Proceedings of the International Academy of Ecology and Environmental Sciences, 2013, 3(3): 247-256

Article

Chlorophyll content, productivities and biomass allocations of seagrasses in Talim Bay, Lian, Batangas, Philippines

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Received 20 April 2013; Accepted 20 May 2013; Published online 1 September 2013

Abstract

This study determined the chlorophyll content, productivities and biomass allocations of three abundant species of seagrasses in Talim Bay, Lian, Batangas. Philippines: *Enhalus acoroides*, *Cymodocea rotundata,* and *Thalassia hemprichii*. Four seagrass meadows in the bay were selected based on their terrestrial sources of nutrient loads. Results reveal that seagrasses at South Matuod (a site which receives nutrient load drained mostly from corn- and cane-fields), yields the highest GPP (Gross Primary Productivity), but R (Respiration) is higher than GPP, and therefore NPP (Net Primary Productivity) was negative. The same pattern of productivity values were observed in the other sites implying that seagrasses were not making enough oxygen for their life processes at the time of the study (October to November 2010). Although the NPP of seagrasses was negative in Talim Point, (a site which does not receive nutrient load from terrestrial area serving as the control site), they had the highest chlorophyll *a* and *b* content with the other sites. R in this site is the lowest despite its low GPP, suggesting a more efficient primary production. Seagrasses in Kayreyna (which receives nutrient load from primarily from sewerage as well as farmland, i.e., near one creek that drains houses) had the highest total average Wet weight (WW), Dry Weight (DW) and Ash-Free Dry Weight (AFDW) while those seagrasses collected in South Matuod had the lowest biomass. The low biomass of seagrasses in Matuod could be related to their very low productivity and low chlorophyll content needed for such production. Kayreyna is characterized by seagrasses with second highest chlorophyll content after Talim point, and in terms of productivity, two of seagrass species in this site *E. acoroides* and *T. hemprichii* are among those with the lowest R. Evidently, seagrasses in Talim Point, Shields Marine Station (the site which receives primarily agriculture run-off, i.e., near a creek that drains mostly the hillside), and South Matuod, allocated the more biomass in their leaves than their roots. Based on the results, implications for further studies particularly on ascertaining the impact of nutrient loads to the seagrass meadows were highlighted.

Keywords seagrass productivity; biomass allocation; chlorophyll content; Batangas Philippines.

Proceedings of the International Academy of Ecology and Environmental Sciences
ISSN 2220-8860
URL: http://www.iaees.org/publications/journals/piaees/online-version.asp
RSS: http://www.iaees.org/publications/journals/piaees/rss.xml
E-mail: piaees@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

Biogeochemical cycling, benthic faunal habitat and coastal trophodynamics require a highly productive ecosystems including seagrass meadows (Hillman et al., 1989; Walker, 1989; Cebrián and Duarte, 1997; Perry and Dennison, 1999; Costanza et al 1997; Duarte and Chiscano, 1999). In the tropics, seagrass meadows have an annual production of 975-3614 gDW m^{-2} $year^{-1}$, which make them some of the most productive ecosystems in the world (Wirachwong and Holmer, 2010; Heijs, 1985; Vermaat et al., 1995; Nakaoka and Aioi, 1999; Rasheed et al., 2008).

Two important physiological variables, which also indicate the condition and status of a wide range of ecological processes, are Gross Primary Productivity (GPP) and Net Primary Productivity (NPP) (Fourqurean and Zieman, 1991; Dennison, 1987; Zieman and Wetzel, 1980). GPP of an ecosystem is the rate at which energy is captured during photosynthesis; thus, it is the total amount of photosynthetic energy captured in a given period of time. Plants respire to provide energy for their life processes, which uses some of the energy of photosynthesis. The energy that remains in plant tissues after respiration has occurred is the NPP, which is defined as the net flux of carbon from the atmosphere into green plants per unit time. Hence, it is a fundamental ecological variable because it measures the energy input to the biosphere and terrestrial carbon dioxide assimilation (Dawes, 1998).

Chlorophyll content provides a measure the relative contribution of seagrass to the total meadow production as potential sources of carbon for consumers. The chlorophyll concentration is useful in estimating productivity as well as indicator of light stress in seagrasses (Dawes, 1998).

Biomass, on the other hand, greatly influences carbon fixation as well as energy and nutrient transfers (Tomasko and Hall, 1999; Heck et al., 1995; Duarte and Sand-Jensen, 1990; Brower et al, 1990; Dawes, 1998). Usually the influence of a species in a community is directly related to the species' biomass. Values of biomass can be used also instead of density in computing some diversity indices resulting in measures of biomass diversity (Brower et al., 1990).

In Talim Bay, Lian, Batangas, Philippines, seagrass meadows grow abundantly. Seagrasses that thrive in the bay may exhibit variation in biomass allocation, chlorophyll content and productivities. Determining the possible variations in the values of these attributes may provide insights on their existing limiting factors. Moreover, the meadows in the bay receive nutrients through creeks and rivers that drain mostly from agricultural (corn and canefields) areas while others receive nutrients primarily from sewerage of households and beach resorts. Thus, the results could be used to support future effort to explore the impact of elevated or decreased nutrient availability to seagrasses.

The main purpose of this study is to answer the following questions: Under the prevailing water column and sediment nutrient availability in different seagrass meadows in Talim Bay, what is the condition of the seagrass meadows terms of chlorophyll content and primary productivity (GPP, R, NPP) of the seagrasses as well as their biomass allocations in their ground or below-ground components.

2 Materials and Methods

The study was conducted in four specific sites in Talim Bay, Lian, Batangas (Fig. 1) (13° 58' 46.92" N 120° 36' 56.77 E"). Four seagrass meadows in the bay were selected based on their terrestrial sources of nutrient loads: two meadows which receive nutrient load drained mostly from corn and canefields (South Matuod) and from primarily agriculture run-off (i.e., near a creek that drains mostly the hillside (Shields Marine Station); a meadow which receives nutrient load from primarily from sewerage as well as farmland (i.e., near one creek that drains houses) (Kayreyna), and one which does not receive nutrient load from terrestrial area (Talim Point) serving as the control site. The basis of site selection is a prelude to further studies, which could examine the impact of nutrient loading on seagrass meadows in the bay.

Fig. 1 Study sites in Talim Bay, Lian, Batangas (13° 58’ 46” N 120° 36’ 56 E”).

Three species of seagrasses (*Enhalus acoroides Cymodocea rotundata,* and *Thalassia hemprichii)* and the sediments these plants grow in were sampled in the four sites. Sampling of seagrasses and sediments was be done by snorkeling. Above- and belowground biomass was obtained by collecting 10 replicate acrylic cores (inner diameter =10 cm length 30-50 cm) along 3 10-m transects, set up in seaward direction and were separated by 10 m, which were brought to the laboratory, sorted into above- and belowground parts, and then obtain fresh biomass (Terrados et al., 1999).

Primary Productivity. To describe the primary production of seagrasses in the study sites, chlorophyll *a* and *b* content was determined using a spectrophotometer (Genesys 20 Spectrophotometer) and the Primary Productivity (GPP), Net Primary Productivity (NPP), and respiration (R) were measured through light and dark bottle technique. The modified Light and Dark Bottle Technique is based on the works of Thomas (1988). Two BOD bottles were used in incubating the seagrasses and two more for the incubation of the phytoplankton. The amount of DO that the phytoplankton produced was determined because the bottle for the seagrasses (both light and dark) also contained phytoplankton. Initial bottle oxygen level was measured first. Then 10 g per species seagrass were placed separately inside the reagent bottles. The reagent bottles were then filled with seawater, avoiding bubbles to be trapped. The bottles were incubated for one hour underwater on a large white pail at about 0.75 m depth. After incubation, bubbles formed at the mouth of the bottles were measured using a ruler. Then the probe of the DO analyzer was immersed. Oxygen of light and dark bottle produced by the phytoplankton was also determined. The results will be recorded as follows:

A1 = Light bottle of species A; A2 = Dark bottle of species A
A1b = Bubbles of light bottle of species A;
P1 = Light bottle of phytoplankton; P2 = Dark bottle of phytoplankton
IB = Initial bottle oxygen level; N = Incubation time in hours
PQ = Photosynthetic quotient (use 1.2); RQ = Respiratory quotient (use 1.0)

Before proceeding with any calculations, bubbles were converted first to mg/L from mm. This conversion could be carried out using the graph showed by Thomas (1988). In converting the bubbles, the following steps was done: (1) for each bottle, the volume of gas will be determined from their diameter; (2) subtract the total dark bottle bubble volume from the total light bottle volume; (3) convert the result (volume of oxygen in reagent bottle) to mg/L by multiplying by 2.31; and (4) add the result to the dissolved oxygen analyzer reading for the light bottle. Then the succeeding calculation is done:

$LB = A1 – P1$

$DB = A2 – P2$

$GPP = [375.9 (LB – DB) (N x PQ)] / 3333$

$NPP = [375.9 (LB – IB) (N X PQ)] /3333$

$R = [375.9 (IB – DB) / (RQ/N)] /3333$

The factor 375.9 converts the results to standard volume ($1m^3$) while 3333 standardizes the results to a liter basis.

Dawes (1998) explained that NPP is the Net photosynthesis, which reflects the use of oxygen in respiration, whereas GPP refers to gross photosynthesis, which is the sum of corrected respiration and net photosynthesis.

Chlorophyll Analysis by Spectrophometry (Dawes, 1998). Two major steps were undertaken: pigment extraction and chlorophyll measurement. In extracting pigment, the following steps were done: (a) Collected samples (n= 5 to 10) are weighed (wet: use 0.1 to 0.5 g $sample^{-1}$) and the pigment extracted. (b) The samples are grounded using in a test tube using liquid nitrogen instead of a mortar and pestle or a ground homogenizer. All grinding and extraction are done under low light and at 10 to 12^0C (cold room, ice bath), because the pigments are easily degraded by light and heat. Gloves and safety glasses were worn during the procedure. (c) Chlorophylls *a* and *b* are extracted by grinding in 80% spectroanlyzed acetone for 1 min in 2 to 3ml of the extracting fluid. (d) The slurry of powder and solvent is poured into centrifuge tubes marked to 6-10 ml and the grinding apparatus is flushed with the solvent until the tube is filled to the mark. The extract is centrifuged (4,500 rpm, 2 to 5 min) in the cold using a tabletop centrifuge. (e) The supernatant is decanted into a cuvette and the absorption is measured at appropriate wavelengths on a calibrated spectrophotometer. In measuring chlorophylls, Yoshida (1976) suggested that the after absorbance is measured using a spectrophotometer at 663 mu and 645 mu. The following calculations were followed:

$\text{Chlorophyll } a = 0.0127 \times D663 – 0.00269 \times D645$

$\text{Chlorophyll } b = 0.0229 \times D645 – 0.005468 \times D663$

$C = Ca + Cb$

$C = 0.202 \times D645 + 0.00802 \times D663$

Consequently, this equation was expressed in mg per liter using this formula:

$C= 20.2 \times D645 + 8.02 \times D663 \times \text{ dilution factor } (50/1000 \times 100/5 \times 0.5)$

C= mg chlorophyll/g fresh weight sample

where C = Total chlorophyll (grams per liter, $g\ l^{-1}$)

D663 = absorbance at 663 mu

D645 = absorbance at 645 mu

Ca = concentration of chlorophyll *a* in grams per liter ($g\ l^{-1}$)

Cb = concentration of chlorophyll *b* in grams per liter ($g\ l^{-1}$)

Biomass. The seagrasses sampled at each site were sorted by species, then by above-ground (shoots) and below-ground (horizontal and vertical roots), which were then weighed to obtain fresh weight. There were brought to the laboratory for oven-drying (60^0C) until constant weight, which represented both the organic and inorganic contents of the sample or dry weight. Next, the dried sample is combusted by placing the sample in the muffle furnace at 550°C for 1 h. Cooled and weighed until a constant weight is achieved.

All of the organic content (carbon) is burned off- all of the carbon in the sample reacts with oxygen to produce carbon dioxide. Carbon dioxide is a gas, so it leaves the sample. The ash that is left over is thus the inorganic contents of the sample. The AFDW is then the dry weight (inorganic + organic contents) minus the weight of the ash (inorganic contents only). AFDW is therefore the weight of the organic content of the sample. Although *Enhalus acoroides* was included in the collection, its biomass was not reported here, because this species was not observed in Site 1-Talim Point. Only the biomass of seagrasses (*Thalassia hemprichii, Cymodocea rotundata,* and *Halodule pinifolia*), which were common in the four sites were analyzed and compared.

Statistical Analysis. In ascertaining the differences in nutrients, chlorophyll content, productivities, and biomass allocation, Independent samples Nonparametric Kruskal-Wallis test, Chi-square test and One-way ANOVA were used.

3 Results

3.1 Chlorophyll content and primary productivity (GPP, R, NPP)

Seagrasses with highest chlorophyll content was found at Site 1-Talim point (34.548 mg l^{-1}), followed by Site 4-Kayreyna (8.390 mg l^{-1}), then Site 3-SMS (1.888 mg l^{-1}), and lowest at Site 2-South Matuod (1.05 mg l^{-1}) (Table 1).

The mean chlorophyll content per species across sites (not shown in the table) revealed that for *T. hemprichii* had the highest content (54.127 mg l^{-1}), followed by *H. pinifolia* (43.798 mg l^{-1}), and *C. rotundata* (41.356 mg l^{-1}). *E. acoroides* has the lowest content (6.743 mg l^{-1}).

In all sites, R was found to be higher than GPP resulting to negative NPP values (Table 2). Site 2-South Matuod has the highest GPP (1.120 mg l^{-1} h^{-1}) but it has the highest R (3.114 mg l^{-1} h^{-1}) and lowest NPP (-3.737 mg l^{-1} h^{-1}). The same pattern of productivity values was observed in the other sites.

Table 1 Chlorophyll (*Chl*) *a* and *b* content of the seagrasses sampled at the 4 study sites.

Site	Seagrass Species	A_{663} (absorbance at 663 mu)	A_{645} (absorbance at 645 mu)	*Chl a* (g l^{-1})	*Chl b* (g l^{-1})	Total *Chl* Content (mg l^{-1})
1-Talim Point	*Thallasia hemprichii*	0.915	1.876	0.0098	0.0380	41.571
	Cymodocea rotundata	0.619	1.333	0.0043	0.0420	29.414
	Halodule pinifolia	0.644	1.489	0.0042	0.0306	32.660
			Mean Chlorophyll Content:			*34.55*
2-South Matuod	*Enhalus acoroides*	-0.032	0.000	-0.0004	0.0002	-0.128
	Thallasia hemprichii	0.333	0.019	0.0042	-0.0014	1.721
	Cymodocea rotundata	0.116	0.054	0.0013	0.0006	1.561
			Mean Chlorophyll Content:			*1.052*
3-SMS	*Enhalus acoroides*	0.048	0.092	0.0001	0.0018	2.044
	Thallasia hemprichii	0.219	0.045	0.0027	-0.0002	1.786
	Cymodocea rotundata	0.183	0.054	0.0022	0.0002	1.833
			Mean Chlorophyll Content:			*1.888*
4-Kayreyna	*Enhalus acoroides*	0.411	0.157	0.0048	0.00136	4.826
	Thallasia hemprichii	0.754	0.298	0.0088	0.00271	9.049
	Cymodocea rotundata	0.696	0.285	0.0081	0.00272	8.548
	Halodule pinifolia	0.865	0.380	0.0100	0.00396	11.138
			Mean Chlorophyll Content:			*8.390*

Table 2 Net primary productivity (NPP), gross primary productivity (GPP) and respiration (R) of the seagrasses in the study sites.

Site	***Enhalus acoroides*** **(mg l^{-1} h^{-1})**			***Cymodocea rotundata*** **(mg l^{-1} h^{-1})**			***Thalasia hemprichii*** **(mg l^{-1} h^{-1})**			***Halodule pinifolia*** **(mg l^{-1} h^{-1})**			**Mean per Site (mg l^{-1} h^{-1})**		
	GPP	**R**	**NPP**	**GPP**	**R**	**NPP**	**GPP**	**R**	**NPP**	**GPP**	**R**	**NPP**	**GPP**	**R**	**NPP**
1-Talim Point	---	---	---	0.424	0.706	-0.847	0.413	0.834	-1.001	0.248	0.782	-0.938	1.085	2.321	-2.785
2-South Matuod	0.880	0.851	-1.021	1.120	0.846	-1.015	0.836	1.114	-1.336	0.852	1.155	-1.386	2.811	3.114	-3.737
3-SMS	0.060	0.846	-1.015	0.175	0.758	-0.909	0.200	0.785	-0.942	0.039	0.876	-1.052	0.410	2.419	-2.903
4-Kayreyna	0.684	0.845	-1.015	0.686	0.819	-0.983	0.793	0.800	-0.963	0.751	0.941	-1.130	2.230	2.563	-3.075
Mean per species	0.541	0.847	-1.017	0.660	0.808	-0.969	0.610	0.810	-1.080	0.547	0.990	-1.189	1.817	2.699	-3.238

Note: species not observed in the site.

In Site 1-Talim Point, although its NPP is negative (-2.785 mg l^{-1} h^{-1}), it was the highest compared with the other sites. Its R is the lowest (2.321 mg l^{-1} h^{-1}) despite its low GPP (1.085 mg l^{-1} h^{-1}). Among the seagrass species across sites, GPP was highest in *Cymodocea rotundata* (0.660 mg l^{-1} h^{-1}) and decreased along the following sequence: *Thalassia hemprichii* > *Halodule pinifolia* > *Enhalus acoroides* (0.541 mg l^{-1} h^{-1}). On the other hand, R was highest in *Halodule pinifolia* (0.990 mg l^{-1} h^{-1}) and decreased along the following sequence: *E. acoroides* > *T. hemprichii* > *C. rotundata* (0.808 mg l^{-1} h^{-1}). NPP was least negative in *C. rotundata* (-0.969) and increased along the following sequence: *E. acoroides* < *T. hemprichii* < *H. pinifolia*.

In the case of three seagrasses common to all the sites, *C. rotundata, T. hemprichii,* and *H. pinifolia* found at Site 2-South Matuod had the highest GPP (1.120 mg l^{-1} h^{-1}; (0.836 mg l^{-1} h^{-1}; 0.852 mg l^{-1} h^{-1}, respectively) while those at Site 3-SMS had the lowest (0.175 mg l^{-1} h^{-1}; 0.200 mg l^{-1} h^{-1}; 0.039 mg l^{-1} h^{-1}, respectively).

All the seagrasses at Site 2-South Matuod has the highest R (*E. acoroides*: 0.851 mg l^{-1} h^{-1}; *C. rotundata*: 0.846 mg l^{-1} h^{-1}; *T. hemprichii*: 1.114 mg l^{-1} h^{-1}; and *H. pinifolia*: 1.155 mg l^{-1} h^{-1}). On the other hand, those with lowest R were *E. acoroides* and *T. hemprichii* at Site 4-Kayreyna (0.845 mg l^{-1} h^{-1}; 0.851 mg l^{-1} $h^{-1}$and 0.800 mg l^{-1} h^{-1}, respectively) and *C. rotundata* and *H. pinifolia* at Site 1-Talim Point (0.706 mg l^{-1} h^{-1} and 0.782 mg l^{-1} h^{-1}, respectively).

E. acoroides had the least negative NPP at Site 3-SMS and Site 4-Kayreyna (-1.015 mg l^{-1} h^{-1}); *C. rotundata* at Site 1-Talim Point (-0.847 mg l^{-1} h^{-1}); *T. hemprichii* at Site 3-SMS (0.942 mg l^{-1} h^{-1}). Lastly, *H. pinifolia* had the least negative R (-0.938 mg l^{-1} h^{-1}). All these seagrasses showed their most negative R in Site 2-South Matuod (*E. acoroides*: -1.021 mg l^{-1} h^{-1}; *C. rotundata*: -1.015 mg l^{-1} h^{-1}; *H. hemprichii*: -1.336 mg l^{-1} h^{-1}; *H. pinifolia*:-1.386 mg l^{-1} h^{-1}).

Although differences in chlorophyll content were observed, these were not however significant statistically (χ^2=12.000; df=9; p>0.05 for *E. acoroides, T. hemprichii, C. rotundata,* and (χ^2=8.000; df=9; p>0.05 for *H. pinifolia*). The differences in GPP (*F*=2.763; df=3; p>0.05), R (*F*=0.159; df=3; p>0.05), and NPP (*F*=0.158; df=3; p>0.05) of all seagrasses across sites were found also to be statistically insignificant using One-way ANOVA.

3.2 Biomass allocation of seagrasses

On the average, seagrasses in Site 7-Kayreyna had the highest total WW (7.447 g f wt m^{-2}), DW (0.779 g f wt m^{-2}) and AFDW (0.501 g f wt m^{-2}) (Table 3). In contrast, those seagrasses collected in Site 2-South Matuod had the lowest total WW (1.758 g f wt m^{-2}), DW (0.288 g f wt m^{-2}) and AFDW (0.178 g f wt m^{-2}).

Analysis of biomass allocation revealed that the seagrasses that allocated most of their biomass in their leaves were those collected at Site 3-SMS (WW=2.14 g f wt m^{-2}; DW=0.264 g f wt m^{-2}; AFDW=0.181 g f wt m^{-2}) while those at Site 4-Kayreyna allocated most of their mass on their roots (WW=5.46 g f wt m^{-2}; DW=0.523 g f wt m^{-2}; AFDW=0.319 g f wt m^{-2}).

Seagrasses that allocated the least biomass in their leaves were those at Site 1-Talim Point (WW=1.092 g f wt m^{-2}; AFDW=0.083 g f wt m^{-2}). In contrast, those from Site 2-South Matuod allocated the least biomass in their roots (WW=1.014 g f wt m^{-2}; DW=0.162 g f wt m^{-2}; AFDW=0.083 g f wt m^{-2}).

Consistently, the above:below ratio was highest in Site 2-South Matuod (WW: 1.119; DW: 0.695; AFDW:2.025)) and lowest in Site 4-Kayreyna (WW: 0.317; DW: 0.391; AFDW: 0.451).

Results of Independent Samples Kruskal-Wallis Test to ascertain differences in WW, DW, and AFDW of seagrasses across sites revealed that observed differences were not significant (WW: K-W=3.769; df=3; p>0.05; DW: K-W=2.949; df=3; p>0.05; AFDW: K-W=2.333; df=3; p>0.05). When differences in below-ground versus above-ground biomass were tested, non-significant differences were also noted (WW above-ground: K-W=2.128, df=3, p>0.05; WW below-ground: K-W=3.821, df=3, p>0.05; DW above-ground: K-W=1.462, df=3, p>0.05; DW below-ground: K-W=2.897, df=3, p>0.05; AFDW: above-ground: K-W=1.433, df=3, p>0.05; AFDW below-ground: K-W=3.000, df=3, p>0.05).

Table 3 Above-ground (shoots) and below-ground (roots) biomass of the seagrasses sampled at the 4 study sites.

Site	Seagrass Species	Wet weight (WW) (g f wt m^{-2})				Dry weight (DW) (g d wt m^{-2})				Ash free dry weight (AFDW) (g afd wt m^{-2})			
		Above-ground	Below-ground	Total	Above: Below ratio	Above-ground	Below-ground	Total	Above: Below ratio	Above-ground	Below-ground	Total	Above: Below ratio
1-Talim Point	*Thalassia hemprichii*	2.476	3.107	5.583	0.797	0.287	0.506	0.793	0.567	0.175	0.330	0.505	0.530
	Cymodocea rotundata	0.662	0.762	1.424	0.869	0.054	0.145	0.199	0.372	0.026	0.059	0.085	0.441
	Halodule pinifolia	0.138	0.751	0.889	0.184	0.069	0.156	0.225	0.442	0.048	0.1	0.148	0.480
	Average mass:	*1.092*	*1.540*	*2.632*	*0.617*	*0.137*	*0.269*	*0.406*	*0.460*	*0.083*	*0.163*	*0.246*	*0.484*
2-South Matuod	*Thalassia hemprichii*	1.260	2.484	3.744	0.507	0.231	0.397	0.628	0.582	0.162	0.203	0.365	0.798
	Cymodocea rotundata	0.862	0.295	1.157	2.922	0.118	0.034	0.152	3.471	0.1	0.016	0.116	6.25
	Halodule pinifolia	0.111	0.262	0.373	0.424	0.028	0.056	0.084	0.5	0.023	0.029	0.052	0.793
	Average mass:	*0.744*	*1.014*	*1.758*	*1.284*	*0.126*	*0.162*	*0.288*	*1.518*	*0.095*	*0.083*	*0.178*	*2.614*
3-SMS	*Thalassia hemprichii*	3.07	9.093	12.163	0.338	0.369	0.756	1.125	0.488	0.248	0.479	0.727	0.518
	Cymodocea rotundata	3.001	2.382	5.383	1.26	0.38	0.291	0.671	1.306	0.269	0.115	0.384	2.339
	Halodule pinifolia	0.350	0.722	1.072	0.485	0.042	0.13	0.172	0.323	0.026	0.062	0.088	0.419
	Average mass:	*2.140*	*4.066*	*6.206*	*0.694*	*0.264*	*0.392*	*0.656*	*0.706*	*0.181*	*0.219*	*0.400*	*1.092*
4-Kayreyna	*Thalassia hemprichii*	3.576	9.968	13.544	0.359	0.487	0.874	1.361	0.557	0.353	0.627	0.98	0.563
	Cymodocea rotundata	2.011	4.948	6.959	0.406	0.236	0.388	0.624	0.608	0.175	0.162	0.337	1.08
	Halodule pinifolia	0.373	1.464	1.837	0.255	0.045	0.307	0.352	0.147	0.016	0.169	0.185	0.095
	Average mass:	*1.987*	*5.460*	*7.447*	*0.340*	*0.256*	*0.523*	*0.779*	*0.437*	*0.181*	*0.319*	*0.501*	*0.579*

4 Discussion

In all the study sites, R was found to be higher than GPP resulting to negative NPP values. The site that receives nutrient load drained mostly from corn- and cane-fields (i.e., Site 2-South Matuod) has the highest GPP but it has the highest R, and therefore lowest NPP. The same pattern of productivity values was observed in the other sites. The seagrass meadow which does not receive direct nutrient load from terrestrial area serving as the control site (i.e., Site 1-Talim Point, although its NPP is negative, had the highest NPP compared with the other sites. R is the lowest despite its low GPP, suggesting a more efficient primary production. This implies that the nutrient loads had drastically affected the productivity of the seagrasses. This may be cause over-nourishment of the area and block the light that reaches the seagrasses.

The three seagrasses common to all the sites *C. rotundata, T. hemprichii,* and *H. pinifolia* found at Site 2-South Matuod had the highest GPP, these seagrasses have also the highest R, implying imbalance in the production of photosynthetic products. This could also explain why those seagrasses which, receives primarily agriculture run-off through a creek that drains mostly the hillside (i.e., Site 3-SMS) had the lowest GPP. GPP was highest and NPP is least negative in *Cymodocea rotundata*. R was highest (or least negative) in *Halodule pinifolia* but in general, the other seagrasses showed their most negative R in Site 2-South Matuod. These variations in the productivity of the seagrasses support the observation that light requirements of seagrasses is species-specific (Waycott et al., 2007).

Chlorophyll concentration is useful in estimating productivity as well as indicator of light stress in seagrasses. In this study, chlorophyll analysis was done to measure the relative contribution of seagrass to the total meadow production as potential sources of carbon for consumers (Dawes, 1998). Results show that seagrasses found in the control site has the highest chlorophyll content and least in a site where nutrient load is greater. This deviates to the general observation that increased chlorophyll concentration is a response to reduced light availability (Zieman and Wetzel, 1980; Wiginton and McMillan, 1979). Seagrasses in the control site compared to those in the site where more nutrient load was noted appeared to be less stressed by light availability because the water. A possible explanation to this lies on the turbidity, which was documented during the actual observation. These contrasting results provide an impetus for further studies to identify other limiting factors for chlorophyll concentration in the seagrasses found in the bay. Thus, the apparent cause of the low productivity of the less nutrient-loaded seageasses was the very low chlorophyll content. Light stress that should increased chlorophyll content is therefore ruled out at least, at this point; instead other factors, e.g., nutrient concentration and availability might have induced this pattern.

The biomass of seagrasses collected in the 4 sites revealed that on the average, seagrasses in the site which receives nutrient load from primarily from sewerage as well as farmland, i.e., near one creek that drains houses (i.e., Site 4-Kayreyna) had the highest total biomass). Those seagrasses collected in Site 2-South Matuod had the lowest total biomass. Thus far, this low biomass of seagrasses can be related to their very low productivity and low chlorophyll content needed for such production.

In sum, seagrasses in Talim Bay exhibit variation in biomass allocation, chlorophyll content and productivities that needed further investigation particularly in determining their existing limiting factors. Nutrients loads need to be quantified so as to validate the apparent impact on the seagrass in the bay.

Acknowledgement

This work was supported by the scholarship awarded to the first author by the Advanced Science and Technology Human Resource Development Program (ASTHRDP) of the Department of Science and Technology (DOST) of the Philippines and Faculty and Staff Development Program of Ateneo de Naga University, Philippines. The authors wishes to thank W.R.Y. Licuanan and M. Samson for their guidance in the conduct of this study. Special thanks to F. C. Patron, B. Hernandez and R. Reyes for their assistance during the data collection.

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