Seasonal variation of water quality of the selected mariculture parks in Northern Mindanao, Philippines

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Abstract. Monitoring of water quality is one of the crucial considerations for mariculture activity. The water quality determines the conditions in which living matter can exist. The quality of the water varies from place to place, with the seasons and climate. Thus, a seasonal monitoring of water quality of the three mariculture parks in Northern Mindanao, located in Balingasag, Misamis Oriental, Surigao del Norte and Lopez Jaena, Misamis Occidental, was carried out from April, 2013 to May, 2014. The temperature, dissolved oxygen, salinity, pH, total suspended solids, depth, water transparency and water nutrients showed a significant variation between seasons. Low water temperature and high DO levels were observed during north-east monsoon. The year-round nutrient concentrations in the Parks were observed at evident levels where some areas surpassed the standard concentrations for marine fish culture signifying a possible presence of pollution in the water. Generally, however, levels of these physico-chemical parameters in the three mariculture parks are still within the allowable limit fit for marine fish production.

Key Words: physico-chemical parameters, water quality, season, climate, DO, salinity.

Introduction. Water quality is the heart of successful fish culture. Fish is fully dependent in water in performing its functions such as breathing, excreting wastes, feeding, growing and reproducing. The quality of the products and the success of the industry, therefore, depend on the water quality. Poor water quality can result in low profit, low product quality and potential human health risks. Thus, it is vital for the government to regulate aquaculture and put in place laws that will protect the water environment (PHILMINAQ, 2008). The present study generally aims to determine the changes of water quality of the three Mariculture parks in Northern Mindanao in different seasons (Northeast and Southwest monsoons, and Easterly) which could also lead to determination of season favorable for mariculture production.

Material and Method

Project sites. The Mariculture parks were selected based on the extensity of Mariculture activities in the area. Balingasag Mariculture Park, which was launched last 2007 and has an area of 195 hectares has been operating for several years and is heavily stocked, while Surigao City Mariculture Park and Lopez Jaena Mariculture Zone are still in its initial stage of development. Surigao City Mariculture Park, which was launched last in 28 February 2008 has an area of 500 ha covering five coastal barangays namely: Nabago, Day-asan, Capalayan, Cabongbongan and San Isidro. The Mariculture Park in Lopez Jaena, Misamis Occidental was established and launched on 18 February 2011. It sprawls a stretch of 313.26 ha and is zoned for different aquaculture activities. The coastal water of the mariculture zone encompasses Barangays Katipa, Biasong, Eastern Poblacion, Western Poblacion, and Sibugon (Figure 1). A total of 18 sampling stations were established in Balingasag, 17 in Lopez Jaena and 14 in Surigao Mariculture Park, which were distributed inside and outside the park.

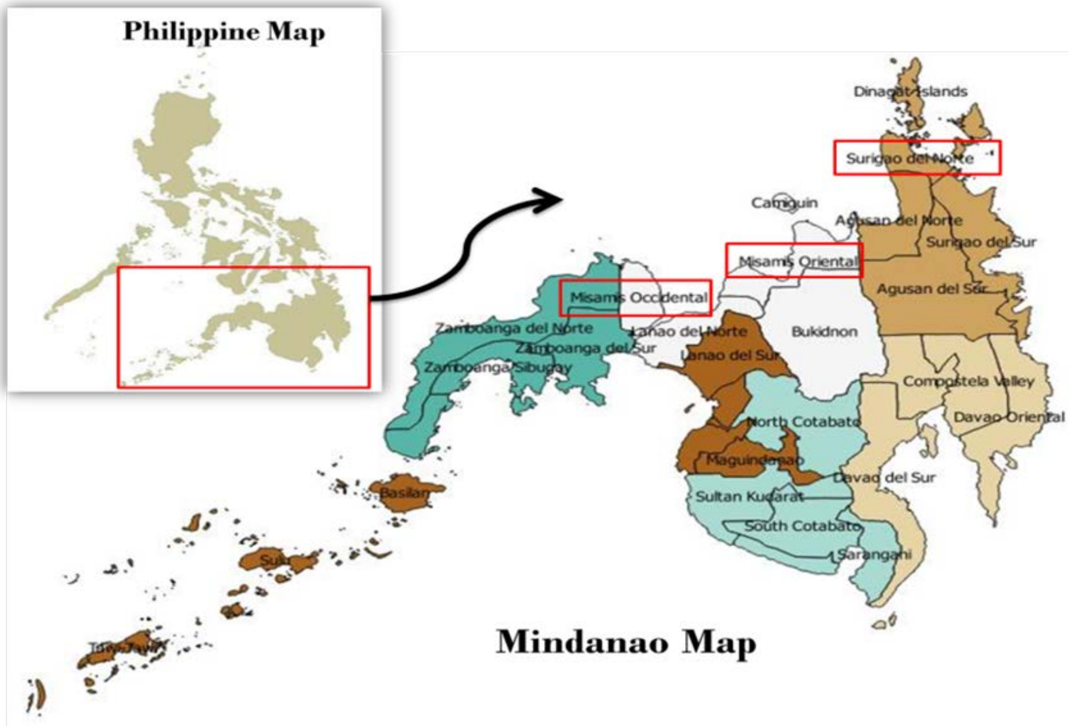

Figure 1. Map of the study area located in three provinces of Northern Mindanao, namely; Misamis Occidental, Misamis Oriental and Surigao del Norte.

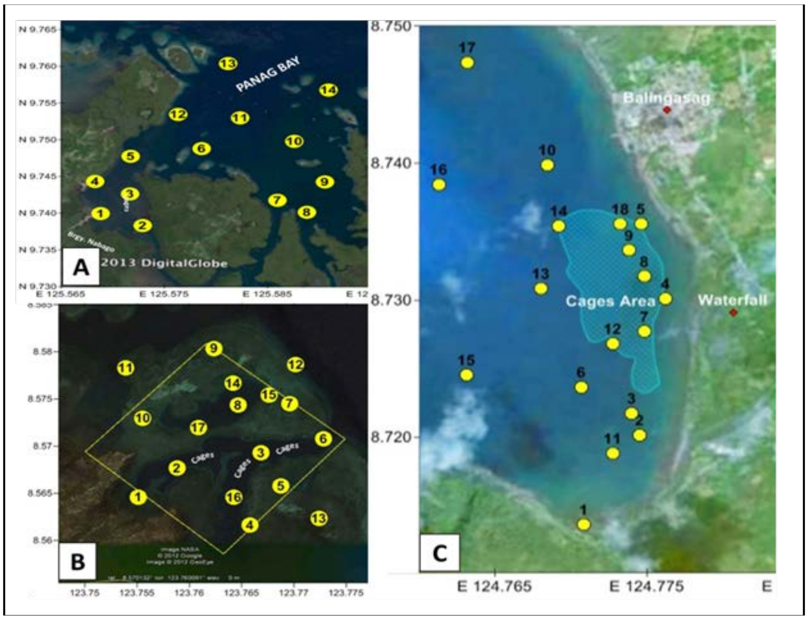

Figure 2. Google Earth map of the three mariculture parks showing the different sampling stations. (A) Surigao City Mariculture Park, (B) Lopez Jaena Mariculture Park, and (C) Balingasag Mariculture Park.

Collection of samples and analysis. Collection of samples was conducted in May, 2014 (Northeast monsoon), October, 2014 (Southwest monsoon) and April, 2013 (Easterly). Water samples were collected using LaMotte water sampler at the surface (0.5 m), 10 m, 20 m, 30 m and bottom, depending on the depths of each sampling station (Figure 3). Water temperature, pH, dissolved oxygen and salinity were measured in situ using the

HORIBA Multi Water Quality Checker U-50 Series. The water transparency was measured using the modified secchi disk and total suspended solids were determined based on APHA (1995). Inorganic nutrients in the water, such as NO_3-N, NO_2-N, NH_3-N and PO_4-P were carried out using the spectrophotometric methods described in APHA (2005).

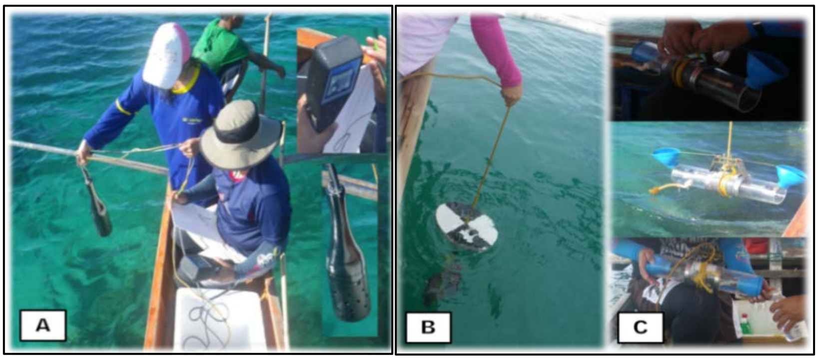

Figure 3. Collection of data using (A) HORIBA Multi Water Quality Checker U-50 Series, (B) Secchi disk, and (C) LaMotte water sampler.

Results and Discussion. Low water temperature was observed during NE monsoon averaging 26.13±0.66°C, and relatively warmer water during Easterly (29.01±1.998°C) and warmest in SW monsoon (29.29±1.54°C) (Figure 4).

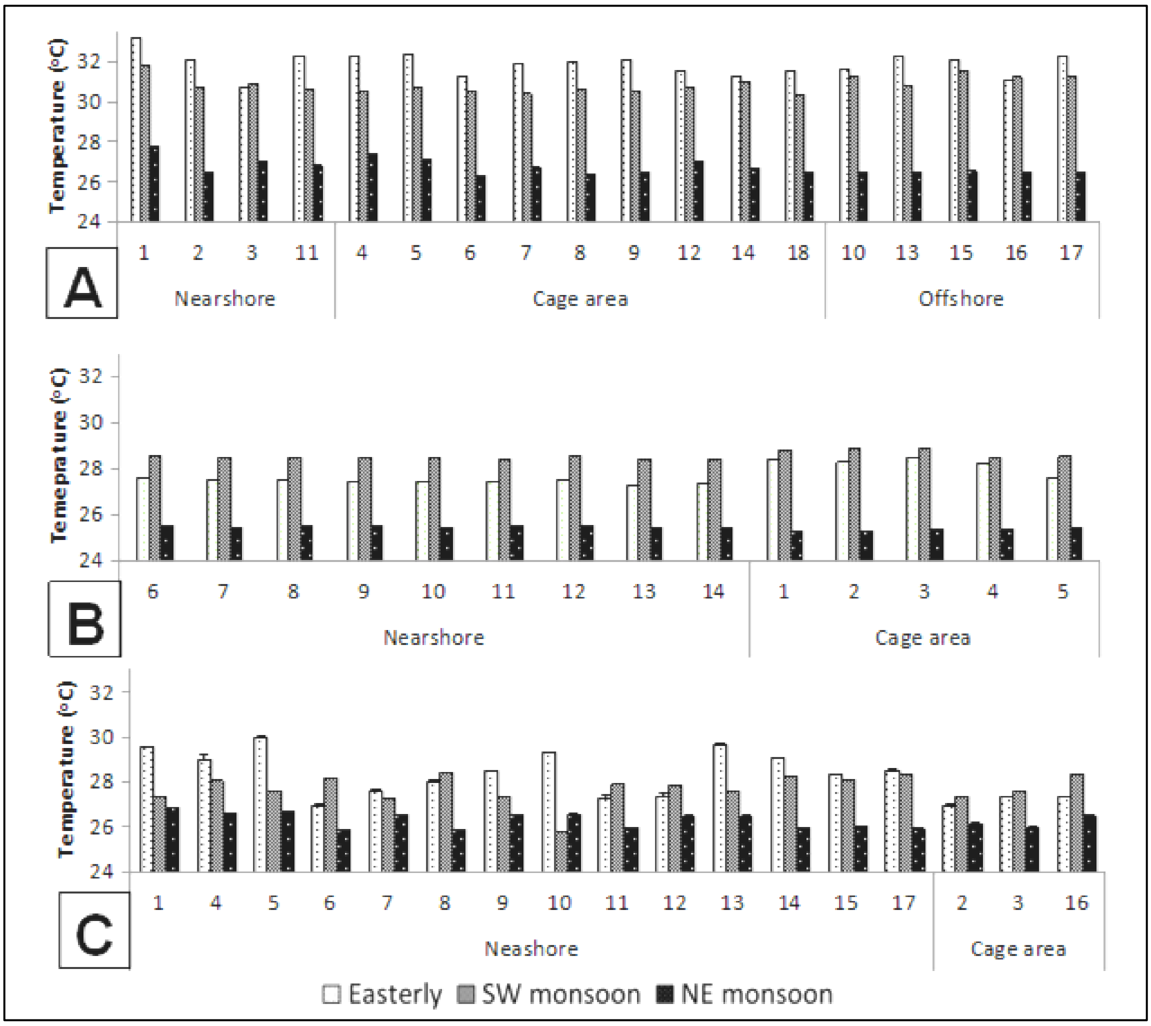

Figure 4. Mean temperature levels (°C) in all sampling stations of the three Mariculture parks in Northern Mindanao; Lopez Jaena MP (A), Surigao MP (B) and Balingasag MP (C) in different seasons.

The environmental conditions conducive to blooms usually occur during the warmer months in areas subject to high nutrient influxes (Prema 2013), while low water temperature affects the metabolic activity of the organisms. As body temperature decreases, changes in the physical chemistry of the cell produce a reduction in metabolic activity (Johnston & Dunn 1987). These levels, however, were within the ideal range (26 to 28^{o}C) considered suitable for most tropical marine life aquaculture and for edible oyster production (21 to 31^{o}C) (Prema 2013). Some areas in Balingasag during Easterly (31.89±0.58^{o}C) and SW monsoon (30.86±0.40^{o}C) exceeded the DENR standard level for fish propagation (25 to 31^{o}C), but these concentrations were still optimum for better growth rate of mussel (Prema 2013). Cold wind blown from Mount Malindang (Figure 5) keeps the sea surface water of the coast of Lopez Jaena colder during SW monsoon (25.8 to 28.2^{o}C), blanketing the warm temperature brought by southwest wind, thus, making the water column and bottom warmer in this season (Figure 6).

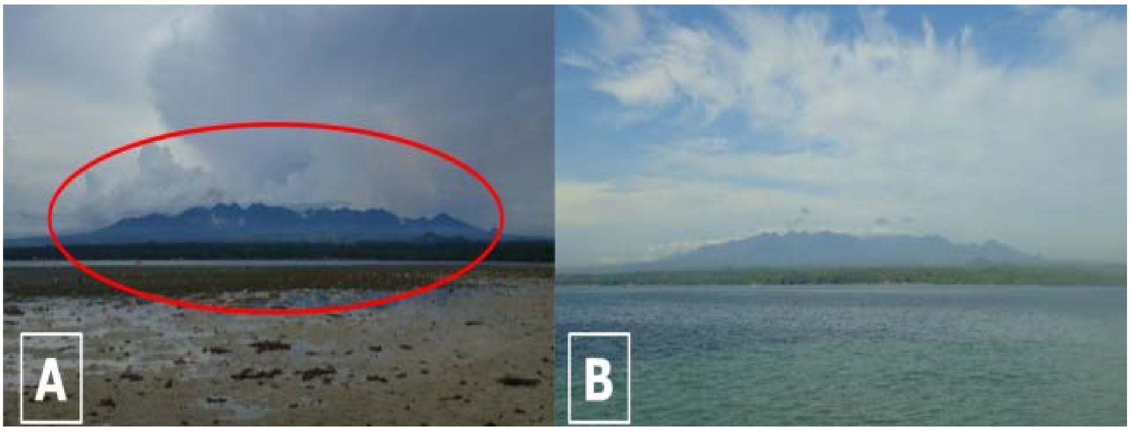

Figure 5. The Lopez Jaena mariculture park during low tide (A) and high tide (B) with Mount Malindang towering behind.

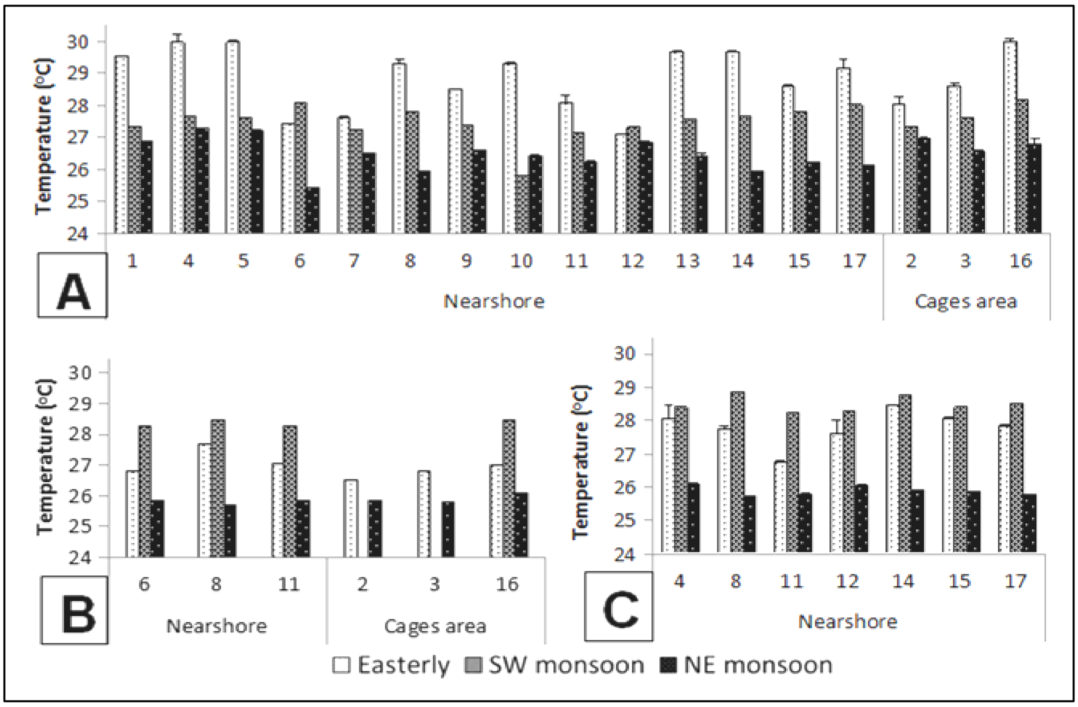

Figure 6. Mean temperature (^{O}C) levels in all sampling stations in Lopez Jaena Mariculture Park at the (A) surface, (B) 10 meters, and (C) bottom, in different seasons.

Significantly, the water temperature in the parks differ by season ($p<0.05$), signifying that the water is highly influenced by the climate. It coincides to the shifting of the seasons from NE monsoon to SW monsoon. No long range of temperature fluctuation occurred within the season. The sudden change in water temperature will affect fish metabolism, oxygen consumption, ammonia and carbon dioxide production, feeding rate, food conversion, and fish growth (Loka 2015). The solubility of oxygen is greater in colder water than in warm water, thus high concentrations of dissolved oxygen in the parks; Balingasag (6.60±1.09 ppm) Lopez Jaena (7.08±2.79 ppm) and Surigao (7.69±1.50 ppm), were observed during NE monsoon, which passed the permissible level for marine fish culture of at least 6 mg/L (Prema 2013) and a saturation level of at least 5 ppm required by the DENR (DAO 1990, 2008) (Figure 7a, b).

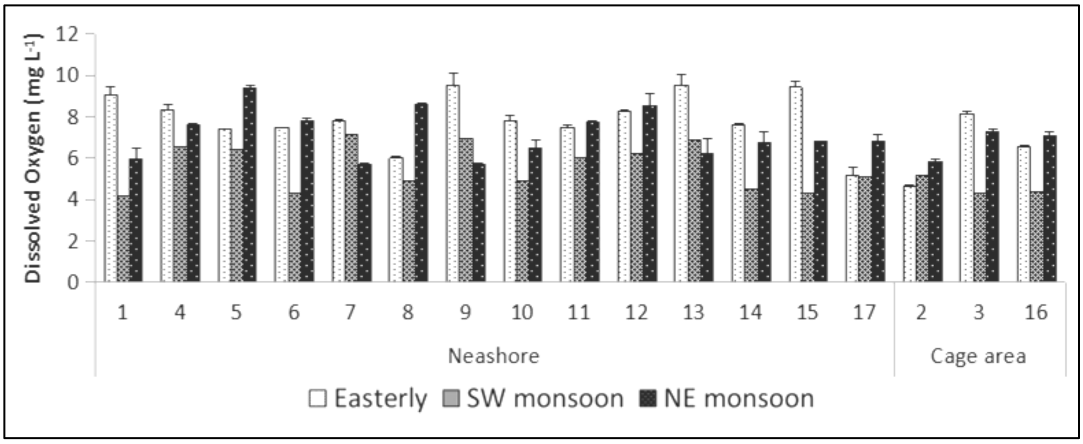

Figure 7a. Mean dissolved oxygen (mg/L) levels in all sampling stations of Lopez Jaena Mariculture Park in different seasons.

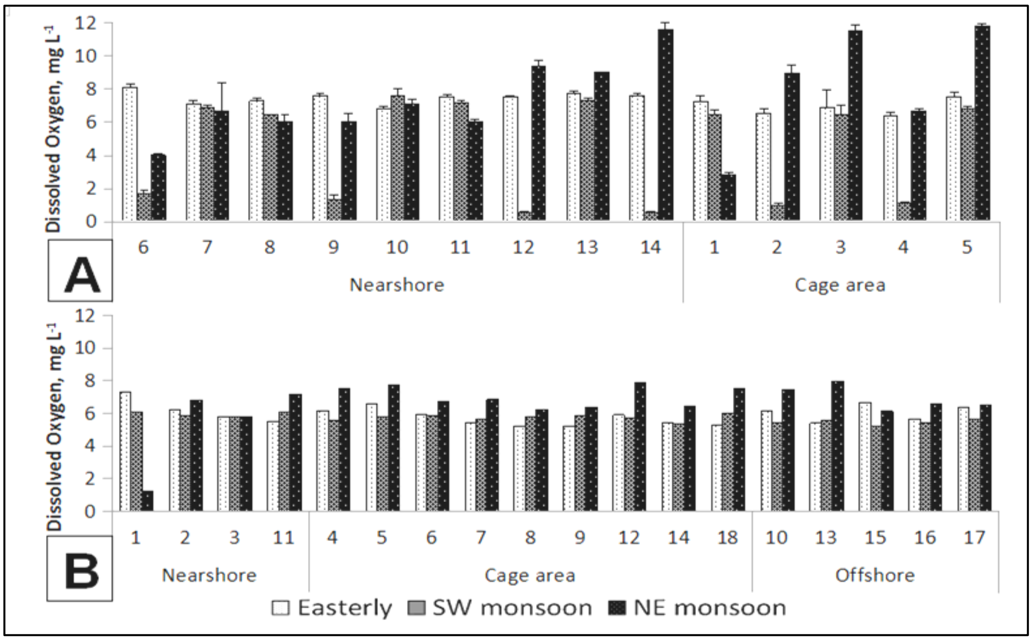

Figure 7b. Mean dissolved oxygen (mg/L) levels in all sampling stations of Surigao MP (A) and Balingasag MP (B) in different seasons.

Several areas in Surigao and Lopez Jaena Mariculture Parks had concentrations lower than 3 ppm during SW monsoon. Values lower than this can put undue stress on the fish, and levels reaching less than 2 mg/L may result to death (but 3 mg/L to some species (PHILMINAQ 2008). Currents and waves typically increase the amount of oxygen in the water and can be removed by seawater through the activity of living organisms (respiration) and organic decomposition (Drever 1997 cited in Rosli et al 2010). Dissolved oxygen levels in surface, and lower strata of shallow waters may be important in certain species of flora and fauna. The areas where there are significant low levels of dissolved oxygen are restricted circulation, abundant organic matter, industrial discharge, sewage etc. Oxygen depletion occurs in deep marine waters with thermal or salinity stratification occur (Levings 1980 cited by Jack et al 2009). The depth of the lagoon in Surigao where cages installed ranged from 3 to 9 m indicating possible occurrence of fish kills if the area is heavily stocked. Generally, DO levels in the parks are still high, but due consideration must be given to some areas during SW monsoon. The water pH in different seasons was still in the normal and favorable concentrations for seawater (7.69±0.16) (Figure 8).

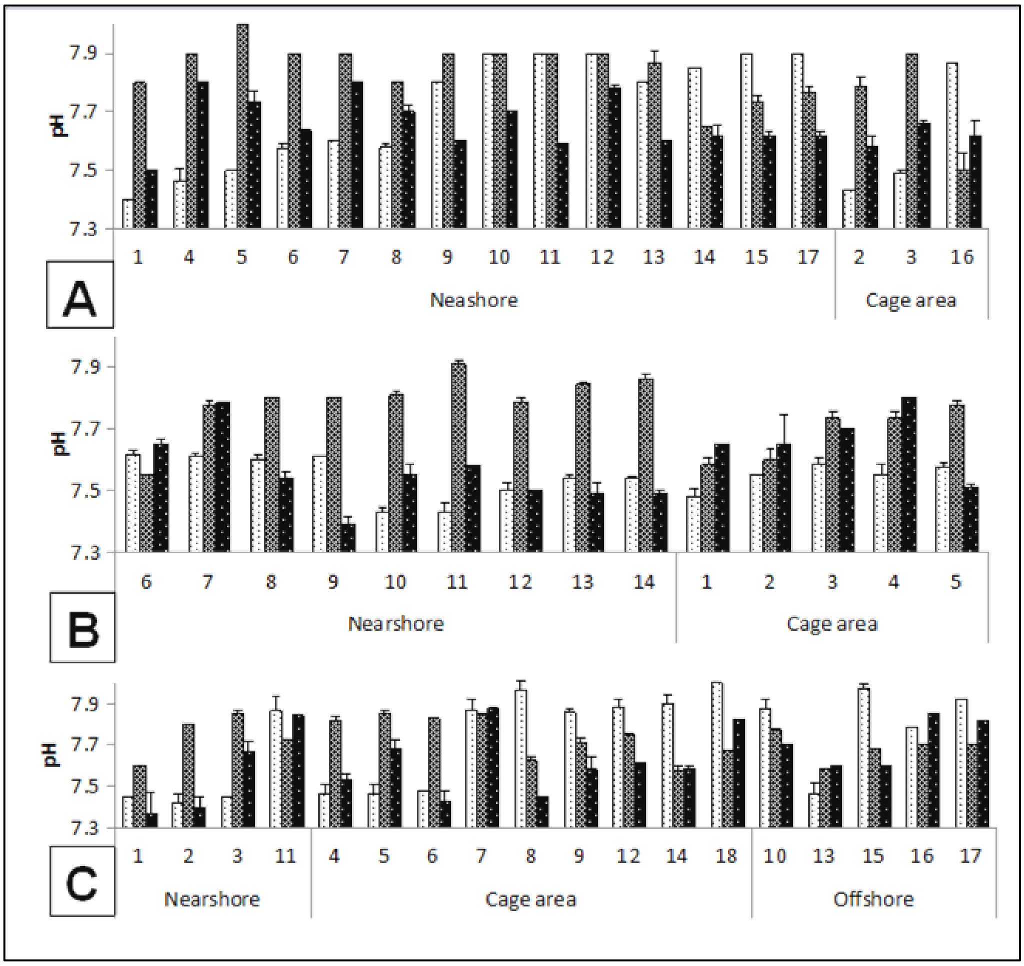

Figure 8. Mean pH levels in all sampling stations of Lopez Jaena MP (A) and Surigao City MP (B) and Balingasag MP (C) in different seasons.

Natural waters range between pH 5.0 and pH 10.0 while seawater is near pH 8.3. This water parameter can be toxic at a certain level and also affect the fish health. For most freshwater species, a pH ranging 6.5 to 9.0 is ideal, but most marine animals typically cannot tolerate as wide range pH as freshwater animals, thus the optimum pH is usually between pH 7.5 and 8.5 (PHILMINAQ 2008; Prema 2013). Below pH 6.5, some species experience slow growth. At lower pH, the organism's ability to maintain its salt balance is affected and reproduction ceases. At approximately pH 4.0 or below and pH 11 or above, most species die (PHILIMINAQ 2008). Good water pH concentration could be attributed to high consumption of carbon dioxide in the water. Seasonal salinity levels with a mean value of 37.55±1.105 ppt were observed to be within the desirable range of 30 to 40 ppt for marine water and preferred salinity range of 25 to 40 ppt, evading abrupt changes, for mariculture activity (Prema 2013), indicating no intrusion of freshwater even these areas particularly Surigao is a recipient of various tributaries, which might be due to the dense mangroves surrounding the park (Figure 9). In Lopez Jaena, low salinity levels were observed at the surface layer of the water during SW monsoon ranging from 3 to 33 ppt due to the weather condition during the collection of water samples. The high influx of freshwater due to heavy rains changed the salinity concentration at this layer, because at the water column and bottom, concentrations at this season with a mean value of 35.65±2.27 ppt were within the optimum range for mariculture production (Figure 10).

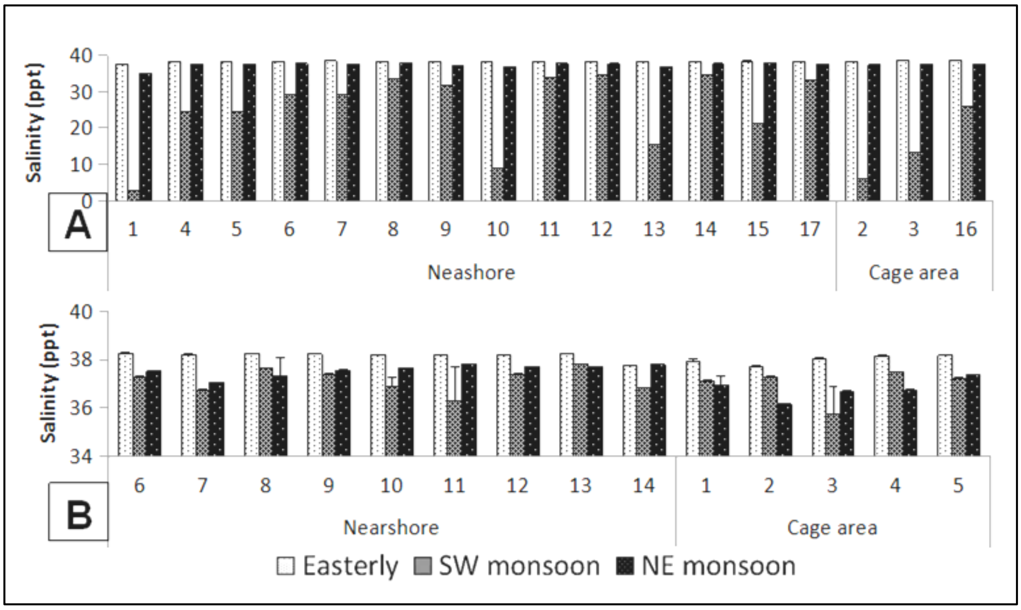

Figure 9. Mean salinity (ppt) levels in all sampling stations in Lopez Jaena MP (A) and Surigao MP (B) in different seasons.

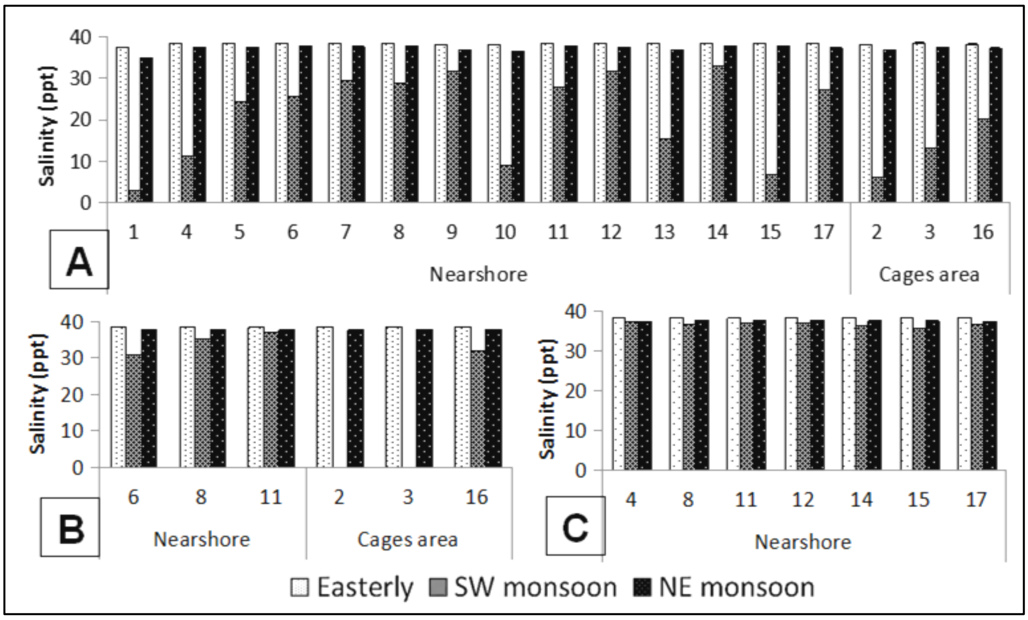

Figure 10. Mean salinity (ppt) levels in all sampling stations in Lopez Jaena Mariculture Pak at the (A) surface, (B) 10 meters, and (C) bottom in different seasons.

Depth (m), total suspended solids (g/L) and water transparency (m). Lopez Jaena has the wider tidal flat among the parks monitored wherein only the lagoon and channels are too deep to expose during extreme low tide with depths of 12 meters, and a range of 16 to 35 meters, respectively, thus installations of cage were done in the channels (Figure 11). This characteristic makes the area critical for oxygen exchange and flushing of accumulated wastes and nutrients. Congestions in the channels of the cages could result to adverse impacts which made regular water quality monitoring a must. The park of Surigao City is also unique in terms of its topography, surrounded by dense mangroves and numerous islets going farshore where gyres usually occur during flooding and ebbing of water (Figure 11), thus cages were installed at the lagoon, with depth ranging from 2 to 9 meters, because it is protected from turbulent waters and storms. Outside the lagoon, the depth ranged from 13 to 50 m. The mean depth of the park (21.3 m) passed the optimal depth range for bangus *(Chanos chanos)* production (at least 12 to 15 m deep). The Mariculture park of Balingasag has an undulating topography with shallow water nearshore averaging 35 meters and 122 m offshore (Figure 11).

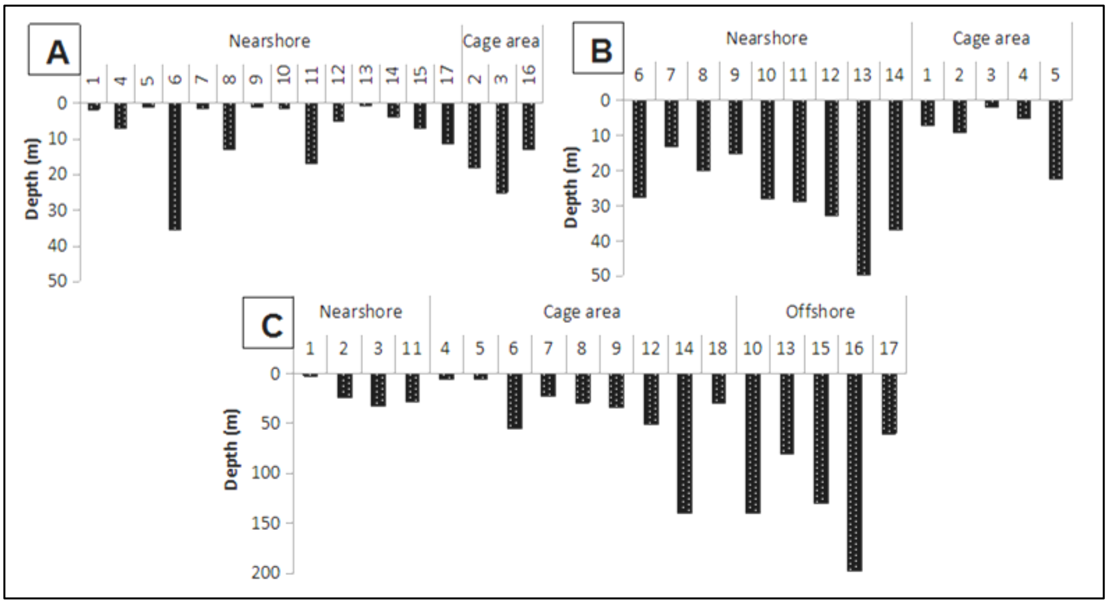

Figure 11. Depth of the different sampling stations in Lopez Jaena MP (A), Surigao City MP (B) and Balingasag Mariculture Park (C).

Generally, the parks were within the depth range of 6 to 10 m (low tide) that is considered ideal condition for marine aquaculture. Cages should be in sufficient depth to maximize the exchange of water and to avoid chemical and bacterial interactions, net damage and predation of the fish by crab and bottom organisms (Prema 2013). TSS levels revealed to be also within the permissible limit of 0.08 g solids/L (DAO, 2008) for fish propagation and 400 mg or 4 g solids/L for mussel grow-out (Prema 2013). Consequently, relative to its depth, water visibility was still high reaching up to 14 m, 16 m and 17.1 m averaging 8.93 m, 10.86 m and 8.97 m in Lopez Jaena; 17 m, 21 m, 13 m averaging 11.4 m, 10.1 m and 9 m in Surigao; and 14 m, 13.5 m and 22.9 m averaging 8.68 m, 8.88 m, 14.53 m in Balingasag during NE monsoon, Easterly and SW monsoon, respectively (Figure 12). The water is still within the optimum visibility for marine culture of <5 meters as yearly mean (Prema 2013). However, the TSS levels showed to be greater than the concentration of 0.02 g or 2 mg solids/L suitable for net cage culture (Prema 2008), and the tolerance level for corals of 0.0039 g solids/L (Figure 13). Turbidity and color in the water may result from colloidal clay particles, from colloidal or dissolved organic matter or from an abundance of plankton. Effects of high concentration of suspended solids depend on the exposure time and current speed (Prema 2013). In Balingasag, higher concentrations of TSS were observed during Easterly (0.060±0.148 g solids/L) and SW monsoon (0.048 ±0.017 g solids/L) particularly in shallow areas which may due to turbulent water at this season, bringing sediments and suspended particulate matters to the water column. The same observation was displayed in Surigao at these seasons with average values of 0.031±0.002 g solids/L and 0.030±0.011 g solids/L, respectively. River runoff, sewage from the communities surrounding the park, and detritus and debris from the mangroves may highly influence the level of dissolved solids in the area. High concentration of TSS in some areas in Lopez Jaena during NE monsoon (0.028±0.003 g solids/L) was attributed to water movement and current during this season as the park is generally shallow. Relatively lower concentrations were observed during Easterly (0.021±0.024 g solids/L) and SW monsoon (0.019±0.0145 g solids/L).

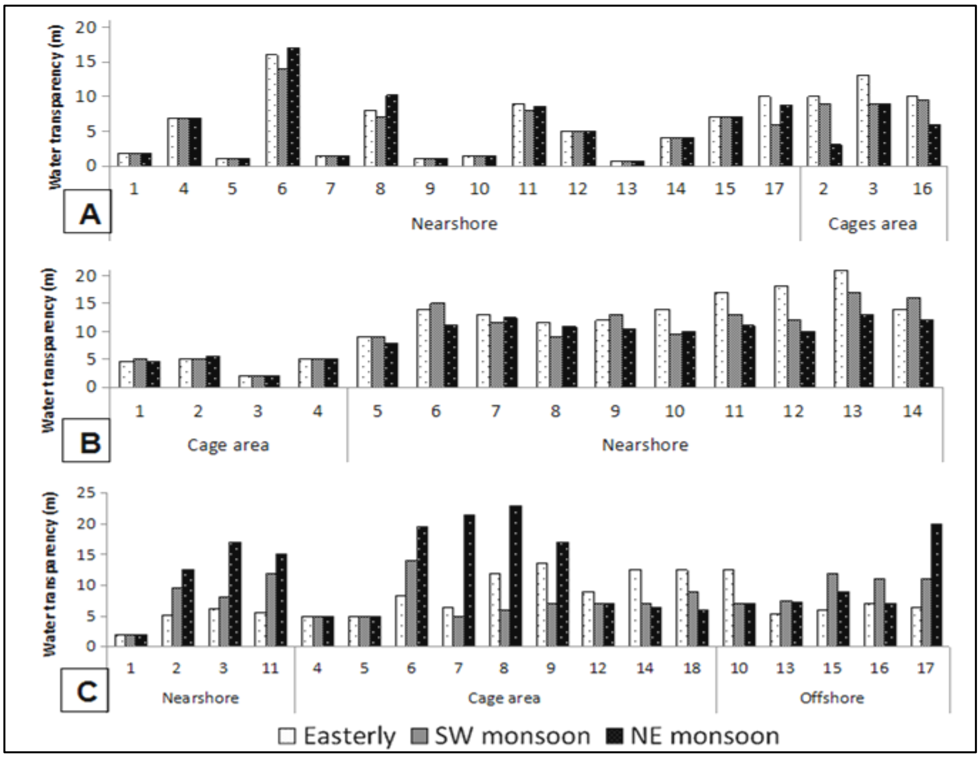

Figure 12. Water transparency (m) of all sampling stations of the three Mariculture parks of Northern Mindanao; Lopez Jaena MP (A), Surigao MP (B) and Balingasag MP (C) in different seasons.

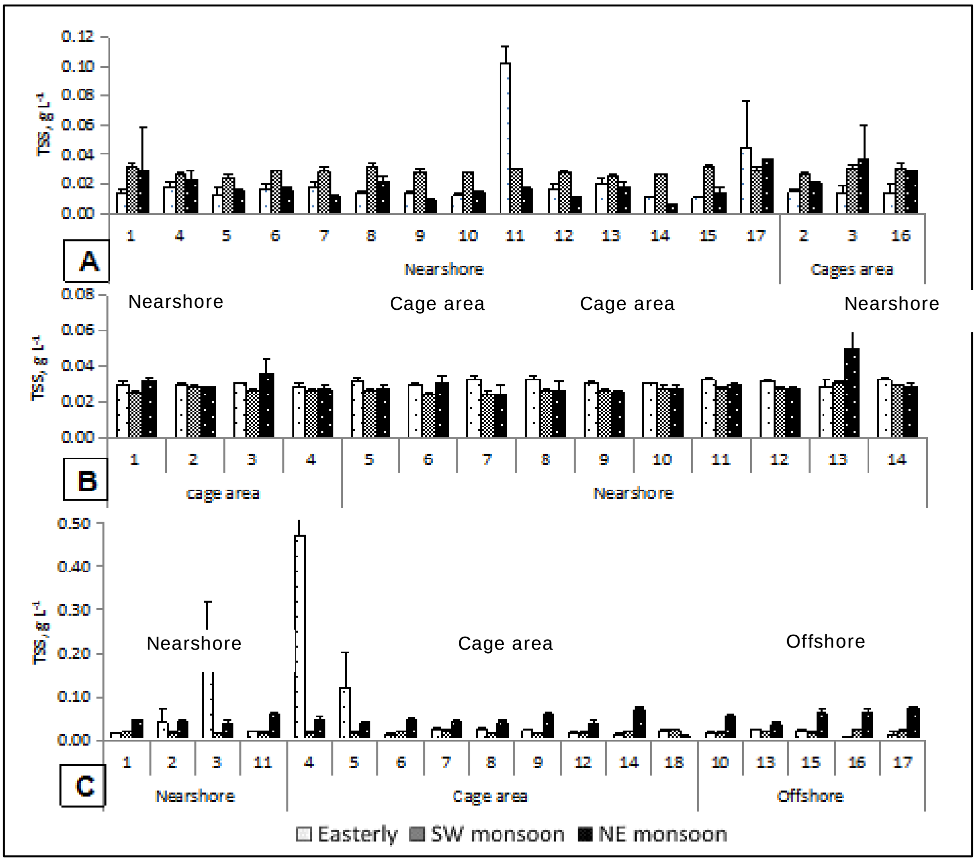

Figure 13. Total suspended solids (mg/L) in all sampling stations of the three Mariculture parks of Northern Mindanao; Lopez Jaena MP (A), Surigao MP (B) and Balingasag MP (C) in different seasons.

The establishment of various culture systems in the parks might cause additional sources of suspended solids, and therefore, would require regular monitoring otherwise it would result to some negative effects, such as decreasing the amount of light penetration necessary for efficient photosynthesis, and lower the production of dissolved oxygen that might pose fish kills in the future.

Nutrients*.* Evident concentrations of nutrients were detected during NE monsoon in Surigao (0.097±0.098 mg NH_3-N/L, 0.079±0.057 mg NO_2-N/L, 0.046±0.016 mg NO_3-N/L, and 0.049±0.049 mg PO_4-P/L) and Balingasag (0.084±0.030 mg NH_3-N/L, 0.067±0.049 mg NO_3-N/L), and SW monsoon in Lopez Jaena (0.084±0.0184 mg NH_3/L) (Figure 14-17). Normally in coastal area, sewage discharge and industrial pollution are the main sources of higher level of ammonia in seawater (Prema 2013). The rough time for the cage investors and the community living along the coast in Balingasag is during SW monsoon. Big waves and turbulent water occurred during this season, bringing up the accumulated wastes and nutrients or particulate matters to the water column, and causing to the destruction of cages and its mooring system.

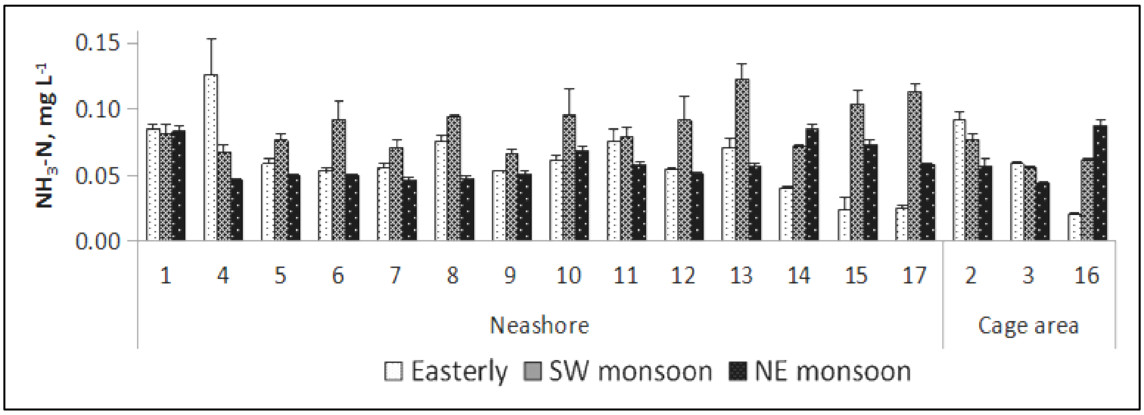

Figure 14a. Ammonia levels (NH_3-N, ppm) in all sampling stations of Lopez Jaena Mariculture Park in different seasons.

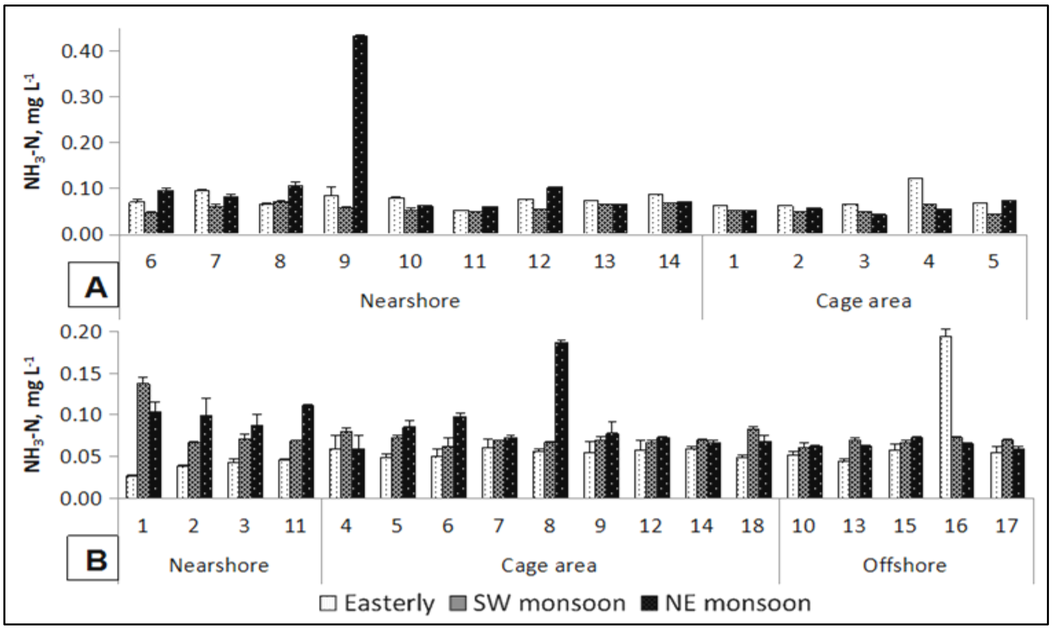

Figure 14b. Ammonia levels (NH_3-N, ppm) in all sampling stations of Surigao MP (A) and Balingasag MP (B) in different seasons.

Due to stormy water, caretakers tend to finish their job fast, resulting in an uncalculated feeding rate; throwing great amount of artificial feeds to the fish which causes to the high amount of unconsumed feeds; thus, nitrite levels in Balingasag were observed to be higher at the surface during SW monsoon (0.023 to 0.055 mg NO_2-N/L). Nitrogenous organic wastes come from uneaten feeds and excretion of fishes thus the concentration of ammonia-N is positively correlated to the amount of food wastage and the stocking density (PHILMINAQ 2008). During the survey in Surigao Mariculture Park, only three fish cages were operating in the area thus, high concentrations of ammonia in the park could be attributed to many possible reasons: (1) the park was generating visible amount of pollutants from the activity, (2) agricultural run-off via river, debris and sewage discharges from the communities surround the park, (3) high organic loads from the mangroves, and (4) wastes and excess feeds from lobster production in Barangay Day-asan, Surigao del Norte. This indicates that establishments of more cages in the area might increase this nutrients level leading to degradation of the park which could be avoided with regular monitoring, proper management and sound culture systems.

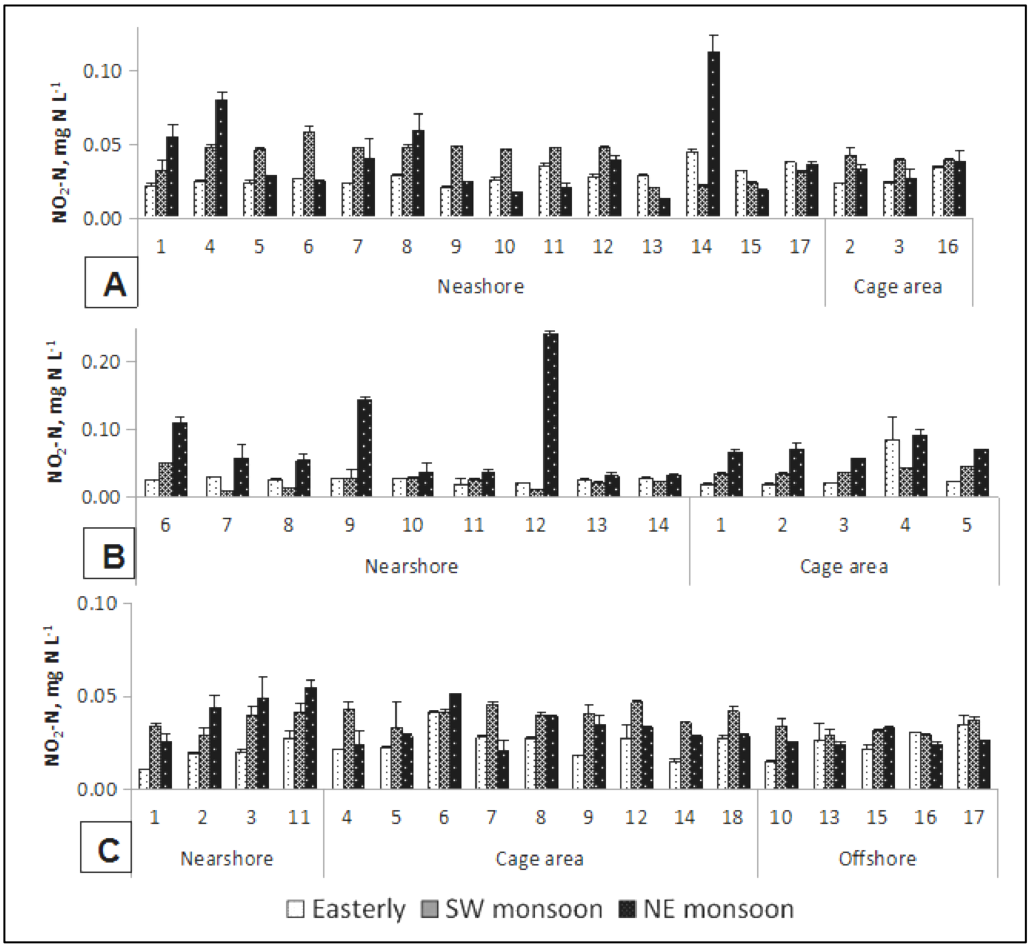

Figure 15. Nitrite levels (NO_2-N, ppm) in all sampling stations of the three Mariculture parks of Northern Mindanao; Lopez Jaena MP (A), Surigao MP (B) and Balingasag MP (C) in different seasons.

The lagoon and channel of Lopez Jaena evidently had high phosphate concentrations during SW monsoon. Impaired water quality may be observed around farms in nearshore or intertidal habitats where flushing is minimal. Protection of water quality will be best achieved by siting farms in well-flushed waters (Price & Morris 2013). Generally, nutrient concentrations were relatively lower than the standards values (10 mg NO_3-N/L, 0.5 mg PO4-P/L) set by DENR for fish propagation and the desirable level of total inorganic nitrogen (<0.1 mg/L) for mariculture activity (Prema 2013).

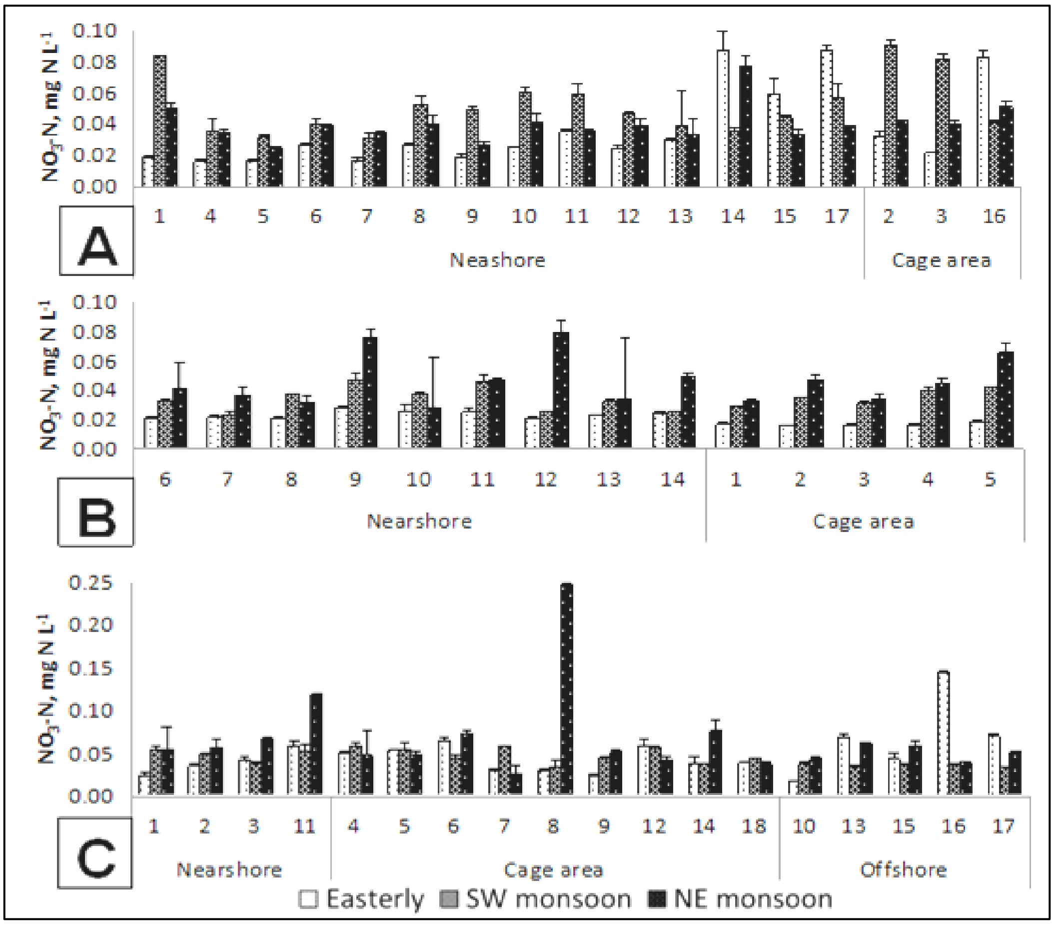

Figure 16. Nitrate levels (NO_3-N, ppm) in all sampling stations of the three Mariculture parks of Northern Mindanao; Lopez Jaena MP (A), Surigao MP (B) and Balingasag MP (C) in different seasons.

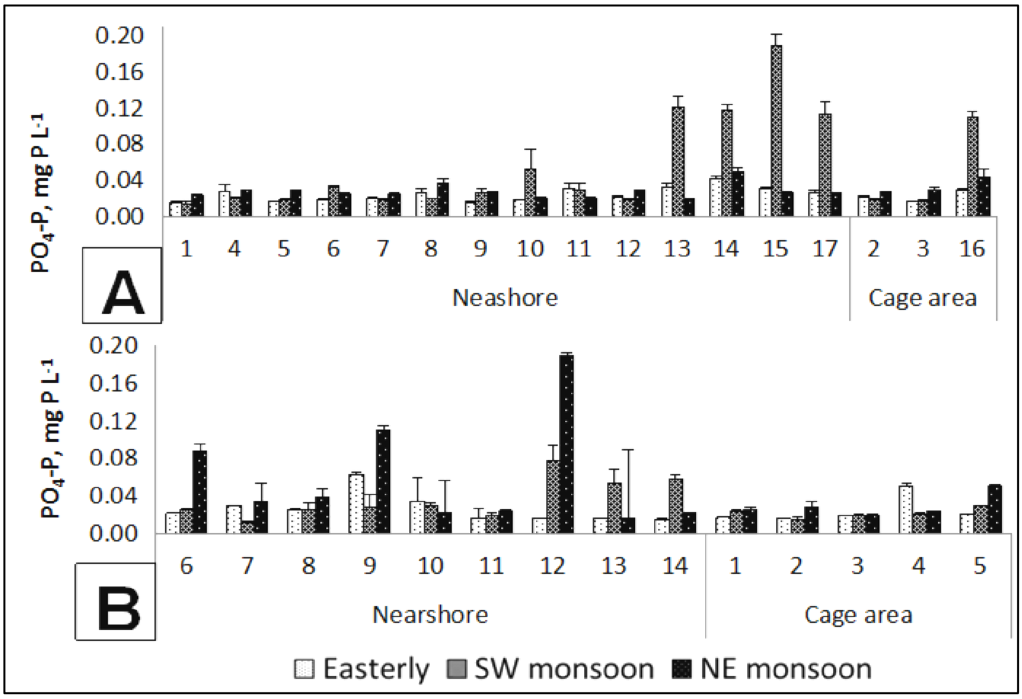

Figure 17a. Phosphate levels (PO_4-P, ppm) in all sampling stations of Lopez Jaena MP (A), and Surigao MP (B) in different seasons.

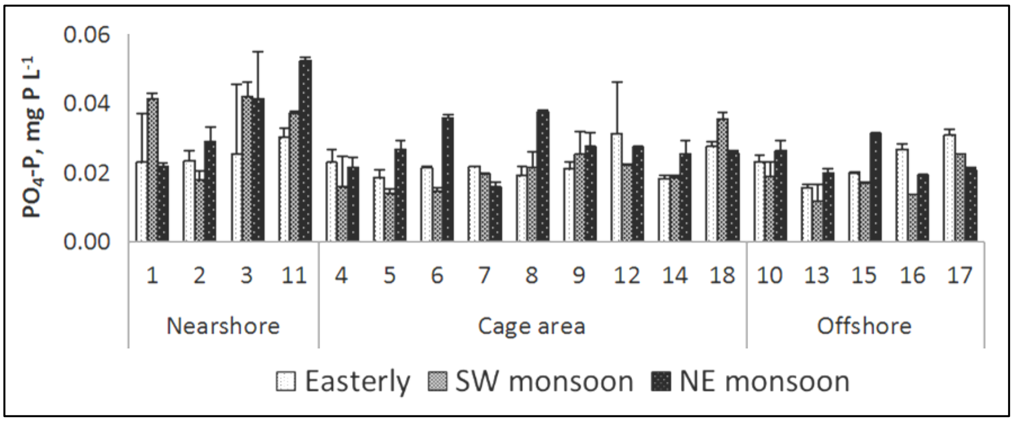

Figure 17b. Phosphate levels (PO_4-P, ppm) in all sampling stations of Balingasag Mariculture Park in different seasons.

However, ammonia levels revealed to be much higher than the allowable limit (0.05 mg NH_3-N/L) for marine fish propagation (DAO 2008), the tolerance level (at least 0.01 mg NH_3-N/L) for marine fish culture (Huguenin & Colt 1989) and the saturation level (0.06 mg NH_3-N/L), which can damage the fish gill, affect osmoregulation, and reduce the oxygen-carrying capacity of blood, thus increase oxygen demand of tissues, while some areas reached the level of 0.1 mg/L that usually indicates polluted waters (Prema 2013).

Conclusions and Recommendations. The water quality of the three Mariculture parks in Northern Mindanao was considerably fit for mariculture production. Seasonal variations of the physico-chemical parameters were significant. Based on the results, seasonal cropping was still appropriate; however, some areas in Surigao and Lopez Jaena during SW monsoon where low oxygen was observed to be low, and evident nutrients concentrations of the three parks particularly during NE monsoons, must be considered upon establishments of culture systems in the area as potential sources of inorganic nutrients could be observed from excess feeds, animal excreta and metabolic wastes. The following are recommended for sustainability of the mariculture industry of the three parks:
(1) Installment of additional cages must consider depths and in well-flushed areas to avoid fish kills and loss of investments;
(2) Regular monitoring of feeding rate. Feeding efficiency is reported to be the major reasons for decreased nutrient loading in the water;
(3) The government's program of intensifying aquaculture can only be achieved if the quality of the environment will be able to sustain these activities, and have a much aware and knowledgeable community. Therefore, determination of the carrying capacity of the Mariculture Park to carry a number of cages, and strengthening of IEC programs for the residents to increase their level of awareness on the conservation of the coastal resources, are highly required for a much sound industry;
(4) Application of the Integrated Muti-Trophic Aquaculture (IMTA) system is recommended not only to optimize the economic benefits that can be derived from the activity but to lessen the nutrient loading in the water. It is a technology designed for polyculture of different marine organisms in the surface (seaweeds absorbed the nutrients), water column (fish eats the feed and bivalves absorbed the dissolved excess food) and in the bottom of the cage (invertebrates like sea cucumber grazed on the excreta of the fish and leftover that settled). It is reported to be more effective and efficient in absorbing or lessening pollutants in the water, and more profitable as it would harvest different species at the same time with less investment. This present study was a rapid assessment of the water condition in the parks with respect to the seasons; NE monsoon, Easterly and SW monsoon, thus intensive and regular monitoring are highly needed to check the extent of increase of these nutrients and other physico-chemical parameters with time, and to avoid adverse impact such as collapse of mariculture

industry, occurrence of waterborne diseases and diminishment of the diverse population of marine plants and animals in the area.

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References

Huguenin J. E., Colt J., 1989 Design and operating guide for aquaculture seawater systems. Amsterdam, Elsevier.

Jack J. P., Abdsalam A. T., Khalifa N. S., 2009 Assessment of dissolved oxygen in coastal waters of Benghazi, Libya. Journal of Black Sea/Mediterranean Environment 15:135-156.

Johnston I. A., Dunn J., 1987 Temperature acclimation and metabolism in ectotherms with particular reference to teleost fish. Symposia of the Society for Experimental Biology. Volume 41:67-93, Cambridge University Press, Cambridge.

Levings C. D., 1980 Demersal and benthic communities in Howe Sound basin and their responses to dissolved oxygen deficiency. Canadian technical report of fisheries and aquatic sciences, No 951, Department of Fisheries and Oceans, West Vancouver Laboratory, Canada.

Loka J., 2015 Importance of water quality in mariculture. Central Marine Fisheries Research Institute, Karwar Research Centre of CMFRI, Karwar.

Prema D., 2013 Site selection and water quality in mariculture. Central Marine Fisheries Research Institute, Kerala, India.

Price C. S., Morris J. A. Jr., 2013 Marine cage culture and the environment: twenty-first century science informing a sustainable industry. NOAA Technical Memorandum NOS NCCOS 164, 158 pp.

Rosli N., Gandaseca S., Ismail J., Jailan M. I., 2010 Comparative study of water quality at different peat swamp forest of batang Igan, Sibu Sarawak. American Journal of Environmental Sciences 6(5):416-421.

*** APHA (American Public Health Association), 1995 Standard methods. 19th edition, American Public Health Association, Washington DC.

*** APHA (American Public Health Association), 2005 Standard methods for the examination for water and wastewater. 21st edition, Washington DC.

*** DAO, 1990 Revised water usage and classification/Water quality criteria amending section Nos. 68. DENR Administrative Order No. 34 Series of 1990.

*** DAO, 2008 Water quality guidelines and general effluent standards of 2008, Revising DAO 34 and 35, Series of 1990, DENR Administrative Order 2008.

**** PHILMINAQ, 2008 PHILMINAQ: Mitigating impact from aquaculture in the Philippines. PHILMINIQ final activity, recommendations and conclusions report. 6th Framewrok Programme. 8/2006 to 02/ 2008. Annex 2. Water quality criteria and standards for freshwater and marine aquaculture.

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