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Composition and Abundance of Plankton Communities in Mangrove Estuary of Tubajon, Philippines

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Abstract

Tubajon has a semi-enclosed estuary characterized by shallow depth and slow water exchange being disrupted by a mangrove barrier. In an attempt to assess the environmental condition of the mangrove estuary of Tubajon, this study determined the composition and abundance of plankton as a bioindicator in the aquatic environment along with the physicochemical parameters. The Surfer software was used to generate the bathymetric profile of the area. The sensor data logger was used to determine the dissolved oxygen (DO), salinity, pH, and temperature of water. The spectrophotometric method determined the chlorophyll-*a* content of water, and the cadmium copper method measured the nitrate concentration. Plankton was identified using the taxonomic keys. Results showed a total of 18 taxa of phytoplankton belonging to dinoflagellates and diatoms that were able to adapt the lower light conditions and nutrient-impoverished water. Dinoflagellates were the most numbered phytoplankton. Copepods were the dominant group among the zooplanktons. Chlorophyll-*a* content (<0.05 µg/L), DO (<4 mg/L) and nitrate concentration (<0.1 ppm) were relatively small indicating less productivity and oligotrophic condition. The results might be due to less water exchange, high water retention caused by the presence of a mangrove barrier, and the anthropogenic activities by the nearby settlers. This study may provide relevant information for any conservation effort in the area.

Keywords: bathymetric, bioindicator, chlorophyll-*a*, oligotrophic, zooplankton

Introduction

Mangrove ecosystem is the predominant type of vegetation covering about 25% of tropical and subtropical coastlines worldwide (Krumme & Liang, 2004). It is the most complex estuarine ecosystem, and its constantly changing environment has proved to be an important area of study. It is a very dynamic system where water circulation and terrestrial influences induce high variability in the distribution and structures of planktonic populations (Morgado et al., 2007).

Plankton plays a critical role in the aquatic environment. Phytoplankton initiates the marine food chain by serving as food to primary consumers. Phytoplankton contributes to about 90% of the total production in marine ecosystem that supports commercial fisheries (Karthik et al., 2012). As the primary producer located at the base of the food chain, phytoplankton is the fundamental component of an aquatic ecosystem. Occurrence and abundance of phytoplankton indicate the quality of water concerning pollution that significantly affects the fishery potential (Robin et al., 2010). The increase in phytoplankton growth leads to the rise in chlorophyll-*a* concentration and primary production.

Likewise, zooplankton is of paramount importance as prey for many juvenile mangrove fishes due to being ubiquitous and dominant, relatively small-sized, and its abundance. In mangrove ecosystems, zooplankton also forms a key trophic link in aquatic food webs (Krumme & Liang, 2004). Water flow, salinity, and temperature changes in estuarine driven by weather and climate influence largely the fluctuations in abundance of zooplankton.

Estuaries are vulnerable to invasion by non-indigenous species owing to exposure to primary transport vectors that can significantly modify species composition and biotic interactions resulting in remarkable changes in abundance (Winder & Jassby, 2010). The distribution and structures of particular faunal compositions of the area reflect these processes. Such modifications have significant effects at other levels but have adverse effects on phytoplankton and zooplankton structures through changes in their species composition, diversity, and densities (Morgado et al., 2007).

Barangay Tubajon is one of the coastal areas of Laguindingan that lies within Macajalar Bay. It has a semi-enclosed estuary containing isolated marine waters. Mangrove barrier disrupts the continuous water exchange in an open system. The disruption results to slow water movement that is a characteristic of a lagoon. The limited exchange of water with the adjacent ocean characterizes the lagoon habitat. These features could have adverse effects on the ecosystem's dynamic condition.

Plankton satisfies conditions to qualify as suitable indicators because they are simple and are capable of quantifying changes in water quality (Onyema, 2007). Hence, this study aimed to assess the composition and abundance of plankton in mangrove estuary of Tubajon. Specifically, this study determined the bathymetric profile and physicochemical parameters of water, identify and enumerate the plankton in the area.

Materials and Methods

Description of the study area

The coastal area of Barangay Tubajon in the Municipality of Laguindingan, Misamis Oriental province was the study site (Figure 1). Barangay Tubajon is one of the coastal barangays of Laguindingan, which lies within Macajalar Bay. It has a 31-hectare of Marine Protected Area (MPA) which covers an extensive seagrass meadow, mangrove, and coral reef. However, due to numerous mangroves planted, continuous water circulation tends to cease near the shorelines, causing an isolation of marine water in some parts of the area.

The isolated water becomes the significant area of the study where the five sampling stations were established. Station 1 (8^0 37' 17.74" N and 124^0 28' 15.56" E) is approximately 15 meters from the shoreline making it prone to anthropogenic disturbances by nearby settlers. Station 2 is situated at 8^0 37' 19.24" N and 124^0 28' 11.76" E with a distance of 126.78 meters from Station 1. Tidal changes and water influx coming from the adjacent ocean due to the absence of mangrove barrier that restrains water flow characterize this site.

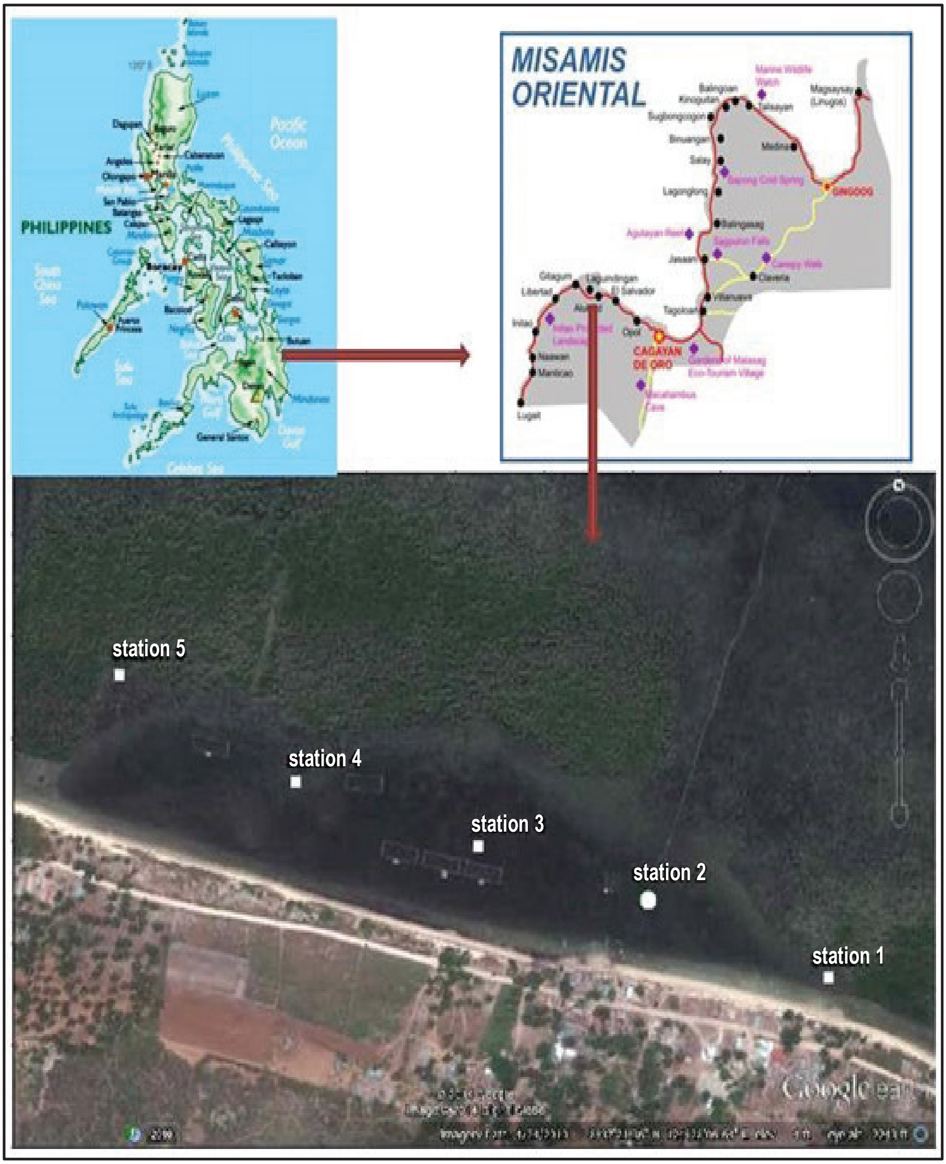

Figure 1. Geographical locations of the five sampling stations established at mangrove estuary in Tubajon.

Station 3 (8^0 37' 20.75" N and 124^0 28' 6.31" E) is situated at the center of the lagoon, 169.16 meters away from Station 2. Located very close to the planted mangroves is Station 4 (8^0 37' 21.74" N and 124^0 28' 2.26" E) which is 127.07 meters away from Station 3. Established in the most isolated part of the lagoon, Station 5 (8^0 37' 23.49" N and 124^0 27' 57.45" E) is 158.68 meters away from Station 4.

Bathymetric profile determination

The five sampling points were set up within the isolated waters in the area using the global positioning system in April 2014. Within a given location, a simple bathymetric profiling was done. In this method, transect attached with weights that act as sinkers along the water column was placed in water. As the weights reached the lowest point of the water column, the water depth was recorded. Using the Surfer version 7.00 mapping and editing software, the depth data were processed to generate a quick view of the bathymetric profile of the area.

Physicochemical determination

Dissolved oxygen (DO), salinity, pH, and temperature of water were determined using a sensor data logger placed strategically in the area. Water sample collection was done twice per day during the high tide and low tide. Water sampler was used to collect 250-ml water in three replicates from sub-surface in each station to determine the nitrate and chlorophyll-*a* content. The spectrophotometric method was used to analyze the chlorophyll-*a* content, and the cadmium copper method was used to determine the nitrate concentration (Parsons, 2013).

Plankton collection

Plankton net was towed horizontally in the area to collect the plankton. The samples were kept in 250-ml bottles with 5% formalin and brought to the laboratory for phytoplankton and zooplankton identification.

Identification and enumeration of plankton

Classification of the taxa was up to the generic level using the taxonomic keys (Tomas, 1997). The number of cells counted in a gridded 1.0-ml improvised counting chamber (ICC) using an inverted microscope represents the abundance of each species. The subsample (1.0 ml) drawn from the concentrated sample was dispensed into the counting chamber and scanned thoroughly to count all the cells.

Abundance of each species was calculated as the number of individuals per cubic meter of water filtered through the net and was equated to 1 liter. The densities in cells L^{-1} of different phytoplankton and zooplankton species were determined by dividing the cell number from the concentrated sample by the volume of water filtered by the net.

Statistical analysis

The Shannon diversity index of plankton was determined using Biodiversity Pro. Analysis of variance was used to establish if there is a significant difference in DO, salinity, pH, temperature, and nitrate between tides at each sampling station.

Results and Discussion

Bathymetric profile

The depth of the study area ranges from 0.9 to 1.8 m (Figure 2). The deepest part was along the middle part of the lagoon with an average depth of 1.8 m. The shallowest part was near inshore at 0.9 m. The depth starts to increase starting from the shoreline towards the middle part of the lagoon, and then suddenly decreases towards the mangrove reserve. The lagoon tends to have a basin shape. The muddy substrate characterizes the bottom part.

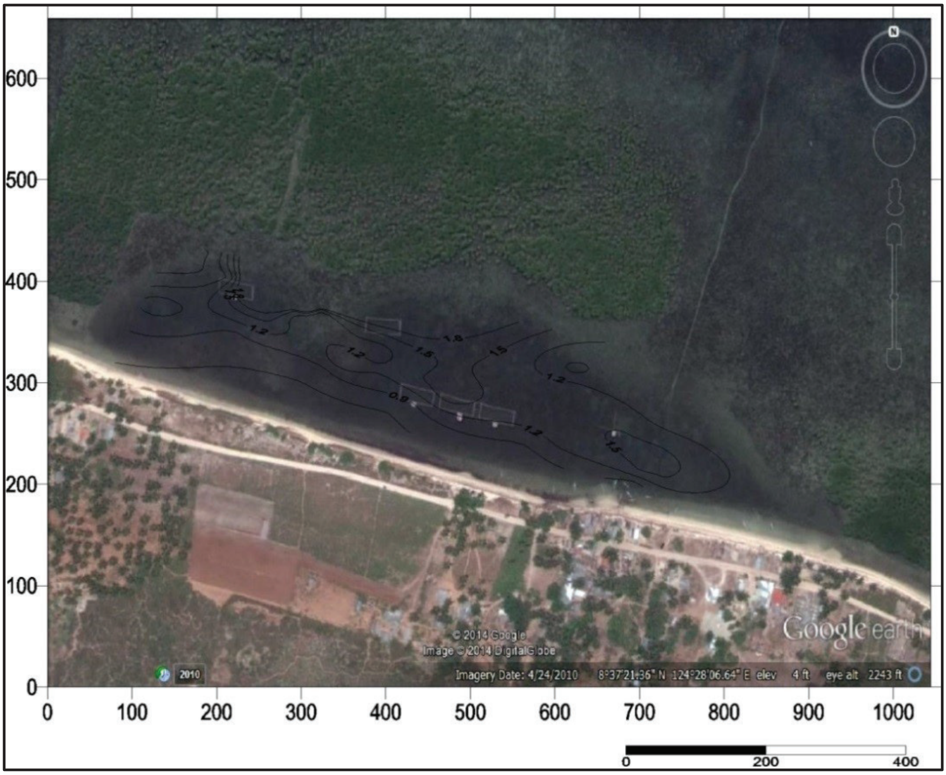

Figure 2. Basin-shaped bathymetric profile of the lagoon in Barangay Tubajon, Laguindingan, Misamis Oriental (the darker the lines, the greater the depth).

Physicochemical parameters

Figure 3 shows the mean readings of DO, salinity, pH, and temperature. Fish requires 4.0 mg/L of dissolved oxygen to survive. Oxygen levels that remain below 1-2 mg/L for a few hours can result in massive fish kills (Nollet & De Gelder, 2000). The concentration of dissolved oxygen below 4.0 mg/L is unhealthy for many aquatic community inhabitants (Environmental Protection Agency [EPA], 2006). In this study, the average DO readings at the surface, and deep waters during high tide were 6.16 ppm (parts per million) and 6.84 ppm, respectively. During low tide, the average dissolved oxygen readings were 3.53 ppm at the surface and 3.14 ppm at the bottom.

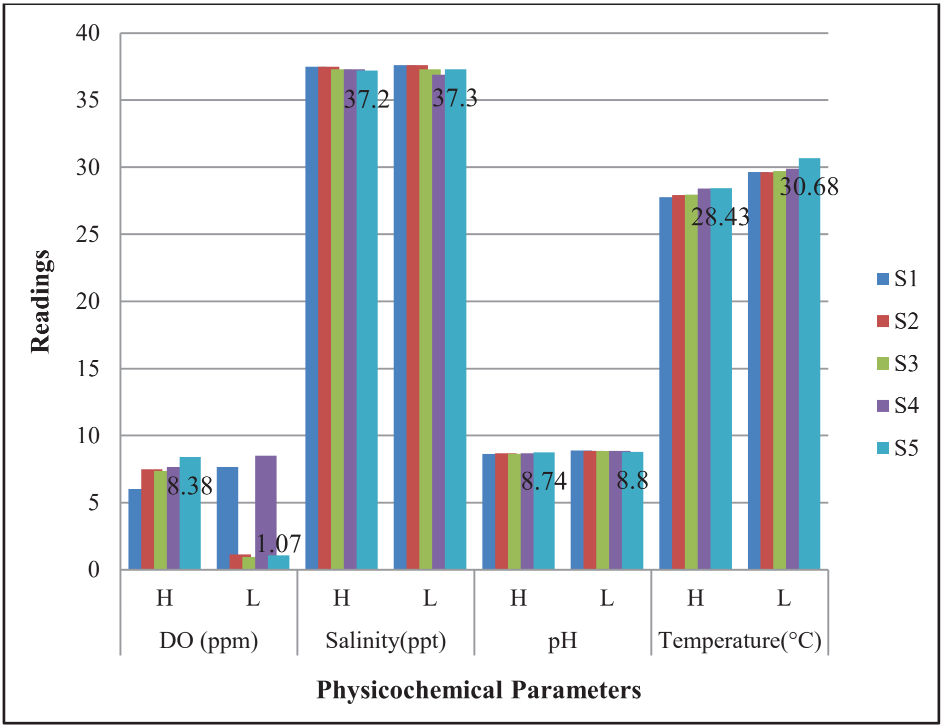

Figure 3. Mean readings of physicochemical parameters in the mangrove estuary of Tubajon during high tide (H) and low tide (L). S1, S2, S3, S4, and S5 represent the sampling stations.

Results showed that the average dissolved oxygen in the area is within the range that can sustain marine life. However, deep waters considerably have lower dissolved oxygen readings compared to surface waters because of poor mixing with the atmosphere and limited light for aquatic photosynthetic plants that could have increased the amount of oxygen (New Jersey Department of Environmental Protection, 2014). The decrease in DO was also evident during low tide where its concentration dropped to 1.07 ppm in Station 5. The result implies that the bottom is anoxic due to less or no intrusion of seawater in the area. According to Bornman and Adams (2005), in the absence of tidal currents and strong freshwater inflow, the oxygen level in closed estuaries may decrease in bottom waters. The noticeable decrease of DO and low chlorophyll-*a* concentration during low tide in this study supports the claim. Breitburg et al. (1997) added that low dissolved oxygen concentration is common in aquatic ecosystem especially bottom of lakes, estuaries, and coastal marine system that have high nutrient loadings, and least stratification in water layers with differing densities. This condition allows microbial degradation of organic matter that depletes bottom-layer oxygen and inhibits re-aeration of waters. Moreover, the muddy substrate of the area indicates high organic matter that may cause more oxygen consumption.

Estuarine pH levels range from 7.0 to 7.5 at the average in the fresher sections, and from 8.0 to 8.6 in the more saline areas (EPA, 2006). In this study, the mean pH in the area ranged from 8.81- 8.86 indicating an alkaline pH, but the level remains ideal for an estuarine environment. Regarding salinity, the area has a reading of more or less 37 ppt (parts per thousand) indicating that waters in the area may be euhaline having the salinity reading similar with the ocean (Lalli & Parsons, 1997).

Nitrate is the most abundant fixed nitrogen source in the ocean but may vary in concentration depending on habitat. The study showed that the nitrate concentration in the area ranged from 0.024–0.061 ppm and 0.046–0.095 ppm during low tide and high tide, respectively (Figure 4). The low concentration of nitrate during low tide indicates that the in situ accumulation of nitrate did not exceed the nitrate concentration in the overlying water (Usui et al., 1998) as shown by its distinct increase during high tide. Nitrate level in surface waters seldom exceeds 0.1 mg/L as N, but waters influenced by human activity typically contain up to 5 mg/L as N. Levels over 5 mg/L N indicate pollution by the animal or human waste or fertilizer runoff (EPA, 2006). The nitrate concentration in the area is relatively low based on the standard values.

According to Lancelot and Muylaert (2011), phytoplankton can use most of the available nutrients in estuaries with long retention time and favorable underwater light climate for photosynthesis. In this study, this condition could be the reason for the low nitrate concentration in the area. Denitrification which is the dissimilatory nitrate reduction that occurs in anoxic condition could be the other cause of the low nitrate concentration in the area. The occurrence of this process requires a supply of organic materials as well as the oxidized form of nitrogen such as nitrate and nitrite (Usui et al., 1998).

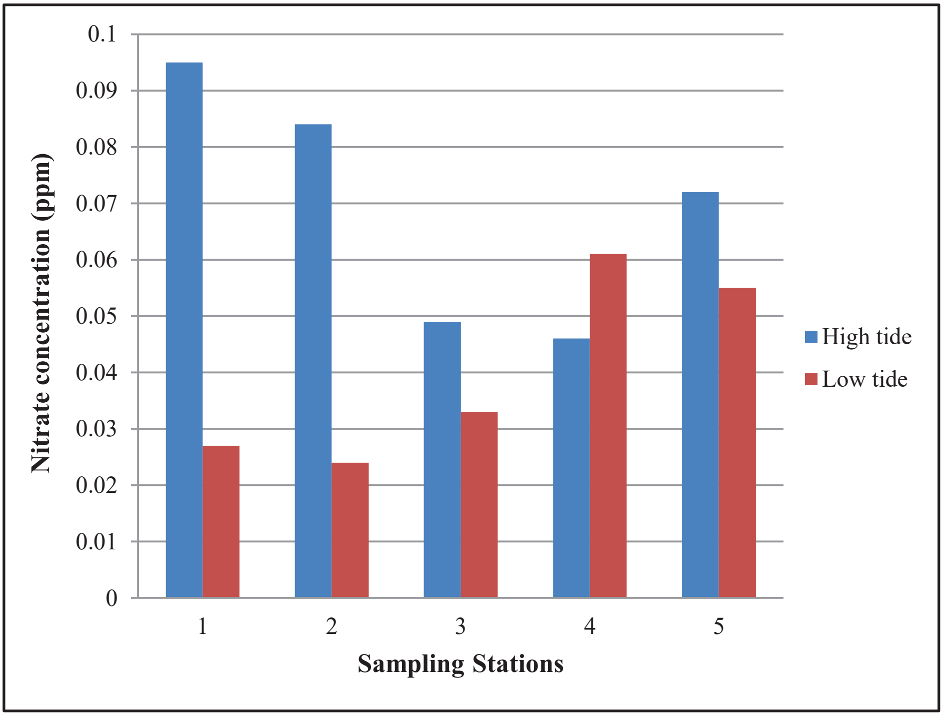

Figure 4. Nitrate concentrations in five sampling stations established at mangrove estuary of Tubajon.

Analysis of variance showed that there was no significant difference in pH, temperature, dissolved oxygen and salinity between tides and within sampling stations. However, there was a significant difference in nitrate concentration between tides ($p<0.05$) (Table 1). Nitrate concentration was low at low tide and relatively high during high tide. The difference might be due to low in situ accumulation of nitrate than the overlying water.

Table1. Analysis of variance for nitrate between tides.

	ANOVA				
	Sum of squares	**df**	**Mean square**	**F**	**Sig.**
Between Groups	.002	1	.002	5.725	.044*
Within Groups	.003	8	.000		
Total	.005	9			

*Significant at $p<0.05$.

Figure 5 shows the chlorophyll-*a* concentration in five sampling locations. Chlorophyll-*a* in the area ranged from 0.0049 to 0.1430 μg/L. These values are relatively small, which indicate low productivity. In the five stations, the chlorophyll-*a* concentration was highest in Station 2 but lowest in Station 4. The level is low based on the standards set by EPA (2006) for marine waters. The exchange of waters coming from the outside of the lagoon may contribute to the chlorophyll-*a* concentration in Station 2.

In this study, it is evident that chlorophyll-*a* concentration decreases in water entering the lagoon. The decrease could indicate that there is a lesser degree of planktonic transport within the lagoon. Being isolated from any water exchange, Stations 3 to 5 had lower chlorophyll-*a* concentrations than Station 1. However, Station 2 had relatively greater chlorophyll-*a* since it was more affected by tidal changes resulting to a greater degree of planktonic transport compared to other stations.

The rate of water motion is probably slow even if tides affect the movement directly. The slow movement may result in only a little influx of water being able to penetrate inside the lagoon. Although there is a need to deploy clod cards to determine the rate of water movement inside the lagoon, the consequence of a given isolated area due to a mangrove barrier creates significant changes to the ecosystem. Chlorophyll-*a* concentration was lowest inside the lagoon (<0.05μg/L) which Lalli and Parsons (1997) classified this condition as oligotrophic. The sediments were muddy as compared to the sandy-coralline sediment outside. The numerous residential households adjacent to the lagoon could be a factor for the input of nutrients in the area.

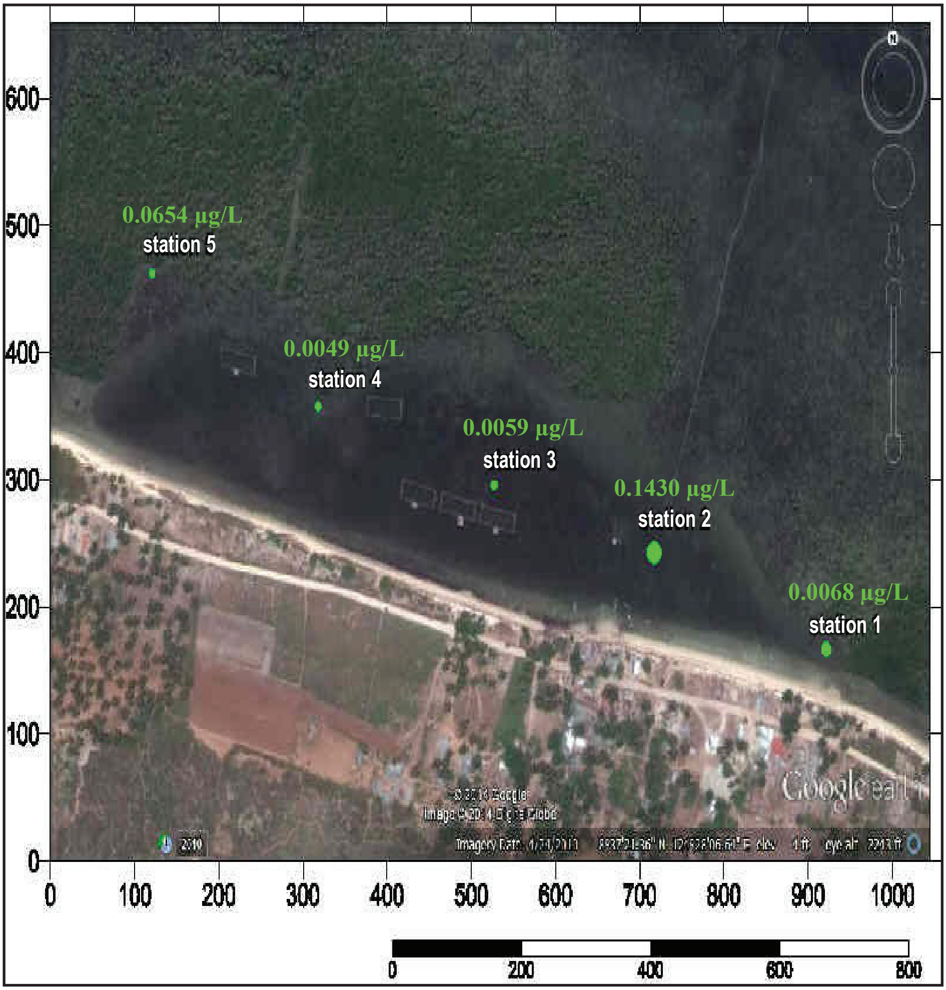

Figure 5. Map showing the various concentrations of chlorophyll-*a* (in µg/L) in five stations established at mangrove estuary of Tubajon (the bigger the green circle, the greater is the chlorophyll-*a* concentration).

Plankton composition and abundance

Results showed that there were 18 taxa of phytoplankton in the area belonging to different genera (Table 2). Of the total number of taxa, 11 belong to dinoflagellates (Class Dinophyceae) and six to diatoms (Class Bacillariophyceae). *Chlamydomonas* sp. has the highest density among the dinoflagellates and *Nitzchia* sp. among the diatoms. The abundance of dinoflagellates and diatoms in the area showed similar results to the studies of Morgado et al. (2007), Fehling et al. (2012), and Tas (2013). According to Lalli and Parsons (1997), these two taxa are among the best studied of the planktonic algae and are often the dominant phytoplankton in temperate and high latitudes.

High diversity of dinoflagellates indicates oligotrophic condition (Tas, 2013) which is also evident with low chlorophyll-*a* (<0.5 μgL^{-1}) and nitrate concentration in the area. Dinoflagellate species showed the more homogeneous distribution in a wider area than diatoms. The higher tolerance of dinoflagellates to the existing ecological conditions than diatoms may explain the situation. Moreover, dinoflagellates are better adapted to living under lower light conditions and in nutrient-impoverished water making them the most numerous of the phytoplankton in stratified, nutrient-poor tropical and subtropical waters (Lalli & Parsons, 1997).

Diatoms were also dominant in the area. They could thrive well in widely changing hydrographical conditions (Perumal et al., 2009). The predominance of diatoms in phytoplankton assemblage is a common phenomenon in coastal waters. Diatoms are larger compared to other phytoplanktonic components, increasing their rate of sinking. Thus, to overcome this problem, diatom always prefers to inhabit and dominates the phytoplankton community in the shallow coastal region (Karthik et al., 2012), such as the mangrove estuary of Tubajon.

The study showed a total of nine zooplankton taxa in the area. Copepods (98%) were the most dominant group with Zoea having the highest density. The result is similar to the study of Krumme and Liang (2004). In estuaries, the patterns of zooplankton abundance and distribution are complex and extremely variable. This variation results from interactions of various factors, such as the fact that zooplankton organisms can feed on other sources than phytoplankton, and are consequently less dependent on phytoplankton dynamics. Tidal currents and river flows are also responsible for the variability in zooplankton abundances by affecting the period that a given zooplankton population persists in the estuary (Morgado et al., 2007).

Table 2. Enumerated plankton in mangrove estuary of Tubajon.

Plankton	Abundance (cells L^{-1})	Relative abundance (%)	Density	Group
Phytoplankton				
Amphora sp.	167	0.20	0.17	Dinoflagellates
Ceratium sp.	500	0.60	0.5	Dinoflagellates
Clamydomonas sp.	44000	52.70	44	Dinoflagellates
Dinophysis sp.	500	0.60	0.5	Dinoflagellates
Navicula sp.	167	0.20	0.17	Dinoflagellates
Oscillatoria sp.	1167	1.40	1.17	Dinoflagellates
Peridinium sp.	833	1.0	0.83	Dinoflagellates
Pleurosigma sp.	1167	1.40	1.17	Dinoflagellates
Rhabdunima sp.	13333	15.97	13.33	Dinoflagellates
Surirella sp.	1000	1.20	1	Dinoflagellates
Trichodismium sp.	167	0.20	0.17	Dinoflagellates
Coscinodiscus sp.	2833	3.39	2.83	Diatom
Nitzschia sp.	13667	16.37	13.67	Diatom
Pseudonitzschia sp.	500	0.60	0.5	Diatom
Rhizosolenia sp.	1500	1.80	1.5	Diatom
Skeletonema sp.	500	0.60	0.5	Diatom
Thallassiosira sp.	667	0.80	0.67	Diatom
Thalasionema sp.	833	1.0	0.83	Diatom
Total	**83501**	**100**	**83.501**	
Zooplankton				
Apendicularia sp.	166.67	0.52	0.17	Urochordata
Balanus sp.	166.67	0.52	0.17	Copepod
Calanus sp.	9500	29.38	9.5	Copepod
Copilia sp.	166.67	0.52	0.17	Copepod
Crossota sp.	166.67	0.52	0.17	Medusae
Limacina sp.	833.33	2.58	0.83	Thecosomes
Nauplius	21000	64.94	21	Copepod
Tintinopsis sp.	333.33	1.03	0.33	Ciliates
Zoea	1000	3.09	1	Copepod
Total	**33333.33**	**100.0**	**33.34**	

Phytoplankton and zooplankton diversities in the area were low (Figure 6). According to Perumal et al. (2009), the distribution and abundance of phytoplankton in tropical waters varied remarkably due to environmental fluctuations. Evidently, the less water exchange in the lagoon due to a barrier and the anthropogenic activities by the nearby settlers could cause the abundance and diversity of plankton. Due to the passive transport of phytoplankton and zooplankton along with the water current, these organisms can only increase within the estuary when net specific growth rates exceed the residence time of the water (Lucas et al., 2009). The net specific growth rate is the balance between phytoplankton growth and losses by lysis, grazing, and sedimentation. Low taxa richness and species diversity of plankton in the area might also be due to reduced water exchange from ocean waters and immigration of marine species (Kimmerer & McKinnon, 1987).

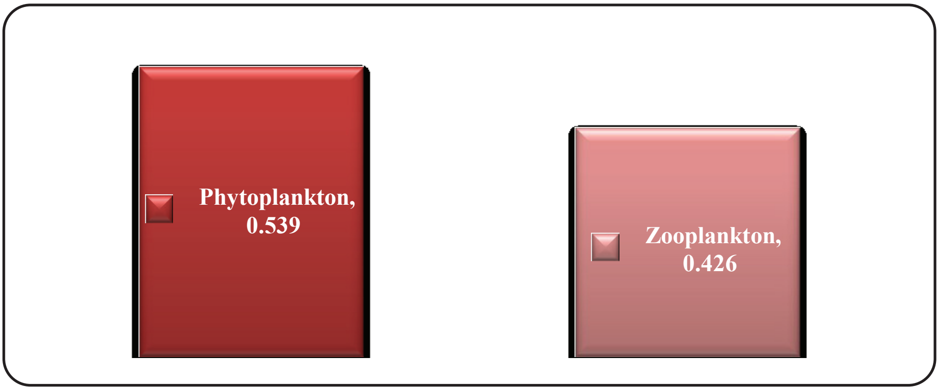

Figure 6. Shannon diversity index of plankton in mangrove estuary of Tubajon.

The mangrove estuary of Tubajon only supports low plankton diversity dominated by dinoflagellates and copepods that are highly adapted to an oligotrophic condition. Comparing with other estuaries in the Philippines, Panguil Bay has relatively higher phytoplankton diversity in particular despite being an exploited estuary in Northern Mindanao (Canini et al., 2013) compared to Tubajon estuary. The phytoplankton diversity in Taklong Island National Marine Reserve, Guimaras Island, is also higher than in Tubajon despite a major oil spill event in the area (Hallare et al., 2011). The presence of a mangrove barrier and numerous houses adjacent to the lagoon as well as the tide changes may have influenced the low levels of nitrate and chlorophyll-*a*, and the plankton community structure in the mangrove estuary of Tubajon. Similar with other tropical mangrove estuaries, nutrient concentration, seasonal shift, and anthropogenic activities have a profound effect on plankton diversity (Saifullah et al., 2015; Van Chu et al., 2014; Polidoro et al., 2014).

Conclusions and Recommendations

Dissolved oxygen, nitrate concentration, and chlorophyll-*a* content were low in the mangrove estuary of Tubajon, indicating low productivity and oligotrophic condition. Species diversity and abundance of phytoplankton and zooplankton were also low. Phytoplankton was dominated by dinoflagellates and diatoms with higher tolerance to the conditions of the mangrove estuary as they adapt better to lower light conditions and in nutrient-impoverished water. The results of the study may reflect the environmental conditions in the ecosystem due to the less water exchange and high water retention of the area caused by the presence of a mangrove barrier, and the anthropogenic activities by the nearby settlers.

The importance of this ecosystem as nurseries and feeding grounds for many commercially important species calls for an urgent conservation measure. Further monitoring of the seasonal changes in the composition, abundance and trophic structure of plankton communities, as well as the physicochemical parameters, may help analyze in detail the ecology of the system for immediate identification of mitigating measures that can be applied to safeguard this vital ecosystem.

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