radiation. This statement was further explained by Kumar *et al.* that the prevalence of difference in temperature was due to the factors such as solar radiation, cloud cover intensity and direction of wind currents and thermal exchanges by tidal currents. During the summer season, the clear sky would have favoured intense radiation thereby increasing the air and subsequently the surface water temperature.

While, during the monsoon season, mixing of cold, fresh waters through river run off coupled with lower air temperature has led to reduction of surface water temperature. Water temperature is probably the most important environmental variable for the sustenance of aquatic flora and fauna (Mariappan *et al.*, 2015).

In the present study, values of water temperature are within the level which is appropriate for aquatic marine life. This is evidenced by having mangrove species specifically Avicennia and Rhizophora in all sampling stations. According to Morrisey *et al.*, (2010), mangrove species dispersal in both global and regional scales is also limited by climatic factors such as low and intense temperatures, patterns of rainfall, and aridity with temperature as the main determinant of patterns of distribution. Further, Giesen *et al.* (2007) stated that mangroves are situated in regions with average annual temperature of about 18°C or higher or with an estimated absolute temperature of greater than 15°C.

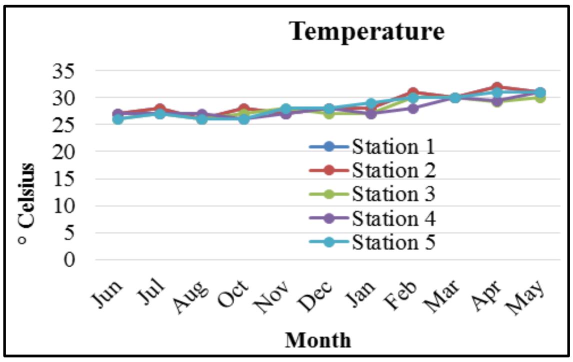

Fig. 8. Monthly trend of water temperature for all sampling stations.

The values of different water parameters investigated were as follows: water pH (7.67-7.73), alkalinity (102-109mg/L), nitrite (0.03-0.05mg/L), ammonia (0.09-0.11mg/L), salinity (32-34 ppt), and water temperature (27-29°C). Significant seasonal variations ($P<0.05$) were observed in nitrite and temperature values. while no seasonal variations ($P>0.05$) were observed in pH, alkalinity, ammonia and salinity values. The observed variations in nitrite values could be due to biological causes like the activity of "nitrogen cycle" bacteria, excretion of nitrogenous compounds by plankton and decay of vegetation. The observed variations in water temperature could be due to solar radiation. During the summer season, the clear sky would have favoured intense radiation thereby increasing the air and subsequently the surface water temperature. While, during the monsoon season, mixing of cold, fresh waters through river run off coupled with lower air temperature has led to reduction of surface water temperature. Meanwhile, the observed salinity values in the present study implied that the mangrove waters in all the sampling stations are saline in nature. It was observed in the present study that all water parameters obtained low values during wet season, while high values during dry season. Water quality fluctuates constantly depending on the season and as well as affected by rainfall and sunlight (http://aquaculture.asia/files/PMNQ%20WQ%20standard%202.pdf). This statement explains why there is fluctuation in all water quality parameters values in the present study. Further, in 2006, a study on physico-chemical and biological properties of the Muthupettai Mangrove was conducted and the results revealed that the ecological conditions of mangrove waters are largely governed by seasonal changes induced by monsoonal cycles which altered most of the physical-chemical and biological parameters (Kumar *et al.*, 2006). Generally, values of all water quality parameters during wet season and dry season are within the ideal range appropriate for aquatic marine life specifically mangrove species which are presence in the sampling areas.

Review of related literature

Decades of failed mangrove plantings around the world have shown the importance of understanding the planting environment and the biophysical factors that act as a stress on an establishing seedling (Lewis and Brown, 2014). Planting mainly Rhizophora spp. seedlings and propagules, regardless of whether this was appropriate for the selected site. In short, too often the wrong species were planted in the wrong place at the wrong time (Quarto, 2012). Also, there is heavy fund for massive rehabilitation of mangrove forests over the last two decades; the long-term survival rates of mangroves are generally low at 10-20%. Poor survival can be mainly traced to two factors: inappropriate species and site selection (Primavera and Esteban, 2008).

The tolerance of mangroves to the bio-physical processes is species-specific; the species of some genera such as Avicennia and Sonneratia are able to tolerate harsher physical conditions such as longer periods of tidal inundation. These are known as pioneer species because they are the first species able to colonize the pioneer mangrove zone, where tidal inundation and waves are highest. Hence, these species would be more appropriate for low elevation rehabilitation zones, where flooding is highest.

Other species may be more suitable for other locations, for example Lumnitzera is better able to colonize other areas such as the edge of the tambak wall (Lewis and Brown, 2014). The interaction between biological and physical processes creates a sensitive feedback relationship allowing adjustment of the landform (in both the vertical and horizontal planes) to changes in sea level may directly or indirectly affect mangrove growth (Lee *et al.*, 2014). Department of Environment, Nature and Resources (DENR) follows bio-physical criteria, e.g. suitable species, sites and seasons to avoid the high mortality rates of many DENR programs on mangrove planting projects (Primavera, 2000). Understanding the biophysical processes that control mangrove survival and understanding which species may be the best suited for the site during the initial planning phase of a restoration project will go some way to improving its ultimate success (Lewis and Brown, 2014).

Conclusion and recommendations

Based on the results of the study, it is concluded that there were seasonal variations in bio-physical and chemical characteristics specifically on nitrite level and temperature of mangrove waters in all five sampling stations located in Barangays Caroan, San Jose and Tapel. All parameters obtained low values during wet season while, high values during dry season in all stations.

This present investigation explains that season is the main factor in the variations of water quality parameter values. The showed marked seasonal variations in the bio-physical and chemical characteristics of water revealed the typical mangrove environmental condition. Furthermore, the results of the study revealed that the overall water quality parameters values of mangrove water in all sampling areas are within the ideal range appropriate for aquatic marine life specifically mangrove species which are presence in the sampling areas.

This present study revealed that the environmental conditions of mangrove waters are largely governed by seasonal changes. Hence, understanding the biological, physical and chemical characteristics of mangrove waters are very important since these influences the aquatic environment specifically mangrove ecosystem. Therefore, the water quality information on the variations during wet and dry seasons can be used as baseline data to support the conservation, management and sustainable development of the mangroves. Based on the findings of the study, the following recommendations are given: (1) In future research for the conservation, management and sustainable development of the mangrove ecosystem, it is necessary to perform annual monitoring of biological, physical and chemical characteristics of mangrove waters should be done and (2) comprehensive assessment will be done through inclusion of all appropriate water quality parameters that could affect the biological, physical and chemical characteristics of the mangrove waters.

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