Seawater Physicochemical Parameters in the Green Mussel Belts in Samar Philippines

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Abstract: Samar's bays are among the few areas where green mussel thrives making it one of the major sources in the country. In 2007, Samar green mussel industry was almost wiped out due to mass mortality of the bivalve. Its survival depends on many variables, one of which is the environmental parameters such as salinity, dissolved oxygen, pH, temperature, chlorophyll, water current, and depth. This paper presents the characteristics of the green mussel belts including the seawater physicochemical parameters as well as a qualitative assessment of water quality from 2004 to 2013 as observed by 92 residents. Results have shown that during normal conditions, the bays the mussel belts are sandy to sandy-muddy substrates. The seabed especially near river mouths are heavily silted and have dark muddy substrates believed to be carried by river waters. During heavy precipitation, the water in the bays changes to brown color. Contaminated water flows from agricultural farms as well as fish ponds. Communities along the river and the coast of the bays dispose their domestic wastes directly into the body of water. The physicochemical parameter varies from in the three bays studied attributed to the different configuration of the bay. Average seawater temperature, salinity, DO, and pH is 26.56^{o}C, 32.13 ppt, 7.03 ppm and 7.32 respectively. The variation is attributed to the volume of water flowing into the bays and the bay's configuration. Residents believe that seawater quality was at its worst state in the years 2007 and 2008 and have improved since then.

Keywords: Maqueda Bay, Villareal Bay, Cambatutay Bay, mussel survival, tahong farms

1. Introduction

The green mussel, *Perna viridis*, can be found only in Indo-Pacific region (Alfaro, et al., 2011; Baker, et al., 2012; and Gobin, et.al., 2013) dispersed to various parts of the world attached to bilge or through ballast water (Perry and Yeager, 2006; McGuire and Stevey, 2009; McDonald, 2012; NOAA 2012). The organism may have been introduced in Maqueda Bay through the same medium by fuel tankers from Manila Bay supplying fuel stocks at the depot in Barangay Jia-an, Jiabong, Samar, and later became biofouling organisms on fish corral in Maqueda Bay area.

The organism later becomes an industry sometime in 1968 (NSCB, nd) or a little later in the middle of 1970s (FAO, nd) and was considered by the Department of Trade and Industry as Eastern Visayas Region One-Town-One-Product. The mussel industry has helped in alleviating the socio-economic conditions of the fisher folks along the mussel belts in Samar reaching 109,471 metric tons in 2005. In 2006, production was 10,616 metric tons to 491.41 metric tons in 2007 an abrupt decline of about 90.3% and 95.37% respectively. Samar contributes 17% of green mussel in 2009 (DA, 2009).

In 2009 the former Bureau of Fisheries and Aquatic Resources (BFAR)

Regional Director Juan Albaladejo said that the mussel farms in Jiabong Samar Philippines have been suffering from "white tide" a phenomenon caused by excess phosphates and nitrates on the seabed. He further revealed that there was about 90% decrease of mussel production in the area, amounting to almost PhP 38 million losses to the industry which has affected a total of 137 registered farmers in the area (Docdocan, 2009). Another report has blamed on the farming methods which has increased sedimentation in the mussel beds, causing the culture area to become shallow to the point that it will no longer be suited for growing green mussel (Guerrero, 2008; Asokan and Mohamed, 2008; Baylon and Tandang, 2015). This information points to many directions, all, however, are associated with the environment specifically the physicochemical conditions of seawater in the mussel farms.

The physicochemical environment of water bodies together with the growth pattern of individuals plays important roles in phytoplankton dynamics with light, a temperature considered as the major factor affecting its growth (Pal and Choudhury, 2014). Turbulence or water motion is a result of the combination of forces from the rotation of the earth; winds, solar eradiation, and tidal cycle generate different types of water motion which affect the phytoplankton population to a greater extent (ibid). There are four major nutrient elements like carbon, nitrogen, phosphorus, and silica (C, N, P and Si) are considered as major factors controlling phytoplankton productivity in any aquatic ecosystem (ibid).

Aside from C, N, P, and Si there are also organic matter present in coastal aquatic bodies are compound mixtures of allochthonous and autochthonous sources which includes primary production by intrinsic aquatic plants, contributions from tidal transportation, land-use changes, and agricultural runoff and from municipal and industrial discharges (Nazneen and Raju, 2017). The littoral and planktonic (considered as autochthonous sources) as well as the allochthonous source of organic material in an aquatic system depend on the dimension of the body of water and the types of terrestrial community that deposit organic material into it (Ecology Center, 2017).

The three bays of Samar are one of the highly affected by algal blooms in the country. According to Caturao (2001) of the Southeast Asian Fisheries Development Center (SEAFDEC), the first outbreak of harmful algal bloom was in 1983 in Maqueda Bay and Samar Sea. This phenomenon has been regularly recurring to date.

This paper aims to have a glimpse of the three bays of Samar regarding the seawater physicochemical parameters under normal conditions as well as the characteristics of the bays.

2. Objectives

The study aims to describe the geophysical characteristics, seawater physicochemical parameters, and the water quality condition according to residents in the three bays of Samar. Specifically, it determined the following;

1. Profile of the Cambatutay, Maqueda and Villareal Bays
2. Seawater temperature, salinity, dissolved oxygen, and pH,
3. Differences in the physicochemical parameters of seawater in the bays of Samar

4. Coastal seawater quality from 2004 to 2013 as observed by residents.

3. Methodology

3.1 Research Design:

The study employed quantitative and qualitative approaches to present the current status of the bays in Samar where the green mussel is farmed. It used primary and secondary data for analysis. Inferential statistics were used to determine differences of observations from the three bays. Selected residents in the three bays were also asked to assess the water quality condition from 2004 to 2013 using a checklist.

3.2 Research Environment:

The study was conducted in the bays of Samar, Philippines. Presented in table 1 are the coordinates while in figure 1 is the map showing the observation sites in Cambatutay, Maqueda, and Villareal Bays. The determination of water parameters was made on a stationary location for two days of February 2014 using instruments. There were pockets of rain before and during the data gathering which may have influenced some of the parameters considered.

Samar is a tropical climate. There is significant rainfall throughout the year even in the driest month (www.climate-data.org). The condition during data gathering is considered to be normal in the area.

Table 1. Observation sites coordinates

Bay	Coordinates	
	Latitude	Longitude
Cambatutay	11° 54' 15" N	124° 46' 51" E
Maqueda	11° 43' 45" N	124° 57' 10" E
Villareal	11° 37' 10" N	124° 55' 12" E

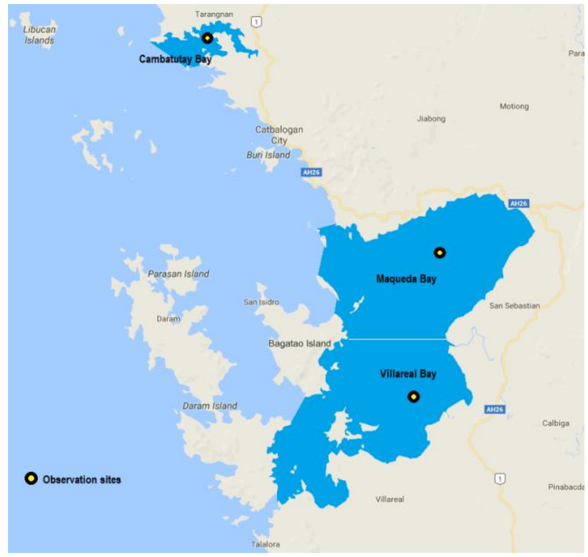


Figure 1. Seawater physiochemical parameters observation sites (Map source: Google Map)

3.3 *Data gathering and tools:*

Seawater temperature, dissolved oxygen, salinity, and pH were measured with the use of the alcohol-filled thermometer, dissolved oxygen-meter, refractometer, and pH-meter, respectively. Water current profiles of each mussel-belt were observed by adopting the Eulerian method which involved the measurements of the speed and direction at one point only at given location (NOAA-c, nd.). Measurements were performed continuously every 30 minutes in 48-hours per month for 2-months to determine as to whether there is variability between observation periods. The temperature of seawater was collected ½ meter from the surface.

Data collection at each mussel-belt was measured on a stationary motorboat anchored at the sites with coordinates indicated in table 1 and as shown in figure 1.

The water quality from 2004 to 2013 was evaluated by the selected residents of the three bays. A total of about 92 selected residents living in the area since 2000 were asked about the quality of seawater in the three bays. They were first given an idea how to rate the water quality through an example for common understanding.

3.3 *Data Analysis and presentation:*

Differences in the observed data were analyzed using One-way ANOVA and post-hoc Turkey HSD Test to determine if observations are different between stations specifically between different mussel farms and the control station. Data was presented in tables, graphs (line, and bar charts) and maps.

4. Results and Discussion

Environmental parameters of the sea affecting growth, survival, and productivity of marine organisms include light availability, oxygen levels, water movement, salinity and pH (Science Learning Hub, 2009). The preceding sections will present the profile of the study site, including the geographical and geological characteristics as well as the physicochemical parameters of waters in the bay.

4.1 Essential Geographical and Geological Features of Samar Bays

The mussel belts in the Province of Samar have some essential features that could influence the variability of water quality in the study areas. River systems and fishery production facilities are essential features that link the terrestrial areas with the marine environments. Water quality in mussel belts can change temporally influenced by various natural processes.

4.1.1 Cambatutay Bay.

This mussel belt has slightly sloping bottoms, which declines from its shorelines towards the central section of the Bay. The seabed forms a channel starting from the inner easternmost section to the wider portion which had flat bottoms with uniform depths of 3.66 m at mean lower low water periods. The seabed along the inner-narrow portions of the Bay had muddy substrates. From the shorelines along the wider portions of the area, the seabed is sandy and becomes sandy-muddy substrates towards 1.0 m water depths. The shallowest flooded portions of Cambatutay Bay have water depths of 0.305 m at mean lower low water period, while the deepest portion (4.88 m) of the area could be noted along its outer western periphery. At mean low lower periods, the estimated average water depth of the Bay area is 2.79 meters.

Figure 2. Portion of Cambatutay River with fishponds (Map source: Google Map)

Cambatutay Bay has served as the catch basin of terrestrial waters in the area. The innermost section of the Bay is connected to and served as the outlet of waters from Cambatutay River. This same river also serves as the basin of waste water influxes from fishponds and tributary which is the outlet of garbage leaches from various sources and especially from the solid waste disposal facility of Catbalogan City at Barangay San Vicente, Catbalogan City. However, in the study of Bardelas et al. (2016), the leachate produced from the dumpsite flowing through the intermittent stream nearby is diluted with water from the watershed of the area reducing the concentration level of contaminants.

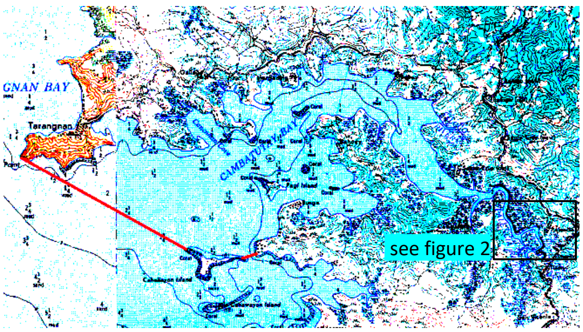


Figure 3. Bathymetry Map of Cambatutay Bay (Source: NAMRIA)

4.1.2 Maqueda Bay.

The bay is a largest shallow estuarine area located along the central western coasts of Western Samar. It has slightly sloping to relatively flat bottom. The seabed slightly declines starting from the shorelines around the area towards the central section of the Bay where it forms a relatively smooth and flat bottom. From its central sections, the bottom further declines towards the north western channel between Darajuay Daco and Majaba Islands, Catbalogan City.

On the other hand, the seabed in its western section inclines towards the northern shorelines of Basiao Island, Catbalogan City, and abruptly declines towards the channel between the southern point of Majaba Island and the western point of Basiao Island and Tubigan point (southeast of Buad Island), Zumarraga, Samar.

During the mean low lower water periods, the least water depths of 0.305 m is along the near-shores of the Bay. The western waters of Maqueda Bay, is a channel with depths of 0.91 m that connects to Bucalan River. During lowest low water, the Bay has an estimated average water depth of 4.59 meters with the deepest part situated between Basiao and Majaba Islands of Catbalogan City and the Magaan Point, Zumarraga, Samar estimated at 38.40 meters.

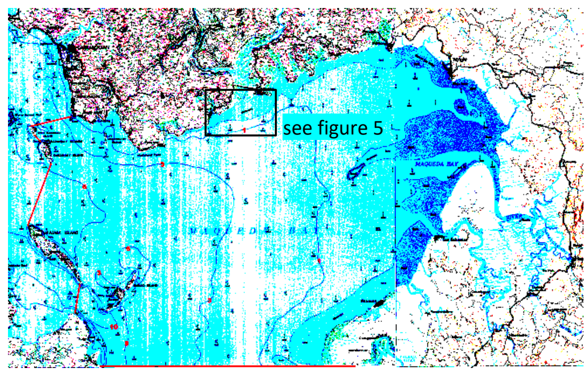


Figure 4. Bathymetry Map of Maqueda Bay (Source: NAMRIA)

Except in few sites of the Area, the inner part of Maqueda Bay has a seabed characterized by muddy substrates with fine-grain silts on top. The characteristic of bottom substrates usually alters during inclement weather. With the effect of the water movement, these silts are washed out, and the nature of the bottom changes to relatively hard sandy-muddy substrates. Sites with sandy seabed can be noted in the southern waters of Catbalogan City. A very narrow area of the sandy bottom is also noted in the inner section of the Bay between Paranas and San Sebastian, Samar, where it obviously forms a sandbar during low tide.

Figure 5. Heavily silted delta of Magbag River, Jiabong Samar (Map source: Bing Map)

Maqueda Bay receives freshwater supply regularly from various sources through the three major river systems in the area. Magbag River in Jiabong, Samar, has upstream connected to a relatively long stream which extends up to 15-km landward which stream catches contaminated and silt-laden waters from uplands and adjacent rice farmlands, especially during heavy rainfall. Adjacent to this river are the four fishponds which highly depend on its water supply from the same river. During the highest water levels, the waters of Magbag River mixed with saline waters from Maqueda Bay and was observed to consequently poured into the Bay by the influence of ebb tide and downstream flow of water during heavy rainfall.

The second of these river systems in the Maqueda Bay area is the Bucalan River which has a wide mouth situated in the inner section of Maqueda Bay. This river serves as catchment of silt-laden waters from connecting rivers and creeks which extend more than 5-km landward of the Municipality of Hinabangan and San Sebastian, Samar. A large volume of silt-laden waters from these sources, including those from various fishponds at the southern coastal vicinities of Paranas, Samar, exited to Maqueda Bay area through the mouth of Bucalan River. This process usually occurs during heavy rainfall.

Thirdly, the San Sebastian River in San Sebastian, Samar, is also a source of the river system in Maqueda Bay area. This is also connected to the upstream that extends approximately 10-km landward of the municipality. The large volume of silt-laden waters is poured into the Maqueda Bay through its mouth located east of the town proper. The stream found in the vicinity of Barangay Hitaasan, San Sebastian, Samar, had been observed to have been catching waters from the rice farmlands and drained to the Bay area.

4.1.3 Villareal Bay.

This bay has relatively flat to slightly sloping bottoms. The seabed slope is in a declining fashion starting from the shorelines of Calbiga, Pinabacdao, and Villareal, Samar, to its central section where it forms the flat bottoms. The bottom slopes further decline slightly towards the vicinities of Zumarraga, Samar, where it forms the Buad Channel.

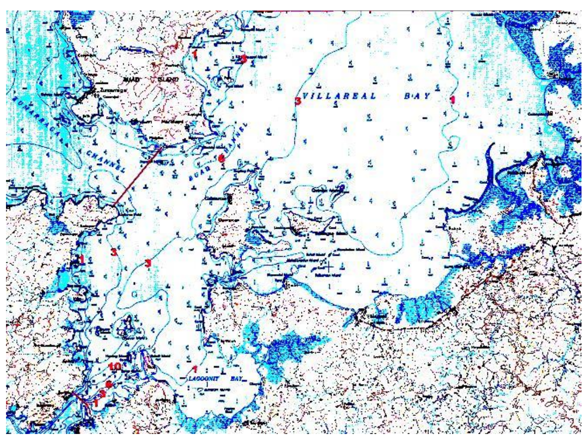


Figure 6. Bathymetry Map of Villareal Bay (Source: NAMRIA)

Furthermore, the south western water of the Bay area has the bottom topography which has almost a similar trend with that in the north eastern areas. The seabed slopes further decline slightly towards the vicinity of Oacon island of Daram, Samar and Lagimit Island of Talalora, Samar where it abruptly slopes and forms a channel connecting the Daram Channel.

Villareal Bay has shallower waters compared to Maqueda Bay. During mean lower low water period, the flooded areas, especially near the shorelines, have the least water depths of 0.305 m. The Bay has an estimated average water depth of 4.36 meters. The deepest part was noted in the entrance of Daram Channel at the south western section of the bay with an estimated water depth of 27.43 meters.

Bottom substrates in the Bay were sandy-muddy along shallower sections and altered to the muddy seabed in deeper waters. Approximately 20 cm thick of silts were noted on the bottom along waters of 2.0 m deep or more. This bottom feature was observed in vicinities adjacent to the river systems at the north eastern sections.

Villareal Bay has various river systems compared to the Maqueda Bay area. There is the Calbiga River. It has its mouth found at the eastern section of the Bay and is one among the longest rivers in the Province of Samar estimated at 18-km long and 10-m deep, and it's upstream connects to the famous Lulugayan Falls in Calbiga, Samar. This same Calbiga River also receives runoff waters from the uplands, converged with silt-laden freshwater and continuously flows downstream, especially during heavy rainfall. Second to these river systems is the Pasigay River that is a narrow river and 1-km river in Calbiga, Samar, acting as catchment of waters from rice farmlands. Waters from these two rivers, Calbiga and Pasigay, exit through their mouths to Villareal Bay area.

Still contributing to the Villareal Bay water system are the Tinago and Libonao Rivers. These are located in Pinabacdao, Samar, at the Eastern section of the Villareal Bay. Tinago River is relatively short extending approximately from 3.5-km landward of Pinabacdao, Samar. Like other short rivers, it also receives runoff waters from terrestrial areas and contaminated waters from fishponds along the riverbanks.

Libonao River is the relatively long river in the Municipality of Pinabacdao which extends approximately from 10-km landward. Upstream of this river also serve as catchment of runoff and silt-laden waters from upland and rice farmlands. Libonao River, also, serves as the transport medium of wastes and garbage coming from Barangay Nabong, Mambog, and Bangon, including the waste waters from fishponds which are usually poured into the Bay during heavy rainfall.

Moreover, there are five (5) shorter river systems in the Villareal Bay which can be found in the Municipality of Villareal, Samar. The mouth of Cambuco River has been noted in the south eastern section of the Bay. This is upstream of this same river which extends from 2 to 3 km which also receives the contaminated waters from rice farmlands and the wastes and garbage from Barangay San Fernando and Santo Niño, Villareal, Samar, and observed to drain into the South eastern section of the Bay during the onset of low tide.

Also, there are three (3) small creeks situated in the Barangays of Igot, Macopa, and Nagcaduha, Villareal, Samar, which are connected to the fishponds and rice farmlands in the barangays as mentioned earlier. Contaminated waters from agricultural production facilities are also drained into the southern waters of the Bay during the onset of low tide. The mouths of the shorter Banquel River, Jambayan River, Catmon River and Candihog River are observed at the western coasts of Villareal, Samar. The upstream section of these river systems extend at the range of 3-km to 4-km where they receive waste waters from fishponds and rice farmlands, and drained into the Laguimit Bay at western waters of Villareal, Samar.

The existence of the river systems along the terrestrial area of the mussel-belts could have influenced the temporal changes of the bottom sediments in the locale of this study. Very fine grain sediments classified as silt were found in the seabed of the mussel-belts of Maqueda Bay and Villareal Bay. During heavy rainfall, waters in these rivers were obviously turbid contributed by silt. Because of their very fine structures, silts are transported into the marine environments where they settle and are deposited.

All three bays have dark muddy substrates. Closer to the bays is sandy-muddy as these areas receive sediment-rich water from waterways such as rivers and creeks. The Cambatutay bay receives water from one major river while Maqueda receives from three (3) major rivers. Villareal receives waters from four(4) major rivers, five (5) minor, and three (3) creeks. Most of Villareal Bay area shallower than Maqueda but it has the deepest sea along the Daram channel reaching to 27.4m.

4.2 Seawater Physicochemical Parameters

4.2.1 Seawater Temperature

The seawater temperature in the three observation sites is affected by the weather. The average temperature in Catbalogan during the observation period ranges from 19.5 C^o to as high of 34.0 C^o. As shown in table 2, the seawater temperature gathered in 2 days at a 30-minute interval in February 2014 have shown slight variation between bays, many are not significantly different from each other except when Cambatutay Bay and Villareal Bays temperature were compared. The said significant difference is attributed to a localized rain during the observation period that has affected the temperature level of Villareal Bay as well as the geographical characteristics of the site where circulation is more constrained. In the study of Orale and Fabillar (2011), water circulation specifically at the southern part of the bay is relatively trapped thereby affecting temperature variation. The second set of observations were made in March 2014 where ambient temperature ranges from 21.8 C^o to 35 C^o. The seawater temperature, on the other hand, ranges from 26.5 C^o to 31 C^o or an average of 28.42 which was shown to be significantly higher than the first set of observations.

The observed seawater temperature values are found to be within the optimum levels for mussel growth survival.

Table 2. Temperature (^{o}C) in Mussel Belts (January -March 2014)

	Mussel-belts (Bays)		
	Cambatutay	Maqueda	Villareal
n	96	96	96
Min	24.50	24.50	25.00
Max	30.00	30.50	30.00
Mean	26.65	26.78	26.26
SD	1.41	1.41	0.76
t – test (p)			
Cambatutay		0.5238	*0.0184
Maqueda			**0.0018

** Significant at 95% CI ** significant at 99% CI*

4.2.2 Seawater Salinity

Salt in the ocean comes from rocks on land, eroded and dissolved by rain which is partly acidic. The dissolved ions (chloride and sodium) found its way to the sea (NOAA-b, nd) and distributed all over the world through the ocean current. This parameter is equally essential in the life history and growth of mussels, especially in estuarine areas where significant variations usually occur as influenced by natural and anthropological events. Data have shown that despite the relatively lower water temperature and the rain shower during the observation period, the seawater salinity was normal and was not significantly changed. This is because waters specifically of Cambatutay and Maqueda Bays have an unhindered flow of tides. The tidal cycle has facilitated the vertical mixing of the seawater in the area causing the salinity at normal values. It was however noted that data gathered after a precipitation event slightly reduced the salinity of the water specifically near the mouth of the rivers. In January 2014, seawater salinity in the observation sites ranged from 28.00 – 35.00 ppt, 31.00 – 35.00 ppt in February and 31-35 ppt. in March 2014.

Table 3. Salinity (ppt) in Mussel Belts (February 2014)

	Mussel-belts (bays)		
	Cambatutay	Maqueda	Villareal
n	96	96	96
Min	31.00	31.50	26.00
Max	35.00	35.00	32.00
Mean	33.60	33.69	29.11
SD	1.01	0.85	1.42
t – test (p)			
Cambatutay		0.505	**0.000
Maqueda			**0.000

** Significant at 95% CI ** significant at 99% CI*

The data shown in table 3 were taken February 2014. Statistical tests show that Villareal Bay water salinity is significantly very different from the waters of Cambatutay and Maqueda Bays. The lower seawater salinity (about 4ppt average) was due to rain that resulted into higher runoff water flowing to the bay through its drainage systems. Unlike Cambatutay and Maqueda bays where waters from the Samar Sea enter unhindered, Villareal bay is different. The semi-closed configuration of the bay makes it longer for seawater from other areas to mix with the bay's water.

4.1.5 Dissolved Oxygen

Aquatic organisms require oxygen in a specified amount for its metabolism and respiration, when that amount is not met can have adverse physiological effects (ANZECC/ARMCANZ, 2000). Even short period anoxic and hypoxic events can cause major "kills" of aquatic organisms which are caused by the decomposition of organic matter by oxygen-utilizing bacteria (OZCoasts, nd). Some sources of nutrients to coastal waterways are coastal discharges from various activities in the land which includes outfalls from industry, waste from aquaculture and agriculture operations and even discharges from sea crafts (ibid) and other human activities. Rainfall during the dry season in tropical regions can mobilize organic-rich detritus in the coastal waters which can have a very high biological oxygen demand (ibid). The dissolved oxygen (DO) consumption and production are influenced by plant and algal biomass, light intensity, water temperature (due to the influence of photosynthesis) and are subject to seasonal and diurnal variation (Cornell & Miller, 1984).

Table 4 presents the comparative dissolved oxygen content data in the three mussel belts.

Table 4. Dissolved Oxygen (ppm) in Mussel Belts (February 2014)

	Mussel-belts (bays)		
	Cambatutay	Maqueda	Villareal
n	96	96	96
Min	6.35	6.5	6.20
Max	7.65	8.0	7.45
Mean	7.11	7.20	6.79
SD	0.25	0.28	0.26
t – test (p)			
Cambatutay		*0.0198	**0.000
Maqueda			**0.000

** Significant at 95% CI ** significant at 99% CI*

The two two-day observation of DO in the study sites conducted in January to March of 2014 varies site per site and time of observation. This is primarily due to tidal exchange and the production and consumption of oxygen by plants and algae during day time (through photosynthesis) and respires at night (OZCoasts, nd). Data gathered when the sea was rough due to typhoon "Agaton" appears to have increased to an average of 7.43 $\pm$ 0.29 ppm DO in Maqueda and Cambatutay Bays through aeration due to waves and faster ocean current. The significant difference in the DO level in the Villareal Bay is attributed to the factors like its geographical characteristics which hinders the flow of water thus affecting other physicochemical parameters.

4.1.6 Seawater pH

The pH of seawater has an essential role in the life history and some biological activity of green mussels. While pH does not vary greatly in time and space along open oceans, its high variations in near-shore areas can exceed 1 unit owing to biological activity (Cornwall, et al., 2013). Low pH affects the balance of sodium and chloride in the blood of aquatic animals. When sodium is depleted, hydrogen ions are taken into its cell causing death due to respiratory failure or the loss of regulation in osmotic pressure. Further, a pH level lower than 4.5 is harmful to aquatic environments while higher values can also cause adverse biological effects (Jacob, 2017).

Table 5. Seawater pH in Mussel Belts (February 2014)

	Mussel-belts (bays)		
	Cambatutay	Maqueda	Villareal
n	96	96	96
Min	6.90	6.4	6.70
Max	8.00	7.95	7.95
Mean	7.40	7.24	7.31
SD	0.26	0.34	0.27
t – test (p)			
Cambatutay		**0.0003	*0.0197
Maqueda			0.1158

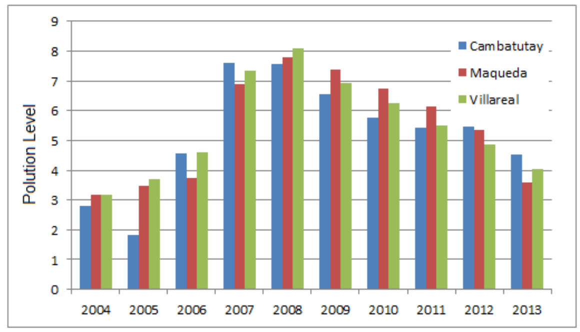
** Significant at 95% CI ** significant at 99% CI*

Table 5 shows that pH of seawater in Cambatutay is significantly higher than Maqueda and Villareal Bays. The variability of seawater pH in the three mussel-belts must have been influenced by various processes such as the volume of freshwater flowing into the bays from rivers and the size of the bays as well. There is one major river with water exiting to Cambatutay Bay while there are many river flows to Maqueda and Villareal bays. This is the most likely reason of its lower pH value as freshwater has lower pH plus the presence of other chemicals carried by the river water collected from its surrounding environment. These rivers collect nutrients from upland farms, fish ponds and sewage from communities living nearby the rivers. There are about 50 villages located nearby rivers exiting to Maqueda and Villareal Bays as well as its coasts. The nutrient-rich water triggers rapid algal growth (EPA, nd.) that in right conditions eventually dies resulting to decrease in dissolved oxygen and increase in CO_2. Omstedt et al. (2010) expressed that increased nutrient load increases the amplitude in the pH. The observed pH in mussel belts in Samar ranges from 6.4 to 8 and are considered to be within the optimum level for mussel growth and survival.

4.1.7 Seawater Quality as Observed by Coastal Community

In 2007, the area experienced massive mass mortalities of green mussel. Bureau of Fisheries and Aquatic Resources hypothesized that the traditional use of bamboo poles in mussel farming led to increased siltation and prevented the adequate water circulation in the Maqueda Bay area. Farmed mussel continuously exposed to hypoxic conditions become stressed brought about by critically low levels of oxygen, thus affecting their survival and making them susceptible to secondary microbial infections resulting into mass mortalities (PNA, 2009). BFAR added that the phenomenon was caused by an excess phosphates and nitrates on the seabed. In a clean-up activity, more than 18,000 pieces of the deteriorated bamboo slump from the seabed of the mussel farming sites in Jiabong Samar (Cebu, 2009). Organic materials were degraded by bacteria in the absence of oxygen, converting it into methane and carbon dioxide mixture (Adekunle and Okolie, 2014). This must have caused the dissolved oxygen in Samar mussel belts to decline and reach to its critical levels detrimental to the growth of mussel.

As shown in Figure 7, the residents have rated similarly the quality of the three bays from 2004 to 2013. They all agree that the year 2007 and 2008 was the poorest condition with the rating of 7 to 8 or moderately to very polluted condition. This evaluation may have been attributed to their most recent experience thy have; the mass mortality of green mussel. Since 2008 to 2013, the water quality has improved according to the residents. In 2013, they still considered the bay's water a little bit slightly polluted.



Legend: Extremely Polluted (9) | Moderately Polluted (7) | Slightly Polluted (5) | Clean (3) | Very Clean (1)

Figure 7. Residents Pollution Rating of the Bays

Respondents to the interview agree that coastal zones must be protected to avoid the recurrence of the mass kill of green mussel in 2007. Solid and water waste disposal remains a critical issue that Local Government Units (LGUs) has yet to address. Communities found along the coast and rivers continue to throw all kinds of waste that eventually ends up into the bays. Siltation from the upstream also contributes to the water quality of the bays that need to be addressed. They also shared that the staking method of mussel farming must be minimized to maintain or improve the water quality of the bays.

5. Conclusion and Recommendation

The characteristics of Cambatutay, Maqueda, and Villareal Bays are different which have influenced the varying physicochemical parameters of its seawater.

Water temperature and salinity in Villareal Bay is significantly lower than the other bays due to the relatively larger volume of cooler fresh water entering to Maqueda and Villareal Bays. This is also the reason why pH in the later is lower as freshwater has lower pH.

The lower DO level in Villareal Bay compared to the other Bays is may be attributed to its closed nature. Water circulation is better in Maqueda, and Cambatutay Bay attributed to its configuration.

Human-induced factors such as poor solid and water waste disposal management as well as the type of mussel farming are a continuing threat to the water quality in the Bays. The same needs intervention to avoid recurrence of the mass kill of green mussel.

6. Bibliography

Adekunle, KF., and Okolie, JA. (2015). A Review of Biochemical Process of Anaerobic Digestion. Advances in Bioscience and Biotechnology, 6.

Alfaro, AC., Jeffs, AG., Gardner JPA., Bollard Breen BA., and Wilkin J. (2011). Green-lipped Mussel in GLM 9, New Zealand: Fisheries Assesment Report, 2011 No. 48, Ministry of Fisheries, Wellington.

ANZECC/ARMCANZ (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. http://www.environment.gov.au/about-us/publications/archive#water Accessed January 8, 2017

Asokan, PK., Mohamed, KS., Sasikumar, G. (2013). Mussel Farming and Hatchery. Central Marine Fisheries Research Institute. CMFRI Manual Customized Training Book.

Australian Online Coastal Information, OZCoasts, (n.d.). Dissolved oxygen. http://www.ozcoasts.gov.au/indicators/dissolved_oxygen.jsp Accessed January 8, 2017

Bardelas JP., Celajes KMC., Fungo JAA., Paclian MCP., Tugado CF., Orale, RL. (2016). Catbalogan City, Philippines Open Dumpsite Leachate Transport. Journal of Academic Research, 1(02), 10-18 http://ojs.ssu.edu.ph/index.php/JAR/article/view/103/91 Accessed June 3, 2017

Baker, P., Fajans JS., and Baker SM. (2012). Habitat Dominance of a Nonindigenous Tropical Bivalve, Perna viridis (Linnaeus, 1758), in a Subtropical Estuary in the Gulf of Mixico. Journal of Molluscan Studies, 78(1).

Baylon, CC and Tandang, KJL. (2015). The Pinoy Longline: An Innovative and Sustainable Way to Grow Green Mussels. DOST PCAARD S&T Media Service. http://www.pcaarrd.dost.gov.ph/home/portal/index.php/quick-information-dispatch/2587-the-pinoy-longline-an-innovative-and-sustainable-way-to-grow-green-mussels Retrieved Nov 1, 2016.

Catutao, RD. (2001). Harmful and toxic algae. In G. D. Lio-Po, C. R. Lavilla, & E. R. Cruz-Lacierda (Eds.), Health management in aquaculture (pp. 159-172). Tigbauan, Iloilo, Philippines: Aquaculture Department, Southeast Asian Fisheries Development Center.

Cebu E., Ay-ay, RC., Alpino, JP. (2009). Assessment and Validation on the Presence of Bamboo Stumps for the Coastal Clean-up of the Municipal Waters of Jiabong Samar.

Climate-Data.Org, Climate: Catbalogan (n.d.), https://en.climate-data.org/location/19983/#climate-graph Accessed November 3, 2017.

Connell, DW, and Miller, GJ. (1984). Chemistry and Ecotoxicology of Pollution. John Wiley & Sons, N.Y.

Cornwall, CE., Hepburn, CD., McGraw, CM., Currie, KI., Pilditch, CA., Hunter, KA., Boyd, PW., and Hurd, CL., (2013). Diurnal fluctuations in seawater pH influence the response of a calcifying macroalga to ocean acidification. Proceedings of the Royal Society B: 280: 20132201

Department of Agriculture. (2009). Mussel Profile. Agriculture and Fisheries Market Information System. https://afmis.da.gov.ph/index.php/component/docman/doc_download/901-musselsprofile2009.html *Accessed June 2, 2017*

Docdocan, R., (2009). White tide killing tahong in Samar town. ABS-CBN . http://news.abs-cbn.com/nation/regions/02/28/09/white-tide-killing-tahong-samar-town Accessed June 2, 2017.

Ecology Center (2017), Species Richness, Autochthonous and allochthonous production. https://www.ecologycenter.us/species-richness/autochthonous-and-allochthonous-production.html Accessed November 2, 2017.

Environmental Protection Agency, EPA. (nd.). Nutrient Pollution: The Problem. https://www.epa.gov/nutrientpollution/problem Accessed August 2, 217.

Food and Agriculture Organization, FAO (nd). Overview of the Philippine Aquaculture. http://www.fao.org/docrep/003/x6943e/x6943e06.htm Accessed September 3, 2017

Gobin, J., Agard J., Madera J, Mohammed A. (2013). The Asian Green Mussel Perna viridis (Linnaeus 1758(: 20 Years after Its Introduction in Trinidad and Tobago. Open Journal of Marine Science, 3.

Guerrero III, RD. (2008). Eco-Friendly Fish Farm Management and Production of Safe Aquaculture Foods in the Philippines, Philippine Council for Aquatic and Marine Research and Development and Food Fertilizer Technology Center for Asian and Pacific Region.

Jacob, S. (2017). How can a biological system be affected by a change in pH levels? Sciencing. https://sciencing.com/can-affected-change-ph-levels-6165622.html Accessed September 3, 2017

Li, M. (2013). On Methods to Calculate Average Tidal Current Velocity. Digital Manufacturing and Automation (ICDMA), 2013 Fourth International Conference on Digital Manufacturing and Automation

McDonald, JI. (2012). Detection of the Tropical Mussel Species Perna viridis in Temperate Western Australia: Possible Association Between Spawning and a Marine Heat Pulse. Aquatic Invasions, 4(7)

McGuire, M, and Stevely, J. (2009). Invasive Species of Florida's Coastal Waters: The Asian Green Mussel (Perna viridis). Florida Sea Grant College Program. National

Oceanic and Atmospheric Administration and United States Department of Commerce.

National Aeronautics and Space Administration, NASA (nd). https://science.nasa.gov/earth-science/oceanography/physical-ocean/salinity Accessed June 2, 2017.

National Mapping and Resource Information Authority, NAMRIA. (1956). Maps 3955 I, 3995 II, 3994 I, and 4055 III. http://www.namria.gov.ph/download.php Accessed January 3, 2017.

National Oceanic and Atmospheric Administration, NOAA. (2012). Invasive Alien Species: A Growing Threat in Regional Seas. Global Invasive Species Program, UNEP: Regional Seas.

National Oceanic and Atmospheric Administration, NOAA-a. (n.d). Ocean Facts: What is a current? https://oceanservice.noaa.gov/facts/current.html Accessed June 2, 2017

National Oceanic and Atmospheric Administration, NOAA-b. (n.d). Why is the ocean salty? https://oceanservice.noaa.gov/facts/whysalty.html Accessed June 2, 2017

National Oceanic and Atmospheric Administration, NOAA-c. (nd). Currents: How are Currents Measured. https://oceanservice.noaa.gov/education/kits/currents/07measure1.html Accessed March 8, 2008.

National Statistical Coordination Board, NSCB, (nd). Jiabong: The Mussel Capital of Eastern Visayas. www.nap.psa.gov.ph/ru8/profiles/Municipal_Profile/Municipal_Profile_Jiabong_Samar.pdf Accessed September 3, 2017

Nazneen S. and Raju NJ (2017). Distribution and sources of carbon, nitrogen, phosphorus and biogenic silica in the sediments of Chilika lagoon. Journal of Earth System Sciences, 126(1), Indian Academy of Sciences.

Omstedt, A., Edman M., Anderson LG., Laudon H. (2010). Factors Influencing the Acid-Base (pH) Balance in Baltic Sea: A Sensitivity Analysis. Tellus B, 62(4).

Orale, R. L., & Fabillar, L. A. (2011). Coastal Waste Transport in Catbalogan City, Philippines, and Nearby Towns. Iranica Journal for Energy and Environment, *2*(1), 92-103.

Pal, R. and Chouldhury, AK. (2014). An Introduction to Phytoplanktons: Diversity and Ecology, DOI 10.1007/978-81-322-1838-8_2. Springer India 2014

Perry, H, and Yeager, D. (2006). Invertebrate Invaders: Established and Potential Exotics Gulf of Mexico Region. Coastal Impact Assistance Program, Mississippi Department of Environmental Quality, Gulf Coast Research Laboratory, The University of Southern Mississippi.

Philippine News Agency, PNA. (2009). Mussel Catch in Samar Recovering after Clean-up. http://pnatacloban.blogspot.com/2009/08/mussel-catch-in-samar-recovering-after.html Accessed June 1, 2017.

Sanchez A & Hernandez CO. (2013). Sediment Transport Patterns Inferred from Grain-Size Trends: Comparison of Two Contrasting Bays in Mexico.

Science Learning Hub. (2009). Environmental conditions are affecting the sea. The University of Waikato, New Zealand. https://www.sciencelearn.org.nz/resources/141-environmental-conditions-affecting-the-sea Accessed February 2, 2017

Verney R., Jany C., Thouvenin B., Pairaud I., Vousdoukas M, Pinazo C., Ardhuin F., Cann P. (2013). Sediment Transport in the Bay of Marseille: Role of Extreme Events. Coastal Dynamics.