

4. Production

Production includes all matter elaborated by the algae (whether it is ultimately eaten, washed out or dies of other causes) over the period considered. Total mortality, when constant, is equal to production over biomass. Therefore, in steady-state models, it is safe to treat estimates of total mortality (Z) as equivalent to production/biomass ratio (P/B), (Allen, 1971). Hence, the budget equation is in the form below (delos Reyes, 1993).

$$P_i = M_{pi} - M_{ni} - C_i = 0$$

Where: P_i is the production of species i,
 M_{pi} its predator mortality,
 M_{ni} other mortality, and
 C_i : the fisheries catch of species i.

The production data obtained from various sources, including that from the Bureau of Agricultural Statistics (BAS) were taken to mean as is.

5. Conversion Factors Used

Calculations of algal production from net primary productivity (NPP) was based on the conversion factor of 20 or it means that there is 20-fold times algal biomass production from algal-carbon assimilated. While the ratio of algae to fish production used was 0.007 in the open water and 1/25 was used in fishpens where planktivorous species of fish are cultivated in captivity. The conversion factor of chlorophyll content to algal biomass was 6.7 instead of 67 (APHA, 1976) based on 1.5 percent chlorophyll content in algae (DM) and 100 percent moisture content of the algae.

Reliability of Data

The primary and secondary data gathered were compared in a tabular form to examine whether there were some data that showed big discrepancies, hence, the latter were analyzed and/or discarded.

RESULTS AND DISCUSSION

Water Quality of the Lake

The variation of the water temperature over the entire lake was small, within a magnitude of three degrees (28-31°C) (Table 1). Time series analysis done for this parameter in the lake showed a decreasing trend over a period of twelve years, that is, from 1980 to 1992 (delos Reyes, 1995).

The depth of the lake had an average value of 3.34 meters (Table 1), although the usual average depth reported for the lake was 2.8 meters (Sogreah, 1974; Santiago, 1988).

Table 1. Some Physico-Chemical Data in the Four Bays of Laguna Lake, July 25 to September 3, 1997*

BAYS	South	Central	West	East
Temperature				
Air	24.00	27.00	30.00	30.00
Water	30.60	28.70	28.70	28.00
Depth (m)	3.00	3.00	3.25	4.13
Secchi disk depth (cm)	75.00	55.00	15.00	35.00
pH	8.55	8.64	8.69	8.44
Salinity (ppt)	1.00	2.00	2.00	2.00
Dissolved oxygen-surface (g.mL)	7.20	3.30	0.40	8.00

NOTE: Primary data

Table 2. Net Primary Productivity (NPP) in the Three Depths of the Four Bays of Laguna Lake, July 25 to September 3, 1997*

STATION	NPP (g-C/m²/day)
I. South Bay	8.80
II. Central Bay	2.08
III. West Bay	10.14
IV. East Bay	6.45
AVERAGE	6.87

NOTE: Primary data

Table 3. Mean Chlorophyll Content of the Algae in the Four Bays at Different Depths in Laguna Lake, July 25 to September 3, 1997^{1/}

BAYS/DEPTH	Mean Chlorophyll Values (ug/L)		
	chl a ^{2/}	chl b	chl c
I. South Bay			
Surface	52.49467	35.10187	5.31293
-0.5 m	29.27730	19.77333	4.01333
-1.0 m	49.06267	33.52400	18.72693
Average	43.61150	29.46640	9.35106
II. Central Bay			
Surface	119.94400	62.48000	(12.57260)
-0.5 m	147.36267	15.56900	(49.31587)
-1.0 m	52.41333	28.56400	9.93120
Average	106.57333	35.53767	(51.96100)
III. West Bay			
Surface	27.93800	45.24000	15.17547
-0.5 m	44.86933	59.49267	(2.69147)
-1.0 m	39.97133	23.34133	4.94235
Average	39.59222	42.69133	17.42640
IV. East Bay			
Surface	22.94667	16.77733	8.17600
-0.5 m	22.47600	13.28800	6.53712
-1.0 m	3.16400	27.53200	1.27333
Average	16.19556	19.19911	5.32882

Table 3b. Mean Values by Depth for Every Chlorophyll Type, Regardless of the Bay

DEPTH	mg/L		
	chl a	chl b	chl c
Surface	55.83200	39.89867	3.35733
-0.5 m	60.99467	27.03200	(10.36533)
-1.0 m	36.15200	28.24000	8.08267
Average	50.99289	31.72356	0.35882

1/ Primary data

2/ chl a, b, c = chlorophyll a, b, c

Table 4. Mean Cell Density of the Algae in the Four Bays at Different Depths in Laguna Lake, July 25 to September 3, 1997

BAYS/DEPTH	Biovolume (g/m ²)			
	Blue-green algae	Diatoms	Green algae	Total
I. South Bay				
Surface	0.38590	0.23730	-	0.62320
-0.5 m	0.01645	0.00292	-	0.01937
-1.0 m	0.33659	1.51560	0.00736	1.85955
II. Central Bay				
Surface	0.17839	0.02737	-	0.20576
-0.5 m	0.14662	0.00997	-	0.15659
-1.0 m	0.05480	0.03687	0.01140	0.10307
III. West Bay				
Surface	0.00139	0.73014	0.00210	0.73273
-0.5 m	0.00935	1.09135	0.00058	1.10128
-1.0 m	-	-	-	-
IV. East Bay				
Surface	0.00995	0.42876	0.00010	0.43881
-0.5 m	0.01826	0.45101	0.00323	0.47250
-1.0 m	0.00608	0.30377	0.00087	0.31072

Table 4b. Mean Values by Depth for Every Group of Algae, Regardless of the Bay

DEPTH	g/m ²			
	Blue-green algae	Diatoms	Green algae	Total
Surface	1.14390	0.35590	0.00030	0.50010
-0.5 m	0.04770	0.38880	0.00100	0.43740
-1.0 m	0.09940	0.46410	0.00490	0.56830

The transparency of the water never went deeper than 1 meter, the deepest recorded value was 75 cm in the South Bay and the shallowest was 15 cm in the West Bay. Transparency of the water is inversely related to turbidity. Turbidity values for the lake ranged from 30 to 200 mg/L of SiO₂ (1967-88) (LLDA-WHO, 1978; Sogreah, 1991). This is rather a high turbidity value due to the lake's shallowness, unprotected nature of the lake from wind action, ease in resuspension of the bottom sediments, or it may also be due to high concentration of the algae at certain period.

There are remarkable correlations of lake turbidity with water temperature and wind velocity. It appears that a prolong period of strong wind during the cooler months supported by a high water viscosity and low water temperature is one of the factors for high turbidity. It is also possible that the bottom sediments of clayey particles have a great cooling effect on the water and the strong wind current cools off the water column faster when it is shallow. Hence, the lake water seemed to be getting cooler with shallowing of the water depth.

Previous data showed no apparent relationship existed between turbidity and the algal density (LLDA-WHO, 1978). However, the constancy of the pH values towards the alkaline side strongly indicates that the greater bulk of the microorganisms in the lake are photosynthetic phytoplankton that take up CO₂ and bicarbonates and cause shifting of pH towards higher values (Round, 1973).

Primary Productivity of the Lake

Primary productivity in Laguna lake is really synonymous to phytoplankton productivity because phytoplankton are numerous and very minute that they form the bulk of the lake's biomass. They are responsible in converting radiant energy into biochemical form of energy in their body. They use water as the hydrogen donor for the reduction of carbon dioxide (CO₂), the latter forming the carbon skeletal framework for the different organic compounds synthesized. Concomitant to carbohydrate production is the release of oxygen (see chemical equation of photosynthesis). This is the oxygen being measured in the incubation of the light and dark bottles at various depths in the lake, wherein it is assumed that for every mole of O₂ (32 grams) released there is an equal and corresponding 12 C atoms being "fixed" in the system.

Hence, primary productivity can also mean the rate of photosynthesis, the basis of the food chain. This is expressed as some measure of biomass (C) per unit of time (day and year), per surface area (m², ha). Net primary productivity in the lake is expressed as g C/ m²/day⁻¹.

1. Primary data

The net primary productivity data (NPP) that was obtained from the three depths of each of the four bays of Laguna Lake from July 25 to September 3, 1997 showed that the West Bay (by the Binangonan side) had the highest value (10.14 g C/m²/day) while the lowest value was noted in Central Bay (2.08 g C/m²/day) with a mean value of 6.87 g C/m²/day. This is a mean value from 12 samplings. When these values are compared to the data obtained by LLDA our data are about 10 x higher than their monthly and annual values. For example, the monthly mean values for the West Bay in July to September for 1986, 1987 and 1988 ranged from 0.4 to 1.45 g C/m²/day (Charlton, 1993) while the annual mean values for the same year were 0.70, 0.74 and 1.0 g C/m²/day, respectively (Table 6). This means that the mean values from 32 samplings per month and 384 samplings per year would result in a 1/10 decrease in the NPP values as compared to 12 samplings only. It is also possible that analysis of our samples within four hours after sampling yielded values that are close to the time of sampling. Moreover, our samplings and analysis were done by the same person that eliminated the error due to greater variations. We also used the three hour incubation period instead of 12 hours (LLDA's method) that facilitated our work yielding the same result by extrapolation to the whole day. Moreover, our samplings were done always in the morning that usually yields higher values than measurements taken towards the end of the day, as in the case of LLDA. In fact, one of the recommendations of Charlton (1993) to LLDA was also to measure the lowest oxygen each day at daybreak as well as the ambient oxygen at the end of the day when NPP work is done. According to him, the difference should give the true open water net daytime areal community production (NDACP).

Chlorophyll a (chl a) values in the lake during our study showed a broad range from 3.164 to 147.363 ug/L (Table 3). Values as high as 150 ug/L were also earlier noted in the West Bay in 1987 (Charlton, 1993). Based on the Chlorophyll values recorded for the lake, it indicates that the lake is highly eutrophic (Vollenweider, 1971). Our study shows that Central Bay had the highest chl a followed by the following sites in decreasing order: South Bay, West bay and East bay. The trend was similar to that observed in 1987 and 1988 (Charlton, 1993). A comparison of the chl a values in different depths shows that generally, the 0.5 meter depth had relatively higher values than the surface with the 1.0 meter depth having the least value. This is also the trend observed in the NPP parameter.

Of the accessory chl pigments analyzed, chl c was observed to be the least in composition which is logical because this is of minor component in the algae (Martinez and Dionisio-Sese). Relatively, chl c was observed to be highest in West Bay, followed by the South, then East, and the least amount was noted in Central Bay. This type of chlorophyll was noted to be always high at the surface of the lake than in the other depths. This means the algae that contain an abundant chl c, like the diatoms, were predominantly found on the surface of the water and in the West Bay than, in Central Bay. Analysis of chl c in algae is not difficult, but because of its relatively lower composition in the cells it is usually not used for estimating algal biomass.

Analysis for chlorophyll b (chl b) showed that the highest value was noted in the West Bay, followed by the following sites in decreasing order: Central Bay, South Bay and East Bay. It is noted that when a site had a chl a:b ratio of 1.5 or higher, then the place had relatively fewer diatoms compared to the green and blue-green algae.

The mean cell density of the algae in the four bays showed that blue-green and diatoms equally predominate the waters in the lake with the green algae of the least in composition.

Of the three methods used in estimating primary productivity, it is apparent that the Biovolume and the chlorophyll analysis are more closely related to each other (Table 8).

2. Secondary Data

The net primary productivity data (NPP) that was obtained from 1985 to 1996 from LLDA had annual mean values ranging from 0.66 to 1.75 g C/m²/day which are equivalent to 48 up to 127.75 metric ton of algae/ha/yr (Table 6). A relatively high mean value of 6.87 for 1997 may be due to one sampling done for each bay (Table 2). As you would have noted the mean annual NPP values presented by LLDA are relatively low because these are average monthly values from the four bays and the value from each bay was the mean value for the various depths up to 1 meter.

Time series analysis done on NPP over a period of twelve years, shows that there is a decreasing tendency for NPP values (delos Reyes, 1995). This is also the trend that was observed in the data gathered from 1980, 1985 to 1996.

When the available algal production values from 1986 to 1988 were examined for correlation with some other variables, such as, secchi disk depth, turbidity and biomass, it was noted that there was a strong negative correlation between NPP and turbidity (Charlton, 1993). Monthly NPP values for the West, East and Central bays showed minimal differences in the order of a factor of two or three. Hence, when the monthly NPP values for the West bay were studied, it was noted that there was a rise in NPP in May that coincided with the usual increase in rainfall at the end of the dry spell. Furthermore, decreasing wind speeds and the low lake levels at this time of the year which lessen the prevalence of deep mixing could have been more conducive to algal growth.

NPP values in the cooler months did not show an increasing trend, instead, there was a peak in July followed by a low value in September and a rising trend in November. Hence, it can be surmised that primary productivity did not follow a seasonal cycle for the three years studied. The pattern is also true on an annual scale, and this needs further investigation. But there seems to be a seasonal turbidity cycle regardless of the salt intrusion or "backflow" from Manila Bay through Pasig River. Laguna Lake is indeed prone to wind driven re-suspension of bottom sediments, especially since it is shallow (mean depth of 2.8 - 3.0 m). Wind speeds follow a seasonal cycle with a minimum in August rising to a maximum in April. The decline in water level between October and May seems to coincide with the higher wind speeds that tend to stimulate the re-suspension of the lakes bottom's particles.

Although, the hypothesis that “backflow” tends to cause “cleansing” of the lake water and concominantly cause good algal growth may not hold true all the time. For example in 1987 there was no backflow and yet the succeeding months did not show relatively low NPP values (Charlton, 1993). Hence, there may be several factors acting at one time to give the impression that “Backflow” or salt intrusion is responsible for the productivity cycle of the lake.

On the other hand, NPP did not show any correlation with algal biomass because when NPP is observed to be high, then the production per unit biomass in the lake was also high (Charlton, 1993). NPP is usually three times higher than the algal biomass values (Tables 2 to 4).

The chlorophyll content of the algae found in the lake compared well with what is usually found in the field (Martinez-Goss and Dionisio Sese, 1995) (Table 3). The chlorophyll a:b ratio ranged from 6 to 1 which means that there is a diverse group of algae in the lake ranging from the blue-green algae to green and diatoms (Table 4 and 5). The diatoms were found to be relatively numerous in the lake, except at the time of algal bloom wherein the blue-green algae *Microcystis*, *Oscillatoria*, *Anabaena* and *Calothrix* are in abundance.

Algal bloom due to *Microcystis* had its peak in 1972 to 1974 and its occurrence decreased since 1981. Hence, algal bloom may not always mean that this is favorable for growth of the fish because generally the fishes show preferential food for some groups of algae. Stomach content analysis of the perch showed that the feed was mostly composed of diatoms (Delmendo, 1968). Other algae were not observed probably because they got degraded easily while the cell wall of the diatoms remained intact but the protoplast got digested by the fish. It seems that when there is algal bloom, especially due to *Microcystis* the effect was a massive fish kill as in 1972, 1973, and 1974 (Delmendo, 1974).

Fishery Production

A total of 20 species of finfishes are included in the study of which 30 percent are phytoplankton feeders (Table 9). A greater percentage of the fishes are omnivores (40 percent) while the rest are carnivores (15 percent), herbivores (10 percent), and detritivores (5 percent).

Table 5. List of Algae Observed in Laguna Lake, July 25 to September 3, 1997

Blue-Green Algae	Diatoms	Green Algae	Euglenoid
<u>Aphanothece</u>	<u>Coscinodiscus</u>	<u>Ankistrodesmus</u>	<u>Trachelomonas</u>
<u>Calothrix</u>	<u>Cyclotella</u>	<u>Coelstrum</u>	
<u>Lyngbya</u>	<u>Melosira</u>	<u>Pediastrum</u>	
<u>Microcystis (Anacystis)</u>	<u>Melosira spiralis</u>	<u>Planktosphaeria</u>	
<u>Nostoc</u>	<u>Navicula</u>	<u>Tetraedron</u>	
<u>Oscillatoria</u>	<u>Nitzschia</u>		
<u>Phormidium</u>			
<u>Plectonema</u>			

Table 6 shows the estimation of fish production based on algal productivity (NPP or C_{14}). The estimated fish yields based on the given NPP value of 1.49 g C/m²/day for 1990 were different using two different formulas, i. e., A (where ecotrophic efficiency (EE) was considered and the conversion factor from algae to fish was 0.007) and B (did not consider EE and used .04 as the conversion factor).

Using formula A, the fish yield was 17,912 mt per year of 10% higher than harvest data of BAS. Formula B, on the other hand, predicted a fish yield equivalent to 367,565 mt per year, which was 2,163% higher than catch data of BAS. Formula A was used in Table 6.

Table 7 shows the estimation of potential fish production based on estimated algal biomass thru either chlorophyll analysis or biovolume. The trend of the calculated potential fish yield based on algal biomass (biovolume method) shows a peak value in 1976 (51,595 MT) which may be due to the high biomass obtained by Nielsen, et al., (1983) and the high ecotrophic efficiency. The patchy regional algal agglomerations with biomasses that were far beyond normal values reported in the fishkill study in 1977 in Central Bay supports the high algal biomass figure obtained by Nielsen in 1976.

Table 8 shows all the fish production figures, i. e., actual fish production (BAS), as well as the three potential fish production estimates.

**Table 6. Estimated Potential Fish Production Based on Algal Productivity
(NPP of C14) in Laguna Lake, 1978-1997**

YEAR	BAYS	A	B	C	D	E	F	G	H
		Net Primary Productivity (NPP) (g C/m ² /day)	Carbon Production B=Ax3.65 (C/ha/yr)	Algal Biomass Production Rate C=Bx20 (mt/ha/yr)	Ecotrophic Efficiency (EE) ²	Algae Consumed (E=CxD) (mt/ha/yr)	Potential Fish Production F=Ex0.007 ³ (mt/ha/yr)	Area of Open Water (ha)	Potential Fish Production H=FxG (mt/yr)
978-198*		1.000	3.650	73.00	0.715	52.195	0.365	79,600	29,054
978-198**		1.040	3.796	75.92	0.715	54.280	0.380	73,600	27,968
1980		2.100	7.665	153.30	0.715	109.610	0.767	79,600	61,053
1985	WB ⁴	0.576							
	CB	0.626							
	EB	0.925							
	SB								
	LOOC	0.662							
	AVE.	0.700	2.555	51.40	0.715	36.540	0.256	62,000	15,872
1986	WB	0.770							
	CB	0.640							
	EB	0.670							
	SB								
	LOOC	0.860							
	AVE.	0.740	2.701	54.02	0.715	38.620	0.270	70,400	19,008
1987	WB	0.900							
	CB	0.980							
	EB	0.880							
	SB								
	LOOC	1.230							
	AVE.	1.000	3.650	73.00	0.715	52.200	0.365	76,100	2,776
1988	WB	0.600							
	CB	0.690							
	EB	0.670							
	SB								
	LOOC	0.660							
	AVE.	0.660	2.409	48.18	0.715	34.450	0.241	79,200	19,087
1989	WB	0.440							
	CB	0.760							
	EB	0.720							
	SB								
	LOOC	0.630							
	AVE.	0.640	2.336	46.72	0.715	33.400	0.234	84,200	19,703
1990	WB	1.260							
	CB	1.830							
	EB	0.970							
	SB								
	LOOC	1.900							
	AVE.	1.490	5.438	108.76	0.279	30.340	0.212	84,490	19,703
1991	WB	1.710							
	CB	1.740							
	EB	1.500							
	SB								
	LOOC	2.050							
	AVE.	1.750	6.387	127.74	0.279	35.640	0.249	83,750	20,854

continued,

Table 6. Estimated Potential Fish Production.... continuation.

YEAR	BAYS	A	B	C	D	E	F	G	H
		Net Primary Productivity (NPP) (g C/m ² /day)	Carbon Production B=Ax3.65 (C/ha/yr)	Algal Biomass Production Rate C=Bx20 (mt/ha/yr)	Ecotrophic Efficiency (EE) ²	Algae Consumed (E=CxD) (mt/ha/yr)	Potential Fish Production F=Ex0.007 ³ (mt/ha/yr)	Area of Open Water (ha)	Potential Fish Production H=FxG (mt/yr)
1992	WB	1.810							
	CB	1.410							
	EB	1.040							
	SB								
	LOOC AVE.	1.390	5.146	102.92	0.279	28.710	0.201	83,520	16,788
1993	WB	1.920							
	CB	1.060							
	EB	0.360							
	SB								
	LOOC AVE.	2.410	5.256	105.12	0.279	29.330	0.205	79,660	16,330
1994	WB	0.930							
	CB	0.420							
	EB	0.260							
	SB								
	LOOC AVE.	1.020	2.409	48.18	0.279	13.440	0.094	77,870	7,320
1995	WB	1.350							
	CB	0.660							
	EB	0.580							
	SB								
	LOOC AVE.	0.820	2.847	56.94	0.279	15.890	0.111	83,800	9,302
1996	WB	0.820							
	CB	0.580							
	EB	0.530							
	SB								
	LOOC AVE.	1.190	2.847	56.94	0.279	15.890	0.111	80,000	8,880

¹ NPP data from Laguna Lake Development Authority except 1978-1984; 1997; 1978-1984* derived from BCEOM, 1984; 1978-1984** data derived from LLDA-WHO, 1984; 1980 derived from C14 study of Nielsen (1981);

² EE derived from delos Reyes, 1995

³ Conversion factor of 0.007 derived from SOGREAH, 1974

⁴ WB=West Bay; CB=Central Bay; EB=East Bay; SB=South Bay; Loo, Cardona Rizal

Table 7. Estimated Potential Fish Production Based on Algal Biomass, P/B and Ecotrophic Efficiency (EE) in Laguna Lake, 1820-1997¹

YEAR	A Algal Biomass (mt/ha)	B P/B Production/B iomass	C Algal Productivity C=AxB (mt/ha)	D (EE) Ecotrophic Efficiency	E Algae Consumed (E=CxD) (mt/ha/yr)	F Potential Fish Production Rate F=Ex0.007 ² (mt/ha/yr)	G Area of Open Water (ha)	H Potential Fish Production H=FxG (mt/yr)
1820	0.9075	268.36	243.54	0.163	39.70	0.278	90,000	25,020
1920	0.8250	268.36	243.54	0.162	39.45	0.243	90,000	24,840
1950	0.8250	268.36	221.40	0.157	34.76	0.242	90,000	21,870
1968	0.8250	268.36	221.40	0.156	34.54	0.242	90,000	21,780
1973	0.8250	268.36	221.40	0.156	34.54	0.242	85,000	20,570
1974	0.8250	268.36	221.40	0.156	34.54	0.242	85,000	20,570
1974 *	1.5122	146.90	405.81	0.156	63.31	0.443	85,000	37,655
1975 *	0.3996	146.90	58.10	0.715	41.54	0.291	85,000	24,735
1976	0.8250	146.90	121.19	0.715	86.65	0.607	85,000	51,595
1980	0.6055	146.90	88.95	0.715	63.60	0.445	79,600	35,422
1982 *	0.4577	146.90	67.24	0.715	48.08	0.337	64,900	21,871
1983 *	0.4255	146.90	62.83	0.715	44.92	0.314	54,900	17,239
1990	0.6688	146.90	98.25	0.279	27.41	0.192	84,490	16,222
1996 ³	1.1650	146.90	171.14	0.279	47.75	0.334	80,000	26,720
1997 ⁴	1.3490	146.90	198.17	0.279	55.29	0.387	80,000	30,960

¹ Algal biomass for all years except 1973-1976; 1982-1983 based from delos Reyes, 1995; algal biomass for 1973, 1974, 1976 based from Nielsen, et.al 1983; algal biomass for 1974*, 1975*, 1983* based from LLDA-WHO, 1984; P/B and EE based from delos reyes, 1995

² Conversion factor of 0.007 based on SOGREAH, 1974

³ Based on chlorophyll analysis of LLDA

⁴ Based on chlorophyll analysis from one sampling per bay

Table 8. A Comparison of the Potential Fish Production (Metric Tons/Year) from Different Sources in the Open Water of Laguna Lake, 1820 to 1997¹¹

YEAR	Production ²	Indirect Means		
		Net Primary Productivity ³	Biomass	
			Biovolume ⁴	Chlorophyll ⁵
1820			25,020	
1920			24,840	
1950			21,870	
1968			21,780	
1973			20,570	
1974			37,668	
			20,570 ¹⁰	
1975			24,735	
1976			51,595	
1978-1984		29,083 ⁷		
1979	9,887			
	30,940.17 ⁶			
1980	14,761	61,074 ⁸	35,422	
	20,403.98 ⁶			
1981	20,424			
1982	19,218		21,871 ¹⁰	
1983	13,360		17,238 ¹⁰	
1984	29,637			
1985	25,544	15,778		
1986	34,797	18,905		
1987	19,158	27,804		
1988	16,867	18,954		
1989	15,881	19,612		
1990	16,245	17,948	16,222	
1991	16,618	20,895		
1992	16,999	16,789		
1993	21,745	16,326		
1994	18,020	7,299		
1995	24,431	9,289		
	6,350.4 ⁹			
1996	13,061	8,896		26,720
	1,104.9 ⁹			
1997 ¹¹		78,327	34,960	30,960

¹ EE and P/B based on the calculated values by ECOPATH II (delos Reyes, 1995)

² From: Bureau of Agricultural Statistics (1996)

³ Calculated from NNPP data mostly taken from LLDA-EPD

⁴ Based from the biomass data taken mostly from delos Reyes (1995).

⁵ 1996 data from: LLDA-EPD; 1997 - primary data

⁶ From: Mercene, 1977

⁷ From: Sogreah, 1991

⁸ From C14 data, Nielsen, 1981

⁹ From: FRS, BFAR Region IV

¹⁰ Based from the biomass data taken from LLDA-WHO, 1984

¹¹ Based on single sampling per bay of three depths per sample

The three different methods of estimating potential fish yield can not be completely compared statistically because there is not single year where all the three estimated values are given together with the BAS value.

At most we can compare the production values based on NPP with the BAS production data for 13 years (1980, 1985 - 1996); and production values based on biovolume with the BAS production data for three years (1980, 1983, 1990). A close relationship is observed between the estimated production data based on NPP and the BAS production data but only from 1988 to 1993. This means that only 50 percent of the pairs of values are close to each other.

The estimated fish yields based on biovolume and BAS production are close only for 1983 and 1990. The estimates based on NPP and biovolume figures are close to each other in 1990. The NPP figure for 1997 involved only one sampling, therefore, we can not safely make a conclusion. The same can be said of the estimated values from biovolume and chlorophyll content in 1997.

Estimated Fish Biomass

The fish biomass was computed from actual fish production as reported by BAS using the formula:

$$B = \frac{P}{(P/B)}, \quad \text{where: } B = \text{biomass}$$

$$P = \text{production data from BAS}$$

$$(P/B) = \text{obtained from delos Reyes, 1995}$$

There are 20 species of finfishes calculated for their biomass (Tables 9 and 10). The highest biomass recorded was for mudfish (Ophicephalus striatus) at 4,930.76 metric tons in 1986.

Table 11 compares the fish biomass values estimated as above (A) with those derived from delos Reyes (1995) as estimated by ECOPATH II model (B). For all the estimates, the values obtained by the ECOPATH II was much larger than those estimated from the actual fish production data. This is understandable because ECOPATH II estimated biomass from catch data that are even larger than the catch data of BAS. For example, the catch for *therapon* in 1990 reported by delos Reyes (1995) was 10.498 MT/km² or 8,398 metric tons for the whole lake (800 square kilometers). On the other hand, BAS reported a catch figure of 1,407 metric tons for the whole lake. However, the catch supposedly should not exceed the potential production.

Table 9. List of Fish Species Included in this Study*

Phytoplankton Feeders	Others
<p>1. Milkfish <i>Chanos chanos</i> Forskal (Tag. Bangus)</p> <p>2. Mullet <i>Mugil Valenciennes</i> (Tag. Banak)</p> <p>3. Tilapia <i>Oreochormis niloticus</i> Linn. (tag. Tilapia) = <i>Tilapia niloticus</i> <i>Oreochormis mossambicus</i> Peters</p>	<p>1. Carp <i>Cyprinus carpio</i> Linn. (Tag. Karpa)</p> <p>2. Catfish <i>Arius manilensis</i> Valenciennes (Tag. Kanduli) <i>Arius batrachus</i> Linn. (Tag. Hito)</p> <p>3. Climbing Perch <i>Anabas testudineus</i> Bloch (Tag. Martiniko)</p> <p>4. Clupeids <i>Anodontosoma chacunda</i> (Tag. Tawilis; herring) observed only in 1820-1920</p> <p>5. Eel <i>Anguilla marmorata</i> (Tag. Igat) = <i>A. mauritiana</i></p> <p>6. Goby <i>Glossogobius giurus</i> Buchanan-Hamilton (Tag. Biya)</p> <p>7. Gourami <i>Trichogaster</i> (Tag. Guraming maliit; Eng. Pla-salit) <i>Osphronemus</i> (Tag. "giant gurami")</p> <p>8. Mudfish/Murrel/Snakehead <i>Ophicephalus striatus</i> Bloch (Tag. Dalag) = <i>Channa striata</i></p> <p>9. Ornate sleeper <i>Ophiocara aporos</i> Bleeker (Tag. Papalo)</p> <p>10. Spade fish <i>Scatophagus argus</i> (Tag. Kitang)</p> <p>11. Tarpon <i>Megaplops cyprinoides</i> Broussonet (Tag. Buan-buan, bidbid)</p> <p>12. Tawes <i>Puntius javanicus</i> (Tag. Tawes)</p> <p>13. Therapon <i>Therapon plumbeus</i> Kner (Tag. Ayungin)</p>

* Silver side fish (Tag. gono) is not included here

Table 10. Estimated Fish Biomass (mt/year) Based on BAS Fish Production Data in Laguna Lake, 1979-1996

SPECIES	P/B1	1979		1980		1981		1982		1983		1984		1985		1986		1987	
		Production (mt)	Biomass (mt/yr)	Production (mt)	Biomass (mt/yr)	Production (mt)	Biomass (mt/yr)	Production (mt)	Biomass (mt/yr)	Production (mt)	Biomass (mt/yr)	Production (mt)	Biomass (mt/yr)	Production (mt)	Biomass (mt/yr)	Production (mt)	Biomass (mt/yr)	Production (mt)	Biomass (mt/yr)
A. Phytoplankton Feeders																			
1. Milkfish <i>Chanos chanos</i>	4.80		15.83																
		76	15.83	190	39.58	10,888	2,268.33	12,025	2,505.21	6,032	1,256.67	3,025	630.21	1,526	317.92	4,640	966.67	1,184	246.67
2. Mullet <i>Mugil (Banak)</i>	0.70							1	1.43	4	5.71	5	7.14	6	8.57	10	14.29	14	20.00
3. Tilapia <i>Oreochormis aureus</i> <i>Oreochormis mossambicus</i>	5.34	511	96.69	2,585	484.08	2,222	416.10	1,685	315.54	1,789	335.02	6,541	1,224.91	6,631	1,241.76	8,767	1,641.76	4,379	820.04
B. Others																			
1. Carp <i>Cyprinus carpio</i>	1.25	434	347.20	731	584.80	426	340.80	334	267.20	249	199.20	733	586.40	3,235	2,588.00	5,652	4,521.60	3,399	2,719.20
2. Catfish <i>Arius manilensis (Kanduil)</i> <i>Arius batrachus (Hito)</i>	1.55 1.55	497 324	320.65 209.03	1,410 1,369	909.68 883.23	467 1,235	301.29 796.77	532 909	343.23 586.45	745 827	480.65 533.55	3,530 1,968	2,277.42 1,269.68	2,607 1,907	1,681.94 1,230.32	3,500 3,954	2,258.06 2,550.97	2,335 2,175	1,506.45 1,403.23
3. Climbing Perch <i>Anabas testudineus (Martiniko)</i>	0.75					5	6.67											9	12.00
4. Clupeids <i>Anodontosoma chacunda</i>	5.50																		
5. Eel <i>Anquilla sp</i>	0.80 **	4	5.00	5	6.25			1	1.25	4	5.00	11	13.75	10	12.50	9	11.25	6	7.50
6. Goby <i>Glossogobius giurus sp (Biya)</i> <i>Microgobius sp (Dulong)</i>	2.72 2.72	2,474	909.56	2,111	776.10	765	281.25	243	89.34	895	329.04	4,436	1,630.88	2,844	1,045.59	866	318.38	1,041	382.72
7. Gourami <i>Trichogaster</i> <i>Osphronemus</i>	0.75 *	18	24.00	7	9.33	57	76.00	45	60.00	51	68.00	76	101.33	30	40.00	78	104.00	60	80.00
8. Mudfish/Murrel/Snakehead <i>Ophicephalus striatus (Dalag)</i>	0.75	750	1,000.00	2,250	3,000.00	1,618	2,157.33	1,102	1,469.33	997	1,329.33	2,789	3,718.67	1,951	2,601.33	3,698	4,930.67	2,227	2,969.33
9. Ornate sleeper <i>Ophiocara aporos</i>																			
10. Silver side																			
11. Tarpon <i>Megaplops cyprinoides</i>	0.60																		
12. Tawes <i>Puntius javanicus</i>																			
13. Therapon <i>Therapon plumbeus (Ayungin)</i>	2.64	4,799	1,817.80	3,959	1,499.62	2,609	988.26	1,596	604.55	1,383	523.86	6,247	2,366.29	4,748	1,798.48	3,529	1,336.74	2,323	879.92

continued.

Table 10. Estimated Fish Biomass..., continuation.

SPECIES	P/B1	1988		1989		1990		1991		1992		1993		1994		1995		1996	
		Production (mt)	Biomass (mt/yr)	Production (mt)	Biomass (mt/yr)	Production (mt)	Biomass (mt/yr)	Production (mt)	Biomass (mt/yr)	Production (mt)	Biomass (mt/yr)	Production (mt)	Biomass (mt/yr)	Production (mt)	Biomass (mt/yr)	Production (mt)	Biomass (mt/yr)	Production (mt)	Biomass (mt/yr)
A. Phytoplankton Feeders																			
1. Milkfish <i>Chanos chanos</i>	4.80	3,377	703.54	3,140	654.17	3,212	669.17	3,286	684.58	3,361	700.21	1,286	267.92	4,620	926.50	3,857	803.54	226	47.08
2. Mullet <i>Mugil (Banak)</i>	0.70																		
3. Tilapia <i>Oreochromis aureus</i> <i>Oreochromis mossambicus</i>	5.34	4,186	783.90	3,892	728.84	3,981	745.51	4,073	762.73	4,166	780.15	7,046	1,319.48	6,768	1,267.42	10,025	1,877.34	5,302	992.88
B. Others																			
1. Carp <i>Cyprinus carpio</i>	1.25	2,782	225.60	2,586	2,068.80	2,645	2,116.00	2,706	2,164.80	2,768	2,214.40	747	597.60	750	600.00	3,591	2,872.80	453	362.40
2. Catfish <i>Arius manilensis (Kanduli)</i> <i>Arius batrachus (Hito)</i>	1.55 1.55	1,888 1,302	1,218.06 840.00	1,755 1,210	1,132.26 780.65	1,795 1,238	1,158.06 798.71	1,836 1,266	1,184.52 816.77	1,879 1,295	1,212.26 835.48	2,863 57	1,847.10 36.77	2,357 8	1,520.65 5.16	1,865 45	1,203.23 29.03	2,667 30	1,720.65 19.35
3. Climbing Perch <i>Anabas testudineus (Martiniko)</i>	0.75	1	1.33	1	1.33	1	1.33	1	1.33	1	1.33								
4. Clupeids <i>Anodontosoma chacunda</i>	5.50																		
5. Eel <i>Anguilla sp</i>	0.80 **																		
6. Goby <i>Glossogobius giurus sp (Biya)</i> <i>Microgobius sp (Dulong)</i>	2.72 2.72	737	270.96	885	325.37	905	332.72	926	340.44	947	348.16	3,218	1,183.09	1,075	395.22	824 5	302.94 1.84	1,026 5	377.21 6.67
7. Gourami <i>Trichogaster</i> <i>Osphronemus</i>	0.75 *											17	22.67			6	8.00		
8. Mudfish/Murrel/Snakehead <i>Ophecephalus striatus (Dalag)</i>	0.75	1,110	1,480.00	1,032	1,376.00	1,056	1,408.00	1,080	1,440.00	1,105	1,473.33	263	350.67	148	197.33	392	522.67	204	272.00
9. Ornate sleeper <i>Ophiocara aporos</i>																			
10. Silver side																			
11. Tarpon <i>Megaplops cyprinoides</i>	0.60																		
12. Tawes <i>Puntius javanicus</i>																			
13. Therapon <i>Therapon plumbeus (Ayungin)</i>	2.64	1,479	560.23	1,375	520.83	1,407	532.95	1,439	545.08	1,472	557.58	6,248	2,366.67	2,294	868.94	3,821	1,447.35	3,148	1,192.42

Table 11. A Comparison Of The Calculated Fish Biomass For Selected Species MT/Ha) in the Open Water of Laguna Lake Based on Production Data of BAS (A) and the Biomass Calculated by ECOPATH II Model (B)¹

Year	Grams per cubic meter				
	1973	1974	1975	1976	1977
Blue-green algae	36	26	-- ^a	1.30	-- ^a
Green algae	<1	<1	<1	1.00	-- ^a
Diatoms	4	7.10	-- ^a	5.00	-- ^a
Average	14	12		2.43	

Note:

a = data incomplete

CONCLUSIONS

The fish production calculated from the net primary productivity data is a good estimate of the actual fish production (BAS). Likewise, fish production can be calculated from algal biovolume. Fish biomass values computed from the fish catch by the ECOPATH II model do not tally with those computed from the Bureau of Agricultural Statistics (BAS) production data.

RECOMMENDATIONS

In order to validate the results of this study more primary data should be gathered using the three methods of estimating primary productivity, which are net primary productivity (NPP), biovolume, and chlorophyll *a* analyses for about 5 to 10 years. This kind of extensive study can be undertaken in collaboration with all the research and academic institutions around Laguna Lake.

Moreover, since the diatoms usually predominate the phytoplankter of Laguna Lake both in quantity and types, and since they are the preferred natural food of the phytoplankter fish feeders, probably a means of estimating primary productivity based on chl *c* can be studied.