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Full Length Research Paper

Carrying Capacity of Net Primary Productivity of Laguna Lake, Philippines

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A model was developed to determine the carrying capacity of net primary productivity of Laguna Lake measured in terms of water quality variables, namely: (1) physicochemical properties such as pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chloride, ammonia (NH_3), nitrate ($N0_3$), phosphate (PO_4), total nitrogen (TN), total phosphate (TP), turbidity, alkalinity; (2) microbiological (total coliform); and (3) heavy metals (chromium (Cr), Cadmium (Cd), lead (Pb), copper (Cu), iron (Fe), nickel (Ni) and zinc (Zn)). A 10-year period (1999-2008) water data of the Laguna Lake Authority (LLDA) was used in the development of the carrying capacity model. Results of the Pearson correlation test showed that among the variables with significant correlation between net primary productivity and water quality were the parameters on pH (0.204), biological oxygen demand (0.304), chloride (0.376), nitrate (-0.207), phosphate (-0.151), total phosphate (-0.112), turbidity (-0.133), alkalinity (0.113), total coliform (0.179), and iron (-0.140). It means that water quality has changed significantly over the past years that these parameters can cause harm to the fishes and other aquatic life of the lake. In the regression analysis using stepwise method showed that the significant predictors of net primary productivity were: (1) chloride with R value of 0.376; (2) chloride and nitrate with R values of 0.428; (3) chloride, nitrate and total coliform with R value of 0.478; and (4) chloride, nitrate, total coliform and biological oxygen demand with R value of 0.496. The final model contained four (4) predictors which were found to have significant to NPP. The R value means that the independent variables in the model can account for about 49.6 or 50 %t of the variance to NPP. However, this also indicates that another 50% of the variance to NPP can be explained by other limiting factors. Carrying capacity of net primary productivity of the lake water in 10-year period (1999-2008) was in decreasing trend. It implies that the four (4) parameters poses threat to the aquatic environment of the lake, particularly on the growth of the natural food (algae) used for fish production. The model of carrying capacity of net primary productivity was developed in which NPP could be a function of the water quality parameters expressed as chloride, nitrate, total coliform, and biological oxygen demand. These parameters will also serve as one of the limiting factors that could affect the productivity of the water.

Keywords: Languna Lake, Productivity of Laguna Lake Philippines.

INTRODUCTION

Carrying capacity, environmentally speaking, refers to the size of a population that can live indefinitely in an environment without doing any harm to the environment. In layman's term it means, "Everything in the world is linked together in which one thing affects everything." It is used as a helpful tool to make important decisions, i.e. "How to Save the Laguna de Bay?"

Calculating carrying capacity is a complex tool in which the first step is to specify what variables to measure that may affect a particular population. One must measure the carrying capacity on determining how the variables effected the population and to what extent do they affect the unsustainable environment.

There are many ways to measure carrying capacity because of the many variables that effect populations in certain environments. An example is the study being conducted by Drillon and Rigler (1974) to estimate the amount of phosphorus in lake water. He calculated the carrying capacity of phosphorus because it is one of the basic restrictive elements in the lakes. This means that scientists can measure phosphorus to test a lake's nutrition and make assumptions as its productivity and with the use of certain equations, the carrying capacity can be determined.

Another important work is the concept of nutrient loading applied on the elements such as nitrogen and phosphorus. It determined the eutrophication spectrum and productivity of the lake. This information was applied to Lake Sunapee because it is oligotrophic and nutrient loading is a possible option to make it eutrophic (Carrying Capacity Literature Review, 2004).

Carrying capacity is very difficult to measure accurately due to innumerable variables that effect population sustainability in certain environments. To obtain an accurate estimate, it is best to focus on one variable that has had a noticeable effect, i.e. the water quality. Measure the presence of that variable as it already exists and use of model to measure what extent to that variable can exist while sustaining a healthy population within that environment, i.e. the "*Saving the Laguna Lake*."

Laguna Lake, otherwise known as "Laguna de Bay", is considered as one of the largest inland waters situated at the heart of the CALABARZON, Philippines which is now at the state of water deterioration and the situation is getting worse because of the poor water quality and occurrence of algal bloom which damages the net primary productivity of the lake for fish production.

Since there are many assessment and evaluation researches conducted in the Laguna Lake, the development of carrying capacity of the lake is one of the niches to be studied. Hence, this study of the Ecosystems Research and Development (ERDB) was conducted to develop the carrying capacity model measured using the net primary productivity and water quality.

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REVIEW OF LITERATURE

Defining Carrying Capacity

Carrying capacity is a term of measurement. It measures both living and non-living objects and relates to the maximum amount of an organism or object that can be supported by a given amount of space. This limit depends on the larger of variable environmental factors. Carrying capacity can be concerned with population growth of humans and other species of living organisms (Paehlke, 2004). In the ecological sense, carrying capacity is related to the "study of population dynamics." When a species grows rapidly over the carrying capacity of its environment (i.e. overpopulation), it becomes a problem (Dashelsky, 1993). When the species crowds its environment (i.e. ecosystem, habitat, etc.) resulting in diminished resources, its "growth will decline". When this occurs, the population of the species will "level off" and eventually cease to grow or even suffer from a severe decline (Paehlke, 2004).

An example of defining the environmental carrying capacity is in the context of fish aquaculture. Carrying capacity of fish aquaculture is the maximum number of fish of a given species that may be safely grown in the considered water body. The maximum number is limited by a variety of factors. Certainly, if the maximum number exists for a single aquaculture occupying a given area, then the available area for fish cultures induces the upper limit. However, this limit may be much higher than the carrying capacity. Computation of carrying capacity must be based on the condition which limits the stock maximally. In other words, it must be based on the limiting condition (Tarzan, L, *et al*., 1998).

Determining Carrying Capacity Model

Several models have been developed in determining carrying capacity in fish production and other related lake water ecosystem. One of the models developed was to estimate the production carrying capacity of water bodies based on nutrient inputs from aquaculture and other sources, flushing rates, and the risk of algal blooms for three different sites of the Philippines, namely: (1) Bolinao for marine site; (2) Dagupan, site of brackish water; and (3) Taal Lake for freshwater site. The results suggested that aquaculture production in Taal Lake was greater than the sustainable carrying capacity. Aquaculture structures in Bolinao were close to carrying capacity during average tidal exchange but greater than the carrying capacity during low tidal exchange and no winds. Aquaculture production in the Dagupan estuary has not overcome its carrying capacity even during low flow. However, during very low flow and no tidal flushing, carrying capacity has been overcome (Tarzan Legović, *et al*., 2008).

Another model of carrying capacity developed by Martin, M. R. *et al*. (1998 was the analysis of water quality and land use in the Blue Mountain Lake. The project aimed to: (a) assess existing water quality in the lake and its tributaries; and (b) use the monitoring data in a water quality response model in order to predict the impact of development within the Lake's watershed. The water quality data indicated that Blue Mountain Lake is in oligotrophic state wherein a significant decline in water quality was experienced in 1993. Total phosphorus concentrations have increased from around 3 parts per billion (ppb) in 1978 to between 8 and 9 ppb in 1998. Chlorophyll *a* concentrations have increased from around 1.5 ppb in 1994 to around 1.8 ppb in 1997, with an average of 3 ppb in the east basin during 1998. Transparency has decreased from around 10 meters in 1993 to around 6.5 meters in 1998.

The model for a decrease in water quality to a chlorophyll *a* concentration of 2 ppb predicts total allowable for new development consisting of 38 seasonal and 20 year-round homes. The trend in water quality, however, it is likely that Blue Mountain Lake reached the threshold levels even with the present level of development.

METHODOLOGY

A 10-year period (1999-2008) water data of the Laguna Lake Authority (LLDA) was used in the development of the carrying capacity model. The carrying capacity of Net Primary Productivity (NPP) was simulated with the water quality variables, namely: (1) physicochemical properties such as pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chloride, ammonia (NH_3), nitrate ($N0_3$), phosphate (PO_4), total nitrogen (TN), total phosphate (TP), turbidity, alkalinity; (2) microbiological (total coliform); and (3) heavy metals (chromium (Cr), Cadmium (Cd), lead (Pb), copper (Cu), iron (Fe), nickel (Ni) and zinc (Zn)). Quantitative analysis was applied using Pearson correlation and regression test.

Pearson correlation analysis was used to test the degree of linear relationship among the variables. In the correlation analysis, the statistical level of significance used was at 0.01 and 0.05. After determining the significant parameters, multiple regression analysis using stepwise method was used to test if linear dependence existed among the variables and generate the model.

The regression equation of the carrying capacity of net primary productivity was presented in the general form of:

Y predicted $= b_0 + b_1 X_1 + b_2 * X_2 + b_3 X_3$

or

NPP is the function of water quality express as physicochemical properties + microbiological + heavy metal

where:

b_O = constant

X_1 = parameters of physicochemical

X_2 = parameter of microbiological

X_3 = parameters of heavy metals

b_1, b_2, b_3 = coefficient values of X_1, X_2 and X_3

Under the stepwise procedure, one variable at a time was added until no additional variable makes a significant contribution to the model. Simulating the different factors and parameters, the final model generated the significant parameters that influence or affected the net primary productivity of the lake. The test of the adequacy of the model was computed using the observed correlation. The computed residual values were used to explain the significant effects of the variables under study.

F value was computed to determine the reliability of the independent variables as a predictor of the dependent variable in the study subjected at 0.05 level of significance. The standardized beta coefficient was determined to examine the values for regression equation for predicting the dependent and the independent variables.

Based on the results of the regression analysis, a model of carrying capacity was developed. The values of R and R^2 were computed to examine the correlation between the observed and predicted values of the dependent variable and the strength of association between independent and dependent variables. The R^2 change was also computed to indicate the increase/decrease in prediction as another variable is added to the model.

RESULTS AND DISCUSSION

Status of Water Quality in Laguna Lake

A. Physicochemical Properties

Table 1 presents the 10-year period (1999-2008) data of the physicochemical properties of the lake water. The lake water was measured in terms of parameters on pH, DO, BOD, Chlorine, Ammonia, Nitrate, Phosphate, Total Nitrogen, Total Phosphate, Turbidity and Alkalinity.

pH - It was observed that the pH levels of Laguna Lake exhibited within the standard acceptable range from 6.5 to 8.5 unit for Class C water classification. Except in 2003, pH concentration was at 3.461 units in which falls below the standard unit resulting to acidic condition of the water. The pH level of the lake water needs to be in neutral condition for the growth and reproduction of the fishes and other living organisms.

Dissolved Oxygen - DO levels of the lake water had an annual mean concentration which ranged from 7.189 to 11.156 mg/l. It indicated that the water has a high DO concentration as compared to the detection limit of 0.01

Table 1. Physicochemical properties of Laguna lake water

YEAR	PHYSICOCHEMICAL PROPERTIES					
	pH (unit)	**Dissolved Oxygen (DO) mg/l**	**Biological Oxygen Demand (BOD) mg/l**	**Chloride (Cl) mg/l**	**Ammonia (NH_3) mg/l**	**Nitrate (NO_3) mg/l**
1999	8.019	7.903	1.766	369.08	0.01573	.04463
2000	8.033	7.885	1.171	104.22	0.02714	.22445
2001	3.461	7.189	0.386	11.63	0.00181	.01325
2002	8.342	7.967	1.569	219.06	0.06179	.09517
2003	7.375	7.269	1.742	464.94	0.05636	.03979
2004	7.853	8.231	1.818	1009.36	0.06441	.11226
2005	7.939	11.156	2.444	674.06	0.04621	.08293
2006	7.847	8.033	2.206	283.00	0.03820	.20193
2007	8.447	8.608	1.722	291.86	0.05826	.04034
2008	7.767	7.483	1.528	111.47	0.02086	.07892
Mean	7.5083	8.1724	1.6352	353.87	0.03901	0.0933
Std. Deviation	1.1791	3.0623	0.9751	236.48	0.04417	0.1052
Class C Standard Limit	6.5 to 8.5 units	0.01	0.1	350	0.002	0.002

Table 1. Continued…

YEAR	PHYSICOCHEMICAL PROPERTIES				
	Phosphate (PO_4) mg/l	**Total Nitrogen mg/l**	**Total Phosphate mg/l**	**Turbidity mg/l**	**Alkalinity mg/l**
1999	.00801	0.744	0.236831	No data	26.61
2000	.11317	1.386	0.504325	No data	35.53
2001	.03985	.403	0.064819	12.97	73.89
2002	.08135	2.703	0.261819	39.67	84.67
2003	.03153	2.928	0.119656	24.61	47.56
2004	.03244	2.139	0.169058	No data	159.67
2005	.06603	1.288	0.159503	37.25	69.56
2006	.06944	2.078	0.197872	53.75	79.33
2007	.07331	1.597	0.187314	26.11	103.44
2008	.04329	1.827	0.123822	28.97	91.44
Mean	0.0558	1.709	0.202500	22.33	77.17
Std. Deviation	0.0496	1.117	0.138800	21.61	69.38
Class C Standard Limit	0.002	0.5	0.002		0.002

mg/l. It means the lake has adequate amount of dissolved oxygen available for fish and other aquatic organisms.

Biological Oxygen Demand - It was recorded that the annual averages of BOD ranged from 0.386 to 2.444 mg/l. It indicated that the BOD concentration of the water is still in good condition since it is within the standard limit of 0.1 mg/l.

Chloride – It registered for the decade 1999 – 2008 the average mean of 353.87 mg/l which exceeded the standard limit of 350 mg/l for Class C inland water. The amount of chloride was at a very high level in 2004 while the lowest was in 2001. It means that the increasing the amount of the substance would be harmful relative to the use of water for domestic and irrigation purposes.

Table 2. Annual mean of coliform counts in the lake

YEAR	TOTAL COLIFORM
1999	519.56
2000	2466.64
2001	721.67
2002	3108.06
2003	525.31
2004	810.69
2005	1227.19
2006	1163.86
2007	58.83
2008	990.22
Mean	1159.20
Std. Deviation	2597.16
Class C Standard Limit	5,000 MPN/100 ml

Ammonia - The average mean of ammonia was 0.03901 mg/l as compared to the Class C with a standard limit of 0.002 mg/l. For the decade 1998 to 2008, there was an increasing amount of ammonia in the lake which indicated a harmful effect for living organisms.

Nitrate - The amount of nitrate for the decade was at increasing trend and exceeded with the standard limit of 0.002 mg/l. The increasing amount of nitrate contributed to the negative harm to the fishes and other living organism in the lake.

Phosphate – The average mean amount of phosphate in the lake was 0.0558 mg/l which is almost 28 times the Class C criterion of 0.002 mg/l. It showed that this substance would also affect the aquaculture production in the lake.

Total Nitrogen – The observed level of total nitrogen in lake water had an average mean of 1.709 mg/l which exceeded the standard limit of 0.5 mg/l. The results in Table 1 of the lake water monitoring show that 2003 had the highest level of total nitrogen (2.928 mg/l) recorded. It indicated that there were more nitrogenous compounds in lake water coming from agricultural land, domestic sewage and industrial effluents surrounding the lake environs.

Total Phosphate – The average mean amount of total phosphate in the lake water was 0.2025 mg/l which exceeded the standard limit of 0.002 for Class C. Total phosphorus in the lake water supplies the available phosphorus needed for the growth of different organism, however, excessive amounts may cause intensive algal growth, otherwise known as “algal bloom.” For the decade 1998 to 2008, there was an increasing trend of this substance in lake water which can cause algal bloom and may have also brought about the great reduction of oxygen in the lake because one (1) mg of phosphorus from organic source demands about 160 mg of oxygen in a single pass through the phosphorus cycle to complete oxidation (Water Quality Criteria, 1968).

Turbidity - The annual mean turbidity value ranged from 12.97 to 53.75 mg/l in the 7-period. The high levels of turbidity caused loss of the lake water to enable support the diversity of the aquatic organisms. The highest turbidity value was recorded in 2006 (53.75 mg/l) while the lowest was in 2001 (12.97 mg/l. Result of the water monitoring of turbidity indicated there was turbulent flow in the lake water that could affect the aquatic organisms to survive.

Alkalinity – The average mean amount of alkaline was 77.17 mg/l wherein the highest level was recorded in 2004 and 2007. Alkalinity has shown an erratic behavior, but generally on the uptrend. Alkalinity indicates the buffering capacity of the lake for incoming acids and its reduction or loss would be disastrous in the light of increasing acid fluxes such acid rain.

With the observed levels of the aforementioned parameters in which all exceeded the prescribed criteria for Class C inland water, the Lake de Bay is in the state of eutrophication and pollution. The deteriorating condition of the lake water needs immediate action to save it for the use of future generations, but the question is “HOW?”

B. Microbiological

The 1999-2008 monitoring of the total coliform counts is presented in Table 2. Total coliform levels for Laguna de Bay was within the criterion set for Class C inland water at 5,000 MPN/100 ml. Among the 10-year period, 2002 had the highest count with an annual average of 3,108.06 MPN/100 ml followed by 2000 with 2,466.64 MPN/100 ml. The annual averages of coliform level ranged from 58.83 to

Table 3. Heavy metals in the lake water for the 10-year period

YEAR	HEAVY METAL						
	Chromium mg/l	**Cadmium (mg/l)**	**Lead mg/l**	**Copper mg/l**	**Iron mg/l**	**Nickel mg/l**	**Zinc mg/l**
1999	.000000	.000000	.000556	.00000	.000000	.0000	.00000
2000	.000131	.000667	.011111	.00472	1.705556	.0031	.00375
2001	.000000	.000000	.000000	.00000	.000000	.0000	.00000
2002	.000817	.000500	.006897	.00819	.338958	.0033	.00708
2003	.000033	.000611	.005000	.00236	.420000	.0033	.00264
2004	.000225	.000500	.006111	.00364	.327778	.0033	.02208
2005	.001978	.001889	.006667	.00278	.686667	.0033	.00208
2006	.001169	.000811	.006667	.00653	1.141944	.0033	.00750
2007	.000417	.000667	.006667	.00194	.544444	.0033	.00819
2008	.001944	.000611	.008056	.00181	.417556	.0039	.00431
Mean	.000671	.000626	.005773	.00320	0.55829	.0027	.00576
Std. Deviation	.001876	.001081	.010028	.00769	1.078865	.0040	.01657
Class C Standard Limit	0.0002	0.01	0.04	0.01	0.02	0.02	0.01

3,108.06 MPN/100 ml. Results of the analysis indicated that there was potential danger of diarrhea as a serious health problem when the water is tapped for drinking water. It also indicated that no proper sewage particularly those people living in the buffer zone of the lake.

C. Heavy Metal

Analysis of heavy metals in the lake water is presented in Table 3 which include chromium (Cr), Cadmium (Cd), Lead (Pb), Copper (Cu), Iron (Fe), Nickel (Ni) and Zinc (Zn) in 10-year period. The presence of heavy metals showed that all parameters exceeded the prescribed criteria of Class C inland water.

Analysis done by LLDA showed low levels of Cr, Cd, Pb, Cu, Ni and Zn with concentration below the set criteria. However, the concentration of iron was normally high at an average for the decade of 0.5583 mg/l as compared to the criteria of 0.002 mg/l.

As cited in the Book "Ecosystems and People: The Philippine Millennium Ecosystem Assessment (MA) Sub-Global Assessment, 2005) the implication of the presence of heavy metals on water is of grave concern to human health, particularly among the consumers of fish and other products. However, this remains a gap in the current knowledge about the Laguna de Bay ecosystem.

D. Net Primary Productivity (NPP)

Table 4 shows the net productivity of the lake water in a 10-year period. Overall, the average mean of net primary productivity was 4.2016 cell/ml. The most productivity period was 2004 with NPP value of 6.5469 cell/ml while the lowest period was 2000 with the value of 1.9758 cell/ml.

NPP is a measure of the amount of natural food in the lake which provides estimates on the carrying capacity of lake in determining fish production potential. This parameter is important in establishing the trophic status of a body of water. It is a measure of how well the microscopic algae in the waters are photosynthesizing or manufacturing natural food for fish. The range of values of eutrophic water is 150-500 g C m^{-2} yr-1 or 0.3 – 3 g Cm-2 day-1 (Rodhe, 1969). According to the Ecosystems and People Book, (2005), eutrophic waters are characterized by: (a) levels of the nutrients nitrogen and phosphorus which is sufficient for algal growth; (b) turbidity or low light transparency due to dense growth of phytoplankton; (c) massive growth of algae; and (d) fish kills.

Table 4. Net productivity of lake water for the 10-year period

YEAR	NET PRIMARY PRODUCTIVITY (cell/ml)
1999	4.4939
2000	1.9758
2001	2.0186
2002	3.7311
2003	4.3964
2004	6.5469
2005	5.3367
2006	3.5806
2007	5.4050
2008	4.5306
Mean	**4.2016**
Std. Deviation	3.4207

Table 5. Relationships of NPP and physicochemical parameters

VARIABLE	NET PRIMARY PRODUCTIVITY
	Coefficient Value
pH	0.204**
Dissolved Oxygen (DO)	0.098 ns
Biological Oxygen Demand (BOD)	0.304**
Chloride	0.376**
Ammonia	0.077 ns
Nitrate	-0.207**
Phosphate	-0.151**
Total Nitrogen	0.067 ns
Total Phosphate	-0.112*
Turbidity	-0.133*
Alkalinity	0.113*

*Significant at 0.05 level **Significant at 0.01 level ns – not significant

Relationships of NPP and Water Quality

A. NPP and Physicochemical Properties

Table 5 indicates the correlation among the parameters of physicochemical properties and net primary productivity of the lake water. Using Pearson correlation analysis, the parameters significantly related to the net primary productivity were pH (r=0.204), Biological Oxygen Demand (r=0.304), Chloride (r=0.376), Nitrate (r=-0.207), Phosphate (r=-0.151) at 0.1 level of confidence while Total Phosphate (r=-0.112), Turbidity (r=-0.133), and Alkalinity (-r=0.113) at 0.5 level of confidence.

However, there were no statistically correlations with Dissolved Oxygen (DO), Ammonia and Total Nitrogen. Indeed, in the lake, the relationships on the values of some chemical properties were expected not related because of the time and place of sampling varies.

The values of pH, BOD, and Chloride were statistically with high correlation ($P<0.1$) and positive to NPP but nitrate and phosphate have negatively related to NPP. Moreover, significant and negative correlations ($P<0.5$) with total phosphate, turbidity and alkalinity were observed with NPP.

Results revealed that these chemical properties could highly affect the production of natural food in the lake. The signs of the parameters provided the evidences in the deteriorating condition of the Laguna Lake. Thus, these parameters were indicative indicators of measuring the trophic state of the lake.

Table 6. Relationships of microbiological parameter and NPP

VARIABLE	NET PRIMARY PRODUCTIVITY
	Coefficient Value
Total Coliform	0.179**

**Significant at 0.01 level

Table 7. Relationship between NPP and heavy metals

VARIABLE	NET PRIMARY PRODUCTIVITY
	r∞ (Coefficient Value)
Chromium	-0.018 ns
Cadium	0.002 ns
Lead	-0.022 ns
Copper	-0.095 ns
Iron	-0.140**
Nickel	-0.013 ns
Zinc	-0.080 ns

**Significant at 0.01 level ns – not significant

B. NPP and Microbiological

Table 6 shows the relationships of total coliform and NPP. High significant (P<0.1) and positive correlation of total coliform (r= 0.179) was observed with net primary productivity. It was observed the presence of total coliform at varying amount could affect the lake's water productivity. This can be attributed due to lack of sewerage system in the drainage basin wherein many households are now living along the shoreline.

C. NPP and Heavy Metals

Among the parameters of heavy metals with significant relationship to net primary productivity of the lake was iron (r=-0.140). High significant (P<0.1) and negative correlation was observed with NPP. Other parameters such Cr, Cd, Pb, Cu, Ni and Zinc were not statistically significant with NPP (Table 7).

Results revealed that the presence of iron positively affect the lake's water productivity. Iron is an indicative measurement of NPP in which contributes in the deteriorating condition of the lake.

Carrying Capacity Model

The carrying capacity of Laguna Lake was developed in the form of NPP model as a function of the water quality expressed in terms of the physicochemical properties, microbial and heavy metals. Water quality served as the predictors (independent) and NPP as dependent variables.

Using the stepwise procedure, one variable at a time was added until no additional variable makes a significant contribution to the model. Then, all parameters were entered into the multiple regression analysis to determine the predictors of NPP carrying capacity model.

Analysis of variance was presented in Table 8 indicating the significant predictors of the net primary productivity at 0.05 levels of significance. Four models of net primary productivity were generated, namely: (1) chloride with F value of 59.035; (2) chloride and nitrate with F values of 40.057; (3) chloride, nitrate and total coliform with F value of 35.206; and (4) chloride, nitrate, total coliform and biological oxygen demand with F value of 29.014. It indicated that these parameters were significantly linearly dependent to the net primary productivity of the lake.

Table 9 presents the standardized beta coefficients of the predictor variables as these influenced the net primary productivity in the lake water. Since the t-values are all significant, there were enough evidences to infer that net primary productivity can be explained by for (4) independent variables which were found to be significant at 0.5 level of confidence.

Using the beta coefficient, the amount of carrying capacity of net primary production was computed. Based on the 4 models generated, the amounts were: (1) model 1 – NPP = 276.51; (2) model 2 – NPP = 184.01; (3) model 3- NPP = 142.06; and (4) model 4 – NPP = 140.71. Carrying capacity of net primary productivity of the lake water in 10-year period (1999-2008) was in decreasing

Table 8. Analysis of variance (ANOVA) of NPP

Model	Source	Sum of Squares	DF	Mean Square	F-Ratio	P (Sig)
1	Regression	727.336	1	727.336	59.035	0.000[a]
	Residual	4410.706	358	12.320		
	Total	5130.042	359			
2	Regression	941.694	2	470.847	40.057	0.000[b]
	Residual	4196.349	357	11.754		
	Total	5138.043	359			
3	Regression	1175.571	3	391.857	35.206	0.000[c]
	Residual	3962.471	356	11.131		
	Total	5138.042	359			
4	Regression	1265.895	4	316.474	29.014	0.000[d]
	Residual	3872.147	355	10.907		
	Total	5138.042	359			

[a] Predictors: Constant; Chloride
[b] Predictors: Constant; Chloride; Nitrate
[c] Predictors: Constant; Chloride; Nitrate; Total Coliform
[d] Predictors: Constant; Chloride; Nitrate; Total Coliform; BOD

Table 9. Beta coefficient of predictors influencing NPP carrying capacity

Model	Variable	Unstandardized Coefficient		Standardized Coefficient Beta	t	Sig.
		B	Std. Error			
1	Constant	3.037	0.239		12.697	0.000
	Chloride	0.003	0.000	0.376	7.683	0.000
2	Constant	3.548	0.263		13.516	0.000
	Chloride	0.003	0.000	0.375	7.836	0.000
	Nitrate	-5.428	1.271	-0.204	-4.270	0.000
3	Constant	3.344	0.259		12.897	0.000
	Chloride	0.003	0.000	0.375	8.057	0.000
	Nitrate	-6.303	1.252	-0.237	-5.036	0.000
	Total Coliform	0.000	0.000	0.216	4.584	0.000
4	Constant	2.719	0.336		8.089	0.000
	Chloride	0.003	0.000	0.318	6.355	0.000
	Nitrate	-6.011	1.243	-0.226	-4.835	0.000
	Total Coliform	0.000	0.000	0.199	4.236	0.000
	BOD	0.486	0.169	0.145	2.878	0.004

Dependent variable = NPP

trend. It implies that the four (4) parameters of water quality posed threat to the aquatic environment of the lake, particularly on the growth of the natural food (algae) used for fish production.

Table 10 shows the model summary which contains variables which were found to be significant predictors of the NPP. Results of the regression analysis showed four (4) models, namely: (1) chloride with R value of 0.376; (2) chloride and nitrate with R values of 0.428; (3) chloride, nitrate, and total coliform with R value of 0.478; and (4) chloride, nitrate, total coliform and biological oxygen demand with R value of 0.496. The final model contained four (4) predictors which were found to have significant to NPP. The R value of 0.496 for model 4 means that the

Table10. Model summary of NPP carrying capacity of the lake

Model	R	R^2	R Square Change	F Change	Sig. F Change
1	0.376 [a]	.142	.142	59.035	.000
2	0.428 [b]	.183	.042	18.236	.000
3	0.478 [c]	.229	.046	21.012	.000
4	0.496 [d]	.246	.018	8.281	.004

[a] Predictors: Constant; Chloride
[b] Predictors: Constant; Chloride; Nitrate
[c] Predictors: Constant; Chloride; Nitrate; Total Coliform
[d] Predictors: Constant; Chloride; Nitrate; Total Coliform; BOD

independent variables in the model can account for about 49.6 or 50 percent of the variance to NPP. This also indicated that another 50% of the variance to NPP can be explained by other limiting factors.

Simulating the different factors and parameters, the final model generated the significant parameters that influenced or affected the net primary productivity of the lake. This model indicates that these parameters posed threat to the aquatic environment of the lake, particularly on the growth of the natural food (algae) used for fish production. The limiting factors that influenced the net primary production of lake water were chloride, nitrate, total coliform, and biological oxygen demand.

Therefore, carrying capacity of net primary productivity of the lake could be defined as a function of the water quality parameters expressed as chloride, nitrate, total coliform, and biological oxygen demand.

CONCLUSIONS AND RECOMMENDATIONS

The 10-year period data provided evidences the water of Laguna had changed over a period of time wherein the carrying capacity of the lake ecosystem was affected. It was concluded that net primary productivity was significant influenced by four (4) parameters of water quality in terms of chloride, nitrate, total coliform, and biological oxygen demand.

Given these results, a model of carrying capacity of net primary productivity (NPP) in Laguna Lake was developed. NPP is a function of the water quality parameters expressed as chloride, nitrate, total coliform, and biological oxygen demand.

It is also recommended that further research could be undertaken to validate the findings. A more recent data of water quality samples need to be analyzed using the same procedure. Furthermore, other parameters need to be considered in the development of the carrying capacity model in Laguna Lake, i.e. aquaculture production, number of cages and fish pens, human population living along the shoreline, developments along the bay, among others. These parameters are some limiting factors that could affect the productivity of the Laguna de Bay.

LITERATURE CITED

Dashefsky HS (1993). Environmental Literacy. Random House

Drillon PJ, Rigler FH (1974). A Test of Simple Nutrient Budget Model Predicting the Phosphorus Concentration in Lake Water. J. Fish. Res. Board. Can.

Ecosystems and People (2005). The Philippine Millennium Ecosystem Assessment (MA) Sub-Global Assessment. 2005. Environmental Forestry Program, CFNR, UPLB

Martin MR, (provide names of other Authors) (1998). The Carrying Capacity of Blue Mountain Lake: An Analysis of Water Quality and Land Use. Adirondack Aquatic institute, Paul Smith's College, New York

Paehlke R (2004). Carrying Capacity: Conservation and Environmentalism. Ed. 195

Rodhe W (1969). Crystallization of eutrophication concepts in Northern Europe. In Eutrophication: Causes, Consequences, Correctives. The Academy, Washington, D.C.

Tarzan L, Palerud R, White GCP, Regpala R (2008). A Model to Estimate Aquaculture Carrying Capacity in Three Areas of the Philippines. Centre for Marine Research, R. Boškovia Institute. 2Akvaplan-niva AS, Tromso Polar Environmental Centre, N-9296 Tromso, Norway; National Integrated Fisheries Technology Development Centre-Bureau of Fisheries and Aquatic Resources (BFAR-NIFTDC), Bonuan Binloc, 2400 Dagupan City, Philippines