COMMUNITY STRUCTURE OF PLANKTONIC ALGAE IN PAGBANGANAN RIVER, BAYBAY CITY, LEYTE

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ABSTRACT

Planktonic algae are free-floating phytoplankton that abound in aquatic and marine environments. They are the primary producers of aquatic ecosystems thus their role in the ecosystem cannot be overemphasized. This study was conducted in three sites of Pagbanganan River to determine the abundance and diversity of planktonic algae. A total of 39 genera under divisions Bacillariophyta, Chlorophyta, Cyanophyta and Charophyta were recorded. The most abundant and dominant group were the diatoms (Division Bacillariophyta). *Navicula*, *Nitzschia*, *Synedra*, *Melosira* and *Coconies* were the most abundant genera. The upstream, midstream and downstream sites were highly similar in phytoplankton composition and abundance. Phytoplankton were more abundant and dominant but less diverse during the months of April, May and June compared to July, August and September. Temperature, dissolved oxygen and nitrate levels were within safe limits but phosphate was in excess. Abundance was positively correlated with current velocity but negatively correlated with nitrate level.

Key words: phytoplankton, diatoms, diversity, abundance, species composition

INTRODUCTION

In freshwater ecosystems, algae occur either as planktonic or benthic, the former being free-floating or drifting freely within the water column, while the latter are the substrate-associated forms (Bellinger and Sigee, 2010). Being photosynthetic, they are at the base of the ecological pyramid, thus they are the major producers in aquatic ecosystems.

The development of a phytoplankton community in a river depends directly upon the physical factors of flow, turbidity, day length and temperature, where the highest numbers of algae occur during prolonged periods of bright dry weather when the rate of flow and silt are also at a minimum (Belcher and Swale, 1979). Since planktonic algae lie at the bottom of the food chain in aquatic ecosystems, alterations of their community structure critically affects the entire food web.

The Pagbanganan River is one of the major river systems in the city of Baybay. The surrounding Pagbanganan watershed which covers an area of about 16,762 ha, drains into this river and its tributaries. The watershed is classified as a fifth-order basin and consists of 117 streams of all orders (Alvarado, 2005). Pagbanganan River is also one of the twelve major rivers in the island of Leyte that are considered as flood-prone according to the Office of Civil Defense (OCD) based on flooding history (Sun Star Tacloban, 2010). In Baybay, this river is very important to the residents of the city who use it for their daily activities such as laundry, swimming, fishing and for the wallowing of their farm animals.

So far no study on freshwater planktonic algae has been conducted in Pagbanganan River. Knowledge of phytoplankton composition, abundance and diversity is an important input to the present efforts to inventory and document the existing biodiversity of the country. The study specifically attempted to identify the planktonic algae composition in Pagbanganan River; determine their abundance, occurrence, diversity, richness, evenness, dominance and similarity in the three selected sites of the river; compare their composition, abundance, diversity and dominance between sampling

months and to correlate the phytoplankton abundance with the physico-chemical conditions of the river.

MATERIALS AND METHODS

Establishment of the Sampling Stations

A reconnaissance survey was done to identify the three sampling stations along the Pagbanganan River, Baybay City, Leyte. The stations were established in the upstream (Site 1), midstream (Site 2) and downstream (Site 3) parts of the river based on elevation. Site 1 was located in Brgy. Kantagnos while sites 2 and 3 were located in Brgy. Igang, Baybay City. Geographic coordinates were taken from each station using a handheld Global Positioning System (GPS). The selected stations were mapped using the integration of GPS and Arc-View Geographic Information System (GIS) at the GIS Laboratory, Visayas State University, Visca, Baybay City, Leyte (Fig. 1).

Figure 1. Map of Pagbanganan River, Baybay City showing the three sampling stations

Monitoring of Physico-Chemical Conditions

Air and water temperatures (C), water pH, dissolved oxygen, and water current velocity were measured using appropriate instruments during every sampling. Three readings were taken at every sampling station per sampling period. Water samples were also collected and sent to the Central Analytical Services Laboratory (CASL), PhilRootcrops, Visayas State University, Visca, Baybay City, Leyte for the analyses of

sediment load, nitrates and phosphates. The grain size, total nitrogen, extractable phosphorus and organic matter of the sediment were also analyzed at CASL. Weather condition was noted during each sampling period. Monthly rainfall (mm) data were acquired from VSU-PAGASA-PCAARRD Agrometeorological Station.

Phytoplankton Sampling and Microscopic Examination

Sampling of phytoplankton was done once a month from April to September between 8:00 to 11:00 in the morning. While walking, three horizontal tows were made along a 30-meter distance parallel to the river in each sampling station using a Wisconsin plankton net having a mesh size of 80 μm . Collected phytoplankton samples were placed in properly labeled plastic containers and preserved in Lugol's solution and 70% ethyl alcohol.

Phytoplankton samples were examined using an electric compound microscope. Counts were made using a Sedgwick Rafter counting chamber wherein three 1 mL aliquots from each sample from each tow per station were examined. Phytoplankton cells observed were sketched and photos were taken to aid in further identification and documentation. These were counted and identified down to the genus level. The taxonomic works of Bellinger and Sigee (2010), Belcher and Swale (1979) and Palmer (1977) were used as main references for the initial identification of the phytoplankton genera. Digital images from the Protist Information Server (<http://protist.i.hosei.ac.jp.html>) were likewise used in identification.

Data Computation

Phytoplankton abundance was calculated using the following formula,

$$N = C V_s / V_f$$

where:

N = abundance of cell per liter
C = average count per cell
V_s = volume of water sample
V_f = volume of filtered water

where:

$$V_f = d\pi r^2$$

r = radius of plankton net opening
d = distance covered by phytoplankton tow

Occurrence of phytoplankton genera was recorded by indicating a score of one (1) for presence and zero (0) for absence. The Shannon-Wiener Diversity Index, Shannon's Equitability Index, Menhinick's Index, Index of Dominance and Sorensen's Similarity Index were used to assess the diversity, evenness, taxa richness, dominance and index of similarity of planktonic algae, respectively (Magurran, 1984).

Statistical Analyses

Two-way analysis of variance (ANOVA) was used to compare the abundance of phytoplankton between sites and months. Tukey's Honestly Significant Difference (HSD) test was used to determine any significant differences among the values obtained. Pearson Correlation Analysis was used to correlate the occurrence and abundance of phytoplankton to the physico-chemical parameters in the three selected stations of Pagbanganan River.

RESULTS AND DISCUSSION

A total of 39 phytoplankton genera belonging to four divisions was recorded from the three sampling stations from April to September. Of the 39 genera, 21 belong to Division Bacillariophyta; 12 to Chlorophyta; four to Cyanophyta and two to Charophyta (Table 1).

Division Bacillariophyta or the diatoms was the most represented among the phytoplankton divisions encountered. Diatoms successfully colonize and dominate a wide range of aquatic habitats due to their high genetic diversity, with 285 recorded genera with 10,000–12,000 species worldwide (Round et al., 1990). Bellinger and Sigeo (2010) reported that freshwater diatoms can form a large part of the algal biomass because of their abundance in both planktonic and benthic forms, and thus they are a major contributor to the primary productivity of aquatic environments. In Pagbanganan River, this algal group comprised 54% of the total planktonic taxa documented (Fig. 2).

Division Chlorophyta or the green algae was the second most represented with 12 genera comprising 31% of all the planktonic algae taxa encountered. Lee (2008) mentioned that these common freshwater algae have an abundance of chlorophylls -a and -b and differ from other eukaryotic algae in forming the storage product in

Figure 2. Composition of planktonic algae present in Pagbanganan River, Baybay City, Leyte from April to September

The blue-green algae under Division Cyanophyta forms a natural group by virtue of their being prokaryotic (Lee, 2008). These are predominantly freshwater species that include unicellular, colonial, and filamentous forms commonly associated with increased trophic status (Marshall, 2009). In Pagbanganan River, this group was represented by only four genera contributing 10% of the total taxa present. On the other hand, Division Charophyta (charophytes) was the least represented with only two genera and comprised 5% of the total number of taxa.

The lowest number of 32 genera was recorded in April while the highest number of 35 was observed in July and August. The observed increase could be due to the physical and biological modifications of the river. Rainfall was more frequent during these months which may be favorable for other species of algae to grow. Changes in the level of available nutrients through surface run-off as well as water movement, may have altered the plankton composition and occurrence of the river. (Sumich, 1996).

Figure 3 shows that the phytoplankton were found to be most abundant in April with a mean abundance of 1115 cells/L and least in September with only 80 cells/L. Seasonal phytoplankton population variations may occur in response to changes in light intensity, nutrient abundance and grazing pressures (Sumich, 1996). However, it was observed that there was no significant difference in the abundance of planktonic algae between sites. As autotrophs, planktonic algae require sunlight for growth which could explain this observation. Boyd (2000) stated that phytoplankton growth responds favorably to warmth wherein highest growth rates usually occur during summer and growth continues at a slower rate during colder months. Belcher and Swale (1978) also noted that the highest population of algae occur during prolonged periods of bright dry weather.

the chloroplast instead of in the cytoplasm. Graham and Wilcox (2000) reported that chlorophytes are the most diverse group of algae, with about 17,000 known species.

Table 1. Phytoplankton genera identified in the three sampling stations from April to September 2011 in Pagbanganan River, Baybay City, Leyte

Division	Genera	
Bacillariophyta (diatoms)	<i>Achnanthes</i>	<i>Melosira</i>
	<i>Amphora</i>	<i>Navicula</i>
	<i>Bacteriastrium</i>	<i>Nitzschia</i>
	<i>Cocconeis</i>	<i>Pinnularia</i>
	<i>Cyclotella</i>	<i>Rhopalodia</i>
	<i>Cymbella</i>	<i>Stephanodiscus</i>
	<i>Diatoma</i>	<i>Surirella</i>
	<i>Diatomella</i>	<i>Synedra</i>
	<i>Epithemia</i>	<i>Terpsinoe</i>
	<i>Fragilaria</i>	
	<i>Gomphonema</i>	
	<i>Gyrosigma</i>	
Charophyta (charophytes)	<i>Chara</i>	
	<i>Haplotaenium</i>	
Chlorophyta (green algae)	<i>Ankistrodesmus</i>	<i>Oedogonium</i>
	<i>Closterium</i>	<i>Spirogyra</i>
	<i>Cosmarium</i>	<i>Staurastrum</i>
	<i>Diclostera</i>	<i>Stigeoclonium</i>
	<i>Euastrum</i>	<i>Ulothrix</i>
	<i>Monoraphidium</i>	
	<i>Mougeotia</i>	
Cyanophyta (blue-green algae)	<i>Anabaena</i>	
	<i>Nostoc</i>	
	<i>Oscillatoria</i>	
	<i>Spirulina</i>	
Total number of Divisions: 4		
Total number of Genera: 39

Figure 3. Mean abundance (cells/L) of phytoplankton during the six-month sampling period from April to September 2011 in Pagbanganan River, Baybay City

Diatoms were the most abundant and dominant algal group in Pagbanganan River comprising 97.93% of the total abundance throughout the whole sampling period. This was followed by the green algae which contributed 1.51%; blue-green algae with 0.54%; and the charophytes comprising 0.02%. Ludevese (2005) identified 75 algal genera belonging to seven divisions in Calbigaa River, Pangasugan, Baybay City and diatoms were also noted as the most dominant algal genera in the river.

Pickett-Heaps et al., (1990) mentioned that minute holes or pore systems of diatom frustules provide direct interaction between the cell and the outside environment which also permit nutrient absorption and exchange of oxygen and carbon dioxide in aquatic ecosystems. According to Sigee (2005), diatoms have the potential to outcompete other algal groups due to their silica-containing cell walls which require about 12 times less energy for construction compared with the cellulose and peptidoglycan cell walls of other algae. This characteristic may have contributed to the success of these organisms to thrive in large numbers and by far the more common algae in aquatic environments.

The five top most abundant genera of planktonic algae identified in Pagbanganan River were the diatom genera *Navicula*, *Nitzschia*, *Synedra*, *Melosira*, and *Cocconeis*. Figure 4 shows the monthly abundance of the top five most abundant genera superimposed with the mean rainfall data recorded during the sampling period. The dominant genera was most abundant in April when rainfall was lowest, and least abundant in July and September when rainfall was high.

Figure 4. Mean rainfall and mean abundance of the top five dominant genera of planktonic algae present in Pagbanganan River, Baybay City, Leyte from April to September
The genus *Navicula* comprised 29% of the total abundance of all the algal genera

Phytoplankton was most abundant in April (433 cells/L) and least in September (8 cells/L). In Calbiga-a River, *Navicula* was also the most dominant genus (Ludevese, 2005). Kociolek and Spaulding (2003) reported that the genus *Navicula* is the largest genus of algae with over 10,000 species, varieties and forms wherein, most of which are restricted to freshwaters. They added that all representatives of this group are capable of movement because of their raphe system and they may be attached to a variety of substratum types. It has been noted that many *Navicula* species can be pollution-tolerant while some could be pollution-sensitive.

Nitzschia was the second most abundant genus comprising 27% of the overall abundance. Highest abundance was observed in May (254 cells/L) and least in September (21 cells/L). According to Lowe (1974) many species of the genus *Nitzschia* are recognized as indicators of organic pollution in water bodies in which they are found.

Synedra are thin pencil-like cells, solitary or occasionally in fan-shaped colonies which seem to occur mostly in clean-water streams, rivers and lakes but some species also grow in response to nutrients and can dominate in enriched low-land streams (Whitford and Schumacher, 1973). Highest abundance of *Synedra* was in April (166 cells/L) and lowest in September (14 cells/L). It comprised 20 % of the total abundance of planktonic algae in Pagbanganan River.

Melosira species are mostly found in slow to medium flowing open lowland streams and can dominate the periphyton community in moderately enriched situations (Biggs and Kilroy, 2000). *Melosira* was most abundant in April (109 cells/L) and least in September (1 cell/L) comprising 6% of the overall abundance. Cassie (1989) reported that *Melosira* can be considered as both a "clean water species" and "moderately polluted water species".

The genus *Cocconeis* comprised 3% of the overall abundance and was most abundant in May (38 cells/L) and least abundant in September (2 cells/L). *Cocconeis* is a relatively small genus whose members are very widely-distributed in almost all freshwaters where the pH is circumneutral or alkaline and it is a fast-growing, pioneer species that is able to colonize bare substrates quickly which is tolerant of moderate, but not severe, organic pollution (Kelly et al., 2005).

Diversity of Planktonic Algae

Freshwater algae are among the most diverse and ubiquitous organisms on earth occupying an enormous range of ecological conditions which form the base of most aquatic food webs and are

Figure 5. Top five most abundant phytoplankton genera under Division Bacillariophyta – a) *Cocconeis*, b) *Melosira*, c) *Nitzschia*, d) *Navicula*, e) *Synedra*; representative genera under Division Chlorophyta – f) *Closterium*, g) *Monoraphidium*, h) *Mougeotia*, i) *Spirogyra*, j) *Terpsinoe*; Division Charophyta – k) *Chara*, l) *Haplotaenium*; Division Cyanophyta – m) *Anabaena*, n) *Nostoc*, o) *Oscillatoria* and p) *Spirulina* (400x)

critical to studies of ecosystem health (Wehr and Sheath, 2003). According to Luck et al. (2003), adequate population diversity confers greater flexibility on ecological communities for coping with changing environmental conditions without dramatic impact on the entire food chains and food webs. High diversity can also provide assurance for potential substitutes if one food source will decline in number; thus, it is nature's safe plan for emergencies.

Table 3 shows the diversity indices of the planktonic algae community in Pagbanganan River from April to September. High diversity, taxa richness and evenness values were found in the months of July, August and September. September appeared to have the highest diversity (2.48), richness (2.04) and evenness (0.71). However, June had the lowest recorded values of diversity (1.58) and evenness (0.46) while April had the lowest value of taxa richness (0.51) among the sampling months.

In terms of dominance, the opposite trend was evident among sampling months. High dominance was observed from April to June but low in July to September. Highest dominance (0.32) was recorded in June and lowest in September (0.13).

Table 3. Means of diversity indices of the planktonic algae community from April to September 2011 in Pagbanganan River, Baybay City, Leyte

Month	Diversity Indices			
	Shannon-Wiener Diversity Index	Menhlenk's Index (Taxa Richness)	Shannon's Equitability Index	Index of Dominance
April	1.77 ^b	0.51 ^c	0.52 ^c	0.26 ^{ab}
May	1.80 ^b	0.65 ^c	0.52 ^c	0.24 ^{ab}
June	1.58 ^b	0.98 ^{bc}	0.46 ^c	0.32 ^a
July	2.37 ^a	1.41 ^{ab}	0.69 ^{ab}	0.15 ^c
August	2.18 ^a	1.64 ^{ab}	0.62 ^b	0.18 ^{bc}
September	2.48 ^a	2.04 ^a	0.71 ^a	0.13 ^c
Total Mean	2.03	1.20	0.59	0.21

Means in a column followed by the same letter are not significantly different at 5% level of significance, Tukey's HSD

Phytoplankton diversity and richness were high in July to September since there were 34 to 35 genera present during these months compared to only 32 to 33 genera from April to June. The high evenness values from July to September means that the phytoplankton were more or less evenly distributed during these months as compared to the dry months from April to June since the population of the dominant algal groups declined from July to September. In the months of April to June, the diatoms *Navicula*, *Nitzschia*, *Synedra* and *Melosira* were dominant which in turn caused diversity, richness and evenness indices to decline.

Similarity of Planktonic Algae Composition

Table 4 shows the mean similarity index values of planktonic algae between sampling sites across months. Generally, the three sampling sites had high mean similarity index values of 0.94 to 0.96 which means that the generic composition of phytoplankton in the three sites were highly similar.

Table 4. Sorensen's Index of Similarity between sampling sites in Pagbanganan River

Sites	April	May	June	July	August	September	Mean
Downstream and Midstream	0.97	0.95	0.95	0.95	0.97	0.91	0.95
Downstream and Upstream	0.89	0.95	0.92	0.94	0.97	0.95	0.94
Midstream and Upstream	0.95	1.00	0.93	0.92	0.97	0.99	0.96

The high similarity index values among sites could be due to the fact that the three sites were located in adjacent barangays, thus, the physico-chemical characteristics of the sites did not markedly differ from each other resulting to the very high similarity in their phytoplankton composition. Furthermore, since phytoplankton are free-floating, they are easily carried from the upstream to the downstream portions of the river.

Figure 6. Mean air and water temperature and light intensity readings in Pagbanganan River, Baybay City, Leyte from April to September 2011

Water current velocity primarily affects the distribution, composition, and metabolism of photosynthetic organisms in aquatic environments especially in streams and rivers (Dodds and Biggs, 2002). In Pagbanganan River, water current velocity was fastest in April (0.53 m/sec) and in July (0.47 m/sec) and slowest in September with 0.31 m/sec (Fig. 13). The highest current velocity in April was due to the rainy weather during the sampling activity. The amount of water in the river increased but the width of the channel remained the same which made the water flow faster.

Dissolved Oxygen and pH

Dissolved oxygen (DO) refers to the oxygen gas molecules present in the water which comes from the surrounding air and as a product of photosynthesis from aquatic plants. High DO values recorded were in June (4.33 mg/L) and August (4.22 mg/L) while low readings were in July (3.85) and September (3.67 mg/L) (Fig. 11). According to the Philippines Environment Monitor (2004), the national standard for DO is 5 mg/L except for water bodies classified as Class D with standard set at 3 mg/L.

Physico-Chemical Characteristics of the River

Temperature, Light Intensity and Current Velocity

There is a wide range of physico-chemical factors that influence algal community development and abundance in aquatic environments. Temperature is one of the critical environmental factors that determines the metabolic rates and distribution of organisms as well as their possible success in interacting with other organisms (Allan and Castillo, 2007).

Figure 6 shows the air and water temperature readings in the six-month sampling period. Air temperature was relatively high throughout the sampling period except in September when air temperature of 28.44C was lowest which could be due to the cloudy weather observed when the sampling was done.

Water temperature was expectedly high in the dry months from April-June (28.11-28.78C) and low in July (27.67) and September (27.33C). High water temperature was observed in August (28.44C) which coincided with the high light intensity (754.44 ft-cd) during that month. Lewis (2008) reported that tropical flowing waters are characterized by water temperatures that correspond to low oxygen content at saturation and when compared to temperate environments, tropical waters have lower oxygen reserve and higher potential oxygen demand for a given amount of organic loading present in the aquatic ecosystems.

Light energy is needed by freshwater algae in the process of photosynthesis. Highest light reading was recorded in August (745.44 ft-cd) and lowest in May (192.22 ft-cd) and September (142.22 ft-cd). The low light intensities in May and September could have been due to the occurrence of cloudy skies during those months.

Class D refers to fresh surface waters used for agriculture, irrigation, livestock watering, industrial water supply and other inland waters (DENR Administrative Order No. 34, series of 1990). DO levels in Pagbanganan River were below the national standard (5 mg/L) but within the standard (3 mg/L) for Class D freshwater type. However, Behar (1997) also mentioned that DO levels from 4-7 mg/L are still good for many aquatic animals.

The mean pH values of the river water across months were within the acceptable pH range of 6.5-9.0 (Russo et al., 1981), except for July which had the lowest pH (6.22) (Fig. 7). This slightly acidic condition could be due to the rainfall that occurred a day before sampling was done. Surface run-off from the land could bring mineral ions which can alter a slight decrease in pH considering that agricultural lands were noted near the sampling area which could be potential sources of these ions from fertilizers. But according to Roberts (1978) as cited by Jumawan (2005), the pH range of 6.00-9.00 is considered as permissible for aquatic bodies.

Figure 7. Mean current velocity, dissolved oxygen and pH readings in Pagbanganan River, Baybay City, Leyte from April to September 2011

Phosphates and nitrates are required to maintain the growth and metabolism of organisms and they normally occur in small amounts in all aquatic environments. However, excess amounts of these minerals cause eutrophication which is harmful to the aquatic ecosystems around the world (Ansar & Khad, 2005). The compounds containing nitrate ions are highly soluble and can be easily leached away by water and percolate down through the soil while the phosphate forms bond with soil particles making them relatively stable (Keeney, 1989). Strong currents could help release these phosphate forms embedded in the sediment making it available into the water column for utilization by planktonic algae.

Figure 8 shows the monthly abundance of planktonic algae and the levels of phosphate and nitrate in Pagbanganan River. It is also interesting to note that phosphate levels were high during the months of April, May and June than in the months of July, August and September. But an opposite trend was observed for nitrate which was higher from July to September compared to the dry months from April to June.

Figure 8. Monthly abundance of planktonic algae and the levels of phosphates and nitrates in Pagbanganan River, Baybay City, Leyte from April to September

further argued that it would seem reasonable that nutrient transport from water column decreases with freshwater algae density due to this nutrient uptake and increases with current velocity.

Sediment Load, Organic Carbon, Total N and Available P

Figure 9 shows the different levels of sediment load, available phosphorus, organic carbon and total nitrogen in the sediment during the whole sampling period. Sediment load refers to the solid particles produced by weathering and transported through a channel by stream flow. The majority of a stream's sediment load is carried in solution dissolved load or in suspension which could contribute to water turbidity. Turbid water could cause reduction in light penetration due to suspended sediment may alter oxygen relationships in surface water (Oschwald, 1971).

Figure 9. Monthly sediment load, available phosphorus, total nitrogen and organic content levels in Pagbanganan River, Baybay City, Leyte from April to September

Phosphate concentration in Pagbanganan River ranged from 0.258-1.037 mg/L which exceeded the normal range for fresh waters set by the DENR Administrative Order No. 34 Series of 1990 (DAO 34, 1990). This indicates that phosphate as P concentration should not exceed an average of 0.05 mg/L nor a maximum of 0.1 mg/L. This high quantity of phosphates detected in the river most probably came from the laundry soaps and commercial cleaning fluids used by local residents when they did their laundry in the river. Surface run-off during rains could also carry fertilizers from nearby farm lands or residential areas which could have contributed to the increased level of phosphates in the water. It was observed that rice, corn and cassava fields were found in areas adjacent to the river. Excreta from the farm animals wallowing in the river could also have added to the increased P content in the river. According to Smith (1990), the dissolved phosphorus is altered to organic phosphorus as assimilated by phytoplankton and incorporates this into their cells and tissues. As they are ingested by detritivores or zooplankton, this organic phosphorus taken up by the consumers will be excreted as inorganic phosphorus and will be rapidly assimilated by phytoplankton again and the cycle repeats (Holtan et al., 1988).

According to Tepe (2006), the constant recycling of nitrogen through assimilation by planktonic organisms, cell death, mineralization of organic nitrogen, and reassimilation by plankton is a vital aspect of nitrogen dynamics in aquatic ecosystems. Nitrate level in Pagbanganan River was minimal which ranged from 0.125-0.536 mg/L. These levels were below the water quality criteria for nitrate concentration in freshwater ecosystems which is 10 mg/L (DAO 34, 1990). This only indicates that nitrate levels are within safe limits to cause pollution in the river.

It is interesting to note that planktonic algae were most abundant in April (1115 cells/L) when lower levels of nitrates (0.190 mg/L) and phosphates (0.419) were recorded. Whitford (1960) hypothesized that low nutrient concentrations could be due to the nutrient uptake by cells being faster than the rate of diffusion from overlying water to the water near cells. Stevenson and Glover (1993)

Highest sediment load was recorded in September (0.043%) and lowest in August (0.022%). The highest amount of sediment load in the water column reduced light penetration which could have resulted to the low abundance of planktonic algae during that month. According to Wulff et al. (1997), diatoms have the advantage under these conditions since they are capable of active upward migration which is a key mechanism for restoring the oxygenation of the sediment surface through photosynthesis.

Available phosphorus in the sediment ranged from 4.19-5.38 mg/L. High amounts were recorded in July (5.38 mg/L) and August (4.90 mg/L) but lowest in June (4.19 mg/L). The high available phosphorus in the sediments coincides with the high phosphate levels in the water column. Strong water currents mix the water and the sediments releasing nutrients from the sediments to the water column.

Organic carbon (OC) enters the sediments through the decomposition of plant and animal residues in freshwater environments. The amount of organic carbon can influence the availability of essential plant nutrients including nitrogen which can limit plant growth. Richards and Allen (2011) noted that organic carbon and organic nitrogen are a part of the soil organic matter pool derived from plant, animal and microbial residues. Highest organic carbon was recorded in August (0.195 %) and lowest in July (0.078%). Total nitrogen ranged from 0.017-0.044 %. Boyd (1974) mentioned, much of the labile organic matter is likely mineralized or released to the water in soluble organic matter before residues of aquatic plants are assimilated by sediment and the release of nitrogen from sediments certainly contributes to the pool of inorganic nitrogen available to algae and aquatic plants.

Correlation between Phytoplankton Abundance and Physico-Chemical Parameters

There was a significant positive correlation between current velocity and abundance of planktonic algae in Pagbanganan River as revealed by Pearson Correlation Analysis (Table 5).

According to Borchardt (1996) flowing waters along with turbulence and mixing will provide a continual renewal of nutrients that favor the diffusion of nutrients which can stimulate algal growth, respiration, and reproduction.

Schumacher and Whitford (1965) reported that current velocity plays a vital role in phosphate uptake and respiration rate of freshwater algae. Diffusion of required nutrients can limit algal productivity in freshwater ecosystems (Whitford, 1960). An increase in current velocity leads to increase in diffusion. Dodds (1989) observed that the increased photosynthesis of stream cyanobacterium colonies was stimulated with increased current velocity which may be related to higher rates of diffusion of nutrients in the water. This could also be the reason for the increased abundance (1114.88 cells/L) of freshwater algae in Pagbanganan River in April since current velocity was strongest (0.53 m/sec) during that month. Compared to September when the current velocity (0.31 m/sec) was slowest, phytoplankton abundance (79.58 cell/L) was also lowest. This relationship implies the important role of current velocity on the distribution and production of the algal flora in lotic freshwater ecosystems.

Table 5. Correlation between planktonic algae abundance and the different physico-chemical parameters of Pagbanganan River, Baybay City, Leyte

Physico-Chemical Parameter	Pearson Correlation (r)	P value (two-tailed)
pH	0.347	0.158
Current Velocity (m/sec)	0.578*	0.012
Light Intensity (ft-cd)	-0.144	0.568
Water Temperature (°C)	0.322	0.192
Air Temperature (°C)	0.057	0.822
DO (mg/L)	0.136	0.591
Phosphates (mg/L)	0.328	0.184
Nitrates (mg/L)	-0.594**	0.009
Sediment Load (%)	0.033	0.896
OC (%)	0.016	0.949
Total N (%)	0.031	0.903
Available P (mg/kg)	0.044	0.862

** . Correlation is significant at the 0.01 level (2-tailed)

* . Correlation is significant at the 0.05 level (2-tailed)

There could be a potential indication for a positive correlation between phosphate level and phytoplankton abundance but it cannot be confidently claimed or justified in this study and this would merit further investigation to have a clearer picture of its effect on phytoplankton abundance. Osmond et al. (1995) stated that phosphorus is the limiting nutrient in freshwater aquatic systems and when there is an increase of available phosphorus concentration; plants assimilate more nitrogen before the phosphorus is depleted. They added that if all phosphorus is used up, plant growth will cease, no matter how much nitrogen is available in the ecosystem but sufficient availability of phosphorus and elevated concentration of nitrates in freshwater ecosystems will lead to algal blooms.

CONCLUSION

There were 39 phytoplankton genera identified in Pagbanganan River belonging to divisions Bacillariophyta, Chlorophyta, Cyanophyta and Charophyta. The diatoms (Bacillariophyta) were the most abundant and dominant group. The five top most abundant genera were *Navicula*, *Nitzschia*, *Synedra*, *Melosira* and *Coconies*.

Planktonic algae were more abundant during the drier months of April, May and June than the rainy months of July, August and September. Conversely, diversity, taxa richness, evenness and dominance were higher during the wet season. The upstream, midstream and downstream portions were relatively similar in phytoplankton composition and in abundance. Abundance was positively correlated with current velocity but was negatively correlated with nitrate level.

Allan and Castillo (2007) mentioned that in streams with slow currents, filamentous chlorophytes and chrysophytes are abundant whereas in streams with faster currents, diatoms especially *Synedra* dominate. In this study, diatoms were the dominant genera with highest abundance in April when current velocity was strongest, suggesting that diatoms are well-adapted to fast-flowing waters. Interestingly, *Synedra* is one of the top five most dominant genera in Pagbanganan River.

Nitrate levels also had a highly significant negative correlation with planktonic algae abundance. This means that the higher the amount of nitrates in the water, the lower the abundance of planktonic algae. This could imply that the abundance of planktonic algae heavily relied on the nitrate content of the water during the dry months from April to June where phytoplankton abundance was high (303.85-1114.88 cells/L) while nitrate levels were low (0.190-0.225 mg/L). Notably, phosphate levels were also high (0.419-1.037 mg/L) which could mean that phosphate availability was not a problem for phytoplankton consumption during these months. Due to these environmental scenarios, there could be a possibility that planktonic algae consumed the nitrates and stored these in the cells as reserves considering that nitrate levels in Pagbanganan River were very minimal.

In the rainy months (July-September), phytoplankton abundance was low (79.58-186.10 cells/L) and the nitrate levels tend to increase (0.306-0.536 mg/L) even greater than the phosphate levels (0.258-0.386 mg/L). The release of nitrates from the dead phytoplankton cells from the dry season could be one of the contributing factors for the increase of nitrate levels in the water aside from surface run-off from agricultural lands considering that rainfall was more frequent during the wet season. There could also be a possibility that the phytoplankton shifted to consume and store the phosphates more rather than the nitrates since there was a drop of phosphate levels during the wet season.

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