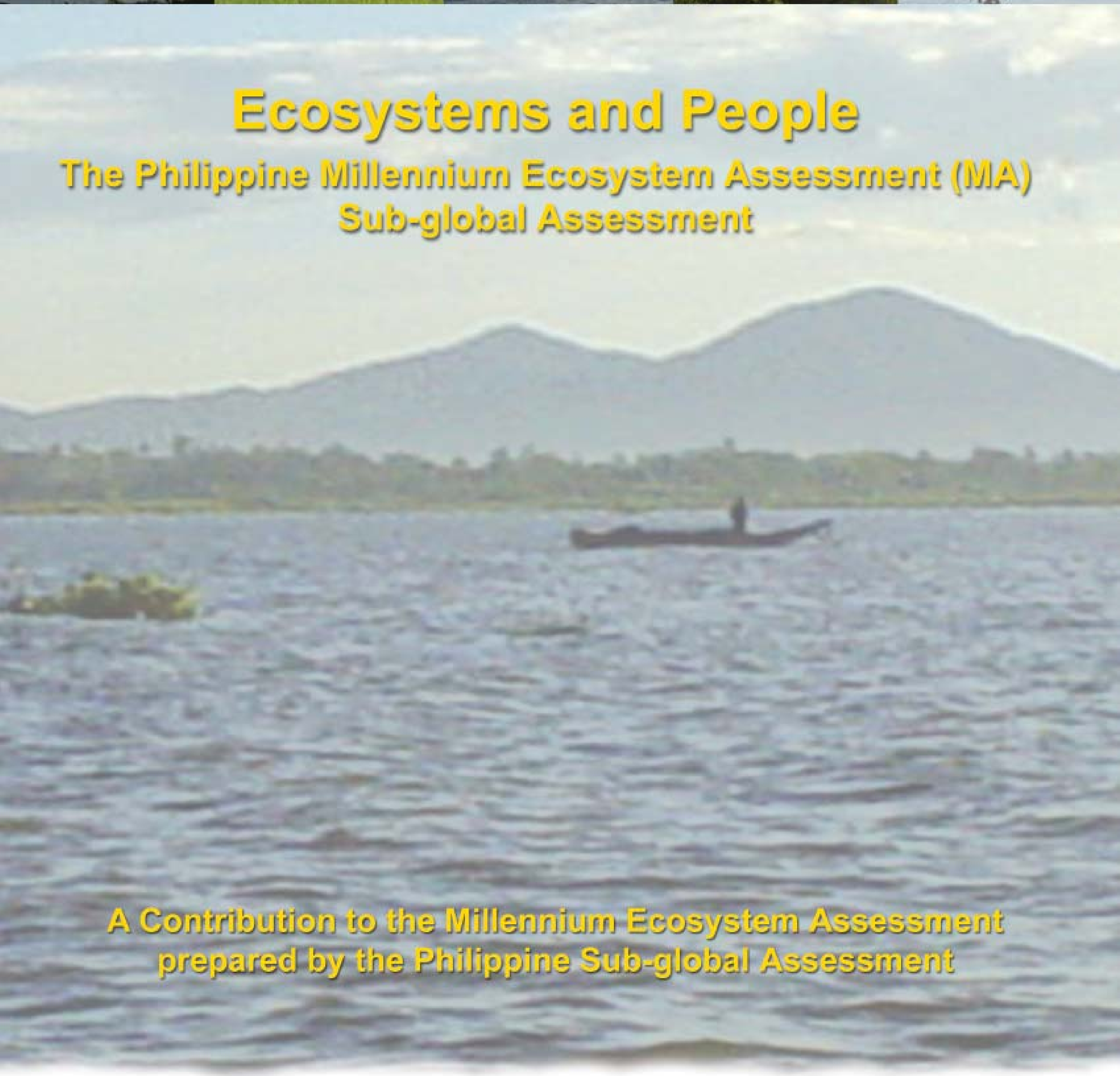




Ecosystems and People

The Philippine Millennium Ecosystem Assessment (MA) Sub-global Assessment



A Contribution to the Millennium Ecosystem Assessment prepared by the Philippine Sub-global Assessment

Millennium Ecosystem Assessment

STRENGTHENING CAPACITY TO MANAGE ECOSYSTEMS SUSTAINABLY FOR HUMAN WELL-BEING

Ecosystems and People

The Philippine Millennium Ecosystem Assessment (MA) Sub-Global Assessment

Ecosystems and People:

The Philippine Millennium Ecosystem Assessment (MA) Sub-global Assessment

Edited by

Rodel D. Lasco
University of the Philippines Los Baños/
World Agroforestry Centre (ICRAF-Philippines)

Ma. Victoria O. Espaldon
University of the Philippines
Diliman

Editorial Assistant
Maricel A. Tapia

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Foreword

The Millennium Ecosystem Assessment (MA) is a timely response to the need of policymakers and resource managers for scientific information on how human welfare is impacted upon by ecosystems changes, and how ecological systems are affected by human activities.

Significantly, through the Philippine MA Sub-Global Assessment focusing on the Laguna de Bay Basin, the Philippines is certain to have directly contributed to the attainment of the UN Millennium Development Goals and Implementation Plan for the 2002 World Summit on Sustainable Development.

The fact that the Sub-Global Assessment of the Laguna de Bay Basin's ecosystems and their services made use of the global MA framework and eventually contributed to the process, as well as published scientific materials and agency reports, and that it has involved a panel of respected local scientists and experts, the findings and result should serve as readily available references and inputs to coming up with options for responding to ecosystem changes.

The choice of the Laguna de Bay Basin is significant from the perspective of the DENR and LLDA. As the lake ecosystem is undergoing rapid and significant changes due to multitude of factors driven by industrialization and urbanization in the watershed, as well as due to the political, economic and ecological significance of the lake basin, it is important that we take stock of the findings and results of the sub global assessment, and bring them to the policy formulation and decision-making process, and in drawing up necessary legislative agenda, if need be.

Specifically, and in relation to the recently enacted Clean Water Act (CWA) under the Republic Act 9275, the DENR should be able to leverage the findings of the sub-global assessment of the Laguna de Bay Basin to drive the implementation of the CWA in the lake region as a declared Water Quality Management Area (WQMA) under section 5 thereof.

At this juncture, and as we are at the stage of advocating the sub-global assessment findings and results in this Policy-Seminar Workshop. We will keep and open mind and positive stand on the need to translate the findings of the sub-global assessment into specific policies that could be mainstreamed in the CWA implementation in the Laguna de Bay Region as a WQMA, among others.

Thank you very much for involving the DENR and the LLDA in this process. Indeed, the involvement of our people in this endeavor has contributed so much in this institutional strengthening and capability building of the LLDA. Designating our key and technical support staff as lead authors, contributing lead authors, and contributors has certainly boosted the drive of the organization towards building a pool of scientists and other professionals within authority.

Message delivered during the Philippine Millennium Ecosystem Assessment Policy Seminar-Work, held on 20 May 2005, at the Traders Hotel, Pasay City, Philippines by:

Dolora N. Nepomuceno
Assistant General Manager
Laguna Lake Development Authority

on behalf of:

Hon. Edgardo C. Manda
General Manager
Laguna Lake Development Authority

Hon. Michael T. Defensor
Secretary
Department of Environment and Natural Resources

Acknowledgments

This publication is the product of the outstanding and untiring efforts of numerous individuals and organizations involved in the Philippine Sub-global Assessment over the past three years. We would like to express our sincerest gratitude to the following for nurturing the pilot Philippine MA Sub-global Assessment through to a successful completion:

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- To Dr. Paul Zafaralla, for the assistance in editing and proofreading some chapters in the report; and
- To Marcus Lee, for the tremendous support and the technical and administrative guidance that he provided from the conception towards the completion of this project.

Financial support for the MA and the MA Sub-global Assessments was provided by the Global Environmental Facility (GEF), the United Nations Foundation, the David and Lucile Packard Foundation, the World Bank, the United Nations Environment Programme (UNEP), the Government of Norway, the Kingdom of Saudi Arabia, the Swedish International Biodiversity Programme, the Rockefeller Foundation, the United States National Aeronautic and Space Administration (NASA), the International Council for Science (ICSU), the Asia Pacific Network for Global Change Research, the Christensen Fund, the United Kingdom Department of Environment, Food and Rural Affairs (DEFRA), the Consultative Group for International Agricultural Research (CGIAR), and the Ford Foundation.

Summary for Decision-Makers

A Report of the Philippine Sub-global Assessment Team

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1. The Millennium Ecosystem Assessment

The Millennium Ecosystem Assessment (MA) is a four-year international work program designed to meet the needs of decision-makers for scientific information on the links between ecosystem change and human well-being. It was launched by United Nations (UN) Secretary General Kofi Annan in June 2001. It is primarily supportive of the needs of the parties to the Convention of Biological Diversity, Ramsar Convention on Wetlands, and the Convention to Combat Desertification. Ultimately, it hopes to be able to contribute to the attainment of the UN Millennium Development Goals and the Plan of Implementation of the 2002 World Summit on Sustainable Development.

The Philippine MA Sub-global Assessment is one of the approved sub-global assessments of MA. It focuses on the Laguna Lake Basin, one of the most important and dynamic land and water formations in the Philippines. The main objectives of the Philippines sub-global assessment are a) to assess the Laguna Lake Basin's ecosystems and their services using the MA framework and b) to contribute to global MA process.

2. The Philippine MA Sub-global Assessment

Three scales and four ecosystem services were included in the assessment of the Laguna Lake Basin. At the farm or village level, the ecosystem service in focus was the provision of food: fish and rice; at the basin level, the overall fishery production and provision of water supply including biodiversity; and at the global scale, an exploration of its influence on climate change.

The Philippine sub-global assessment was conducted by a panel of 25 scientists and experts with background on the natural and social sciences and coming from several research and development institutions in the Philippines. The assessment process relied on several data sources which included published scientific literature preferably on peer-reviewed journals, master plans and sectoral plans for the watershed, project and consultant's reports, and government agency reports.

3. Ecosystem Services

3.1 Water Resources

Finding No. 1: Laguna de Bay has 22 major river tributaries or basins (LLDA in recent reports lists 24 major river basins). Pagsanjan-Lumban River contributes 35 percent of the surface recharge, followed by Sta. Cruz River with 15 percent, and the rest contribute 50 percent. Seven major rivers are regularly monitored for water quality, namely, Pagsanjan-Lumban, San Cristobal, San Juan, San Pedro, Sta Cruz, Bay, and Tunasan Rivers. Rivers in the western side of the lake are heavily polluted with industrial effluents and other wastes. Based on DO and BOD levels, most of these rivers are virtually dead such as San Pedro, Tunasan, San Cristobal, and San Juan rivers with DO and BOD levels below Class C standards. Tanay River is deteriorating as indicated by increasing turbidity, BOD, COD, conductivity, chloride, total phosphorous, and ammonia-nitrogen loads. The problem concerning BOD is most pronounced in rivers.

Finding No. 2: Major sources of pollution of the river systems are domestic wastes both solid and liquid effluents, food processing plant wastes, livestock wastes, chemical manufacturing spillage, various industrial effluents, fertilizers and pesticides from agricultural runoff, and eroded soils from the watersheds. By volume, the domestic sector contributes 68.5 percent; industry, 19 percent; and agriculture, 11.5 percent.

Finding No. 3: The total coliform counts in all rivers are in excess of the allowable limits of 5,000 MPN/100 ml set for Class C rivers. The annual average total coliform values were found to be very high, ranging from 4.64×10^6 to 22.45×10^6 MPN/100 ml. Like the highly polluted tributary rivers that were monitored, Laguna de Bay also suffers from a high bacterial count which poses a constant health hazard to the people depending on the lake resources. However, the cleansing effect of increased salinity during saltwater intrusion in the summer months somehow arrests the increase in coliform count. In areas found in the middle of the lake, the total coliforms are less than the limit of 5,000 MPN/100 ml for Class C water (intended for fishery).

Finding No. 4: Based on their mean levels and trends during the decade 1990-1999, many water quality parameters have already exceeded or fallen below the criteria for Class "C" waters indicating the worsening condition of the lake. Among the parameters that have exceeded the prescribed criteria and showed upward trends are ammonia N, nitrate N, total N, ortho P, total P, COD turbidity, chlorides and hardness; while those that have fallen below the criteria and/or showed decreasing or erratic trends are clarity or Secchi disc readings, DO, pH, and alkalinity.

Finding No. 5: The lack of a centralized or localized sewage treatment facility perpetuates and sustains the unimpeded inflow into the lake of N and P which, together with carbon, are the main elements of eutrophication. Lack of an effective solid waste management program in the basin further complicates the problem.

Finding No. 6: The high nutrient levels notwithstanding algal blooms, which prior to 1984 commonly reached densities of up to a million cells, are now a rarity. This means that the lake's potential fertility is not eliciting a commensurate level of primary production. This situation is a threat to fish production as indeed has become evident in the remarkable declines in both fishpen aquaculture and open fisheries.

Finding No. 7: The biological productivity of this resource has considerably declined. The levels of net primary productivity of 3 to 8 g C m^{-2} day^{-1} observed before the 1990s are now hardly met. Even as the lake is still nutritionally within the eutrophic category, its responsiveness to the extant fertility has declined. This means that nutrients are not the factor limiting the ability of algae to photosynthesize in the lake. Rather this could be another factor, most likely, the sufficiency of light.

Finding No. 8: The variation of chl a over the years indicates that this parameter may have been subject to the indirect effects of infrastructure projects, like the construction of the NHCS and the proliferation of fishpens. The time of construction and short period of operation of the former along with the growth in the area allocated to the latter were marked by significant declines in algal biomass production. The levels of algal biomass associated with the massive algal blooms characteristic of the 1980s have ceased to be observed, or are no longer occurring on a regular basis.

Finding No. 9: Laguna de Bay is presently perennially and critically turbid. Its secchi disk transparency ranges from 0.1 to 0.8 m with an average of 0.4 m. This physical deterioration of the lake dates back to the 1980s or earlier, when big infrastructure projects, like the NHCS was being constructed and operated at the same time that a "fishpen sprawl" was underway. The present depth of light penetration indicates that the lake is dystrophic, meaning it is critically turbid. In its downgraded physical state, the lake has become less hospitable to the photosynthesizing algae that are a natural food to aquatic animals. This type of a relationship may translate into a deteriorated quality of the natural food for fish.

Finding No. 10: The lake is undergoing rapid shoaling. Its latest recorded average depth is 2.7 m which is higher than the earlier reported average depth of 2.5 m. The higher average stems from the narrowed range of its depth. Rapid shoaling is due to the high rate of organic and inorganic matter deposition. Organic deposition is high where the aquatic macrophytes proliferate. Inorganic deposition is accounted for by the tributary rivers and streams.

Finding No. 11: Zooplankton communities in the lake have gone through different stages of display of their natural capacities for growth under various kinds of anthropogenic disturbances. They appear to have been decimated when the fishpen area was large. Reduction of the latter seems to have made way for the zooplankton populations to grow. The zooplankton community dynamics in the lake need further elucidation.

Finding No. 12: It is now established that saltwater intrusion from the Pasig River spreads over the entire lake causing a temporary lake clearing. It is to be expected that Laguna de Bay is accumulating salts from the normally occurring, periodic exchange of waters with Manila Bay. The lake has been seen to exceed the recommended safe level for Class C water resources (350 mg l^{-1}) most especially in summer, in various places. Regardless the increased salinity, Laguna de Bay remains highly turbid today. This means that the expected flocculating effect of saline water when this meets freshwater is no longer markedly evident in the lake because of a strong turbidity development due to sediment re-suspension in this shallow lake.

Finding No. 13: Lake waters are contaminated with toxic and hazardous substances (e.g., heavy metals and persistent organic pollutants including pesticides) coming from the industrial and agricultural sectors. The heavy metals Pb, Cr, Cd, Cu, As, and Hg, at one time or another, have been found in concentrations exceeding the prescribed safe levels for Class C waters. Results of the measurements by various workers differ, underscoring the importance of considering in the interpretation of data, the place and time of sampling, not to mention the operation of the method used in sample preparation. Some of the toxic and hazardous chemicals have found their way in the biota.

Finding No. 14: Lake sediments are likewise contaminated with heavy metals. Some parts of the lake have low levels while other parts have high. Nevertheless, the reported concentrations of heavy metals in the sediments are rated very low. The results of analysis for heavy metals and organic chemicals such as pesticides and other industry-derived, persistent organic chemicals in fish and other biota are inconclusive and need further verification and assessment.

Finding No. 15: Aquatic macrophytes have diminished in the lake. But there has been no documentation of by how much the lake surface area has shrunk as a result of a natural reclamation process based on the deposition of organic matter originating from aquatic macrophytes. Neither has there been a recent estimate of the portion of the lake covered by materials of accretion derived from the complete decomposition of macrophytes of every kind. There is a need to demarcate the bog areas and estimate the rate of shoaling contributed by these.

There are indications that in some parts of South bay an increase, rather than a decrease, in species diversity of emergents has occurred. This is interpreted as evidence that a natural process of soil formation is occurring and that new niches have formed in the transition area to the true terrestrial habitat.

Finding No. 16: Thermal pollution effects, especially in the vicinity of the KEPHILCO Power Plant in Pililla, Rizal, on lake biota have not been adequately explored.

Finding No. 17: Laguna de Bay is in need of rehabilitation, of restoration to a past state that is most acceptable. This past state must be decided on giving due consideration to the benefits that come with rehabilitation given the continuing multiple uses.

3.2 Fish

Finding No. 1: The fisheries of Laguna de Bay have been affected by human, industrial, and environmental factors which resulted in a 64 percent decline in production levels from 1980 to 1996.

Finding No. 2: Species diversity has also significantly declined; of the total 33 species reported to have thrived in the lake at different times, only 5 out of the 9 indigenous species have remained. All the 5 migratory species have disappeared and the catch at present is dominated by the exotic aquaculture species.

Finding No. 3: The establishment of fishpens and fish cages has both positive and negative impacts on the lake fisheries. Pen and cage cultures have increased aquaculture production while the escapement of fishes from the net enclosures has greatly enhanced open water fisheries. However, pen and cage structures in the lake have significantly reduced the area for open water capture fisheries resulting to conflicts between fishpen operators and sustenance fishermen.

Finding No. 4: Although the number of fishermen operating in the lake has been reduced by 50.4 percent, they have remained in marginalized condition and there is a need for a viable alternative and/or supplemental livelihood.

Finding No. 5: Aquaculture operation, to be sustainable, should be limited within the carrying capacity of the lake and the designated aquaculture areas.

Finding No. 6: Escapement of exotic species from aquaculture has adversely affected the fisheries of the lake and there is a need for an effective containment mechanism for invasive exotic species.

3.3 Rice

Finding No. 1: The Laguna de Bay has a shoreland area of around 139 km^2 when the water level of the lake is 10.5 m or 200 cm below the normal (Figure 1).

Finding No. 2: Around 570 km^2 of the shoreland is planted to rice. At an average yield of 4.1 t ha^{-1} (410 t km^{-2}), the area can supply 22,800 t of palay or almost 9,000 t of milled rice, or 14 percent of total rice requirement in the Laguna de Bay Region (Figure 2).

Finding No. 3: The area can readily supply 20 percent of the rice requirement of the basin with improvement in rice cultivation.

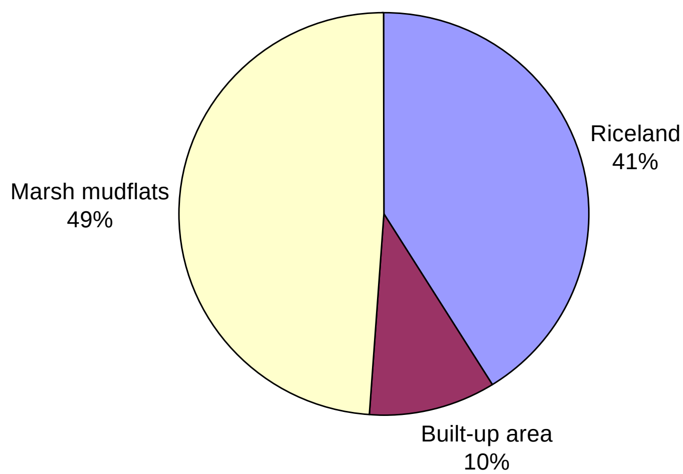


Figure 1. Laguna de Bay shoreline.

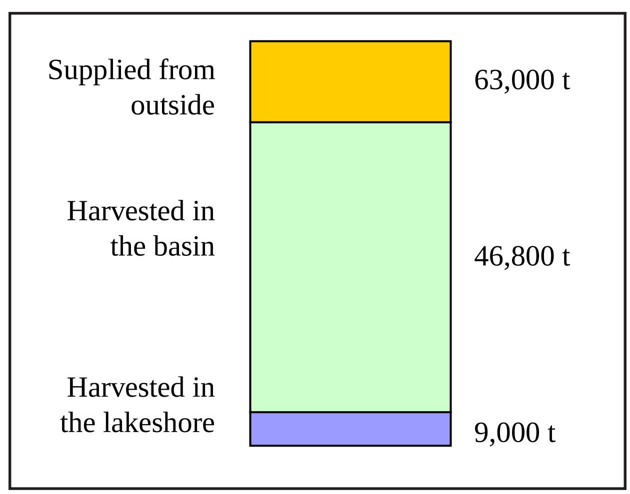


Figure 2. Rice requirements for the basin.

Finding No. 4: The major factors affecting rice production are changes in water level, construction of circumferential road, and land conversion which result to decreasing areas for rice cultivation. Another major factor that may improve shoreland productivity is the use of better rice varieties and better fertilizer management (Figure 3).

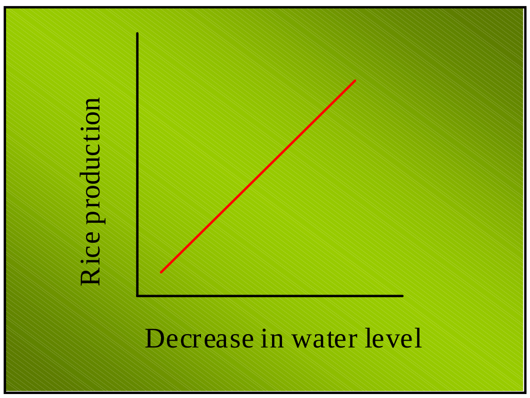
Finding No. 5: Institutional arrangements have been set up by LLDA on the use of shoreland and water of the lake. These arrangements are found in some of the policies issued by the LLDA such as Issuance of Permits for Reclamation Projects and Disallowing Any Non-environmentally Feasible Activities in the Lake (LLDA Board Resolution No. 10) and Moratorium on the Acceptance and Processing of All Public Land Applications Covering Areas Immediately Adjacent to the Laguna De Bay Basin (DAO 27-95).

3.4 Biodiversity

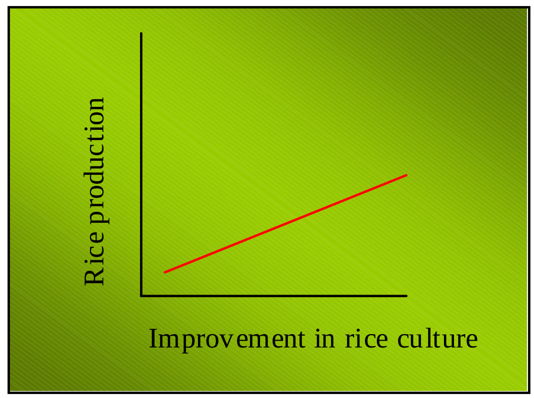
Finding No. 1: There is a continuing lack of recent data and information on the biodiversity of the lake basin, especially for many taxonomic groups, including plants, algae, insects, and other arthropods.

Finding No. 2: Some naturally occurring species have already been completely extirpated from the lake basin, e.g., the Philippine Duck (*Anas luzonica*) in the 1920s and the Philippine Crocodile (*Crocodylus mindorensis*) in the 1950s.

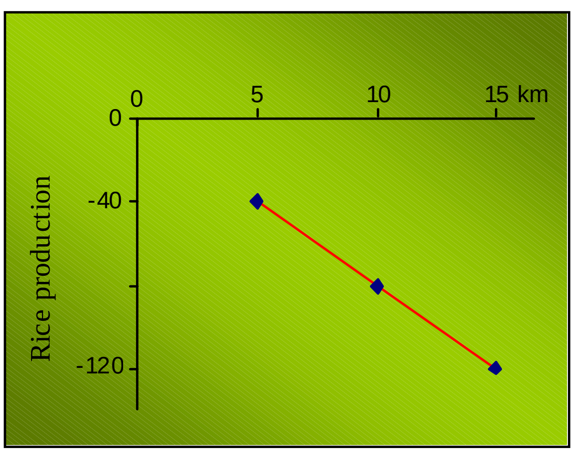
Finding No. 3: The diversity of the indigenous fish, crustacean, and mollusk species in the lake has considerably declined since the late 1950s, while the number of alien species being introduced into the lake continues to increase.



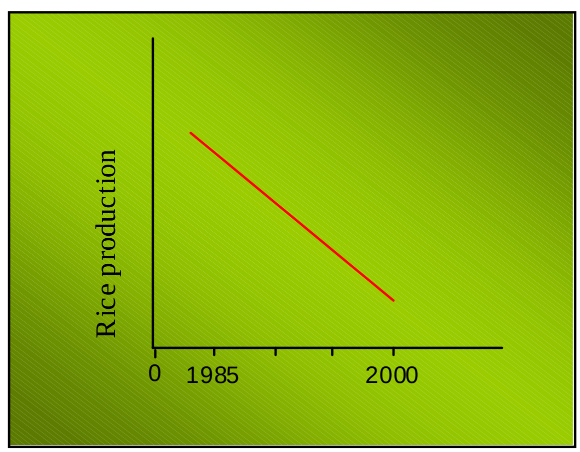
Changes in water level – as the lake level decreases, the area for rice cultivation increases.



- Better rice varieties
- Better fertilizer management



Construction of circumferential road decreases the area for rice cultivation.



- Decrease in land area planted to rice
- Land conversion

Figure 3. Major factors affecting rice production.

Finding No. 4: There are continuing threats to the indigenous biodiversity of the lake basin as a result of introduction of alien species, chemical pollution, over extraction, and reduction of habitats of the wild flora and fauna.

3.5 Climate Change

Finding No. 1: The agricultural sector contributes 1,298.7 kt of greenhouse gases to the atmosphere in the year 2000 from rice paddy fields, livestock, and biomass burning.

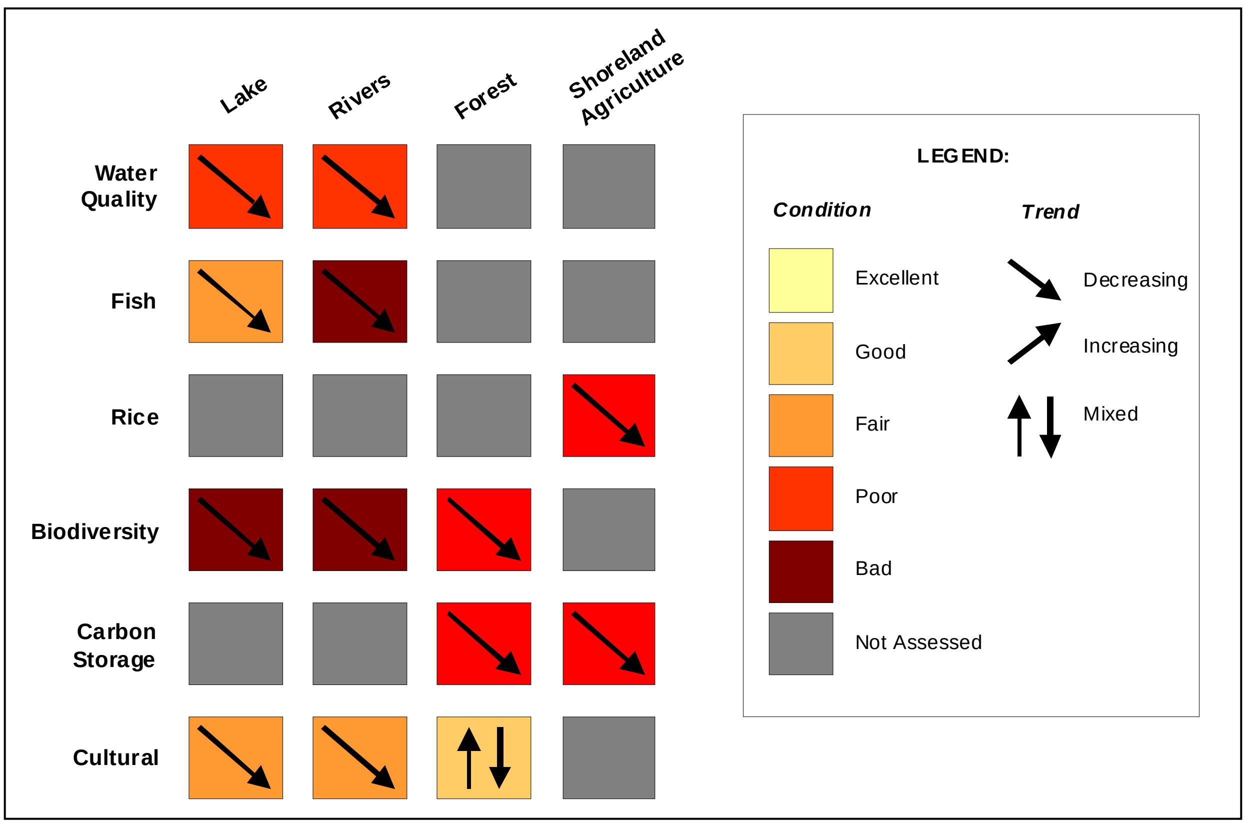
Finding No. 2: The LUCF sector is a slight net source of GHG contributing 924 kt of GHG in the year 2000, about 1 percent of the national total. While much carbon is absorbed by forests (sinks), this is offset by GHG emissions from tree harvesting and fuelwood burning.

Finding No. 3: While the direction (+ or -) and magnitude of impacts of climate change on natural resources (water, forests) and agriculture/food security remains largely uncertain, studies have shown that there would be impacts.

Finding No. 4: Forest lands in the LLB could help mitigate climate change through a) the protection of existing forests with their carbon stocks (about 190 km^2 storing about 2,850 kt C) and b) reforestation and rehabilitation of open and degraded lands (540 km^2 with potential carbon sequestration rate of 1,338 kt CO_2 per year).

Finding No. 5: Climate change is not yet explicitly integrated in planning and implementation of activities in the basin. However, there are many activities that indirectly contribute to mitigation of climate change.

4. Laguna Lake Basin: Conditions and Trends



5. A Summary of the Responses to Various Issues or Problems on the Use of Laguna Lake Basin Resources

Ecosystem Services	Problems	Responses	Assessment
Water quality	Deteriorating water quality	Formation of multisectoral river rehabilitation councils Laguna Lake Master Plan	Fairly addressing water quality problems in some areas
Fish	Declining open fish catch	Development of ZOMAP	Regulated the use of surface lake water for open fishing, navigation, fish sanctuary, and fishpen structures
		Introduction of aquaculture	Improved total fish production but contributed to pollution loading and dominance of exotic species in the lake; Decreased catch from open water
Rice	Decreasing areas for rice growing along the lake	No response	
Biodiversity	Lake: Decline in fish diversity and dominance of exotic aquaculture species	Delineation of fish sanctuary (in the ZOMAP)	Not effective
	Forest: Extirpation and decline of some naturally growing species; Continuing threats to the indigenous biodiversity of the lake	Inclusion of some areas in the biodiversity conservation areas (e.g., Mt. Makiling and Mt. Banahaw - San Cristobal complex)	Regulated harvesting of forest resources in some areas
Carbon Storage and climate change mitigation	Declining capacity to store carbon due to deforestation	Carbon sequestration projects to be implemented Methane reduction project in solid waste	Climate mitigation projects underway through the LLDA

Philippine Sub-global Assessment: Synthesis

RODEL D. LASCO, MA. VICTORIA O. ESPALDON, MARICEL A. TAPIA

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1. Introduction

In the history of mankind, never has there been such severe stress on the world's ecosystems, threatening the survival of the planet Earth itself. It is now generally recognized that the world's present development path is not sustainable (Kates et al. 2000). The reality is that much of the world's environment is already in a very bad state and the situation is getting worse (Rambo 1997).

The Millennium Ecosystem Assessment (MA) was launched by UN Secretary-General Kofi Annan in June 2001. Its main goal is to provide the decision-makers and the public with scientific information on the possible consequences of ecosystems change upon the welfare and well-being of man and other organisms and options for responding to those changes. It is primarily supportive of the needs of the parties to the Convention of Biological Diversity, Ramsar Convention on Wetlands, and the Convention to Combat Desertification. Ultimately, it hopes to be able to contribute to the attainment of the UN Millennium Development Goals and the Plan of Implementation of the 2002 World Summit on Sustainable Development.

A key component of the MA process is the sub-global assessments (SGA) in various regions of the world, one of which is Southeast Asia. The Philippines represents the archipelagic character of the region with more than 7,000 islands. Thus, a unique feature of this study is the focus on basins in an archipelagic island context

The pilot assessment of the Philippine MA Sub-Global Assessment focused on the Laguna Lake Basin. The Basin is one of the most important and dynamic land and water formations in the Philippines. This water body encompasses the whole of Laguna and Rizal provinces including parts of Metro Manila, Batangas, Cavite, and Quezon which are among the fastest growing economic zones in the country. As such, the basin represents a wide array of ecosystems undergoing rapid transitions due to a multitude of factors: economic activities, population increase, industrialization, urbanization and various economic policies and community dynamic, among others. In 2000, its population was about 6.6 million people or 9 percent of the total population of the country.

The main objectives of the Philippines sub-global assessment were a) to assess the Laguna Lake Basin's ecosystems and their services using the MA framework and b) to contribute to global MA process. Three scales and four ecosystem services are included in the assessment of the Laguna Lake Basin. At the farm or village level, the ecosystem service in focus was the provision of food: fish and rice; at the basin level, the overall fishery production and provision of water supply including biodiversity; and at the global scale, an exploration of its influence on climate change. The assessment report is organized in terms of presenting the conditions and trends in each ecosystem service/scale and institutional and policy responses to these changes.

The assessment process follows the approach of the Intergovernmental Panel on Climate Change (IPCC), and relied on several data sources which included published scientific literature preferably on peer-reviewed journals, master plans and sectoral plans for the watershed, project and consultant's reports, and government agency reports.

The Laguna Lake Basin (LLB) is situated within latitudes of 13º 55' to 14º 50' N and longitudes of 120º 50' to 121º 45' E in Luzon Islands, Philippines (Figure 1). It has a total area of approximately 3,813.2 km^2 (watershed area and lake proper). It traverses 12 cities, 49 municipalities, and 2,656 *barangays* or villages. The Laguna de Bay, also known as Laguna Lake, is one of the five largest freshwater lakes in Southeast Asia. It occupies a total surface area of approximately 900 km^2 with a shoreline of 220 km. It has an average depth of 2.5 m and a maximum water holding capacity of about 2.9 billion m^3. Geographically, the lake can be divided into West bay, East bay, South bay, and Central bay. This study used the terms Laguna de Bay and Laguna Lake interchangeably.

Geologically, the watershed is characterized by igneous and sedimentary rocks overlain by alluvial deposits (Bureau of Forestry Manila 1966). The landscape is characterized by mixed topography where 35 percent is gentle, 45 percent is rolling, 15 percent is steep, and 5 percent is very steep slope. In the shoreline, the topography is relatively flat.

The Laguna Lake Basin is under two climatic conditions: Type 1 and Type IV of the Corona Climate System of classification. Type 1 has two distinct seasons, dry from November to April and wet from May to October. Type IV is characterized by evenly distributed rainfall all throughout the year. The lowest air temperatures and highest wind velocities occur from December to February. This causes high water turbulence resulting to high water turbidity. As a consequence, low fish growth is experienced even with ample supply of free nutrients.

In the dry season, the functional minimum water level of the lake is about 10.5 m which is the minimum sea level (msl). When the water level falls below the msl or below the high tide level of Manila Bay, seawater intrusion to the lake through the Pasig River occurs causing an increase in lake water salinity (Francisco 1985).

The total land area of the watershed surrounding the lake is approximately 2,903.2 km^2. As of 2000, agricultural lands were 1,509.66 km^2 (52 percent), open unproductive

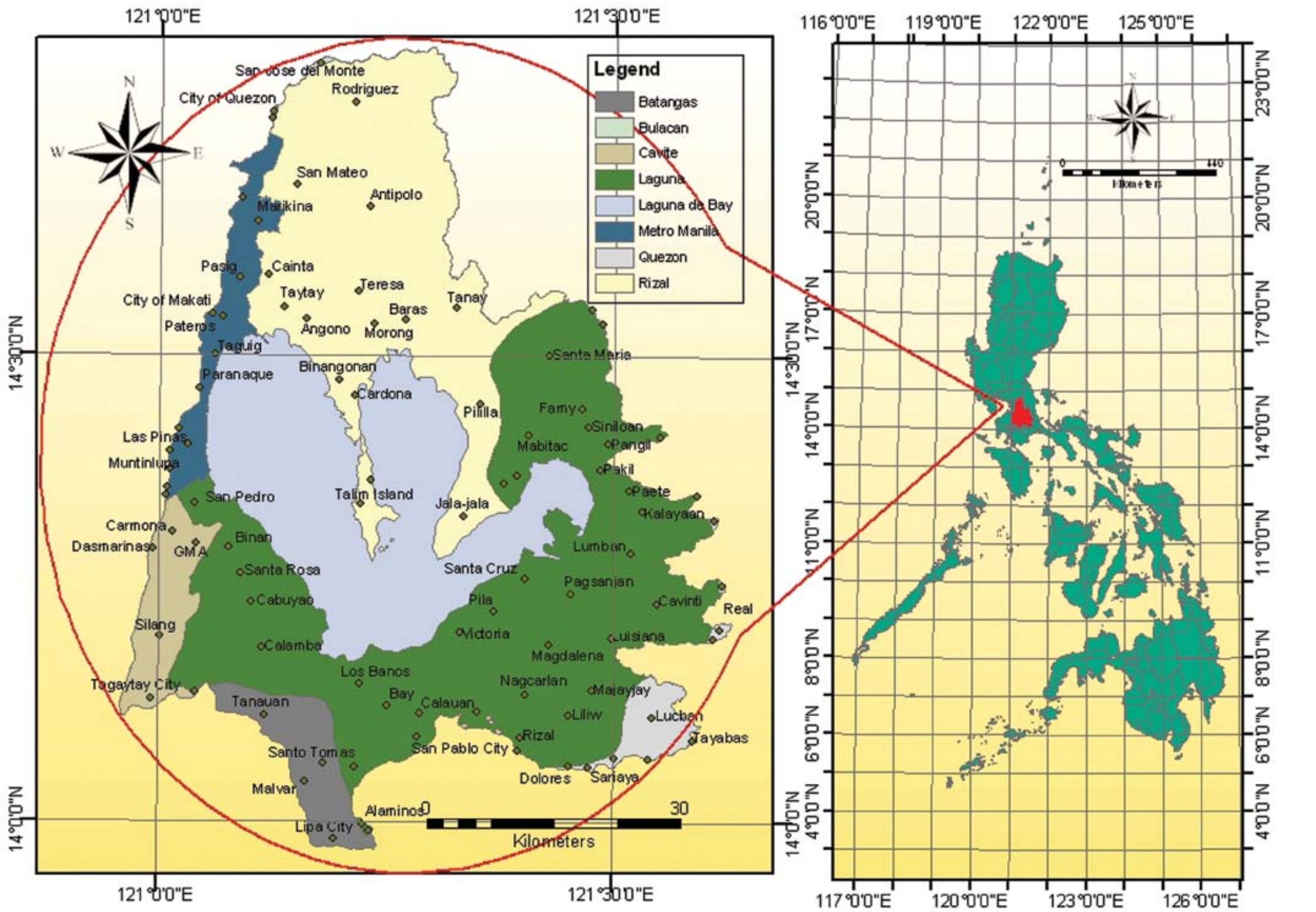

Figure 1. Location map of the Laguna Lake Basin.

grasslands were 406.45 km^2 (14 percent), forested lands were 145.16 km^2 (5 percent), and built-up/industrial were 841.93 km^2 (29 percent). This landuse reflects how the region is transforming into a more industrialized zone.

Urban sprawl caused by the expansion of Metro Manila has resulted in the rapid urbanization and industrialization of the provinces of Cavite, Laguna, Rizal, and Batangas. This provides the people in the basin better opportunities to work in the industrial, commercial, and agricultural sectors being at the heart of Southern Tagalog and at the hub of economic activities.

The management of the Laguna Lake Basin is the main mandate of the Laguna Lake Development Authority (LLDA).

2. Capacity of the Laguna Lake Basin to Provide Ecosystem Services

2.1 The Lake's Watersheds

There are 22 major watersheds (also referred to as river sub-basins) that contribute to Laguna de Bay (Figure 3). Each watershed consists of several sub-watersheds with either a single or multiple outlets into the lake. The biggest watershed is the Marikina River Basin located north of the lake, and the second biggest is the Pagsanjan River in the southeast part of the lake. The Pagsanjan River system contributes about 35 percent of the freshwater inflow, followed by Sta. Cruz River with 15 percent, and the rest contributing 50 percent.

Another important river system is the Tanay River Watershed. It has a total area of 54.75 km^2 and is fed by 15 intermittent and perennial streams or tributaries. The watershed lies at

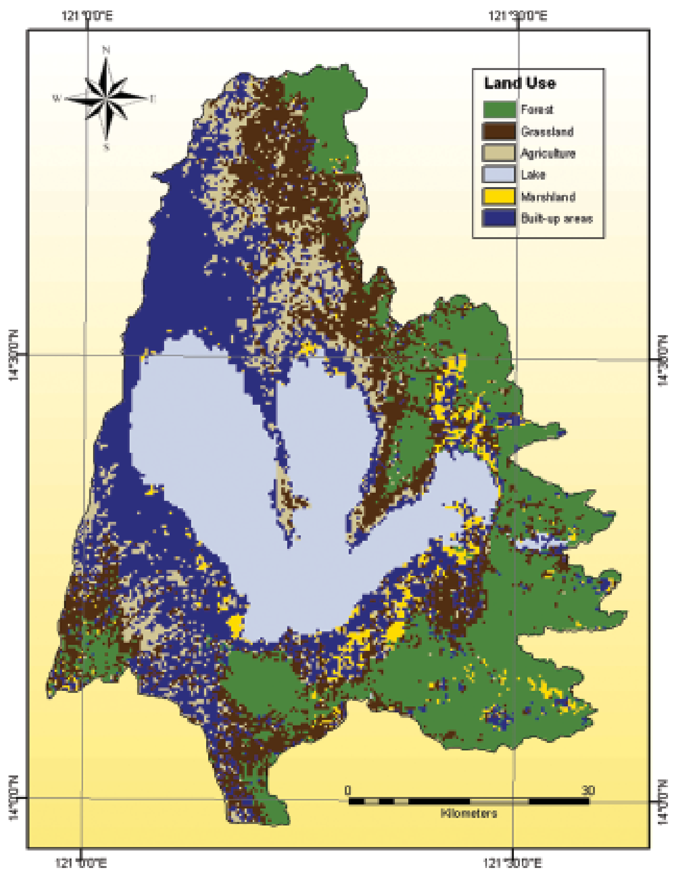

Figure 2. Land use map of the Laguna Lake Basin (ENFOR 2002).

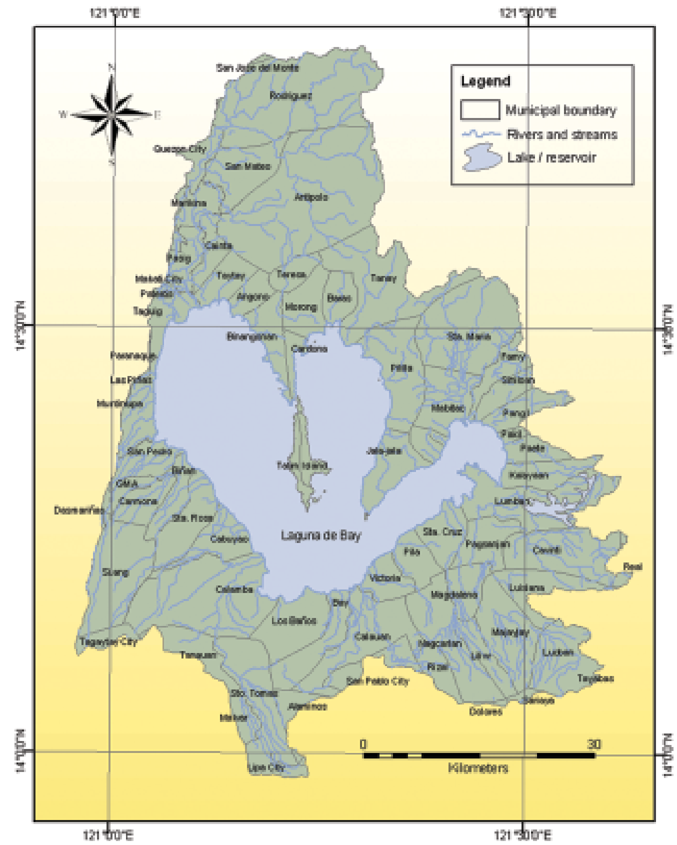

Figure 3. Map of rivers and sub-basins of Laguna Lake Basin (NHRC 2004).

the foot of the Sierra Madre Mountain Range, bounded in the north by the towns of Antipolo, Baras, Teresa, and Montalban; in the east by Quezon Province; in the south, Laguna province and Pililla, Rizal; and in the west by Laguna de Bay.

Finally, at the southern part of Laguna de Bay is the Molawin Watershed. This watershed has an approximate area of 9.218 km^2. The length of the river is 8,970 m. It has 20 streams (intermittent and perennial) with headwaters at an elevation of about 1,020 masl and downstream-most elevation of about 20 masl. This wide variation in elevation also results in the widely fluctuating temperature and precipitation amounts at the site. Subsequently, this affects the peak flows and the time it takes for the total flood flow.

2.2 The Lake's Hydrodynamics

To properly plan and manage the optimum and sustainable use of the lakewater resources, it is crucial to understand lake's hydrodynamics. There are three major factors that drive the lake hydraulics: 1) inflows to the lake from the surrounding watersheds including the Marikina River through Mangahan Floodway (MF); 2) tidal forcing from Manila Bay through Pasig/Napindan River; and 3) surface wind stresses. Other factors that influence lake circulation patterns are presence of structures for fishing industries called fishpens and fish cages, bottom friction (bed shear stress) being a shallow lake (3-6 m deep), occurrence of high turbidity, and the occasional proliferation of hyacinths.

On the flood control function of Laguna de Bay, the current operating rule is that when the Marikina River stage at its Santo Niño station is greater than 14.5 m, the gates at Rosario weir are opened to let the floodwaters enter MF towards the lake. This flood control scheme is designed to protect Metro Manila from being flooded, but it seemed to have ignored its impact on the lakeshore towns around Laguna Lake. In fact, the gate operating policy at Rosario weir does not consider the downstream end conditions such as the lakewater stage or Pasig River stage (Tabios and David 2004). Since the MF was built, there were cases of floodings along Taguig and Taytay and even way down south in Sta. Cruz and Los Baños, and some people perceived these incidents as consequence of the construction of the MF.

Saltwater from Manila Bay through the Pasig River is allowed to enter Laguna Lake, which is desirable to the fishing industry. On the other hand, lake withdrawal for domestic water supply requires a certain, minimum salinity standard that is conflicting to this fisheries salinity requirement. The control of saltwater entering or exiting the lake through Pasig River is through the gate operations of the Napindan Hydraulic Control Structure (NHCS). However, since the NHCS was built, it was always left open as demanded by the fisheries industry.

In 1997, the Southeast Asian Fisheries Development Center (SEAFDEC) – Aquaculture Department and Hohenheim University – Germany conducted a saltwater mapping study of Pasig River backflow. In their survey, they noted that saltwater intrusion normally starts in the last week of April. Water coming from Pasig River flowing into the lake emitted odor of hydrogen sulfide (H_2S) and had high chloride content. By the middle of the month of May and with the onset of the southwesterly winds (locally called *hanging Habagat*), the fast diffusion of salt water in the west lobe or West bay of Laguna Lake was observed. Based on the periodic surveys of the lake and monthly monitoring of stations conducted by SEAFDEC, it was estimated that it takes about 2 to 3 months for the whole lake to clear out due to the effect of saltwater.

With regard to the wind forcing, a recent two-dimensional hydraulic model of Laguna Lake developed by the National Hydraulic Research Center or NHRC (1999) includes a fairly comprehensive model of the watershed inflows (Morel-Seytoux et al. 1999). In this model, the tidal forcing from Manila Bay was defined by hourly data that is available from a continuous data monitoring station. However, the surface wind stresses cannot be adequately described since there are only two or three stations (located in Los Baños and Manila) that continuously monitor wind speed and direction in the vicinity of lake area. Considering the irregular topographic features around Laguna Lake, spatially and temporally varying wind patterns commonly prevail. Thus, in order to properly understand and predict the lake dynamics, a realistic rendering of spatial and temporal variations of the wind field is needed.

As mentioned earlier, fish structures such as fishpens or fish cages in Laguna Lake affect the lake circulation patterns to some extent. Generally, water flow around these structures are retarded due to drag effects of fish cages, or the drag effects of bamboo fences and net enclosures of fishpens. Fishpens exert more drag since their fences extend from top to bottom of the lake while fish cages are floating structures with open spaces underneath (Tabios 2003).

2.3 Water Quality of the River Systems

Of the 22 major river basins, seven are regularly monitored by LLDA for physico-chemical and biological parameters. These are: Pagsanjan-Lumban, San Cristobal, San Juan, San Pedro, Sta. Cruz, Bay, and Tunasan Rivers. The Ecosystems Research and Development Bureau (ERDB) of the Department of Environment and Natural Resources (DENR) had also conducted some studies in San Cristobal, Sta. Cruz, and Pagsanjan Rivers in 1996-1998. The University of the Philippines Los Baños (UPLB) had also done watershed and water quality studies in Tanay River, San Pedro, San Cristobal, and Molawin Creek in the late 1990s.

Based on dissolved oxygen (DO) and biochemical oxygen demand (BOD) levels, most of the rivers on the western side of the lake are virtually dead such as San Pedro, Tunasan, San Cristobal, and San Juan Rivers, with DO and BOD levels failing to meet Class C criteria. This is the result of the high discharge of domestic and industrial wastes from the communities and industrial sites in the area.

Among the seven rivers monitored by LLDA, San Pedro River registered the highest ammonia concentration at 4.075 mg l^{-1} during the month of February and an annual average of 2.235 mg l^{-1}. The rest gave an annual average varying from 0.245 to 0.043 mg l^{-1} with Pagsanjan River registering the lowest level.

The absence of a sound solid waste management system is a major factor contributing to the deterioration of the water quality in the 22 major river basins. A good case is that of Pagsanjan River Basin's tributary rivers. When rivers traverse the town centers as in the case of Majayjay, Oobi, Lumban, Camatian, and Lucban Rivers, they function as the sewers and garbage disposal site for the community.

In 1998, the LLDA conducted water sampling in Pagsanjan River during the wet season and dry season to assess the river's water quality based on the criteria set by the DENR Administrative Order (DAO) 34 Revised Water Quality Criteria for Class C waters. Their analyses revealed that the water quality of Pagsanjan River during the dry season was much better off than during the wet season. During the wet season, 6 of the 11 sampling stations failed to meet the water quality criteria in one or more parameters, while sampling during the dry season revealed only one station (Brgy. Camatian) with undesirable results. Comparing seasonal values of BOD and DO, all values obtained during the dry season were lower than those obtained during wet season presumably due to increased run-off of organic wastes from the watershed. Relative to the other major river basins, Pagsanjan River has the best water quality.

For San Cristobal River Basin, results of water quality monitoring showed that downstream sections were heavily polluted with industrial effluents and sediments. In particular, an increase in conductivity, alkalinity, chloride, hardness, BOD, chemical oxygen demand (COD) and total organic carbon (TOC) as well as phosphates and ammonia was observed from Matang-tubig (upstream) to Looc (downstream). The same trend in the water quality was observed in the case of Tanay River and other rivers monitored by LLDA, i.e., gradual increase in the levels of pollutants from upstream to downstream with most parameters failing to meet the prescribed criteria near the downstream.

For Tanay River, deterioration in water quality was more pronounced in downstream stations as indicated by the abrupt increase in the levels of conductivity, turbidity, BOD, COD, chloride, total phosphorus, ammonia-nitrogen, and total Kjeldahl nitrogen (TKN).

The same is true with Molawin River where results revealed increasing levels of BOD, conductivity, total dissolved solids, hardness, TOC, alkalinity, total and dissolved phosphates, and nitrates from upstream (Mudspring) to downstream (Kabaritan).

As in other watersheds, high BOD/COD and low DO were observed downstream because of the presence of decaying organic matter which uses up dissolved oxygen.

All of the rivers monitored failed to meet the criterion for total coliform count (TCC) of 5,000 MPN/100 ml set for Class C rivers. The annual average total coliform values were all very high and ranged from 4.64×10^6 to 22.45×10^6 MPN/100 ml during the period 1996 to 1999 (LLDA Water Quality Report).

2.4 Lake Water Quality

2.4.1 Sources of pollution and eutrophication

As of 1973, critical levels of pollution were already detected in the lake (SOGREAH 1974). About 5,000 t of nitrogen (N) were estimated to have entered the lake, 26 percent of which came from domestic sources, 36 percent from livestock and poultry, 5 percent from industrial sources, 11 percent from fertilizers, and 22 percent from the Pasig River backflow. The average nitrate concentration was 150 $\mu g\ l^{-1}$ and the total nitrogen was assumed to be between 900-1,000 $\mu g\ l^{-1}$. Inorganic phosphate was below 40 $\mu g\ l^{-1}$ and the total phosphate was below 100 $\mu g\ l^{-1}$. The focus on N was due to the initial findings that N limits algal growth in the lake. A follow-up study conducted from 1975 to 1977 also indicated that nitrogen appeared to be the most likely limiting factor which control algal growth in the complex interaction of nutrient supply, light penetration, water temperature, and lake turbidity.

The reassessment of the status of Laguna de Bay done in 1984 (BCEOM 1984) showed that nitrogen remained to be the main limiting factor in eutrophication, although there were also times when light (at times of high turbidity) and temperature (during the cooler months when blue green algae numbers were low) seemed to be limiting. It was reported that the Laguna de Bay was not yet at the final stage of eutrophication.

Due to its eutrophic character, algal bloom is a common occurrence in the lake prior to 1984 and occurred, but rarely, up to 1990. Lake-wide algal bloom of *Microcystis sp.* with concentration of up to one million algae per milliliter was recorded in 1973. Its most damaging effect in aquaculture was in 1975 (June-July), killing about 5 million milkfish (*Chanos chanos*). Localized fish kills due to the collapse and decay of blue-green algal bloom are also experienced in the lake.

Recent estimate (year 2000) generated through the use of the Laguna de Bay waste load model showed a total input of 13,800 t N yr^{-1} of which 79 percent came from domestic sources, 16.5 percent from agricultural activities, 4.5 percent from industrial effluent, and 0.5 percent from other sources.

2.4.2 Key physico-chemical parameters for water quality

Laguna de Bay has been classified as a Class C inland water (DENR 1990), which means it is suitable for fishery. Assessment of its water quality is based on the criteria for key parameters such as DO, BOD, nitrate, phosphate, dissolved solids, turbidity (or Secchi disk reading), and suspended solids.

Considering both the levels and trends of key parameters, results of water quality monitoring in the last ten years (1990-1999) show that many water quality parameters have already, either, exceeded or fallen below the criteria for Class C waters (DENR AO #34 1990) indicating the worsening condition of the lake (Figure 4). Among the parameters that have exceeded the prescribed criteria and showed upward trends were ammonia N, nitrate N, total N, ortho P, total P, COD, turbidity, conductivity, chlorides, and hardness; while those that have either fallen below the criteria and showed decreasing or erratic trends are clarity, DO, pH, and alkalinity.

For example, the average means of ammonia-N levels for West and East bays for the period 1990-1999 were both 0.27

mg l^{-1}, compared to the Class C criterion of < 0.016 mg l^{-1}, while nitrate-N showed average means of 0.36 and 0.23 mg l^{-1}, respectively, *vs*. the criterion of < 0.3 mg l^{-1}. Similarly, inorganic P (orthophosphate) showed average mean of 0.12 mg l^{-1} in West bay which is 12 times the Class C criterion of 0.01 mg l^{-1}. Inorganic P in 1997 averaged 0.21 mg l^{-1} in West bay.

Dissolved oxygen for the decade 1990-1999 registered average means of 7.6 and 7.4 mg l^{-1} in West bay and East bay, respectively. While these averages are above the criterion of 5 mg l^{-1}, lower values were observed in 1996 especially in the lake bottom. Moreover, the values reported were daytime values reflecting the effect of photosynthesis, and do not reflect the diurnal fluctuation which tends to show lower values toward daybreak.

Likewise, chlorides and COD show alarming upward trends. In 1998, chloride registered annual means of 1,165 and 664 mg l^{-1} in West and East bays, respectively, (which are way above the criterion of 350 mg l^{-1} for Class C Inland Waters) and average means of 437 and 227 mg l^{-1}, respectively, for the last decade, 1990 to 1999. COD also registered the highest annual means in 1998 of 62 and 34 mg l^{-1} in West and East bays, respectively, and average means of 39 and 24 mg l^{-1}, respectively, for the last decade, indicating presence of increasing amounts of oxygen demanding substances, both organic and inorganic.

On the other hand, clarity or secchi disc (SD) readings manifested a decreasing trend up to mid 1997 and in 1996 registered a low annual mean of 21.7 cm for the entire lake compared to the criterion of not less than 100 cm for Class C waters. In fact, SD readings of 10 cm and below were observed in the lake during the dry season from 1986 to 1997. This is quite disturbing because SD is an intensity parameter whose impact depends on its temporal or ambient level more than the annual mean. For the period 1990-1999, the average means for West and East bays are 42 and 40 cm, respectively. During the last ten years, it was only in 1998 when SD readings higher than 100 cm were observed. In that year, an annual mean of 78 cm was registered in West bay. The reason for this was the high level of saline water that entered the lake in that year as indicated by the high chloride levels observed (i.e., mean of 1,165 mg l^{-1} in 1998). But while saline water will increase water transparency, high sodium and chloride contents would be harmful relative to the use of water for domestic and irrigation purposes.

The lake's temperature is just like any other tropical lake that cools in the wet season and warms up in the dry season. The mean seasonal difference is about 6-9ºC, while bottom temperature is about 0.5ºC lower that the surface water temperature. For the decade under review, the average mean temperatures vary narrowly with values 28.7 ± 2.0ºC and 28.0 ± 2.0ºC for West and East bays, respectively. Its trend indicates that while the mean average varies narrowly, the variation between the minimum and maximum temperatures widens during the last 14 years.

In the meantime, the range of values of pH for the past decade seemingly indicates that the lake is a well-buffered body of water with average means of 7.9 ± 0.4 in East bay and 8.3 ± 0.6 in West bay. Lastly, alkalinity has shown an erratic behavior, but generally on the downtrend. 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 as acid rain.

The observed levels of the above parameters alone, which have all exceeded the prescribed criteria for Class C Inland Waters, are enough to see the advanced state of eutrophication and pollution of the lake.

Assessment of the trophic status of the lake using recognized method of trophic assessment and based on key water quality parameters as indicators of trophic state showed that Laguna de Bay is already exhibiting most of the signs and characteristics of an extreme trophic or dystrophic lake (Barril et al. 2002). The levels and trends of water quality parameters such as COD (BOD), chloride, conductivity, hardness, which are on the uptrend, further indicate the advanced age of the lake. Yet, an interesting trend in pH has been noted which show levels higher than the prescribed upper limit of 8.5, especially during recent years (1997-1999) when pH above 9.5 was observed (Rosana et al. 1997; LLDA 1997-1999). Is the lake becoming alkalitrophic which is a type of dystrophic lake?

However, data obtained by LLDA from its regular monthly monitoring of different stations in the lake from 1990 to 1999 showed some parameters, i.e., BOD, NO_3, and DO still within the water quality criteria for Class C water. But, PO_4 concentration exceeded the maximum limit in 1997, which was an El Niño year (Figure 5).

Analysis of heavy metals in water, sediments, and biota of Laguna de Bay showed levels of heavy metals exceeding prescribed criteria for Class C waters. These include cadmium (Cd), copper (Cu), and lead (Pb) (LLDA 1996-1998; Madamba et al. UPLB 1994, 1995, 1997).

While reports of various investigators showed varying levels of heavy metals such as Cd, chromium (Cr^{+6}), Pb, Cu, iron (Fe), nickel (Ni), and zinc (Zn) in the lake water, the analysis done by LLDA (1999) showed low levels of Cd, Cr, and Pb with concentration below the set criteria of 0.01, 0.05, and 0.05 mg l^{-1}, respectively. Pb and Ni were below the detection limit while Zn concentration ranges from 0.10 to 0.3 mg l^{-1}. The concentration of Fe is normally high at an average of

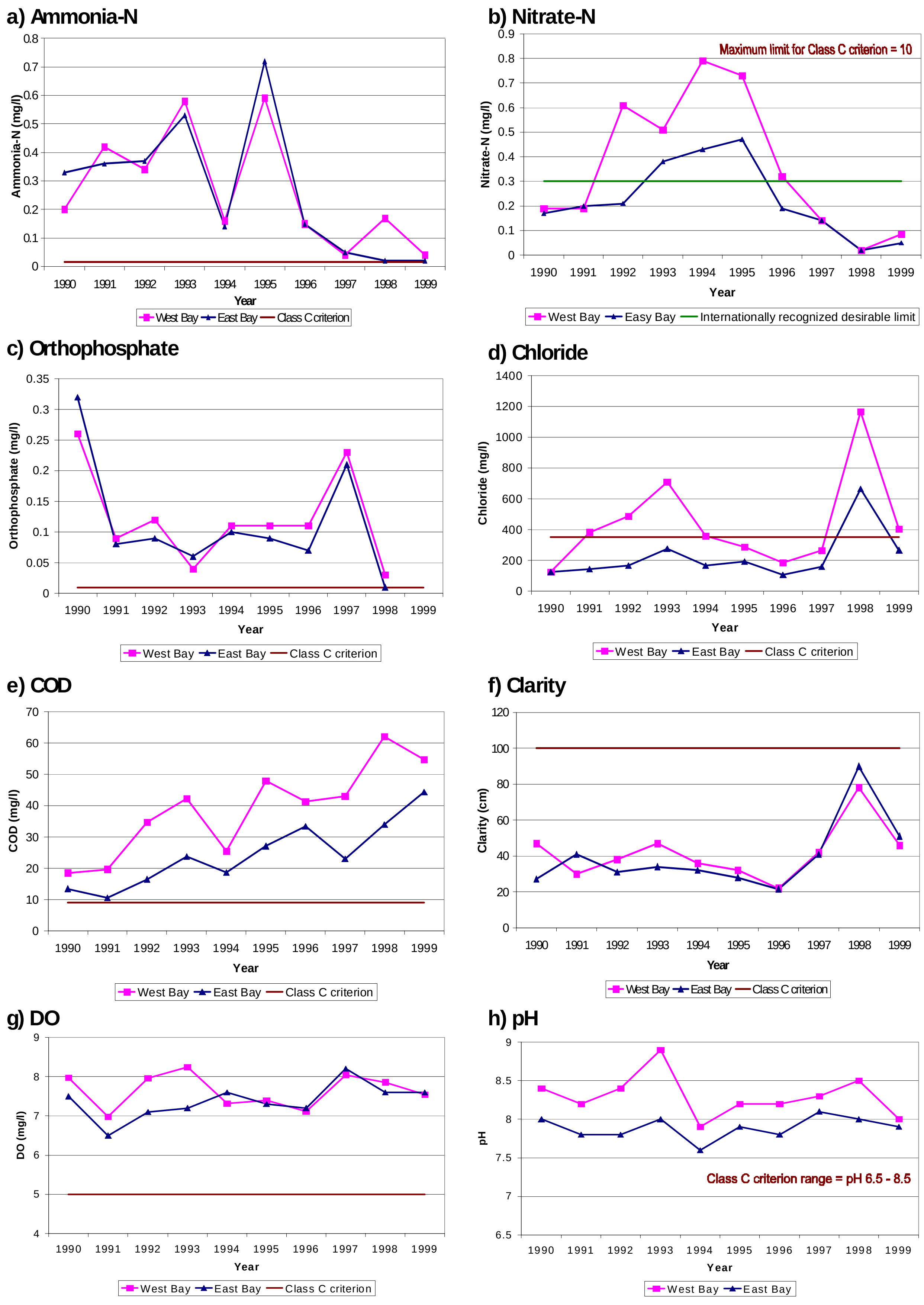

Figure 4. Concentrations of selected water quality parameters in the Laguna Lake, 1990-1999. These parameters have either exceeded or fallen below the criteria for Class C waters (Note: Barril's data = 1990-1996; LLDA data = 1997-1999).

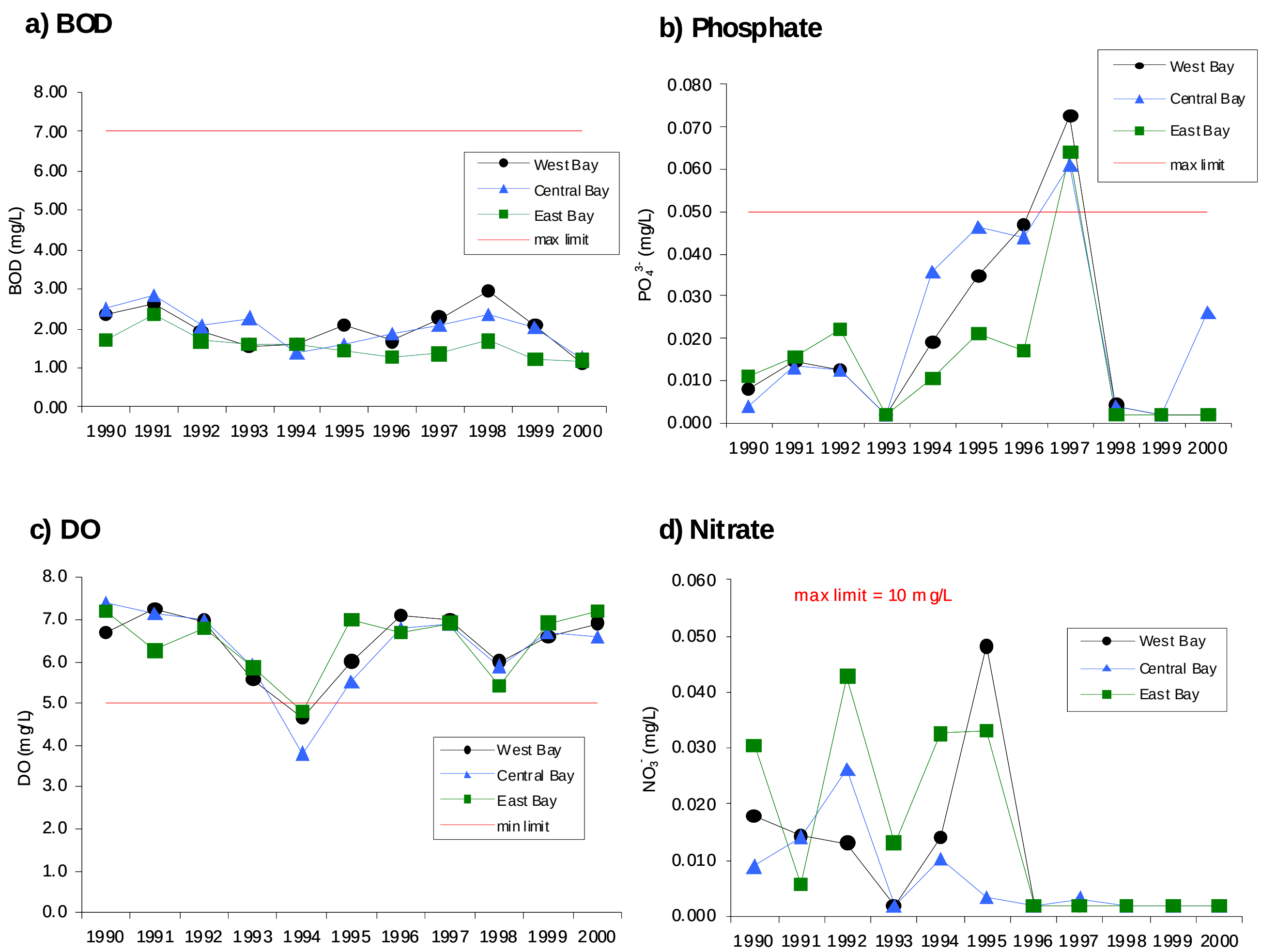

Figure 5. Biochemical oxygen demand, phosphate, dissolved oxygen, and nitrate concentrations in Laguna Lake from 1990 to 2000. These water quality parameters met the criteria for Class C water (Source: LLDA).

1.986 mg l^{-1}. Preliminary studies (NEDO, LLDA, JEMAI 2000) showed that the level of arsenic (As) in the lake ranged from 0.022 to 0.030 mg l^{-1} as compared to the criteria of 0.05 mg l^{-1}.

Heavy metal concentrations in the sediments of the lake are very low (LLDA 1999) except for Ni which has concentrations in the range of 2 to 12 times the average shale values. The lake's overall pollution levels derived from the sediment data can still be described as very low, corresponding to I_{geo} 0 to 2. This is interpreted as unpolluted to moderately polluted (NIGS 1999). On the other hand, studies conducted by UPLB Institute of Chemistry (Madamba et al. UPLB 1994, 1995, 1997; Barril 1998) showed concentration of metals in the sediment samples taken from different parts of Laguna de Bay at generally about 1,000 times greater than the concentrations in the water samples. This is due to the adsorption of the metals in suspended particulates or colloids which eventually settle to form the sediment.

Levels of Cr, Cd, Cu, and Zn were found in the edible portion of different fish species caught in Laguna Lake, but their concentrations were the lowest compared to those in the other parts of the fish. Higher values were observed in the inedible portion and in the entrails. Cu and Zn levels were highest in the entrails, while Cr, Cd, and Pb were highest in the inedible portion.

Analysis of chemical organic pollutants in water and sediment samples from Laguna de Bay (Barril 1998) showed presence of some polyaromatic hydrocarbons (PAHs). The levels of COD in water and oil and grease in sediments were also reported as indicator or harbinger of organic pollutants. Meanwhile, the presence of toxic and hazardous chemicals such as pesticides and other industrial persistent organic chemicals have been indicated in fish and other biota but have not been adequately assessed.

At this point, still very little is known on the extent of pollution in terms of the levels of toxic and hazardous substances such as heavy metals, polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), etc. in the water, sediments, and biota. The removal of these toxicants certainly presents a major problem for the water treatment process, if ever the water will be used for domestic supply.

The implication of the presence of heavy metals and other toxic substances on water, lake sediment, and biota is of grave concern to human health, particularly among consumers of fish and other products. However, this remains a gap in the current knowledge about the Laguna de Bay ecosystem.

2.4.3 Key biological parameters for water quality

2.4.3.1 Total coliform count

Results of LLDA monitoring of the seven (7) major tributaries, particularly from 1996 to 1999 showed that all of the rivers monitored failed to meet the criterion for TCC of 5,000 MPN/100 ml set for Class C rivers. The annual average total coliform values were all very high and ranged from 4.64 x 10^6 to 22.45 x 10^6 MPN/100 ml. Since most of the waters in the lake come from these rivers, the TCC for the lake must also exceed the Class C criterion for surface waters.

Coliform counts of 1.25 million MPN/100 ml in 1985 (Zamora 1986) and 44 million MPN/100 ml in 1993 (DENR-LLDA, Philippine Environmental Quality Report 1990-1995) have been recorded in the lake. This is attributed to the lack of sewerage system in the drainage basin and where most households along the lakeshore communities do not have toilets.

The 1996-1999 water quality report of LLDA, however, stated that total coliform levels in the lake were less than the limit of 5,000 MPN/100 ml for Class C water (intended for fishery). This drastic decline is quite inconsistent with the above observations and must be verified for accuracy.

2.4.3.2 Algal biomass

This biological parameter is an indicator of the amount of plant food available to the herbivores in the food chain. Representing plant matter of algal origin, it can be estimated based on chlorophyll a (chl a), the pigment universally present in autotrophs. Algal biomass does not necessarily correlate with net primary productivity (NPP). The chl a range for eutrophic waters is 10-100 ìg l^{-1}.

The LLDA in the 1970s to 1980s used the wet weight as a measure of algal biomass. The measure is not accurate because of extraneous materials included during weighing including water. According to Zafaralla (n.d.), wet weight may be transformed into chl a using certain assumptions. The procedure yields results that may be compared with known values descriptive of trophic classification. The values extracted in this way showed that West bay was generally eutrophic from 1974 to 1988 with chl a concentration generally about 10 ìg l^{-1}.

Pigment level fluctuations through the period 1974 to 1988 gave some ideas about the possible impacts of some development projects on the amount of the natural food for the fish in the lake. In 1980 an episodic high in algal biomass occurred which was followed by a downward course toward a historic low realized in 1985 until 1988. In that period, West bay deteriorated into a dystrophic state, or one in which the lake's ability for algal production deteriorates even in the presence of elevated levels of plant nutrients. In other words, phytoplankton in dystrophic waters do not express their full potential in producing organic matter even under high nutrient levels. This trend of the 1980s are substantiated by the results of localized studies, like those done in Mayondon, Los Baños where chl a had an annual mean of a low 7.64 ìg l^{-1}.

Data on algal biomass also provide some clues about how one bay compares with another in Laguna de Bay. Central bay was shown by pigment levels to have been eutrophic like West bay in the early 1970s. However, in the course of time, its algal production deteriorated ahead of West bay. Algal biomass in Central bay abruptly fell in the 1970s as the practice of fishpen aquaculture spread in the lake. By 1981, the bay was three years advanced in dystrophication vis-à-vis West bay. This less productive state continued over a long period of seven years, i.e., until 1988.

Was there any development project involving water use that was underway when lake primary production deteriorated? The NHCS was constructed in 1977-1982 and was operated for a short period in 1983 (Santos-Borja 1993). It is interesting to note that the collapse and eventual downtrend in algal biomass production began while this dam was being constructed, and continued even after it was opened in 1983. There was no dependent relationship between photosynthesis and salinity based on the LLDA data according to Charlton (1993). But from the episode of an unprecedented coincidence of ecosystem function deterioration and water-use development project implementation, some clues should emerge about the lake ecosystem's vulnerability, and serve as a valuable guide to lake resources management.

The LLDA began measuring algal biomass in terms of chl a in 1998. In the overall, it found a recovered lake with the annual means ranging from roughly 30 to 34 ìg l^{-1}. Shoreline areas, however, tend to have wider ranges as a result of dumping by wind action. Zafaralla and Mercado (n.d.) noted a range of 12-54 ìg l^{-1} in 1998, and 5-119 ìg l^{-1} in 1999. Like NPP, pigment levels also reveal a spatial differentiation in the lake. In 1998, the LLDA data showed Central bay to have the highest biomass that was about 11 percent higher than West bay. The latter bay equaled the primary production of Central bay only in the dry season. South bay was the least productive. Biomass levels in the lake do change from year to year. In 1999, East bay turned out to be the most productive (Figure 6).

2.4.3.3 Net primary productivity

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 waters are photosynthesizing or manufacturing natural food for fish. The range of values for eutrophic waters is 150-500 g C m^{-2} yr^{-1} or 0.3-3 g C m^{-2} day^{-1} (Rodhe 1969). Eutrophic waters are characterized by: a) levels of the nutrients nitrogen and phosphorus way above that which is sufficient for algal growth; b) high turbidity or low light transparency due to the dense growth of phytoplankton; c) massive growth of algae; and d) recurrent fish kills.

In 1976, the SOGREAH reported an average NPP of 0.53 g C m^{-2} day^{-1}. The value implies that way back in the early 1970s, when fishpen aquaculture was in its infancy, the lake was slightly eutrophic. By the 1980s, productivity underwent phenomenal improvement to a range of 3-8 g C m^{-2} day^{-1} with a mean of 2.1 g C m^{-2} day^{-1} which, by Rodhe's (1969) scale, implies high productivity or that the lake was already highly eutrophic. The values of Nielsen (1983), it must be noted, were obtained using the more exact but less affordable method employing labeled carbon or ^{14}C.

For the period 1990-1998, the LLDA data indicated that the wet period had a higher NPP than the dry (1.35 vs. 0.90 g C m^{-2} day^{-1}), or that eutrophication was low in the wet but slight in the dry. In the lake, tilapia (*Oreochromis sp.*) usually develops a tainted taste from July to September. Such time is when algal blooms usually develop. This means that in general, algae in the lake are abundant because of a high rate of photosynthesis or high NPP during the same period of the year. The 9-year average was 1.123 g C m^{-2} day^{-1} indicative of low eutrophication.

The 9-year LLDA data also showed a spatial differentiation of the lake with West bay and Central bay having a low eutrophic status at 1.46 g C m^{-2} day^{-1} and 1.12 g C m^{-2} day^{-1}, respectively, and East bay slightly eutrophic at 0.76 g C m^{-2} day^{-1}.

The above values for the three bays indicate that Laguna de Bay, in general, compared with what it was in the 1980s when the NPP easily exceeded 3 g C m^{-2} day^{-1}, has deteriorated into a less productive body of water. The trend is definitely toward deterioration, rather than improvement to the mesotrophic status, because other important parameters

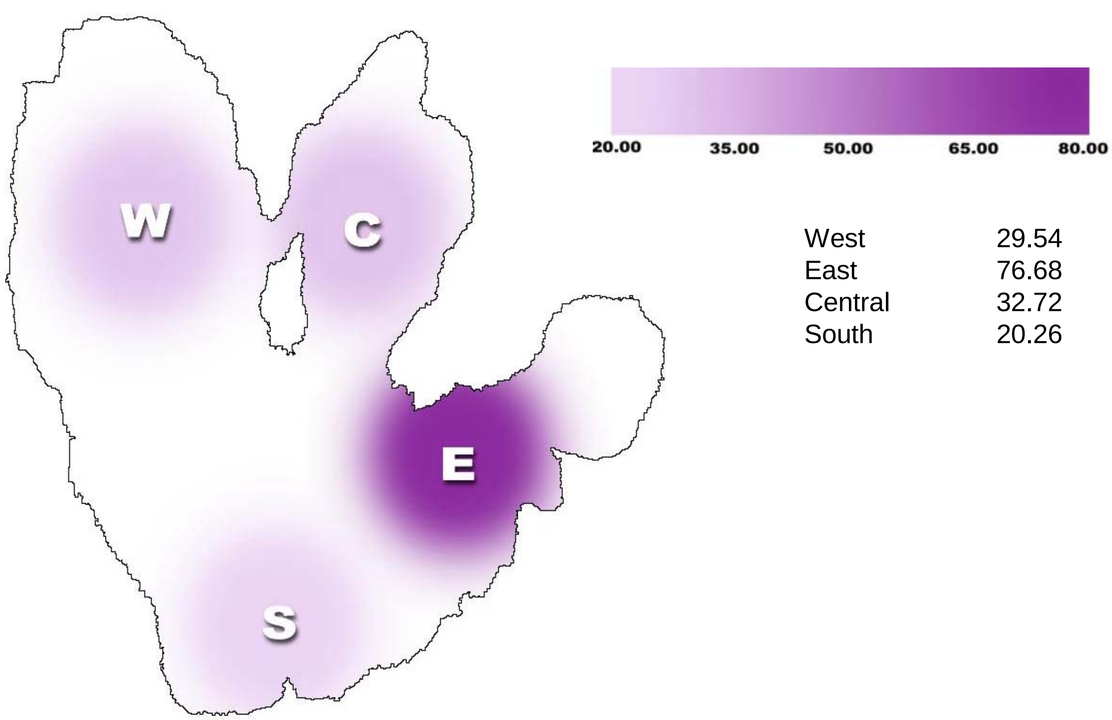

Figure 6. Chlorophyll a levels (ìg l^{-1}) in Laguna de Bay, 1999.

like the secchi disk transparency, ortho-P, and total P levels converge at a point in the lake's history which showed it had a worsened water quality. The layman sees the evidence to this deteriorated state in the perennially turbid, noxious lake waters.

Micro-scale studies by Zafaralla and Mercado (unpublished data) tend to show that NPP in the Putatan area of West bay may reach up to 9.22 g C m^{-2} day^{-1} in the dry, decline to 1.36 g C m^{-2} day^{-1} in the beginning of the wet season, diminish further to 0.78 g C m^{-2} day^{-1} in the middle of the same, then improve in the cool months. There was no statistically significant correlation between NPP and turbidity, nor between NPP and algal biomass, but NPP was found correlated with ortho-P, meaning there could be a common factor influencing their relationship. Their relationship, however, is not one of dependence on each other. Indeed, in the lake, differences are to be expected as regards the values of biological parameters, and some chemical parameters, depending on the time and place of sampling.

3. Ecosystem Services: Conditions and Trends

3.1 Lake as Source of Water Supply

The Laguna Lake, with its ideal location and being the largest freshwater lake in the Philippines, is a vital natural resource (Francisco 1993). There are a number of uses for the lake. The dominant use of the lake is fisheries. Its other uses are for navigation, temporary storage of floodwater, hydroelectric power generation, source of irrigation, and domestic water supply as well as recreation.

While many of the uses of the Laguna Lake are dependent on water quality, they also contribute to the lake's water quality problem (Francisco 1993). The observed levels of water quality parameters confirmed the present condition of the lake as a heavily polluted and highly stressed aquatic ecosystem. This has significantly diminished the uses of the lake as a resource for potable water, recreational activities, tourism, etc.

Meanwhile, the San Cristobal River and its basin provide important functions and amenities to the western part of Laguna. These are: a) as a source of domestic potable water (upper stream only) to more than 200,000 inhabitants in the communities of Cabuyao, Sta Rosa, and Biñan; b) as a source of industrial water to the commercial establishments and factories situated inside the light industrial park in Calamba; and c) as a source of irrigation water downstream for the NIA service areas. It generally represents a typical agro-industrial setting which if properly and scientifically managed could serve as a model for development for other basins with similar or potential characteristics. At present, this tandem of agricultural development in the uplands and industrial development in the lowlands has produced undesirable consequences to the site. A recurrent example of this includes the drying up of ephemeral streams in summer and the occurrence of flash floods during typhoon seasons.

The common source of water in the Laguna Lake region is groundwater. However, due to the rapid increase in population together with the over pumping of water, the reliability of groundwater to supply future water needs is doubtful. This is further aggravated by groundwater contamination caused by leachate coming from dumpsites, septic tanks, etc. At present the lake is being considered as a possible source of domestic water in the region. For this purpose, studies on the dredging of heavily silted lake water are being undertaken. This will establish the feasibility, methodology, and benefits of removing contaminants of lake water.

3.2 Lake as People's Source of Protein and Daily Livelihood

Fisheries is one of the most important traditional uses of Laguna de Bay.

A total of 33 species of fish have been reported to have thrived in the lake at different times consisting of 14 indigenous, 5 of which are migratory, and 19 introduced or exotic.

There are 3,055 fishermen operating in the lake. Full time fishermen comprised 51.4 percent, while 48.6 percent are part time fishermen. Eighty percent of the total fishermen own boats, which are either motorized or non-motorized. Moreover, twenty types of fishing gears are used in the lake, of which 65 percent are categorized as active and 35 percent as passive.

Fishery activities in the lake consist of open water capture fisheries and aquaculture. Production from capture fisheries comes mainly from the operation of seven important fishing gears (gill net, fish corrals, motorized-push net, fyke net, fish trap, fish pot, long line/manual seine fish shelter); while aquaculture production comes from fishpens and fish cages.

Over the years, change in the species composition and relative abundance of fishes in the open waters was observed. In the early 60s up to the 70s, the main bulk of the catch is composed of Silver perch (*Leiopotherapon plumbeus*) and White goby (*Glossogobius giurus*) comprising more than 30 percent of the total catch. In the 1990s, tilapia comprised the major catch, while in 1995-1996. Tilapia and Bighead carp (*Aristichthys nobilis*) dominated the catch. In the year 2000, there has been an alarming increase in the number of Janitor fish (*Hypostomus plecostomus*) in the catch composition from open waters.

Fish production from open waters fluctuated between 1963 to 1996 but showed an overall declining trend at an annual average rate of 2.93 percent over the 33-year period. The lowest production was noted in 1994 at 1,691 t. Meanwhile, production from aquaculture has fluctuated within the 23-year period (1980-2002). The highest production (86,000 t) was recorded in 1984 at the peak of the fishpen operation and lowest in 1988. In general, the total fish production from the lake has declined by 64 percent from 1980 to 1996 (Figure 7). The highest production was recorded in 1984 at 115,891 t, which coincided with the peak of the fishpen operation (Figure 8).

The combined fisheries production from open water capture fisheries and aquaculture used to provide more than two-thirds of the freshwater fish requirement of Metro Manila and adjoining provinces (Borja 1993), but present production could only supply 18 percent of the total fish requirement of the basin population. Moreover, due to the decrease in the lake productivity, the number of fishermen was reduced by 50.7 percent over a 37-year period (1963-1995). They have also remained in marginalized condition, and there is a need for a viable alternative or supplemental livelihood to alleviate their plight.

Laguna de Bay is extensively used for aquaculture in the form of fishpen and fish cages. The success of the early operation of fishpens was attributed to the abundance of natural food, the absence of true plankton feeder among the indigenous economic species of the lake, and the favorable water quality. During the early stage of fishpen operation, milkfish production from the fishpen produced an annual yield ranging from 4-10 t ha^{-1}.

The high profitability of fishpen culture has led to the unregulated proliferation of fishpens in all parts of the lake reaching its peak in 1984 with a total area of 510 km^2. The condition caused an intense social conflict in the lake between the open fishermen and fishpen operators. The fishermen asserted that the dominance of fishpen in the lake has adversely affected their livelihood, reducing their area for open fishing and blocking navigational lanes. The clashes between operators and fishermen became violent, and the government through the LLDA stepped in. A lake zoning map (ZOMAP) evolved which designated areas for fishpen belt, fish sanctuary, navigational lanes, and open fishing areas. As a result, area for fishpen was drastically reduced beginning 1989 and is being sustained to the present 150 km^2 fishpen belt designated by the ZOMAP.

The fisheries of Laguna de Bay have been affected by human, industrial, and environmental factors which resulted to the significant decline both in production and species diversity. Among the drivers of changes in the open water capture fisheries and aquaculture were:

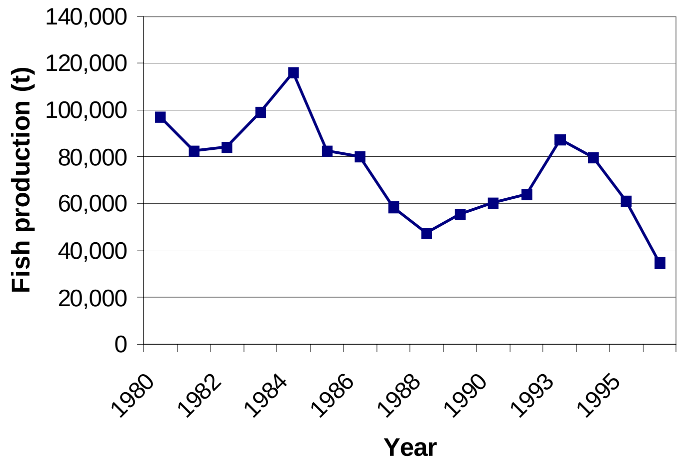

Figure 7. Total fish production, 1980-1996.

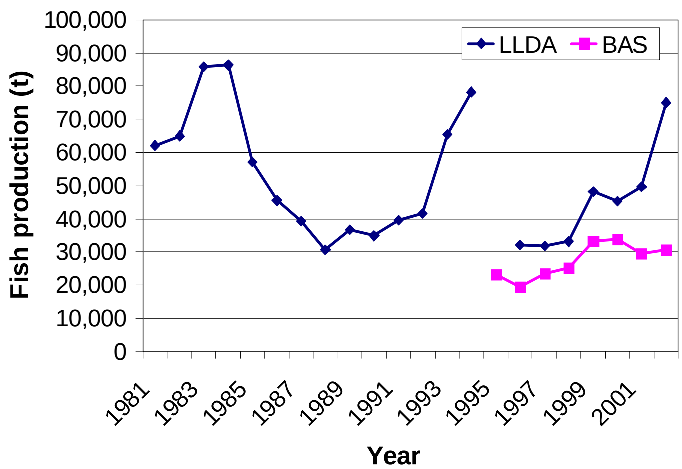

Figure 8. Fish production from aquaculture, 1981-2002.

1. Operation of the NHCS in 1983 prevented the inflow of seawater that played a vital role in the natural primary productivity. Primary productivity of the lake ranged from 2-8 g C m^{-2} day^{-1} prior to the operation of the hydraulic control structure which dropped to 0.79 g C m^{-2} day^{-1} after its operation. The hydraulic control structure also served as a physical barrier in the migration route of marine species entering the lake, hence the reduction of migratory fishes.

2. There is a strong correlation between algal primary productivity and fish production. Estimated algal productivity from 1820 to 1974 ranged from 221 t ha^{-1} yr^{-1} to 406 t ha^{-1} yr^{-1}. These values declined considerably from 46 t ha^{-1} yr^{-1} to 153 t ha^{-1} yr^{-1} in 1978 to date.

   The high algal productivity in 1980 was attributed to the bloom of *Microcystis* which also coincided with the proliferation of fishpens in the lake. The same algal bloom has caused massive fish kills in 1972, 1973, 1975, and 1977.

3. Nineteen species were introduced in the lake either intentional for fishery enhancement or accidental due to escapement from aquaculture. Of these species, the Thai catfish (*Clarias batrachus*) and the janitor fish have adversely affected the lake fisheries.

   The Thai catfish has caused the disappearance of the native catfish either due to niche displacement or introgression. The janitor fish, on the other hand, has created destruction in the lake's physical environment due to its boring breeding behavior and posed a threat to the food web due to its benthic foraging habit.

   The rest of the exotic fishes have contributed significantly to fish production.

4. The use of destructive fishing gears has destroyed the breeding and feeding areas of fish resulting to the decline in production.

5. The establishment of fishpens and fish cages has both positive and negative impacts. Pen and cage cultures have increased production from aquaculture. The escapement of fishes from the net enclosures provided indirect stocking which enhanced open water fisheries. The pen structure provided sanctuary to the kanduli (*Arius sp.*) which led to the recovery of its natural population.

   Pen and cage structures significantly reduced the area for open water capture fisheries resulting to conflicts between fishpen operators and sustenance fishermen. The structures also blocked navigation routes and served as trap for silt particles and macrophytes hindering water circulation

6. Domestic and industrial pollution have contributed to the rapid deterioration of water quality. Fishpen and fish cages also contributed to pollution through direct loading of nutrients from unassimilated food and metabolic wastes. The high levels of phosphate and nitrogen trigger the occurrence of algal bloom resulting either to fish kills or the off-flavor taste of the fishes.

7. Bad weather conditions and the occurrence of typhoons posed direct threat to aquaculture resulting to the destruction of the pen structures and the escapement of the cultured stocks.

3.3 Rice Growing on the Shorelands

Rice is the major agricultural product of the LLB covering 380 km^2 of land. It is cultivated on the mountain slopes as "upland rice". This type of cultivation occupies small spotty areas and the harvest is mainly for home consumption. Rice is also cultivated along the river tributaries and these are mostly "irrigated rice". These ricefields are not affected by the water level of the lake.

The shoreline of the LLB is 220 km. Ricefields on the lakeshore particularly on the southern and eastern sides of Laguna de Bay consist of 136.37 km^2, of which 68.75 km^2 or 50 percent is in the province of Laguna. The shoreland areas are the major areas affected by the water level of the lake. The area of the ricefields varies from year to year depending on the pattern of water withdrawal and the water level. These areas are also irrigated usually by small rivers flowing into the lake.

The lakeshore land is located in different areas along the Laguna de Bay. The shoreland area is estimated to be around 139 km^2 the majority of which is cultivated during the summer season when lakewater level decreases from the regular 12.5 m elevation in the rainy season to 10.5 m during the dry months of the year. Around 57 km^2 of shoreland is planted to rice, and small patches of shorelands are cultivated to various crops such as squash, melons, pole beans, and loofah. At an average yield of 4.1 t ha^{-1} of palay, the area can supply about 11,400 t of milled rice or about 2 percent of the total rice requirement in the basin. At the basin level, 34 percent of the rice requirement within the basin can be supplied within the area.

Rice production in the lakeshore is primarily affected by various factors such as crop yield, area for cropping, nutrient and pesticide management, occurrence of typhoons, and timing of planting (Figure 9). Crop yield is affected by lakewater pollution as irrigation water mainly comes from the lake. Area for cropping however is a serious concern as more and more lakeshore lands are converted to uses other than rice growing. For example, drawdown areas are cultivated with vegetables and other cash crops, like cutflowers. Other areas are also converted to settlement or resettlement areas, or even illegal dumpsites. Occasional flooding which consequently affects water level is also decreasing the area for rice. Lake level modification which is expected to occur with the construction of infrastructures along the lakeshore is estimated to adversely affect the areas traditionally cultivated with rice. This is especially the case in some areas in Laguna where farmers fear that the construction of a viaduct will cause the lake water to rise above the normal level. While there is an expected decline of rice production along the lakeshores, the development of industries around the area and the growing population increase the demand for rice. To meet this demand and to secure availability of rice for domestic consumption, there is a need to find ways to increase crop yield through efficient nutrient and pest management and use of improved variety of rice at the farm level, as well as to find alternative livelihood for the traditional farming communities.

In view of this, DENR and LLDA issued administrative orders and resolutions governing the use and occupancy of these areas. Under these rules, the LLDA issued Shoreland Occupancy Permits to qualified applicants for lease of untitled shoreland areas, subject to the terms and conditions under Board Resolution (BR) No. 23, Series of 1996 as amended by BR 113, Series of 1999. After seven years of implementation of the policies and regulations, the LLDA is still faced with a number of implementation issues: i) development activities have overtaken regulation and control; ii) existing policy tools are ineffective for shoreland restoration and environmental regulation; iii) inadequate resources to monitor shoreland activities and enforce regulations; and (iv) indifference of and blatant disregard of some lakeshore local government units of environmental regulations and requirements.

3.4 Biodiversity of the Laguna de Bay Region: A Basin and a Global Ecological Service

The popularity of biodiversity over the last few decades has risen largely from the increasing public and worldwide interest and concern over environmental issues relating to our terrestrial, aquatic, and marine ecosystems. The increasing demand for precious biological resources by expanding human populations has resulted to the conversion of many natural habitats to other uses and placed hundreds of species to the brink of extinction.

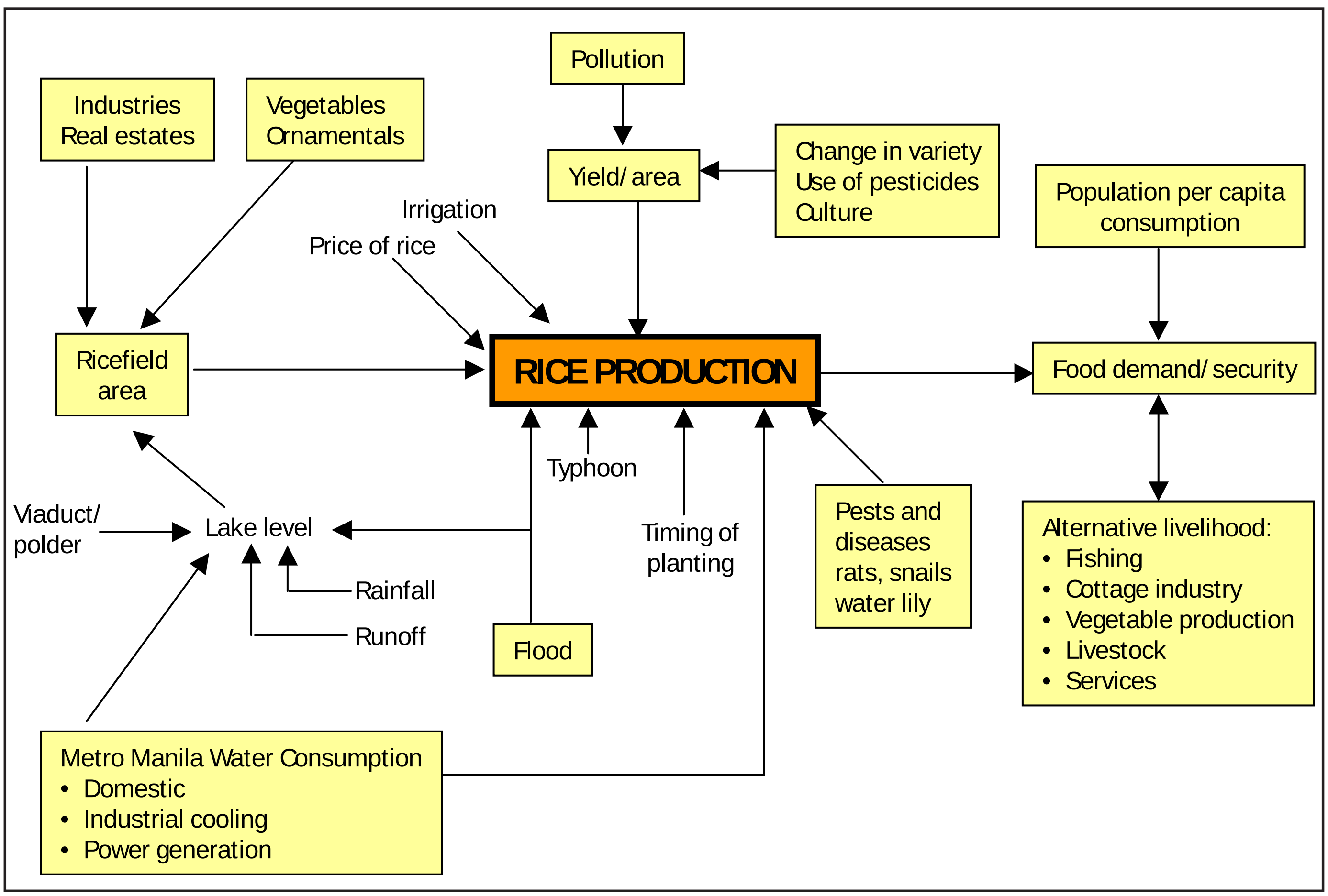

Figure 9. Factors influencing the rice production in the lakeshore areas.

The Philippines is one of the world's mega diverse countries. The country has approximately 13,500 plant species and 24,000 animal species that have been documented so far, of which more than 50 percent are endemic (The State of Philippine Biodiversity n.d.). It is also considered as biodiversity hottest hotspot due to a large number of species facing threats, rarity, or extinction. The LLB is not an exemption to this. However, the continuing lack of recent data and information on the biodiversity of LLB, especially for many taxonomic groups, including plants, algae, insects, and other arthropods limited the scope and level of knowledge of this assessment.

In the Laguna Lake Basin, six specific areas have been recently included as biodiversity priority areas in the Philippines: the lake itself, the Pakil and Real area, Pasig River, Tadlak Lake, Mt. Makiling, and the Mt. Banahaw-San Cristobal complex. These ranked from very high (e.g., Pakil and Real) to extremely high critical (e.g., Mt. Makiling) in priority level.

One important forest resource within the watershed is the 42.44-km^2 Makiling Forest Reserve (MFR). Mt. Makiling is one of the Philippines' 18 centers of plant diversity (Cox 1988; Madulid 1993; DENR-UNEP 1997) and the country's best known biological area owing much to its long scientific history (Pancho 1983). It provides areas for education, training, and recreation for students and professionals. As a natural resource, the MFR is very vital to the region, providing irrigation and industrial and domestic water supply to the surrounding communities. The reserve acts as an important catchment area for the lake while Mt. Banahaw and Mt. Makiling as a whole helps in the generation of electric power through the Mt. Makiling-Banahaw Geothermal Power Plant. Also, the Mt. Banahaw-San Cristobal Complex serves as a religious place for many sects in the Philippines. Pilgrims trek the mountain during the Lenten Season.

An estimated 155 families, 863 genera, and 2,313 species of vascular plants have been recorded from the Laguna Lake Basin. About 64 percent of the species are Philippine endemics. The lake basin is considerably rich containing more than 31 percent of all species in the Philippines and 44 percent of the species occurring in Luzon. About 48 percent of the Philippine endemic species are found within the lake basin. However, four species of plants in the lake basin are regarded as rare and threatened.

The basin is also known to hold 15 species of globally threatened birds; 21 species of birds of very restricted ranges (breeding range of less than 5 M ha); and congregatory water birds representing at least 10 percent of the Asian population. This assemblage constitute about half of all threatened species of birds and restricted range species which are known to occur in the Luzon biogeographic region.

Relatively the mammalian fauna of the Laguna Lake Basin as a whole is not as impressive as that of other Southeast Asian marshlands. There are no large herbivores or carnivores that dwell on this lake basin. The largest of mammals found in the vicinity of this lake are the Philippine Deer (*Cervus marianus*) and the Philippine Warty Pig (*Sus philippensis*), which are found in Mt. Makiling and Mt. Banahaw protected areas. However, the most diverse of mammalian group are the bats and rodents. Of the total 42 species of mammals recorded in the lake basin, more than half (57 percent) are bats (24 species) and 26 percent are rodents (11 species).

A number of mammals in the vicinity of Laguna Lake have also been reported pests to agricultural crops. These include bats, rats, and civet cats. On the other hand, there are also insectivorous mammals that are beneficial to farmers, which include the Common House Shrew (*Suncus murinus*) and bats belonging to the various genera such as Hipposideros, Miniopterus, Myotis, Rhinolophus, and Tylonycteris. These bats feed on insects that infest crops, such as rice, corn, coconuts, and fruit trees, such as mangoes, oranges, pomelo, and others.

A total of 52 species of reptiles have been recorded in Laguna Lake Basin. The majority of them are endemic (27 species), 23 species are residents, one introduced species, and one extirpated species. Meanwhile, a total of 25 species of Anuran Amphibians have been recorded in Laguna de Bay and the surrounding watershed areas. These consisted of three (3) species that were introduced, seven (7) species considered resident, and fifteen (15) species endemic to the Philippines. The diversity of frogs in this particular area is very high, and it is considered a separate biodiversity area for amphibians and reptiles.

The diversity of the indigenous fish, crustacean, and mollusk species in the lake has considerably declined since the late 1950s, while the number of alien species being introduced into the lake continues to increase. The introduction of Golden Snail (*Pomacea canaliculata*) into the country has become a serious environmental problem. The species is now a major pest in ricefields in the lake basin and across the whole of Luzon Island. It has now replaced *Pila conica* the dominant pilid snail in Philippine fresh waters and is seriously threatening *Pila luzonica*, previously common in the lake.

The introduction of exotic species, the destructive harvesting methods, chemical pollution from adjacent factories, and overall industrialization will hasten the conversion of natural habitats and the extirpation of many of the indigenous species in the lake basin. In addition, over extraction and reduction of habitats of the wild flora and fauna continue to pose threats to the indigenous biodiversity of the basin.

3.5 Laguna Lake Basin as a Carbon Sink

Climate change is one of the most alarming problems facing humanity today. As scientists and policy makers at the global arena grapple with this issue, developing countries are also sorting out the implication of climatic shifts to their people, economy, and environment.

The Laguna Lake Basin is basically an agricultural area. As of 2000, agricultural land utilization covers about 1,509.66 km^2 or 40 percent of the watershed's total land area of 3,813.2 km^2. Greenhouse gas (GHG) inventory of the Laguna Lake Basin showed that the agricultural sector contributed 1,298 kt of greenhouse gases to the atmosphere in the year 2000. The sources of emission include domestic livestock, ricefields, grassland burning, burning of agricultural residues, and agricultural soils. Among these sectors, domestic livestock accounts for the largest contributor of CO_2 emissions while the lowest is that from grassland burning.

The basin's forest lands occupy 730 km^2 of which only 190 km^2 are actually covered with forests, while the rest (540 km^2) are mainly denuded lands with grass and annual crops. Biomass growth in the LLB resulted to the sequestration of more than 2,000 kt of CO_2 from the atmosphere, about 3 percent of the nation's total removals by sink based on the 1994 GHG inventory.

However, the LLB is a net source of GHG, emitting about 924 kt CO_2-equivalent in the year 2000. This can be attributed to the high fuel wood consumption by the residents of the basin (0.46 m^3) which negated the amount of carbon sequestered by the growth of trees. In addition, burning and decay contributed to GHG emission in the basin. This is primarily due to clearing of forests for agricultural purposes.

In contrast, national GHG inventories show that the Philippines as a whole is a slight to a huge net sink of carbon. This implies that something must be done in the LLB to either decrease emissions and/or enhance removals to enable to mitigate climate change.

Key mitigation strategies that could be implemented in the LLB to enhance removals by sinks include reforestation and tree planting in the denuded grassland areas of the LLB. Currently, there are 540 km^2 of open lands in the basin. If planted, these lands have the potential to sequester more than 1,338 kt CO_2 per year from the atmosphere (assuming biomass growth rate of 15 t ha^{-1} yr^{-1}), more than enough to turn the basin to a net GHG sink. In addition, sustainable tree farms could also be established to supply the wood and fuel wood requirements of the local communities in the basin. There is almost zero emission when the trees cut are replaced immediately.

4. Ecosystem Trends, Social Conflicts and Institutional Responses

The SGA for the Philippines which focused on the LLB indicated the general trends across the globe. For Laguna Lake Basin, five ecosystem services were considered: water quality, fish production, rice production, biodiversity, and carbon storage, including a brief mention on cultural services.

For water quality, the general conditions of the rivers and the lake itself were poor and deteriorating. The LLDA data showed that the decline however has been noticeably gradual in the last decade, and indicated some successes in the water pollution abatement programs. It was this initial success that landed the lake in the list of the World's Living Lakes.

Fish production is still in good condition, which can be attributed to successes in the aquaculture technology. Much of the fishery production is generated by fishpen and fish cage operation. The trend, however, is still declining. On the other hand, fishery production of the rivers in the basin is in bad state and continues to decline.

Rice production of the shoreland is in good state, although not as productive as its lowland irrigated counterpart. The decline in the production however is mainly due to the reduction of the area cultivated for rice and the aggressive implementation of Republic Act 4850 which stipulates that the shoreland within the 12.5 m elevation is within the jurisdiction of LLDA. This policy has generated negative reactions from rice farmers who have been cultivating the shorelands with rice for several generations and have in fact evolved a system of informal ownership arrangement within the lakeside communities.

Biodiversity of the forest ecosystems within the basin is still in good conditions but is also declining as results of agricultural encroachment, development projects, and continued harvesting of timber from its watershed. Consequently, its carbon storage function is also declining. Mt. Makiling, Mt. Banahaw, and parts of the Sierra Madre Mountain Range are depository of diverse flora and fauna that represent distinct biogeographical zones. Mt. Banahaw, a declared national park under the National Integrated Protected Areas System (NIPAS), remains to be a home to various religious communities who regard it as a sacred mountain. It is also a destination for the curious, for mountain hikers, and recreationists who enjoy the cool waters of Sta. Lucia Falls and River especially during the height of summer. Mt. Makiling, a UPLB forest reserve, serves as an educational

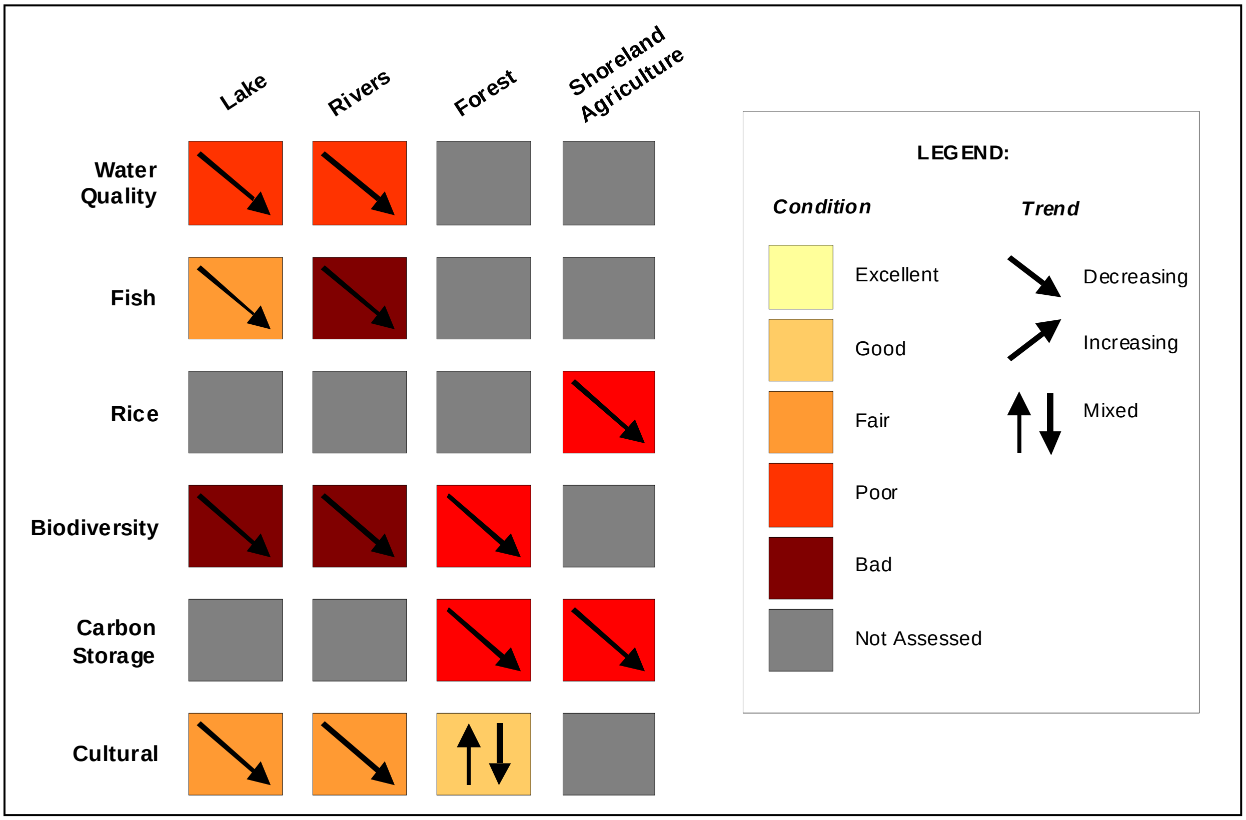

Figure 10. Assessment of the conditions and trends of Laguna Lake Basin ecosystems and the services that they provide.

destination to students of forestry, ecology, geography and related sciences, both from primary to graduate school. It is also identified as one of the 32 ecotourism sites in the country. Biodiversity of the lake and the river, however, is in dismal state. Because of the focus on aquaculture, fish population has been dominated by commercial fishes like tilapia and milkfish. The loss of indigenous fish species in the lake has been attributed to the introduction of exotic species like the janitor fish, tilapia, and milkfish, both intentional and accidental. Figure 10 summarizes the conditions and trends of the various services provided by different ecosystems.

4.1 The Basin of Social Conflicts

The social orientation of a natural resource like the Laguna Lake Basin cannot be underestimated. The present environmental dilemma is much more a result of social processes than it is due to the natural process of lake decay. It is said that the fate of lakes around the world is extinction, but this can take geologic years. Human activities can accelerate the natural decay process a million times, and this is happening to the largest lake in the Philippines. Because it is located in the densest part of the country, the lake is pressured to provide various services for lake communities, huge Metro Manila, and the rest of the basin's burgeoning population: open fishing grounds (since as long as local population can remember), aquaculture (fishpen and fish cages), irrigation, transportation to island of Talim and other lakeshore municipalities and villages, recreational areas (resorts and restaurants), hydropower, and sadly a sink of wastes from various sources – industry, households, and agriculture sectors.

Because of the multitude of resource-use and users, the occurrence of social conflicts is expected, but the magnitude of these conflicts in various time periods varied from petty to serious. Gonzales (1988) summarizes the conflicts into three levels: intrasectoral conflicts between the fishpens and the fishing villages beginning early 1970s; intersectoral conflicts between fisheries and agriculture sectors beginning early 1980s due to the expansion of agri-based infrastructure, notably irrigation system; and multisectoral conflicts emerging among the fisheries, agriculture, and human settlements (especially urban areas of Metro Manila) due to flood related infrastructures such as the MF and the NHCS. These types of conflicts exist up to the present day, although in different intensity.

4.1.1 Intrasectoral conflicts

As the water quality of the lake began to decline since the 1960s to the early part of 1970s, the fishery production, mostly from open fishing, also declined. It was at this time when the fishpen technology provided an option for increasing the lake fishery productivity. The increase in fish production from fishpen was more than 100 percent between 1973-1976 and 1980-1983 while open fishing productivity continued its decline (Rabanal 1986). Fishpen turned out to be a very efficient aquaculture technology that attracted investors. By early 1980s, almost two third of the lake's area was covered with fishpens. At this point, fishermen organizations around the lake clashed with the fishpen operators. The conflict focused on the claim for space at the lake. Open fishermen claimed that the decline of fishery production was attributed to the dense population of fishpen, which covered much of the open fishing grounds. Navigation became a problem for them since passageways were blocked by the unorganized establishment of fishpens all over the lake. Fishermen claimed that their access to the lake water for fishing was reduced and hence their livelihood was threatened. The conflict was confounded by the overall decrease in the fishery productivity as a result of organic pollution originating from fishpen operations. Artificial feeds and fishpen materials added to the pollutants in the lake.

The crisis escalated every minute during that period. Fishpen operators hired armed guards to protect their fishpens from saboteurs. Fishermen were accused of destroying the nets of the fishpens. The tension in the lake caught the public attention. Media covered the conflicts in the lake with regularity, and public opinion came to a conclusion that fishpens must be partially or totally demolished. In the late 1980s, efforts led by the LLDA with the assistance of the military started dismantling illegal fishpens. Typhoons also assisted the process. After a series of discussions and dialogues, a ZOMAP was produced (Figure 11). The ZOMAP designated areas for fishpen operation, open fishing grounds, fish sanctuary, and navigational lanes. This ZOMAP is still in operation to the present. Fish cage technology was also developed and provided the small fishermen with modest capital to engage in aquaculture. The ZOMAP and the aquaculture technology (fishpen and fishcage) allowed the conflicts within the fishery sector to subside and equitably benefit from Laguna Lake fishery resource.

4.1.2 Intersectoral conflicts

This concerns the conflict between fisheries and agriculture. In the early 1980s, a plan to construct the NHCS was conceived. This was primarily to deter the entry of saltwater to the lake. The NHCS was also considered a multipurpose infrastructure: to control floods, to reduce saltwater intrusion into the lake from the Manila Bay backflow through the Pasig River, to reduce pollution of the lake, and to protect Metro Manila's streets from floods. This was in line with the objective of using the lake water for irrigation. The First

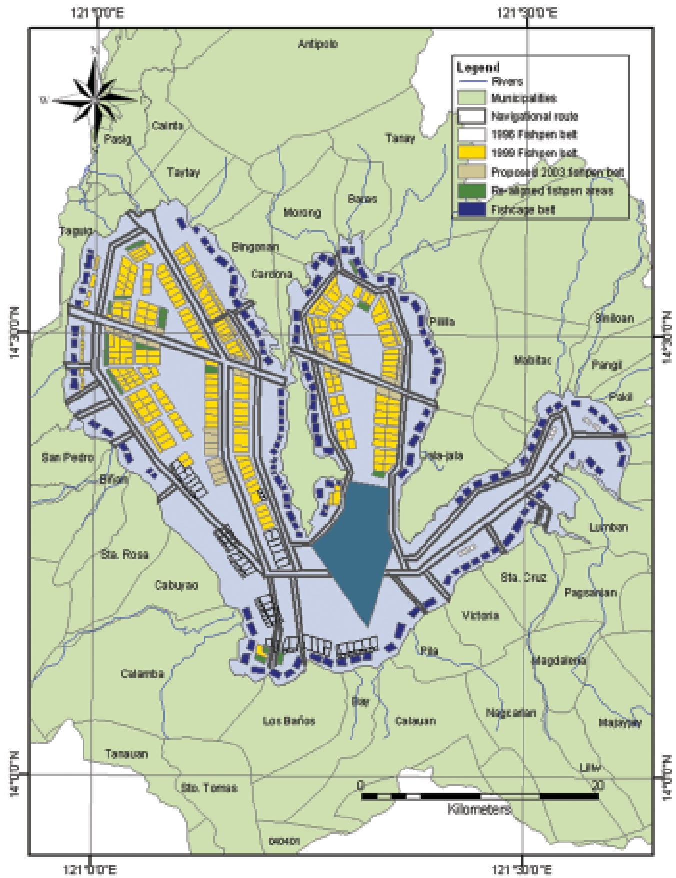

Figure 11. Zone map of the Laguna Lake designating fishpen belt.

Laguna de Bay Irrigation Project was aimed to irrigate a total of 131.6 km^2 of Cavite Friarlands and 12.8 km^2 in Laguna Province. To do this, the salinity of the lake must be reduced in the summer months when backflows normally occur. The implementing agency in this regard was the National Irrigation Administration (NIA). The Second Laguna de Bay Irrigation Project followed shortly after with the construction of a diversion dam in Pagsanjan, which rehabilitated the secondary canals (Gonzales 1988).

The center of the conflict between fisheries and agriculture is the regulation of saltwater intrusion in the lake. Saltwater backflow allows the clearing of the lake water, as the sodium ions in saltwater has the ability to flocculate negatively charged clay colloids in suspension in the lake (Davies 1986). This means that the saltwater clears the water and reduces lake turbidity. Increased light penetration allows the growth of more phytoplanktons which provides fish with abundant food. Fishermen organizations along with fishpen operators demanded the opening of the hydraulic control structure which is being operated by the Department of Public Works and Highways (DPWH). Whether LLDA has a significant hand in the construction or operation of these infrastructures (NHCS and MF), antagonism was mostly directed to LLDA, which they claimed was irrelevant and powerless to do anything about these issues which concerned the operation of NHCS-MF and their consequent negative impacts on the fishery sector.

Negotiation between DPWH and the fishpen and fishermen leaders occurred many times to allow the opening of the structure, especially during summertime when saltwater is most needed by fishery sector. Up to now, the operation of the NHCS from time to time has been viewed as inimical to the interest of the Laguna Lake fishery sector. To date, the plan to divert volume of water from the lake to irrigate agricultural lands of Cavite and Laguna is still waiting to be realized. From the very start, Gonzales (1988) noted that Cavite farmers were hesitant to go into the projected commercial scale vegetable farming. Hence, there is no urgency to reduce salinity of lake water.

4.1.3 Multisectoral conflicts

The multiplicity of uses of the basin gave rise to multisectoral conflicts. This is the kind of conflict between the fishery sector, the agriculture, and the human settlements. One apparent conflict was the use of the lake for storage of floodwaters from Marikina River during the typhoon months to prevent the flooding of Metro Manila. Mangahan Floodway is designed to divert floodwater from Marikina River to the Laguna Lake at the height of typhoons and storing the water by closing the NHCS gates. The floodwater is gradually released through the Napindan channel and the Pasig River, the only outlet of the lake to the Manila Bay. The operation of the Mangahan Floodway in tandem with NHCS has been blamed for the prolonged flooding of lakeshore municipalities like Napindan, Tipas, Taguig, and some parts of Pasig. This claim has logical basis, though no scientific study was conducted. The lake has 22 river tributaries and one outlet river to the Manila Bay, the Napindan River, which further north drains into Pasig River. In the early times, there was natural balance and the watershed condition was healthy. In the 1980s, the NHCS was constructed at the only outlet of the lake, which regulates the water movement. With MF, the water inflow to the lake was significantly increased, hence the level of lakewater during typhoons significantly increased which may have caused some lakeshore towns to submerge and for some areas to have floodwaters longer than the usual experience. The Parañaque Spillway which was supposed to allow outflow of water to the Manila Bay was permanently shelved due to budgetary constraints.

To address the intensifying floods of these lakeshore towns, the DPWH is constructing a road dike in the northern part of the lake to protect these lakeshore towns. The road dike, which will serve both as a road and a dike, will soon be in operation. Whether this new infrastructure will finally address the flooding of lakeshore towns in the northern part of the Laguna Lake Basin is subject to speculations. One reservation about this new engineering solution is the flooding of other areas around the lake that would not be protected by the dike. According to the Environmental Impact Assessment and DPWH experts, this fear is unfounded, and based on existing mathematical models, lake level rise overall within the lake is insignificant to cause intensified flooding in the lakeshore towns located in the southern part of the lake. Some sectors argue however that to rely solely on engineering solution to manage the lake system is myopic since the ability of the lake to store water depends on the overall functioning of the Laguna Lake Basin ecosystems – its watershed and rivers.

Another conflict brewing is that between the local communities and the LLDA. While LLDA serves as the agency with mandate to manage the basin, its programs and policies are not always acceptable to the majority of the fisherfolks and the local community. For example, the lakeshore lands are currently being cultivated to rice, especially when the water level drops to 10.5 m elevation since as far as they can remember. This happens from January to May, when the lakewater level starts to recede. The conflict emerged when the agency, as part of its master plan, commissioned the National Mapping and Resource Information Authority to demarcate on the ground the 12.5 m elevation as lake buffer zone and install concrete monuments around lakeshore areas in 1997. In some municipalities, these monuments were removed by the community members who did not understand the LLDA concerns or who were opposed to the idea of regulating their normal use of the lands for livelihood.

4.2 Responses to Conflicts and Problems on the Use of the Lake Resources

Table 1 presents a summary of services and their related problems and issues. To summarize, institutional responses included the formation of Lake Zone Map or ZOMAP, which designated areas for fishpen operation, fish sanctuary, open fishing, and navigation. It is considered an effective institutional mechanism which addressed the conflict between the fishpen operators and the open fishermen. The development of another aquaculture technology, the fish cage, which requires modest capital and hence accessible to small fishermen allowed the distribution of benefits among the less advantaged fishery sector. In this regard, the LLDA played a major role in diffusing an explosive conflict between what was perceived to be the powerful fishpen operators and the powerless majority of fisherfolks who demanded their moral right to the Laguna Lake for being the traditional user of the resource.

Table 1. A summary of the responses to various issues or problems on the use of Laguna Lake Basin resources.

Ecosystem Services	Problems	Responses	Assessment
Water quality	Deteriorating water quality	Formation of multisectoral river rehabilitation councils Laguna Lake Master Plan	Fairly addressing water quality problems in some areas
Fish	Declining open fish catch	Development of ZOMAP	Regulated the use of surface lake water for open fishing, navigation, fish sanctuary, and fishpen structures
		Introduction of aquaculture	Improved total fish production but contributed to pollution loading and dominance of exotic species in the lake; Decreased catch from open water
Rice	Decreasing areas for rice growing along the lake	No response	
Biodiversity	Lake: Decline in fish diversity and dominance of exotic aquaculture species	Delineation of fish sanctuary (in the ZOMAP)	Not effective
	Forest: Extirpation and decline of some naturally growing species; Continuing threats to the indigenous biodiversity of the lake	Inclusion of some areas in the biodiversity conservation areas (e.g., Mt. Makiling and Mt. Banahaw - San Cristobal complex)	Regulated harvesting of forest resources in some areas
Carbon Storage and climate change mitigation	Declining capacity to store carbon due to deforestation	Carbon sequestration projects to be implemented Methane reduction project in solid waste	Climate mitigation projects underway through the LLDA

Other responses to the conflicts created by government-conceived development projects (particularly by DPWH and NIA) included dialogues and informal negotiations such as in the operation of NHCS. In other cases, the flooding of lakeshore towns which was attributed to the operation of NHCS and MF is resolved by another huge infrastructure – the road dike. Despite its professed intention, the local communities around the lake expressed their reservations that the new structure may just transport the problem of localized flooding to other lakeshore areas.

The degradation of the Laguna Lake water quality however underlies many of its problems. During the administration of LLDA General Manager Carlos Tamboc, a comprehensive program to rehabilitate the 22 river systems flowing into Laguna Lake was launched. This is anchored on the fact that these river systems are directly contributing pollution load into the lake. The rehabilitation program covered a comprehensive survey of the river systems to build a strong baseline information, education, and motivation campaigns; creation of the environmental army (called *Hukbong Pangkapaligiran*); organization of river rehabilitation councils and foundations to ensure multisectoral partnerships and stakeholder involvement; and sustainability of the rehabilitation efforts.

One major strategy to address the degradation of water quality is the formation of river rehabilitation councils. The formation of river councils was motivated by a shared concern among different stakeholders (community members, local government officials, non-government organizations, and civic organizations) to reduce the pollution of the lake and its 22 major sub-basins. LLDA facilitated the process. At present, there are 16 river councils or foundations covering several river basins in the Laguna Lake region (LLDA 2000). These councils or foundations are seen to be effective mechanisms for ensuring multisectoral partnerships and stakeholders' involvement in as well as the sustainability of the rehabilitation efforts. The Board of Directors issued a resolution institutionalizing such councils and extending to these organizations official recognition and support (LLDA 2000).

So far, the experiences of river councils vary, but there are limited successes in some rivers. For example, BISIG-CATA (Biñan, Silang, General Mariano Alvarez, Carmona, and Tagaytay City) River Rehabilitation and Protection Foundation, Inc. has already registered accomplishment. The key players in the action viewed this experience as a process that galvanized their community into taking one definite action: to arrest the decay of the Biñan River. By setting an example, they feel more confident to share with other communities the process and the difficulties that they have gone through, and the fruits of their labor.

At a broader scale, the initiative has assisted other groups in their organizing work in other areas within the Laguna Lake Basin. BISIG-CATA has set up the Biñan River Rehabilitation Project and became a functional example of multisectoral partnerships to address urban environmental problem and potential conflicts arising from the different uses of environmental resources. Members of the foundation served as resource persons in various occasions during organizational seminars being conducted by other councils.

Being more informed and fresh from the Biñan River cleaning up activities, the group shared its experience with their colleagues upstream of Biñan River – the Save Sta. Rosa-Silang River Rehabilitation (S^3R^2). This is a multisectoral river council organized by the LLDA to address industrial as well as domestic pollution of the river that the municipalities of Sta. Rosa and Silang shared. Sta. Rosa and Silang municipalities are dominated by industrial parks, commercial establishments, and residential housing. Silang however remains to be predominantly an agricultural area, with its share of agro-industrial and industrial establishments.

5. Conclusions

The Laguna Lake Basin is a classic model of a multiple resource with multiple users. Its capacity to provide various ecosystem services to various users is continuously being challenged mainly by anthropogenic factors. Deforestation of its watersheds in favor of other uses such as agriculture, industry, and human settlements is expected to cause imbalance in the lake hydraulic processes. Prolonged flooding and gradual shallowing of lakebed due to sedimentation and siltation are detrimental to the welfare of communities living along the lakeshore, including cities and towns. Lakewater quality has deteriorated through the years due to various point sources of pollution: industry, agriculture, and households. Some physico-chemical parameters like nitrate, phosphate, DO, and BOD met the standards of Class C waters, according to LLDA. However, the detection of traces of heavy metals like Cu, Cd, Cr, and Pb, and other PAHs in the water and sediment is a grave concern for human health. Traces of heavy metals are also found in fish although higher concentrations are found in the inedible parts. The concept of biomagnification, however, does not ensure safety from these threats. These studies are only sparse and limited, and no conclusive findings can be established yet.

Fish production is still viable which can be attributed to successes in aquaculture technology. Much of the fishery production is generated by fishpen and fish cage operation. The trend, however, is still declining. On the other hand, fishing in the rivers in the basin is in bad state and continues to decline. This is mainly due to the pollution of major river systems in the basin.

Rice farming in the shorelands is still being practiced the way it was before. The decline in the production, however, is mainly due to the reduction of the area for rice. Many factors contribute to this: land conversion to non-agriculture uses like housing, prolonged flooding in some areas, and implementation of Republic Act 4850 which stipulates that the shoreland within the 12.5 m elevation is within the jurisdiction of LLDA. This is already a brewing conflict between the rice farmers particularly in Laguna. These are the farmers who have been traditionally cultivating the shorelands with rice with an evolved system of informal ownership arrangement or social contracts among themselves.

Biodiversity of the forest ecosystems within the basin is still in good condition. However, it is also declining as results of agricultural encroachment, development projects, and continued harvesting of timber from its watershed. Mt. Makiling, Mt. Banahaw, and parts of the Sierra Madre Mountain Range are depository of diverse flora and fauna that represent distinct biogeographical zones. Consequently, its carbon storage function is also declining.

The multiple resource-multiple users nature of the basin has resulted to various types of social conflicts: intrasectoral, intersectoral, and multisectoral. Within the fishery sector, the fishermen and fishpen operators conflicts at one time in the history of the lake had turned violent. The government through the LLDA with the assistance of the military (and nature—typhoons) had to mediate to settle the conflict. Between the fishery and agricultural sectors was the conflict over the use of irrigation water and open fishing and aquaculture. Fishery sector argued that the control of saline water inflows through the Pasig River, its only outlet to Manila Bay, is detrimental to fishery productivity. The saline water causes the flocculation to occur and results to greater transparency of the lake water, a condition that is conducive to fish growth. Multisectoral conflicts are conflicts occurring between fishery, agriculture, human settlements, and cities and towns due to various development projects like flood control, road dikes, water supply, among others.

An array of institutional and policy responses were designed to address various types of conflicts. A landmark response was the creation of a Lake Zone Map which became the guidelines for the use of the lake surface water. It designated areas for fishpens, fish cages, open fishing, fish sanctuary, and navigational lanes. This prevented the further deterioration of the peace and order problem in the lake basin. ZOMAP emanated from the LLDA, the main agency tasked to manage the lake basin. Another equally significant stride in the effort to control lake pollution was the involvement of local communities in the control and prevention of pollution of the 22 river systems. The efforts started in 1997 when environmental armies were organized to assist in the clean up of the lake. This was the precursor for the formation of multisectoral river rehabilitation councils, which now have taken an identity of its own. They now operate as independent entity from LLDA or from local government. Other responses are mainly legal instruments that LLDA passed like the Laguna Lake Development Master Plan.

In general, the SGA-Laguna Lake Basin focused on the assessment of the conditions of the lake biophysical environment and its relationship with human well-being as measured in terms of its ability to provide ecosystem services such as water, food such as fish and rice, biodiversity, and climate regulation through a study of LLB as a potential carbon storage. The study attempted to highlight the interaction between human well-being and the conditions of the biophysical environment. It also presented accounts of the social dynamics intricately related to the multidimensional nature of the lake basin as a resource and an array of institutional and policy responses. However, several gaps in the science about the lake and lake dynamics still remain:

- What is the extent of pollution with heavy metals and other toxic substances like PAHs in the lake? What are its impacts on human health? What are its impacts to the fishery sector? To other uses like domestic water supply? What is the geography of heavy metal pollution (e.g., sources, concentration, and distribution)?
- What are the significant strides in the activities and proceedings of river rehabilitation councils? What are the areas that need improvement? How do river councils tap community resources and social capital, and even indigenous knowledge?
- How do we encourage communities in the remaining intact watersheds to protect these and reduce lake siltation? What potential mechanisms can be applied? How do we involve local and traditional institutions in the lake basin management?
- How do we regulate land conversions within the basin? How do we synchronize the municipalities comprehensive land use plans/development plans and the Laguna Lake Master Plan?
- How will the construction of more recent development infrastructures, like polder projects, road dikes, dams, influence the ecological and socio-economic dynamics in the lake basin?

These may not be an exhaustive list. However, addressing these gaps in the knowledge may contribute to the sustainable management of the Laguna Lake Basin. Sustainable management regime is one that is decentralized, and involves multistakeholders' interests yet can provide a holistic and coordinated framework that ensures the continuous provision of ecosystem services to the basin's population.

References

Aguilar, N.O., J.D.C. Siopongco, and F.C. Pitargue, Jr., 1990: Species composition and seasonal variation in frequency, density, biomass and rate of production of some aquatic macrophytes at the southern portion of Laguna De Bay. *UPLB Journal*, **1(1)**, 86-96.

Ashton, P.S., 1997: Before the memory fades: some notes on the indigenous forests of the Philippines. *Sandakania,* **9**, 1-19.

Barril, C.R., E.T. Tumlos, R.C. Bato and L.SP. Madamba, 1995: Water quality assessment and management of a hypertrophic lake, Laguna de Bay, Philippines: problems and strategies. Proceedings of the 6th International Conference on the Conservation and Management of Lakes. 23 27 October, Tsukuba, Japan.

BCEOM. 1984. Laguna de Bay Environmental Reassessment Study. Report for Laguna Lake Development Authority. Manila.

Brown, W.H., 1919: *The Vegetation of Philippine Mountains.* Bureau of Science Publication No. 13, Manila, 434 pp.

Bureau of Forestry Manila, 1966: *Reconnaissance Survey Report of Laguna De Bay Watershed*. Forest Protection and Watershed Management Division.

Charlton, M. N., 1993: Laguna Lake (Philippines) Water quality trend analysis study. In: *Laguna Lake Basin, Philippines: Problems and Opportunities,* P.G. Sly, (ed.), ERMP Report #7, UPLB DALHOUSIE U, pp. 115-142.

Cox, R., 1988: *The Conservation Status of Biological Resources in the Philippines*. IUCN, Gland, Switzerland.

Davies, J., 1986: The problems affecting the small fishermen in Laguna de Bay. Service Bureau for Small Fishermen. Sta. Ana, Metro Manila. 22 pp. Reprint.

De Laubenfels, D.J., 1978: The taxonomy of Philippine Coniferae and Taxaceae. *Kalikasan, Philippine Journal of Biology,* **7(2)**, 117-152.

DENR-UNEP, 1997: *Philippine Biodiversity: An Assessment and Action Plan*. Department of Environment and Natural Resources and the United Nations Environment Programme. Bookmark, Inc., Makati, Philippines, 298 pp.

Escobin, A., 2001: *Institutional Arrangement in the Rehabilitation of Biñan River, Laguna, Philippines*. Unpublished MS Thesis (Environmental Science). University of the Philippines Los Baños, College, Laguna Philippines

Espaldon, M.V.O., 2000: Community Participation in Metropolitan Environmental Improvement Program: Stories in the Philippines. A Report to the World Bank, Washington, USA.

Francisco, F.R., 1985: *Management of the Lake Resources: Laguna Lake Development Authority*. Unpublished M.S. Thesis, Philippines.

Francisco, F.R., 1993: A Lake Basin Approach to Water Quality Management: The Laguna de Bay Experience. In: *Laguna Lake Basin, Philippines: Problems and Opportunities*, P.G. Sly (ed.), ERMP Report #7, UPLB DALHOUSIE U, pp. 85-99.

Gonzales, E.R., 1988: *Policy Issues in Philippine Fishery Resource Based Development*. Philippine Institute for Development Studies (PIDS) and University of Sto Tomas Graduate School, Philippines.

Kates, R.W. et al., 2000: Sustainability Science. *Science* **292(5571)**, 641-642.

Lantin, R.S., 2003: *Rice Production: Sustainability and Environmental Concerns*.

LLDA, 1995: The Laguna De Bay Master Plan, Final Report.

LLDA, 1984 1988, 1996-1999: *Water Quality Data on the Laguna de Bay and Tributary Rivers*. Annual Reports. Laguna Lake Development Authority, Pasig City, MM.

LLDA-DENR. Philippine Environmental Quality Report, 1990-1995.

LLDA-NIGS, 1999: *Sedimentation Patterns, Sediment Quality, and Bathymetry of Laguna de Bay: Establishing Environmental Baselines for Lake Management using the Sediment Record*. University of the Philippines, Quezon City, Metro Manila.

Madamba, L.S.P., Q.C. Bariring, and C.R. Barril, 1998: *Heavy metals in the Laguna de Bay Ecosystem*. Progress reports on Assessment and Control of Toxic and Hazardous Substances in Laguna de Bay. Institute of Chemistry, UPLB. College, Laguna (Unpublished).

Mallari, N.A.D., B.R. Tabaranza, Jr., and M.J. Crosby, 2001: *Key Conservation Sites in the Philippines*. Haribon Foundation and BirdLife International. Bookmark, Inc., Makati, Philippines, 485 pp.

Martinez, M.R., 1978: Taxonomy and ecology of algae in fishponds and fishpens of Laguna De Bay, Philippines. In: *Proceedings in Life Sceince: Microbial Ecology*, M.W. Loretit and J.A.R. Miles (eds.), Berlin, Springer-Verlag. pp. 76-79.

Nielsen, B.H., 1983: *Limnological Studies in Laguna de Bay, 1908-1983*. Submitted as part of a terminal report to SEAFDEC, Aquaculture Division, April 1993.

NSO, 2000: Census 2000.

Pacardo, E.P., 1993: Agroecosystem analysis of Laguna Lake, Philippines. In: *Laguna Lake Basin, Philippines: Problems and Opportunities*, P.G. Sly (ed.), ERMP Report #7, UPLB DALHOUSIE U, pp. 212-222.

Pancho, J.V., 1972: Aquatic angiosperms of Laguna de Bay, Luzon. *Kalikasan, Philippine Journal of Biology*, **1**, 94-120.

Pancho, J.V., 1983: Vascular flora of Mount Makiling and vicinity (Luzon: Philippines) Part 1. *Kalikasan, The Philippine Journal of Biology*, Supplement Number 1, Kalikasan Press, 476 pp.

Rodhe, W., 1969: Crystallization of eutrophication concepts in northern Europe. In: *Eutrophication: Causes, Consequences, Correctives*. The Academy, Washington, D.C. pp. 50-64.

Rosana, M.R., V.D. Panisales, A.A. Carandang and J.R. Tolentino, 1997: Primary productivity and production of Tilapia in cages in the South bay area of Laguna de Bay. Paper presented in the Zonal Center for Inland Water, Marine and Aquaculture Seminar-Workshop. Los Baños, Laguna, Philippines, Dec. 1-2.

Santos-Borja, A.C. 1994. The control of saltwater intrusion into Laguna de Bay: socio-economic and ecological significance. *Lake and Reserv. Manage.* **10(2)**, 213-219.

SOGREAH, 1974: *Laguna de Bay Water Resources Development Study*. United Nations Development Programme and Asian Development Bank. Manila

Tabios, G.Q. III and C.C. David, 2004: Competing Uses of Water: Cases of Angat Reservoir, Laguna Lake and Groundwater Systems of Batangas City and Cebu City. In: *Winning the Water War,* A. Rola, H.A. Francisco and J.P.T. Liguton (eds.), Philippine Institute of Development Studies, NEDA, Makati City, pp. 105-131.

Tabios, G.Q. III, 2003: Modelling Imperatives of Manila Bay/ Laguna Lake System. *In: Proc Symposium on Environmental Issues related to Infrastructure Development*. Japan Society for the Promotion of Science-Philippine Department of Science and Technology, Manila Peninsula, Makati City, 2003 August 8-9, pp. 43-52.

Tachikawa, Y., R. James, K. Abdullah, and Mohd. Desa, 2004: *Catalogue of Rivers for Southeast Asian and the Pacific*, Volume V. UNESCO-IHP Publication.

The State of Philippine Biodiversity, n.d.: Available at http:// www.bwf.org/bk/pamayanan/r-rpbiodive.html.

Introduction

RODEL D. LASCO
Chair, Philippine Assessment Panel

MA. VICTORIA O. ESPALDON
Co-chair, Philippine Assessment Panel

CONTENTS

> *"Human well-being and progress toward sustainable development are vitally dependent upon improving the management of Earth's ecosystem to ensure their conservation and sustainability. But while demands for ecosystem services such as food and clean water are growing, human actions are at the same time diminishing the capability of many ecosystems to meet these demands."*
>
> - Millennium Ecosystem Assessment 2003

In the history of mankind, never has there been such severe stress on the world's ecosystems, threatening the survival of planet Earth itself.

It is now generally recognized that the world's present development path is not sustainable (Kates et al. 2000). The reality is that much of the world's environment is already in a very bad state and the situation is getting worse (Rambo 1997). Consider a few indicators of the state of the global environment (Moore 2002):

- The carbon dioxide (CO_2) concentration in the atmosphere has increased by 30 percent since the industrial revolution; methane (CH_4), another greenhouse gas, has increased by 100 percent.
- Total annual flux of sulfur to the atmosphere has increased 50 percent from pre-industrial levels.
- About 50 percent of the total land surface has been transformed by direct human action, 20 percent of land ecosystems have been converted to permanent croplands, and 25 percent of the world's forests have been cleared.
- At present deforestation rates, tropical rainforests will be gone within 100 years while 50 percent of all mangrove forests and wetlands have already been destroyed.
- About 22 percent of recognized marine fisheries are overexploited or already depleted and 44 percent more are at their limit of exploitation.
- Extinction rates are increasing sharply in marine and terrestrial ecosystems around the world.

1. The Millennium Ecosystem Assessment

The passage above is the main rationale for the conduct of the most comprehensive and extensive millennium ecosystem assessment of the century by over 1,000 scientists around the world. The Millennium Ecosystem Assessment or MA is an international work program launched by UN Secretary General Kofi Annan in June 2001. In his 2000 Millennium Report speech, he stated that:

> It is impossible to devise effective environmental policy unless it is based on sound scientific information…In particular, there has never been a comprehensive global assessment of the world's major ecosystem. The planned Millennium Ecosystem's Assessment, a major international collaborative effort to map the health of our planet, is a response to this need" (MA 2003).

The main goal of the MA is to meet the needs of the decision-makers and the public with scientific information on the consequences of ecosystems change upon the welfare and well-being of man and other organisms and options for responding to those changes. It is primarily supportive of the needs of the parties to the Convention of Biological Diversity, Ramsar Convention on Wetlands, and the Convention to Combat Desertification. Ultimately, it hopes to be able to contribute to the attainment of the UN Millennium Development Goals and the Plan of Implementation of the 2002 World Summit on Sustainable Development.

An assessment refers to an activity that takes a stock of a condition and provides judgment to the existing knowledge based on a set of criteria. The MA is a scientific assessment which applies the judgment of experts on existing knowledge to provide credible answers to policy relevant questions (MA 2004). It employs an integrated and multiscale assessment which examines the multiple drivers of ecosystem change at various scales – local, national, regional, and global.

An ecosystem assessment can aid a country or a region by:

- Deepening understanding of the relationship and linkages between ecosystems and human well-being;
- Demonstrating the potential of ecosystems to contribute to poverty reduction and enhanced well-being;
- Evaluating the compatibility of policies established by institutions at different scales;
- Integrating economic, environmental, social, and cultural aspirations;
- Integrating information from both natural and social science;
- Identifying and evaluating policy and management options for sustaining ecosystem services and harmonizing them with human needs; and
- Facilitating integrated ecosystem management.

2. Links Between Ecosystems and People: A Web of Life Taken for Granted

Humans have always been dependent on nature for survival. This is an integral part of us that we have long been taken for granted. We are entering a period in the history of humankind where the results of human's abuse and misuse of ecosystems have taken its toll on the overall capacity of the Earth's ecosystem to support a quality life for human population.

For centuries, ecosystems provide humans with various services. MA defines ecosystem services as the benefits people derive from the environment. These can be categorized into provisioning, regulating, cultural, and supporting services. Provisioning services include food, fuel, timber, water, genetic, and other biological resources. Regulating services are equally significant services that are often times taken for granted or normally ignored. These include climate, disease and flood regulations. Another traditionally excluded in the assessment of ecosystems value are the cultural services that these provide to people. Examples of cultural services are recreational, intrinsic values, inspirational, among others. Supporting services are the processes needed for the maintenance of critical life processes, such as soil formation, primary productivity, and nutrient cycling.

With human population growing, the demand on ecosystem services is continuously increasing and some of the services are traded off for others. For example, forest gives way to agriculture while agricultural areas are being developed into settlements and other built-up areas. In the process, the capacity of the ecosystem to perform other services such as regulatory and supporting, and even cultural, is significantly reduced. Continued deforestation clearly diminishes the ability of forest ecosystem to store carbon or regulate climate and to an extent, regulate floods. If there is continued indifference in the way we utilize ecosystem, human well-being is surely compromised. Human well-being has multiple dimensions and includes attainment of basic materials for good life (although this is a bit subjective), good social relations, freedom of choice, health, and security. Well-being however can be perceived differently by different people and culture, time, situation, and ecological circumstances (MA 2003).

Central to the MA assessment is the focus on human well-being. So what if the water quality of a lake is declining based on various biological and physicochemical parameters? So what if the ability of the lake to hold water (spread over seasons) is declining? So what if pollution in the groundwater is increasing? So what if the forests are being replaced by industry and agriculture? The heart of this assessment is to provide answers to some of the common and ordinary questions that policymakers and decision-makers often posed to scientists. Policymakers and decision-makers include the elected legislative officials, resource managers as well as local communities' who are continuously making decisions that when put together, may tremendously modify the quality of ecosystems.

The MA conceptual framework assumes a dynamic interaction between human community and ecosystem (Figure 1). Human well-being is being indirectly influenced by the demographic processes such as population growth, infant mortality, fertility, and migration. Globalization, trade, market, and policy frameworks are some of the economic processes that also indirectly influence the state of human well-being. Other indirect drivers of changes of human well-being are socio-political, science and technology, and cultural and religious aspects. Changes on land use and land cover, species introduction and removals, and climate change are some of the direct drivers of changes that affect ecosystem and its capacity to provide ecosystem services.

3. The Philippine Sub-global Assessment

A key component of the MA process is the SGAs in various regions and countries of the world, one of which is Southeast Asia. The Philippines represents the archipelagic character of the region with more than 7,000 islands. Thus, a unique feature of this study is the focus on basins in an archipelagic island context.

The Philippines relies heavily on its natural resources primarily terrestrial ecosystems (largely tropical forests) and marine and freshwater ecosystems. Philippine forests have extremely high floral and faunal diversity and are regarded as one of the biodiversity "hottest hot spots" in the world (McNeely et al. 1990). The forests have 13,000 species of plants, which comprise 5 percent of the world's total diversity (DENR/UNEP 1997). The main strategy for biodiversity conservation is through the implementation of the National Integrated Protected Areas System (NIPAS) Law. As of April 15, 2004, a total of 96 protected areas (63 initial components and 33 additional components) have been proclaimed under NIPAS. Among forest areas, those under protection include: all old-growth dipterocarp forests, mossy forests (and forests in areas greater than 1,000 m altitude), forests in slopes greater than 100 percent, and mangrove forests.

Marine ecosystems are also vital to the country's survival. Sixty of the country's 73 provinces are located on coastal zones. A significant portion of the country's economic activities is derived from marine fisheries. The country is also blessed with numerous rivers and lakes, the most famous and largest of which is the Laguna Lake (or Laguna de Bay).

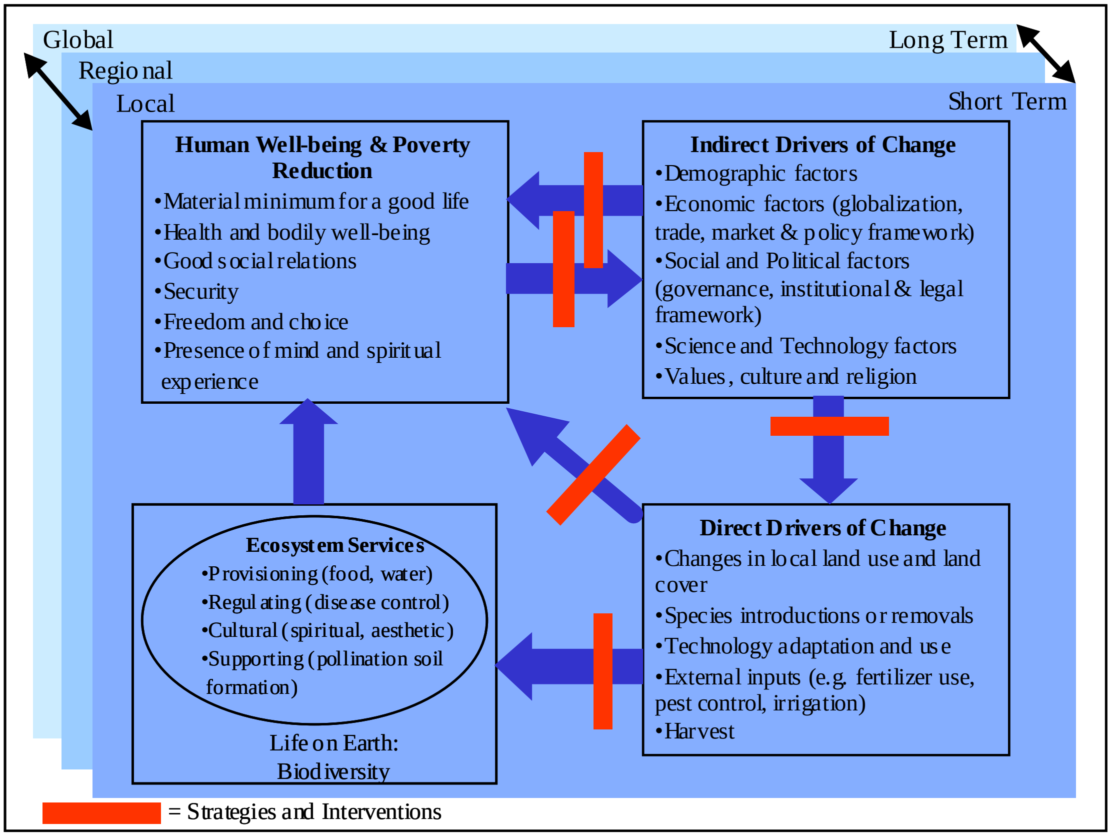

Figure 1. The MA conceptual framework.

Amidst this backdrop, a group of scientists and policymakers from various disciplines in the Philippines conceptualized and implemented this sub-global assessment. The main objectives of the Philippines SGA are: a) to assess the Laguna Lake Basin's ecosystems and their services using the MA framework and b) to contribute to the global MA process.

3. Selection of Study Area

The Laguna Lake Basin (LLB) was chosen as the study site because it represents a wide array of ecosystems undergoing rapid transitions due to a multitude of factors.

The basin is one of the most important and dynamic land and water formations in the Philippines. It straddles Metro Manila and the fast developing region of CALABARZON (composed of the provinces of Cavite, Laguna, Batangas, Rizal and Quezon). In 2000, its population was about 6.6 million people or 9 percent of the total population of the country.

The basin is an important source of agricultural commodities and industrial raw materials. The Laguna Lake is also considered to be the freshwater "fish bowl" of Metro Manila and is important for irrigation, transportation, and energy production.

Because of its proximity to urban and industrial centers, the land and water resources of the basin are under severe stress. The major sources of water pollution are industry, households (waste), and agriculture. It is estimated that industrial pollution contributes about 30 percent to the degradation of water quality of the lake. In 1994, there were 1,481 industrial establishments in the basin mostly involved in chemical production, food processing, and metal manufacture. Household wastes account for a great majority (about 70 percent) of organic wastes discharged into the lake as well as highly pollutive leachate from solid wastes. It is estimated that 60 percent of total households discharge solid and liquid wastes directly into the lake or into its many tributaries.

Fisheries is a major and sensitive concern in the Laguna Lake. It provides income both for large-scale and small-scale operators. The decline in water quality has already affected the levels of fish harvest. It is estimated that there are about 110 km^2 of fish pens in the lake. Equity of resource access is also a major issue as most fishpens are owned by large businessmen. Small farmers eke out their livelihood in the remaining part of the lake not covered with fishpens. Other problems facing the fisheries sector include: uncontrolled stocking density, illegal fishpen construction, illegal fishing, and declining productivity.

Just like the water resources, the terrestrial ecosystems around the lake are also beset by a multitude of problems and concerns. The main driving forces of change include: urbanization and industrial development, shifting cultivation, illegal logging, mining and quarrying, and uncontrolled land conversion.

The impact of land degradation processes is heavily felt in the lake. For example, siltation of the lakebed is one of the most serious problems that threaten the capacity of the lake to provide goods and services. The volume of water in the lake is essential for power generation, irrigation, and navigation. It is roughly estimated that the rate of sedimentation is in the order of 1.5 M m^3 per year.

4. Assessment Approach

The Philippine sub-global assessment was conducted by a panel of 25 scientists and experts with background on the natural and social sciences and coming from several research and development institutions in the Philippines. Each chapter is composed of two or more coordinating lead authors (CLAs) who provide leadership and several lead authors (LA).

Three scales and four ecosystem services were included in the assessment of the Laguna Lake Basin. At the farm or village level, the ecosystem service in focus was the provision of food: fish and rice; at the basin level, the overall fishery production and provision of water supply including biodiversity; and at the global scale, an exploration of its influence on climate change.

The assessment process was patterned after the approach of the Intergovernmental Panel on Climate Change (IPCC). This assessment relied on several data sources. These include published scientific literature preferably on peer-reviewed journals, master plans, and sectoral plans for the watershed, project and consultant's reports, and government agency reports. All data sources were documented (metadata). The assessment has been limited to the available literature obtained from various agencies and institutions, e.g., Laguna Lake Development Authority (LLDA), Bureau of Fisheries and Aquatic Resources (BFAR), Philippine Council for Aquatic and Marine Research and Development (PCAMRD), and University of the Philippines (UP).

In general the MA sub-global study in the Philippines follows the conceptual framework of the MA process (Figure 2). The primary (underlying) drivers and the proximate (pressure) drivers of ecosystems change in the watershed are assessed. Similar to the global process, the assessment has three major components: conditions and trends, scenarios, and responses. The "current conditions and trends" describe the existing condition and historical trend of the natural ecosystems in the study site and their capacity to provide ecosystems services. The "scenarios" component describes long-term future development of the natural ecosystem. Lastly, the "responses" component assesses the various policies and programs in the management of the natural ecosystems. This assessment report is organized in terms of presenting the conditions and trends in each ecosystem service/scale and institutional and policy responses to these changes. A forthcoming companion volume will address future "scenarios".

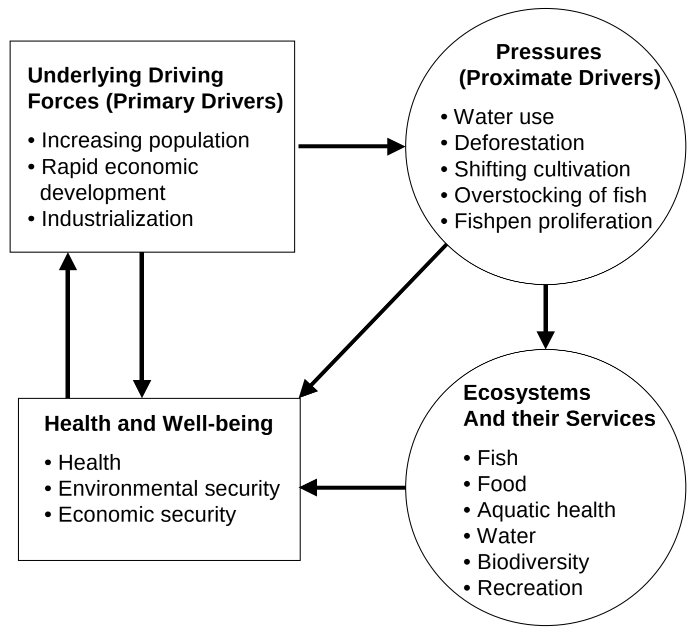

Figure 2. Assessment framework for the Laguna Lake Basin.

References

Kates, R.W. et al., 2000 : Sustainability Science. *Science* **292 (5571)**, 641-642.

DENR-UNEP, 1997: *Philippine Biodiversity: An Assessment and Action Plan.* Department of Environment and Natural Resources and the United Nations Environment Programme. Bookmark, Inc., Makati, Philippines, 298 pp.

LLDA, 1995: *The Laguna de Bay Region and Mt. Makiling Reserve Area Master Plan*. Quezon City, Philippines.

McNeely, J.A., K.R. Miller, W.V. Reed, R.A. Mitternmeier and T.B. Werner, 1990: *Conserving the World's Biological*

Diversity. IUCN, Gland Switzerland; WRI, CI, WWF-US, and the World Bank, Washington D.C.

Millennium Ecosystem Assessment, 2003: *Ecosystems and Human Well-being: Framework for Assessment*. World Resources Institute. Washington, D.C., 245 pp.

Moore III, B., 2002: Chapter 2 Challenges of a changing earth. In: *Challenges of a Changing Earth*, W. Steffen, J. Jaeger, D.J. Carson and C. Bradshaw (eds.). Berlin: Springer-Verlag, pp. 7-17.

Rambo, A.T., 1997: The fallacy of global sustainable development. *Asia Pacific Issues No. 30*, East-West Center, Honolulu, Hawaii, March 1997, 8 pp.

1

Overview of the Laguna Lake Basin

WILLIE P. ABASOLO, JOSEFINA T. DIZON, DOLORA N. NEPOMUCENO

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1.1 Geographic Location and Boundaries

The LLB is located inside the Pasig-Marikina-Laguna de Bay Basin, which is one of the major river basins of the country. It has an aggregate drainage area of 4,522.7 km^2. The basin is situated within latitudes of 13^o 55' to 14^o 50' N and longitudes of 120^o 50' to 121^o 45' E in Luzon Island, Philippines, and 15 km southeast of Metro Manila, the Philippines' center for urban and industrial development (Figure 1.1).

The LLB has a total area of approximately 3,813.2 km^2, of which 76 percent is land and 24 percent is water. It covers all the lands that drained into the Laguna de Bay or approximately 100 rivers and streams including one outlet, the Napindan channel that drains into the Pasig River. This encompasses the whole of Laguna and Rizal provinces including parts of Metro Manila, Batangas, Cavite, and Quezon, which are among the fastest growing economic zones in the country. It traverses 12 cities, 49 municipalities and 2,656 *barangays* or villages.

1.2 Physical Characteristics

1.2.1 Geology

The watershed is characterized by igneous and sedimentary rocks overlain by alluvial deposits (Bureau of Forestry Manila 1966). The landscape is characterized by mixed topography where 35 percent is gentle, 45 is percent rolling, 15 percent is steep, and 5 percent is very steep slope. In the shoreline, the topography is relatively flat.

The LLB is underlain by rocks of various origin and characteristics consisting primarily of agglomerates, pyroclastics, sandy tuff, and cinder beds. These occur in association with other properties in alluvial deposits, reworked tuff, and volcanic ash often displaying desirable hydrogeologic properties.

Complex tectonic and volcanic events, mainly during the Late Tertiary and Quaternary periods, together with large relative sea level changes have produced the basic structure

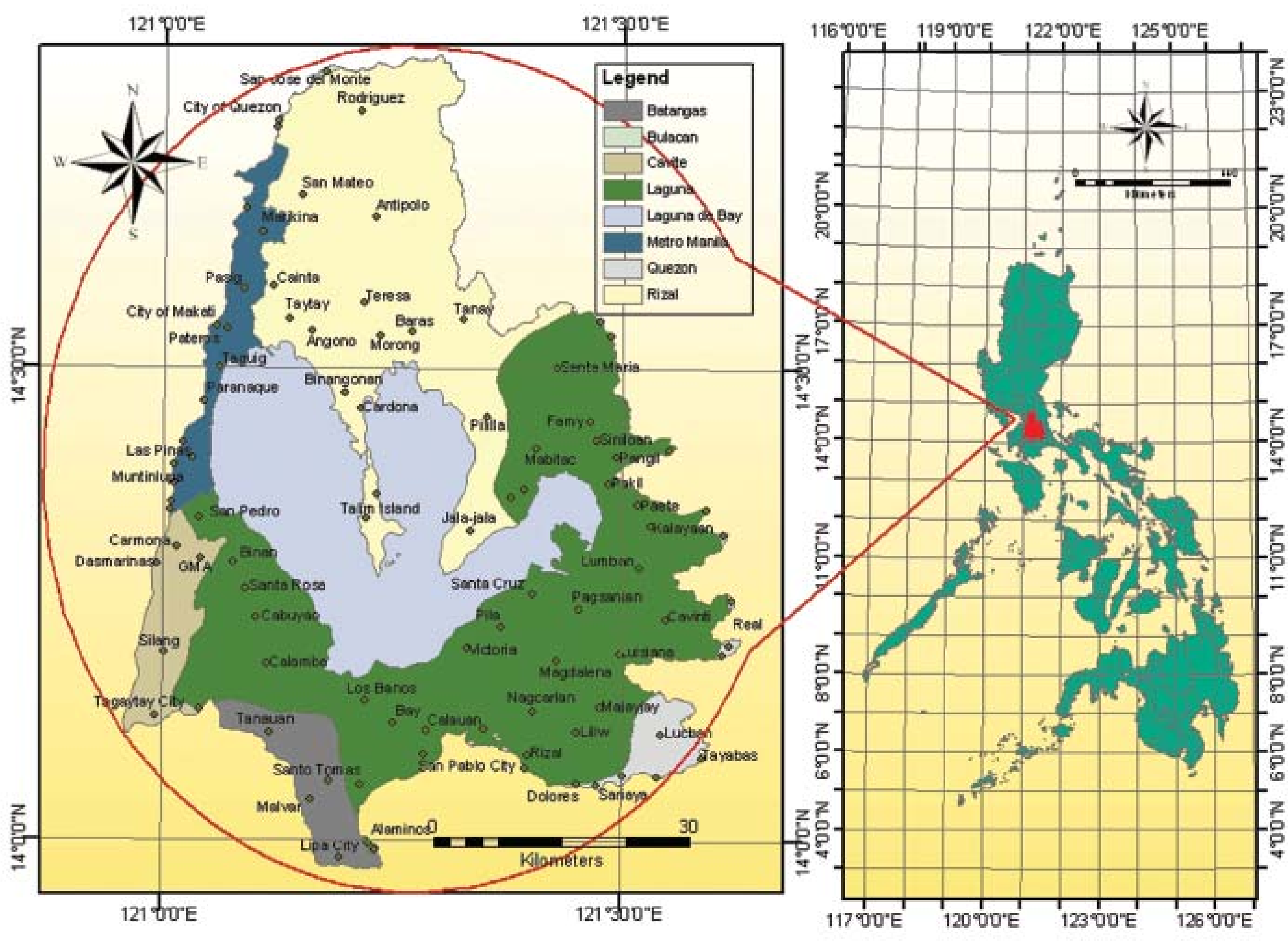

Figure 1.1. Location map of Laguna Lake Basin.

observable today in the area. Table 1.1 summarizes the surface geology and significant geological features (strata) of the LLB followed by its geological map (Figure 1.2).

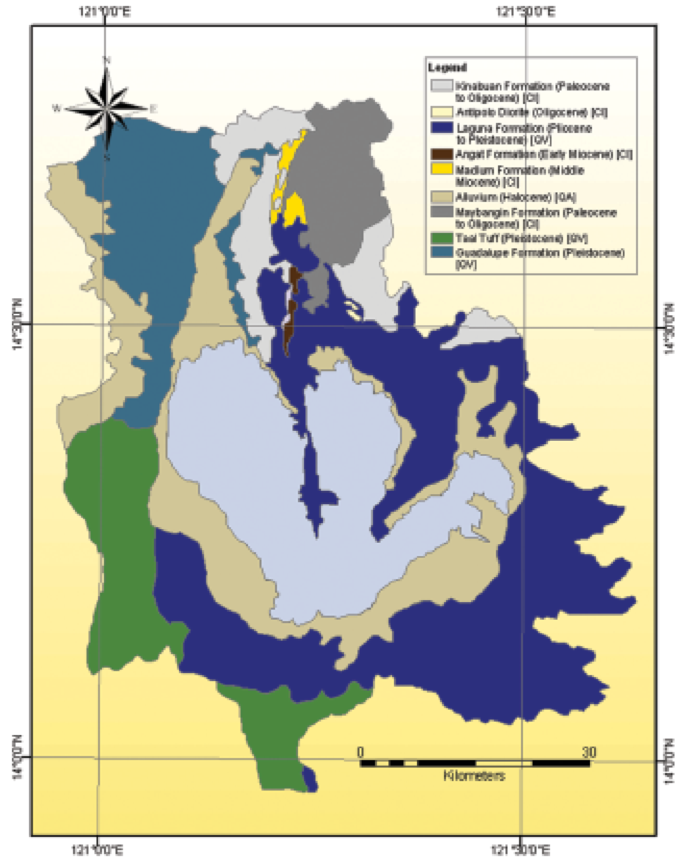

Figure 1.2. Geological map of Laguna Lake Basin.

1.2.2 Meteorology

Based on the Corona Climate System of classification, the LLB is under two climatic conditions. For Rizal province and Metro Manila, the prevailing type is Type 1. This is distinguished by two distinct seasons, dry from November to April and wet from May to October. Type IV condition persists in Laguna and Cavite provinces characterized by evenly distributed rainfall all throughout the year. The area derives its rainfall mostly from the southwest monsoon and the convergent storm cells associated with the Intertropical Convergence Zone from May to October and the northeast monsoon from October to January. Rainfall increases from west to east ranging from 1,700 to 3,500 mm yr^{-1}. On the average, it was estimated that the watershed holds as much as 4×10^9 m^3 of water. From this, one fourth is lost to evaporation while much is used up in irrigation and for domestic and industrial use. Finally, the rest flows back to Manila Bay (Sly et al. 1993).

The mean monthly temperature in the region varies from 25 to 30ºC, and the mean annual temperature is 27ºC. Monthly relative humidity in the basin ranges from 95 percent in August and September to 55 percent in March and April with the mean annual relative humidity taken as 76 percent. The lowest air temperatures and highest wind velocities occur from December to February. This causes high water turbulence resulting to high water turbidity. As a consequence, low fish growth is experienced even with ample supply of free nutrients. Figure 1.3 provides the location of the rainfall stations in the basin and the annual mean isohyetal map based on the 1960-2000 rainfall data.

Table 1.1. Surface geology of Laguna Lake Basin.

Code	Geologic Description	Period	Stratum Area (km^2)	Percentage (%)
Kb	Kinabuan Formation	Cretaceous (-125 M years) to Paleocene (-63 M years)	268.69	5.94
Tmb	Maybangin Formation	Paleocene (-63 M years) to Oligocene (-36 -40 M years)	220.14	4.87
Tad	Antipolo Diorite	Oligocene (-36 -40 M years)	2.99	0.07
Ta	Angat Formation	Early Miocene (-<25 M years)	9.70	0.21
Tma	Madlum Formation	Middle Miocene (-25 M years)	34.40	0.76
Qg	Guadalupe Formation	Pleistocene (-1 M years)	455.41	10.07
Ql	Laguna Formation	Pliocene (-10 -13 M years) to Pleistocene (-1 M years)	1,439.12	31.82
Qt	Taal Tuff	Pleistocene (-1 M years)	445.07	9.84
Qal	Alluvium	Halocene (quaternary/recent)	775.96	17.16
Lk	Lake		871.25	19.26
Total			**4,522.73**	**100.00**

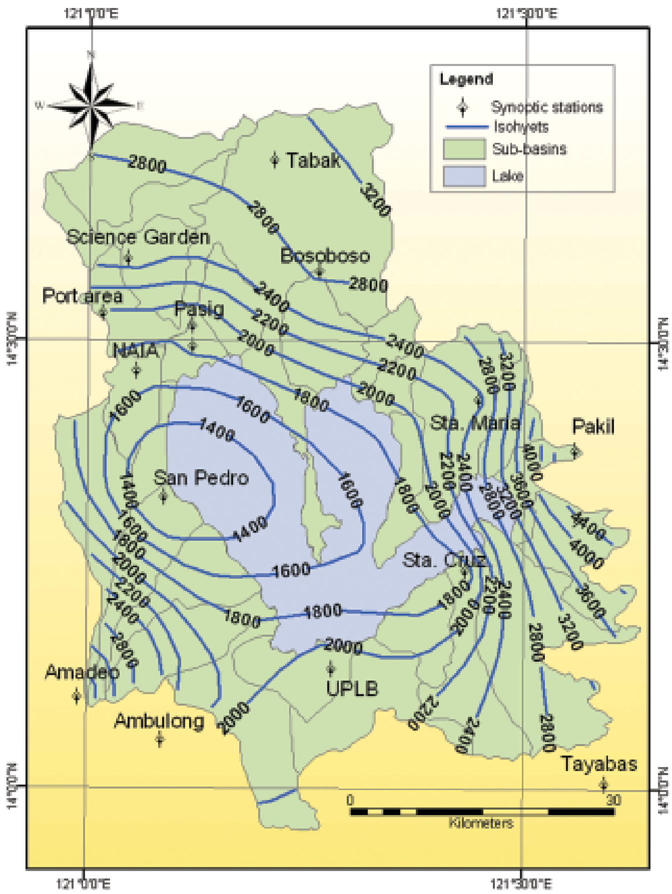

Figure 1.3. Rainfall stations and mean annual isohyetal map in the Pasig-Marikina-Laguna Lake Basin, 1960-2000 (NHRC 2004).

1.2.3 Water Resources

1.2.3.1 Description

An important resource within the watershed is the Laguna de Bay, one of the five largest freshwater lakes in Southeast Asia and considered as one of the Living Lakes in the world. Geologist believed that the bay was of volcanic origin. At the time when the South China Sea was forming, a gigantic volcano in prehistoric Luzon gave a tremendous explosion creating the largest basin in Philippine archipelago. The death of this great volcano gave birth to Laguna Lake Basin.

The lake occupies a total surface area of approximately 900 km^2 with a shoreline of 220 km. It has an average depth of 2.5 m and a maximum water holding capacity of about 2.9 billion m^3.

The bay is actually a trilobate or divided into three bays: the West, Central, and East bays that converge towards the south resembling a large pre-historic bird's footprint which some also refer to as a South bay. At the northeast portion, it is bordered by the Sierra Madre Mountain ranges, in the east by the Caliraya volcanic plateau while in the south and southeastern part by a chain of mountains of Laguna and Batangas provinces including Mt. Banahaw and Mt. Makiling.

One of the main sub-basins or tributaries of LLB is the Marikina River, which has an average annual rainfall of 2,486.2 mm and a drainage area of 534.8 km^2. It runs through the Marikina Valley and large portion of its flood flow is controlled and diverted by the MF towards the Laguna Lake. The remaining water is drained to the Manila Bay through Pasig River. The NHCS regulates the flow between Manila Bay-Pasig River and Laguna Lake by either blocking the high-tide inflow of saline and polluted water from Manila Bay-Pasig River or allowing the reverse seaward flow from the lake. Pagsanjan River, which is the other main tributary of the basin and located at the eastern side, has a mean annual rainfall of 2,170 mm and drainage area of 311.8 km^2. Pagsanjan River also drains to the Laguna Lake.

In the dry season, the functional minimum water level of the lake is about 10.5 m which is the minimum sea level (msl). When the water level falls below the msl or below the high tide level of Manila Bay, seawater intrusion to the lake through the Pasig River occurs causing an increase in lake water salinity (Francisco 1985).

During the wet season, rainfall results in a mean annual high of 12.5 m, which may reach a peak level of 14.6 m. In extremely wet years, widespread flooding may occur owing to the relatively flat topography of lakeshore areas. This is further intensified by the flooding of the Marikina River into the Pasig River which subsequently overflows to the bay through the Napindan Channel.

1.2.3.2 Uses

The most dominant use of the lake is fisheries. In 1997-2000, the lake produced about 37,000-47,000 t of fish. Within the same period, crustaceans and mollusks showed a decline in yield from 1,927 to 574 t and from 101,101 to 85,363 t, respectively.

The lake is commonly used for transport. There are about 5,000 motorized and non-motorized watercraft operating on the lake to transport lakeshore communities to different parts of the region. In addition, 23 barges are used to transport an average of 75,640 barrels of oils and oil products to various supply depots daily.

Through the years, the lake has become a huge waste sink for solid and liquid waste coming from households, croplands, agro-livestocks, industries, and finally from fishery activities. It was estimated that 60 percent of the total households discharge their solid and liquid refuse directly into rivers of the lake. Pollutants are also carried through surface run-off and from back-flows of the Pasig River bringing an estimated 930 t and 420 t of nitrogen (N) and phosphorus (P), respectively, into the lake.

Lake water is used directly and indirectly to generate electricity. The Kalayaan Hydroelectric Power Station in Laguna directly uses water to generate electricity. The station pumped up water to the Caliraya Reservoir to generate about 300 megawatts of electricity. With the proper modification, it can even produce 600 megawatts. The KEPCO Philippine Corp. (KEPHILCO) in Malaya and the National Power Corporation (NPC) in Sucat, on the other hand, uses lake water for cooling.

The lake also provides a whole year supply of water for farmlands in the Laguna de Bay region. The potential area that can be irrigated is approximately 1,024.56 km^2 (LLDA 1995). With irrigation, crop production was improved to more than two times a year, instead of the normal once a year cropping cycle.

There are several industrial plants surrounding the lake. Yearly, approximately 2.04 billion m^3 of lake water is used for cooling down these plants. From this volume, 70 percent is used by power generating plants like NPC, 4 percent by the Philippine Petroleum Corporation, and the rest by other industries.

Despite the current state of Laguna Lake water, communities around the lake also use the lake for recreation. Some communities used it for fishing, boating and sailing, and swimming.

The perennial flooding in Metro Manila has led to another important use of the lake, i.e., as floodwater reservoir. For this purpose, the MF was constructed to connect the Marikina River to the Laguna de Bay. To complement this floodway, the NHCS was also constructed. The NHCS performs dual function. Besides regulating the intrusion of saline water from Manila Bay, it also controls the inflow of polluted water to the lake. With these two structures operating simultaneously, the floodwater from Manila was reduced by diverting the peak flows of the Marikina River to the Laguna Lake for temporary storage (Lee and Adan 1976).

The common source of water in the region is groundwater. However, due to the rapid increase in population together with the over pumping of water, the reliability of groundwater to supply future water needs is doubtful. This is further aggravated by groundwater contamination caused by leachate coming from dumpsites, septic tanks, etc. At present the lake is being considered as a possible source of domestic water in the region. For this purpose, studies on the dredging of heavily silted lake water are being undertaken. This will establish the feasibility, methodology, and benefits of removing contaminants of lake water.

1.2.4 Land Resources

The total land area of the watershed is approximately 2,903.20 km^2. In 1966, it was estimated that from this area, 67 percent or 1,945.14 km^2 was used for agriculture, 8 percent or 232.26 km^2 was open unproductive grasslands, another 8 percent or 232.26 km^2 was used for commercial forest, and the remaining 17 percent or 493.54 km^2 was considered non-commercial forest. Thirty-four years later, a drastic change in land use was observed. As of 2000, agricultural lands were reduced to 1,509.66 km^2 (52 percent), open unproductive grasslands increased to 406.45 km^2 (14 percent), while forested lands were reduced to only 145.16 km^2 (5 percent). The remaining area or 841.93 km^2 (29 percent) gave way for a new land use – built-up/industrial lands (LLDA 2003) (Figure 1.4). This new use is a good reflection of how the region is transforming into a more industrialized zone. Though it provided more job

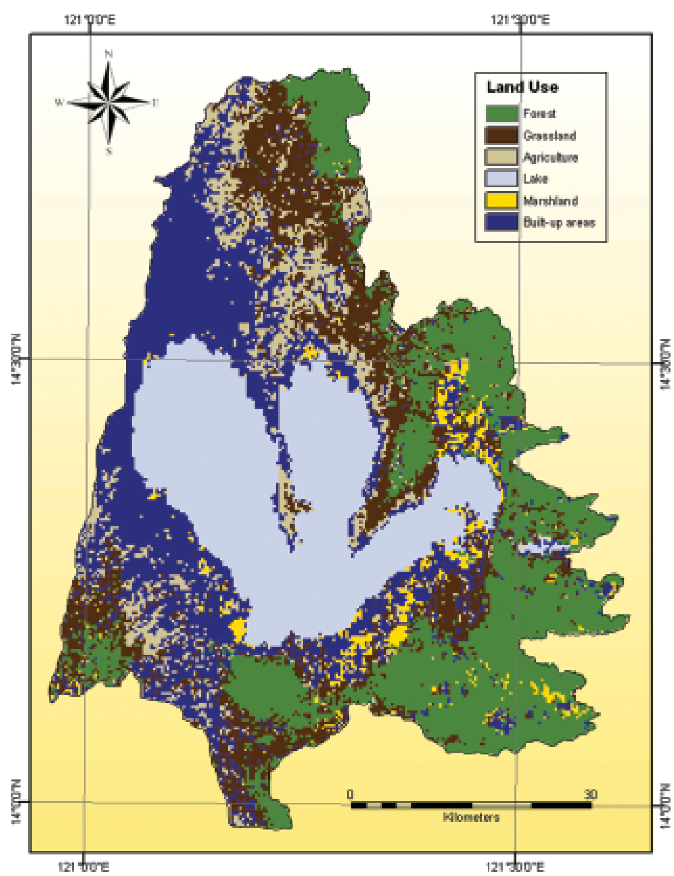

Figure 1.4. Land use map of Laguna Lake Basin, 2002 (ENFOR 2003).

opportunities to its populace, with this change, the forest area for both commercial and non-commercial forests was greatly reduced.

1.2.4.1 Agricultural lands

Flatlands bordering the lake are intensively farmed with a variety of crops. In Pakil, Pangil, Siniloan, Famy, and Sta. Cruz, the most dominant crop is rice, while in Calamba, Cabuyao, Sta. Rosa in Laguna; Sto. Tomas and Tanauan in Batangas; and Carmona in Cavite, the primary produce is sugarcane. The mountainous areas, like former forestlands, grasslands, and moderately sloping areas such as in the northeastern, eastern, and southern portions, are planted to bananas and coconuts (Francisco 1985). Sometimes in marshy places near the coastal regions, fishponds and duck farms are established.

In 1963, the total irrigated rice-cropping areas were estimated to be 184.53 km^2. Twenty years later, it rose to 381.20 km^2 giving a 100 percent increase. This is but normal for rice production will definitely be affected by the increase in population.

1.2.4.2 Grasslands

Grasslands inside timberlands are utilized for grazing. These places are dominated by cogon grass (*Imperata cylindrica*) . whose immature shoots are good animal feeds. Some privately-owned grasslands inside alienable and disposable areas are also used for this purpose.

1.2.4.3 Forest lands

One important forest resource within the watershed is the Makiling Forest Reserve (MFR). By virtue of Republic Act (RA) 6967, this 42.44-km^2 of forest was designated as a training laboratory for the advancement of scientific knowledge on natural resources. This reserve serves as a sanctuary for wildlife and a pool for genetic diversity. It also houses various academic, research, and tourism institutions, e.g., University of the Philippines Los Baños (UPLB), International Rice Research Institute (IRRI), the Boy Scouts of the Philippines (BSP), National Art Center (NAC), and Pook ni Maria Makiling.

As a natural resource, the MFR is very vital to the region, providing irrigation, industrial, and domestic water supply to the surrounding communities. The reserve acts as an important catchment area for the bay while Mt. Banahaw and Mt. Makiling as a whole helps in the generation of electric power through the Mt. Makiling-Banahaw Geothermal Power Plant.

1.2.4.4 Industrial/built-up areas

As of October 2002 (LLDA 2003), there are a total of 3,773 industries situated within the watershed. From this, 599 establishments are wet industries, 591 are dry, 890 are considered as wet and dry, while 229 are unclassified. The rest are monitored and unregistered establishments. Most of the industries are clustered in the north from Manila to Marikina and from Muntinlupa to Calamba. Agro-industries which include livestock raising is principally centered in both the northern area particularly in Montalban, San Mateo, Angono, and Baras in Rizal province, and at the southeast region along Sta. Cruz, Pila, and Victoria in Laguna province. In some areas where industrial materials are very abundant, mining, quarrying, or other extractive activities are conducted.

1.2.4.5 Changes in land use

Since the basin encompasses a portion of Metro Manila, the spill over effect has greatly affected the change in land use in the LLB. The previously planted rice paddies, coconut fields, and sugar plantations have been converted into residential lands and industrial areas. In some cases, both productive agricultural and forested lands must give way to urban developments. This uncontrolled urbanization has led to the building of new houses, roads, water supply systems, sewers, and other public services resulting in the conversion of precious land resource into urban sprawl (Figure 1.5)

1.3. Socioeconomic Conditions

1.3.1 Demography

The LLB represents about 1.3 percent of the country's land area. Within this limited space, 6,601,514 people reside or 9 percent of the total population of the country (NSO 2000). The average household size is 4.99. The more densely populated municipalities are located within or close to Metro Manila and have a population of 2,078,794. In the province of Laguna and Rizal, 1,965,872 and 1,707,218 people, respectively, are residing. This includes natural births and in-migration from other parts of the country because of the perceived better job opportunities in Metro Manila (Table 1.2).

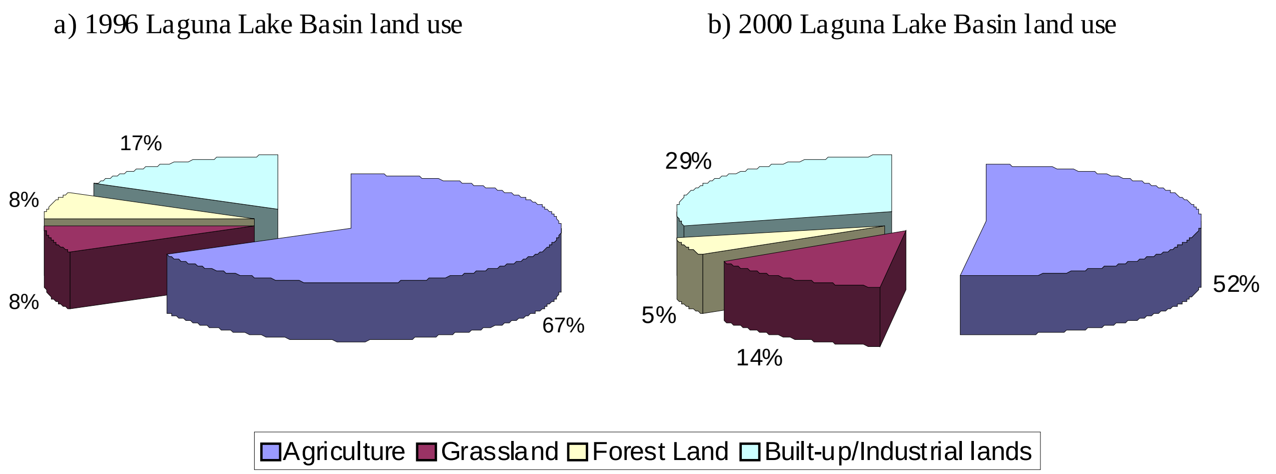

Figure 1.5. Comparative land resources of Laguna Lake Basin, 1966 and 2000.

Table 1.2. Total population of the Laguna Lake Basin (NSO 2000).

Province/Municipality	Total Population	Household Population	Number of Households	Average Household Size
Philippines	**76,498,000**	**76,286,062**	**15,274,579**	**4.99**
Laguna de Bay Basin	**6,601,514**	**6,559,737**	**1,381,68**	
1. Laguna	1,965,872	1,959,080	417,886	4.69
2. Rizal	1,707,218	1,702,110	356,578	4.79
3. Batangas	449,070	448,042	85,896	5.07
Sto. Tomas	80,393	80,343	15,712	
Tanauan	117,539	117,351	21,912	
Malvar	32,691	32,654	6,310	
Lipa	218,447	217,694	41,962	
4. Quezon	38,834	38,770	8,421	4.94
Lucban	38,834	38,770	8,421	
5. Cavite	361,726	353,757	72,459	4.78
Carmona	47,856	47,706	10,430	
GMA	112,446	112,304	22,592	
Tagaytay	45,287	42,003	8,590	
Silang	156,137	151,744	30,847	
6. Metro Manila	2,087,794	2,057,978	440,445	
Marikina	391,170	389,763	80,160	4.86
Pasig	505,058	503,013	107,835	4.66
Pateros	57,407	57,172	12,029	4.75
Muntinlupa	379,310	370,333	78,016	4.75
Taguig	467,375	462,591	102,723	4.50
Manadaluyong	278,474	275,106	59,682	4.61

1.3.2 Economy and Income

Urban sprawl caused by the expansion of Metro Manila has resulted in the urbanization and industrialization of the provinces of Cavite, Laguna, Rizal, and Batangas. This expansion is concentrated at the western bay and is now reaching the southern extremities of the lake. Now, Rizal is about 85 percent urbanized while Laguna is 50 percent industrialized. This provides the people in the basin better opportunities to work in the industrial, commercial, and agricultural sectors being at the heart of Southern Tagalog and at the hub of economic activities.

In 1990, the watershed contributed about PhP 101.3 billion to the Gross Regional Domestic Product (GRDP) of Region IV. It produced a total of $ 257.073 million worth of exports excluding the PhP 38.84 billion worth of local and foreign investments. Eighty percent of the people living in the watershed are highly educated. As a result, the annual family income and standard of living in the region is higher compared to other parts of the country.

1.3.3 Sociocultural/Recreational Values

The variation in the name “Laguna de Bay” or “Bai” or “Bae” has created so much confusion that most contemporary books have attempted but almost none could ascertain. Most historians related one often told story:

> *The province of Laguna was named after the great body of water that forms its northern boundary. The lake, on the other hand, was named after the first town and capital of the province, Bay.*

Chroniclers of the past provided generations of lake stakeholders with rich history and legacy that was the story of the name of the largest lake in the country. The present day Bay existed long before the Spaniards colonized the Philippines. Most ancient Filipinos lived in big settlements along the bays and coastal areas.

Laguna de Bay has been the subject of many literary works, including the novels of Dr. Jose P. Rizal, *Noli Me Tangere* (Touch Me Not) and *El Filibusterismo* (The Filibuster), among others. Laguna de Bay watershed is also the home of several historical and archaeological sites which have been declared by the National Museum. These include Balibago, Cardona (Talim Island), Rizal; Angono, Rizal; Napindan, Taguig; Sideroad Bakery, Taguig; Bagong Bayan, Taguig; Bicutan, Taguig; Malahi, Cardona (Talim Island), Rizal; Mario Santos Property, Sta. Ana, Taytay, Rizal; Lumban, Laguna; Sta. Rosa, Laguna; Pangil, Laguna; and Calamba, Laguna.

Information from the National Museum and National Commission on Indigenous People (NCIP) indicates the existence of Remontado and Dumagat cultural minority groups within the lake watershed.

Laguna de Bay watershed is also gifted with natural and cultural scenic spots, namely: Pagsanjan Falls, Majayjay Church, Morong Church, Magdalena Catholic Church, the underground cemetery in Nagcarlan, Nagcarlan Twin Falls, Hidden Valley Springs, Caliraya Lakes, Los Baños Hot Springs, Mt. Makiling, The Los Baños Science Community, Seven Lakes in San Pablo City, Rizal’s house, Luneta Park, and other spots including Nayong Pilipino, Walls of Intramuros, Cultural Center of the Philippines, and China Town in downtown Manila.

References

Bureau of Forestry Manila, 1966: *Reconnaissance Survey Report of Laguna De Bay Watershed*. Forest Protection and Watershed Management Division.

Francisco, F., 1993: A Lake Basin Approach to Water Quality Management: The Laguna de Bay Experience. In: *Laguna Lake Basin, Philippines: Problems and Opportunities*. Environment and Resource Management Project, Institute of Environmental Science and Management, UPLB, College, Laguna, Philippines.

Francisco, F.R., 1985: *Management of the Lake Resources: Laguna Lake Development Authority*. Unpublished M.S. Thesis, Philippines.

Lee, E.E. and B.L. Andan, 1976: Development and protection of the water resources in Laguna de Bay Basin. Paper submitted to the UN Water Conference.

LLDA, 1995: The Laguna De Bay Master Plan, Final Report.

LLDA, 2003: The Laguna Lake Development Authority website. Available at http://www.llda.gov.ph.

NSO, 2000: Census 2000.

Rebugio, L.L., C.S. Torres, E.R.G. Abraham, and J.O. Sargento, 1998: *Research and Development Issues in Small Mountain Ecosystems: The Case of Mt. Makiling*. MFR Monograph No. 6. Institute of Forest Conservation. College of Forestry, UPLB.

Sly, P.B., 1993: *Laguna Lake Basin, Philippines: Problems and Opportunities*. Environment and Resource Management Project (ERMP) Philippines. Halifax, Nova Scotia, Canada.

Santos-Borja, A. and D. Nepomuceno, 2003: Experience and Lessons Learned Brief for Laguna de Bay. Laguna Lake Development Authority, Pasig City, Philippines.

URSI, 1989: *Laguna Lake Toxic and Hazardous Waste Management Feasibility Study*. Unpublished Report.

2

Laguna Lake's Tributary River Watersheds

LEONARDO Q. LIONGSON, GUILLERMO Q. TABIOS III, ANTONIO M. DAÑO

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2.1. The Laguna de Bay Watersheds and Their Hydrologic Characteristics

There are 22 major watersheds (also referred to as river sub-basins, i.e., either a single river system with one lake outlet or a group of small adjacent rivers with separate outlets) that contribute to Laguna de Bay (Figure 2.1). This count of 22 sub-basins is consistent with the LLDA count of 24 sub-basins, which for LLDA management purposes, is set by separating Morong River from Baras River, and Biñan River from the San Pedro River.

Each watershed consists of several sub-watersheds with either a single or multiple outlets into the lake. The biggest watershed is the Marikina River Basin located north of the lake and the second biggest is Pagsanjan River in the southeast part of the lake. The Pagsanjan River system, located in the southeastern part of the LLB, contributes about 35 percent of the freshwater inflow, followed by Sta. Cruz River with 15 percent, and the rest contributing 50 percent. The tributary sub-basins of Laguna de Bay are enumerated in Table 2.1 (following a clockwise order around the lake).

These rivers strategically represent the typical characteristics of their respective localities including economic activities, demographic patterns, and settlement areas. Watershed characterization in terms of its biophysical and socio-economic features was a key emphasis of the studies that have been conducted.

Figure 2.1. Map of rivers and sub-basins (NHRC 2004).

The Pagsanjan River system contributes about 35 percent of the freshwater inflow. The Pagsanjan-Lumban River system is located in the southeastern part of the LLB. The Pagsanjan River Basin has an extremely rugged topography. As such, a complex web of rivers, streams, creeks, and springs has developed. Consequently, the area is highly susceptible to erosion owing to its predominantly sloping and mountainous terrain.

Volcanic rock deposits predominate the area. These cover approximately 220.92 km^2 or 58.53 percent of the basin. This is to be expected since Mt. Banahaw from where the headwaters emanate is a known extinct volcano.

Of the total land area of the Pagsanjan River Basin, 351.17 km^2 or approximately 93.04 percent of the total area consists of open, cultivated agricultural lands. Brushlands found in Kalayaan municipality constitute 1.98 km^2 (0.52 percent), residual forests of Lucban and Cavinti make up 9.64 km^2 (2.55 percent), while virgin forests situated in Majayjay and Lucban accounts for 15.62 km^2 (4.13 percent) of the whole basin.

The San Cristobal River is the second most polluted river within the watershed. This is the result of the high discharge of chemical residues and industrial effluent from the factories coupled with the reduced storage capacity of the aquifer serving the Matang-tubig springs, and the massive landslide and soil mass movement as a result of agricultural farming on and near the edges of precipitous riverbanks. It has therefore greatly affected the hydrologic integrity of the watershed which directly affects the lake's overall productivity and survival.

The San Cristobal River and its basin provide important functions and amenities to the provinces of Cavite, Laguna, Batangas, Rizal, and Quezon, collectively called CALABARZON. These are: a) as a source of domestic potable water (upper stream only) to more than 200,000 inhabitants in the communities of Cabuyao, Sta Rosa, and Biñan in the province of Laguna; b) as a source of industrial water to the commercial establishments and factories located inside the light industrial park in Calamba; and c) as a source of irrigation water downstream for the National Irrigation Administration (NIA) service areas. It generally represents a typical agro-industrial setting which if properly and scientifically managed could serve as a model for development for other basins with similar or potential characteristics. At present, this tandem of agricultural development in the uplands and industrial development in

Table 2.1. River tributaries surrounding Laguna Lake.

Sub-Basin Name	Drainage Area (km^2)	No. of Sub Sub-Basins	No. of Rivers
Marikina River sub-basin	534.80	84	34
Mangahan sub-basin	87.61	18	10
Angono sub-basin	86.86	36	26
Morong sub-basin	70.21	35	18
& Baras sub-basin	51.88		
Tanay sub-basin	53.44	16	8
Pililla sub-basin	41.19	13	7
Jala-jala sub-basin	72.13	34	17
Sta. Maria sub-basin	204.91	42	19
Siniloan sub-basin	74.31	21	8
Pangil sub-basin	51.14	26	13
Caliraya sub-basin	97.01	26	14
Pagsanjan sub-basin	311.77	53	27
Sta. Cruz sub-basin	148.35	28	13
Pila sub-basin	90.55	12	7
Calauan sub-basin	154.87	27	12
Los Baños sub-basin	102.73	52	24
San Juan sub-basin	191.77	40	15
San Cristobal sub-basin	140.66	44	17
Cabuyao & Sta. Rosa sub-basin	120.13	17	10
Biñan sub-basin	75.55	29	12
& San Pedro sub-basin	56.57		
Muntinlupa sub-basin	43.51	16	9
Napindan-Taguig sub-basin	45.00	--	
Total watershed area	**2,910.12**		

the lowlands has produced undesirable consequences to the site. A concrete example includes the drying up of ephemeral streams during summer and the occurrence of flash floods during typhoon seasons.

Another important river system is the Tanay River Watershed. It has a total area of 54.75 km^2 and is fed by 15 intermittent and perennial streams or tributaries. The watershed lies at the foot of the Sierra Madre Mountain Range, bounded in the north by the towns of Antipolo, Baras, Teresa, and Montalban; in the east by Quezon Province; in the south, Laguna province and Pililla, Rizal; and in the west by Laguna de Bay. The area is a coastal plain in the southwest direction with elevation from 0 to 40 meters above sea level (masl) and gently rising hills and mountains with elevation ranging from 50 to 600 masl in the northeast direction. The watershed has three major types of soil: Bantay loam in the coastal plain, Antipolo clay, and Antipolo clay loam in undulating and rolling upland.

The mainstream of Tanay River is fed from the mountainous portion of Plaza Aldea to the mouth of the lake. Paglitao Springs, Cuyambay Creek, Sapang Sabutan, Daranak, and Batlag Waterfalls provide domestic and irrigation water for farms of the surrounding barangays. The natural flowing water of the river undergoes self-purification which helps recharge the passive flows of water in the lowland areas. Portions of the river water are diverted into irrigation canals to irrigate rice farms and cropland.

The general land use of the area varies from open grassland/ pasture, agricultural/ cultivated land, agro-industrial, mixed orchard land, brushland, and secondary forest areas. Agricultural areas produce primary crops like rice, mango, banana, corn, citrus, and other fruits. Agro-industrial uses include piggery, poultry, and industry like garments/textile factory, cement factory, and quarrying. As a consequence to these massive land conversion activities, the area is very prone to erosion. The most erosion sensitive sites are found in the sub-watersheds of Cuyambay Creek, Upper Tandang Kutyo, Tuyong Ilog, Sapang Sabutan, and Sapang Batlag-Daranak.

Finally, at the southern part of Laguna de Bay liesthe Molawin Watershed. This watershed has an area of 9.218 km^2. The length of the river is 8,970 m. It has 20 streams (intermittent and perennial) with headwaters at an elevation of about 1,020 masl and downstream - most elevation of about 20 masl. This wide variation in elevation also results in the widely fluctuating temperature and precipitation amounts at the site. Subsequently, this affects the peak flows and the time it takes for the total flood flow.

2.2 River Basin's Water Quality

Of the 22 major river basins, 7 are regularly monitored by LLDA for physico-chemical and biological parameters. These are: Pagsanjan-Lumban, San Cristobal, San Juan, San Pedro, Sta Cruz, Bay, and Tunasan Rivers. The Ecosystems Research and Development Bureau (ERDB) of the Department of Environment and Natural Resources (DENR) and UPLB had also done watershed and water quality studies in Tanay River, San Pedro, San Cristobal, and Molawin Creek in the late 1990s.

The absence of a sound solid waste management system is a major factor which contributes to the deterioration of the water quality in the Pagsanjan River Basin's major rivers. When rivers traverse the town centers as in the case of Majayjay, Oobi, Lumban, Camatian, and the Lucban Rivers, they function as the sewers for the community.

In 1998, the LLDA conducted water sampling in Pagsanjan River during the wet season and dry season to assess the river's water quality based on the criteria set by the DENR Administrative Order (DAO) 34 or the Revised Water Quality Criteria for Class C waters (Appendices A1 and A2). Their analyses revealed that the water quality of Pagsanjan River during the dry season was much better off than the wet season. During the wet season, 6 of the 11 sampling stations failed to meet the water quality standards in one or more determinants. During the dry season, only one station (Brgy. Camatian) gave undesirable results. In terms of biochemical oxygen demand (BOD) and dissolved oxygen (DO), all values obtained during the dry season were lower than those obtained during wet season presumably due to increased run-off of organic wastes from the watershed on rainy months.

For San Cristobal River Basin, ERDB did some water quality monitoring in five pre-selected sampling stations from the headwaters to the mouth near the lake proper. The results showed that downstream sub-watersheds were heavily polluted with industrial effluents and sediments (Appendices A3 and A4). In particular, an increase was observed in conductivity, alkalinity, chloride, hardness, BOD, chemical oxygen demand (COD), and total organic carbon (TOC) as well as phosphates (PO_4) and ammonia (NH_3) from Matang-tubig (upstream) to Looc (downstream).

For Tanay River, five sampling stations were identified and selected based on land use. Results revealed that alkalinity and hardness increased from Station 1 (Cuyambay) located in the upstream to Station 5 (mouth of the river). (Appendices A5-A13). This may be due to the ion emissions from the cement factory located within the vicinity. As for pH, it was within the limits (6.5 to 8.5) for Class C water except in Station 3 (pH = 9.09). Likewise, the observed DO levels were within the limits for Class C water except in Stations 4 and 5, where values were below the critical level (5.0 mg l^{-1}) for the survival of aquatic organisms. Deterioration in water quality was more pronounced in Stations 4 and 5 as indicated by the abrupt increases in conductivity, turbidity, BOD, COD, chloride, total phosphorus (P), ammonia-nitrogen (NH_3-N), total Kjeldahl nitrogen (TKN) and chlorophyll a (chl a). Concentration of nitrite (NO_2) and nitrates (NO_3) increased in October due the heavy downpours that caused surface runoff carrying agricultural inputs such as fertilizers.

Biological examinations of the same five sampling stations, revealed four phytoplankton groups, namely: *Cyanophyta* (blue-green algae), *Chlorophyta* (green algae), *Bacillarophyta* (diatoms), and *Euglenophyta* (phytoflagellates). Station 5 (Wawa) had the highest phytoplankton density and the highest chl a content. The high turbidity and suspended solids in the area, however, may have contributed to this high finding. In spite of the presence of phytoplankton that gives off oxygen during photosynthesis, the area was low in DO, indicating the high level of decaying organic matter in the area.

In 1996, UPLB conducted water quality monitoring of the Molawin River, a major tributary of Mt. Makiling. The results revealed increasing concentrations of BOD, conductivity, total dissolved solids (TDS), hardness, TOC, alkalinity, total and dissolved phosphates and nitrates from upstream (Mudspring) to downstream (Kabaritan). (Appendices A14 and A15). On the other hand, no definite trend in COD, turbidity, pH, DO, and ammonia was observed. Nutrients (phosphates and nitrogen fractions) were generally high in Station 4 where the garbage dump is located. Leachates from the decaying garbage and domestic wastes from the residents around the area could have contributed to this high nutrient levels. Parallel to this, the same station exhibited the highest BOD, indicating high biodegradable organic matter content.

As in other watersheds, low DO was observed because of the presence of decaying organic matter, which uses up oxygen. In spite of photosynthetic activity during daytime, DO appeared to be insufficient to sustain the demands of the organic matter decomposition, and because of this, DO has decreased to a level below the critical level of 5 mg l^{-1} for fish survival.

The monthly temperatures of monitored rivers fluctuated from 27ºC to 33ºC. The highest monthly temperature was observed in Tunasan River at 33ºC during the month of May. In terms of annual average, San Cristobal was found to have the lowest temperature at 28ºC. This could be attributed to the presence of 10-30 m of forest buffer in most portions of the river. Average temperature was also observed to be lower than 28ºC in the upper stretch of the river. (ERDB 1998).

The pH values of the monitored tributary rivers are within the permissible range of 6.5 to 8.5 for Class C water. Bay River gave the highest pH reading with an annual average of 7.9. The average alkalinity of the tributary rivers ranged from 32 to 82 mg l^{-1}, which is within the acceptable range of 30 to 500 mg l^{-1}. Pagsanjan River has the lowest annual average alkalinity level of 32 mg l^{-1}, while San Pedro River gave an annual average of 182 mg l^{-1}.

Total hardness and total alkalinity are usually present in the same levels in most rivers, thus, Pagsanjan River which had the lowest annual average alkalinity has also the lowest hardness at 219 mg l^{-1}. Tunasan and San Pedro Rivers were the hardest at an annual average of 407 and 397 mg l^{-1}, respectively. Except for the months of March and April, the total hardness level of all the rivers was below the maximum level for hardness of 500 mg l^{-1} set by the World Health Organization (WHO).

DO concentration is the primary parameter on the suitability of water for the survival and growth of fish and other aquatic life. A river can be considered healthy when at any given time the DO concentration will not fall below 5 mg l^{-1}. Tributary rivers of the lake reflect a grim condition with their DO range of 0.1 to 7.3 mg l^{-1}. Based on this parameter alone, some rivers are virtually dead, like the Tunasan River. The same message is conveyed by data gathered in the sampling stations of the LLDA along the San Pedro, San Cristobal, and San Juan Rivers. The striking contrasts to these are the rivers Sta. Cruz, Pagsanjan, and Bay which exhibited a range of 6-7 mg l^{-1}. All of the latter are located in South bay, an area that is relatively less impacted by industrial effluents.

Tributaries on the western side of the lake – Tunasan, San Pedro, San Cristobal, and San Juan Rivers – have very low DO values ranging from 0.5 to 2.1 mg l^{-1}; while the eastern tributaries – Bay, Sta Cruz, and Pagsanjan Rivers – gave adequate DO from 5.7 to 6.5 mg l^{-1}. This would imply that the latter location is healthier than the former.

BOD indicates the amount of DO removed during decomposition of organic matter in a given time. It is therefore a general indicator of contamination due to biodegradable organics. The BOD criterion for Class C water is set at 7 to 10 mg l^{-1}. Rivers, more than the lake proper, are most affected by industry-derived BOD. Along the length of these rivers, one would expect to find gradients of concentration from the effluent outfall to downriver. For the period 1996-1999 and ever since the start of LLDA's monitoring activities, Tunasan, San Pedro, and San Cristobal Rivers were critically disturbed displaying excessive levels in most time of the year. San Juan, Bay, Sta. Cruz, and Pagsanjan Rivers consistently conformed to the BOD limit.

COD is a measure of the required oxygen to chemically oxidize the organic matter in water. It also estimates the organic matters coming from natural sources such as aquatic plants and from municipal, agricultural, and industrial wastes. The COD data of monitored rivers correspond with the BOD results in Tunasan, San Pedro, and San Cristobal which have high annual average of 131 to 242 mg l^{-1}, while the other four rivers have annual average varying from 17 to 39 mg l^{-1}.

Among the seven rivers monitored by LLDA, San Pedro River registered the highest ammonia concentration at 4.075 mg l^{-1} during the month of February and an annual average of 2.235 mg l^{-1}. The rest gave an annual average varying from 0.245 to 0.043 mg l^{-1} with Pagsanjan River registering the lowest level.

Nitrate is the most highly oxidized form of nitrogen found in wastewater and in trace quantities in surface waters. The maximum limit of nitrate for Class A and Class C waters is set at 10 mg l^{-1}. All the monitored rivers conformed with the maximum limit of nitrate level ranging from nil to 2.242 mg l^{-1}. San Juan River exhibited the highest peak and higher annual average of 0.757 mg l^{-1}, while Pagsanjan River registered the lowest annual average of 0.085 mg l^{-1}.

Total nitrogen is the summation of various forms of nitrogen in water as analyzed in the laboratory. San Pedro River had the annual average of 8.2 mg l^{-1} fluctuating from a high of 14.0 mg l^{-1} during the month of May to a low of 5.2 mg l^{-1} during August. Pagsanjan River registered the lowest annual average of 1.2 mg l^{-1}, while other rivers did not differ much, with an annual average ranging from 1.5 to 2.9 mg l^{-1}.

Significant sources of phosphates are raw or untreated wastewater discharge, agricultural drainage, or industrial wastes with large quantity of phosphorus, detergents, animal feed supplements, and medicines. For Class A and Class C waters, the criterion is set at 0.1 and 0.4 mg l^{-1}, respectively. The seven monitored rivers showed phosphate concentrations ranging from nil to 2.368 mg l^{-1}. San Pedro River had the highest peak during the month of January with an annual average of 0.133 mg l^{-1}. Other rivers had an annual average varying from 0.133 to 0.404 mg l^{-1} and with monthly concentrations within the allowable limit most of the time.

The major sources of phosphorus entering the river systems are domestic sewage effluents including detergents, animal- and plant-processing wastes, fertilizers, chemical manufacturing spillage, various industrial effluents, and to a limited extent, erosion materials in agricultural runoff. Excessive concentration of such elements, which are readily available for algae consumption, may cause intensive algal growth called "algal bloom". San Pedro River registered the highest phosphate level with an annual average of 1.968 mg l^{-1} with January having the highest level at 2.98 mg l^{-1}. San Juan, Sta. Cruz, and Pagsanjan Rivers had an almost similar level of total phosphorus at 0.501, 0.513, and 0.564 mg l^{-1}, respectively.

The total dissolved solids (TDS) refer to the mixture of inorganic salts and organic substances dissolved in water. Under DAO 34, TDS levels should be below 1,000 mg l^{-1} for Class A which also followed for Class C. For all the monitored rivers, the TDS levels were consistently below this limit. The highest annual average concentration was recorded in San Pedro River at 555 mg l^{-1} and a peak of 772 mg l^{-1} in December while the lowest annual average of 237 mg l^{-1} was recorded in Pagsanjan River. For total suspended solids (TSS), DAO 34 allowed no more than 30 mg l^{-1} increase for Class C water. Tunasan River recorded the highest annual average of 174 mg l^{-1} with a high of 598 mg l^{-1} in the month of July. On the other hand, Pagsanjan River recorded the lowest annual average of 11 mg l^{-1}.

Turbidity is a measure of the suspended particles such as sand, silt, clay, organic matter, and microscopic organisms in water, which are usually held in suspension by turbulent flow and Brownian movement. Turbid water has low photosynthetic activity. Tunasan River, which had the highest TSS was the most turbid with an annual average of 84 mg l^{-1} silicon dioxide (SiO_2), followed by Bay River at 40 mg l^{-1} SiO_2, and San Juan River at 31 mg l^{-1}. The rest gave almost similar annual average of 12-16 mg l^{-1} SiO_2.

Chloride is the ionic form of chlorine that forms a significant part of the anions in water. Excessive chlorides especially those formed with sodium result in a salty taste. All the seven rivers gave a chloride reading below the Class C limit of 350 mg l^{-1} throughout the year. San Pedro River, which had the highest peak at 227 mg l^{-1}, registered only an annual average of 82 mg l^{-1}.

Oil and grease normally come from spillage from industries and machinery. The limit of oil and grease for Class A was 1 mg l^{-1} and 2 mg l^{-1} for Class C. Rivers passing through urbanized or industrialized areas had high levels of oil and grease. Tunasan River had the highest peak at 12 mg l^{-1} and an annual average of 5.4 mg l^{-1}, San Cristobal River had an annual average of 3.9 mg l^{-1}, San Pedro at 2.7 mg l^{-1}, and Sta Cruz River at 2.4 mg l^{-1}. San Juan, Bay, and Pagsanjan Rivers recorded oil and grease levels below the Class C limit in most time of the year with an annual average of 1.6, 1.6, and 1.8 mg l^{-1}, respectively.

The limits for heavy metals in Class C water as stipulated in DAO 34 are: 0.01 mg l^{-1} for cadmium (Cd), 0.05 mg l^{-1} for chromium (Cr), 0.05 mg l^{-1} for copper (Cu), and 0.05 for lead (Pb). All the rivers recorded negligible or low levels of Cd, Cr, and Pb except in Tunasan River which gave a one-time value for Cu at 0.09 mg l^{-1}.

The coliform group comprised all of the aerobic and facultative anaerobic gram-negative, non-spore forming, rod-shaped bacteria. It is used as an indicator of the sanitary quality of the water and a major parameter in river classification conducted by DENR. All the monthly values obtained from the seven monitored rivers failed to meet the 5,000 MPN/100 ml criterion set for Class C rivers. The annual average total coliform values were all very high and ranged from 4.64×10^6 to 22.45×10^6 MPN/100 ml.

2.3 Laguna Lake Hydraulic Processes and Resources

To properly plan and manage the optimum and sustainable use of the lake water resources, it is crucial to understand different lake processes. There are three major factors that drive the lake hydraulics: 1) inflows to the lake from the surrounding watersheds; 2) tidal forcing from Manila Bay; and 3) surface wind stresses. Other factors that influence lake circulation patterns are presence of structures for fishing industries called fishpens and fish cages, bottom friction (bed shear stress) being a shallow lake (3-6 m deep), occurrence of high turbidity, and the occasional proliferation of hyacinths.

On the flood control function of Laguna de Bay, the current operating rule is that when the Marikina River stage at its Santo Niño stations is greater that 14.5 m, the gates at Rosario weir are opened to let the floodwaters enter the MF towards the lake. This flood control scheme is designed to protect Metro Manila from being flooded, but it seemed to have ignored its impact on the lakeshore towns around Laguna Lake. In fact, the gate operating policy at Rosario weir does not consider the downstream end conditions such as the lakewater stage or Pasig River stage (Tabios and David 2004). Since the MF was built, there were cases of floodings along Taguig and Taytay and even way down south in Sta. Cruz and Los Baños. Some people perceived these incidents as a consequence of the construction of the MF.

Saltwater from Manila Bay through Pasig River is allowed to enter Laguna Lake, which is desirable to the fishing industry. On the other hand, lake withdrawal for domestic water supply requires a certain, minimum salinity requirement. The control of saltwater entering or exiting the lake through Pasig River through the gate operations of the NHCS. However, since the NHCS was built, it was always left open as demanded by the fisheries industry.

In 1997, the Southeast Asian Fisheries Development Center (SEAFDEC) - Aquaculture Department and Hohenheim University-Germany conducted a saltwater mapping study of Pasig River backflow. In their survey, SEAFDEC research noted that saltwater intrusion normally starts in the last week of April. Water coming from Pasig River flowing into the lake emitted odor of hydrogen sulfide (H_2S) and had high chloride content. By the middle of the month of May and with the onset of the southwesterly winds (locally called *hanging Habagat*) the fast diffusion of salt water in the west lobe or West bay of Laguna Lake was observed. Based on the periodic surveys of the lake and monthly monitoring of stations conducted by SEAFDEC, it was estimated that it takes about 2 to 3 months for the whole lake to clear out due to the effect of saltwater.

With regard to the wind forcing, a recent two-dimensional hydraulic model of Laguna Lake developed by the National Hydraulic Research Center or NHRC (1999) includes a fairly, comprehensive model of the watershed inflows (Morel-Seytoux et al. 1999). In this model, the tidal forcing from Manila Bay was defined by hourly data that is available from a continuous data monitoring station. However, the surface wind stresses cannot be adequately described since there are only two or three stations (located in Los Baños and Manila) that continuously monitor wind speed and direction in the vicinity of lake area. Considering the irregular topographic features around Laguna Lake, spatially and temporally varying wind patterns commonly prevail. Thus, in order to properly understand and predict the lake dynamics, a realistic rendering of spatial and temporal variations of the wind field is needed.

Figure 2.2 provides an overview of the physical system configuration of the Laguna de Bay relative to its 22 sub-basins or watersheds, including Marikina River, and the latter's confluence with Pasig River at Napindan.

Figure 2.3 illustrates for the El Niño months of 1997-1998 the variations of daily rainfall (in Manila and Los Baños rainfall stations, north and south of the lake, respectively), the hourly lake stage, and the salinity in terms of chloride concentrations measured once a month at five lake sampling

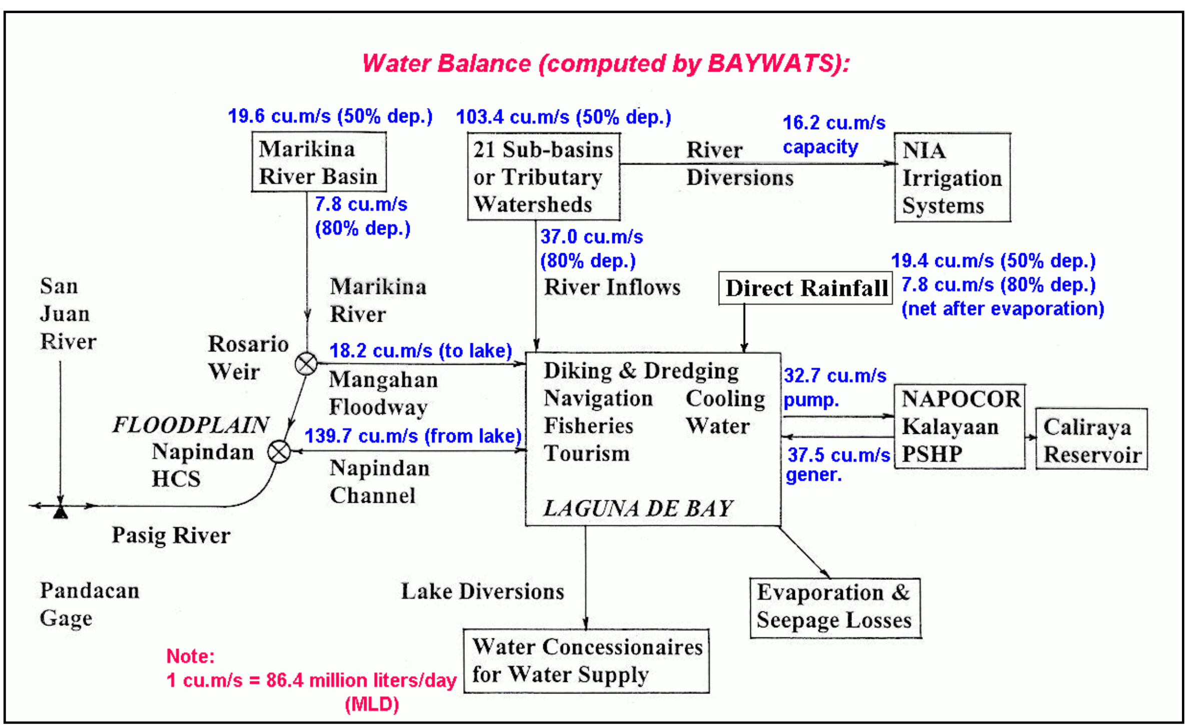

Figure 2.2. A water balance diagram of the Laguna de Bay for the selected mean lows and the 50 percent and 80 percent dependable river flows (NHRC 2000).

stations (sequenced from nearest to farthest from the seaward outlet). The lake salinity maximum arrives first at the West bay V station which is nearest the inflow point of the tidally-affected Pasig River, and last at the farthest East bay II station. The highest salinity levels of the lake were attained towards the end of and after the nine-month drought from September 1997 to May 1998. During the same period the lake stage reached a minimum of 10.5 m (which is 0.5 m above a defined mean low sea-water datum of 10.0 m), a condition which permits the development of maximum seawater intrusion from Manila Bay, through the Pasig River and into Laguna de Bay. This situation was most advantageous for the traditional brackish-water aquaculture and fisheries, but very disadvantageous for potential water supply and irrigation uses.

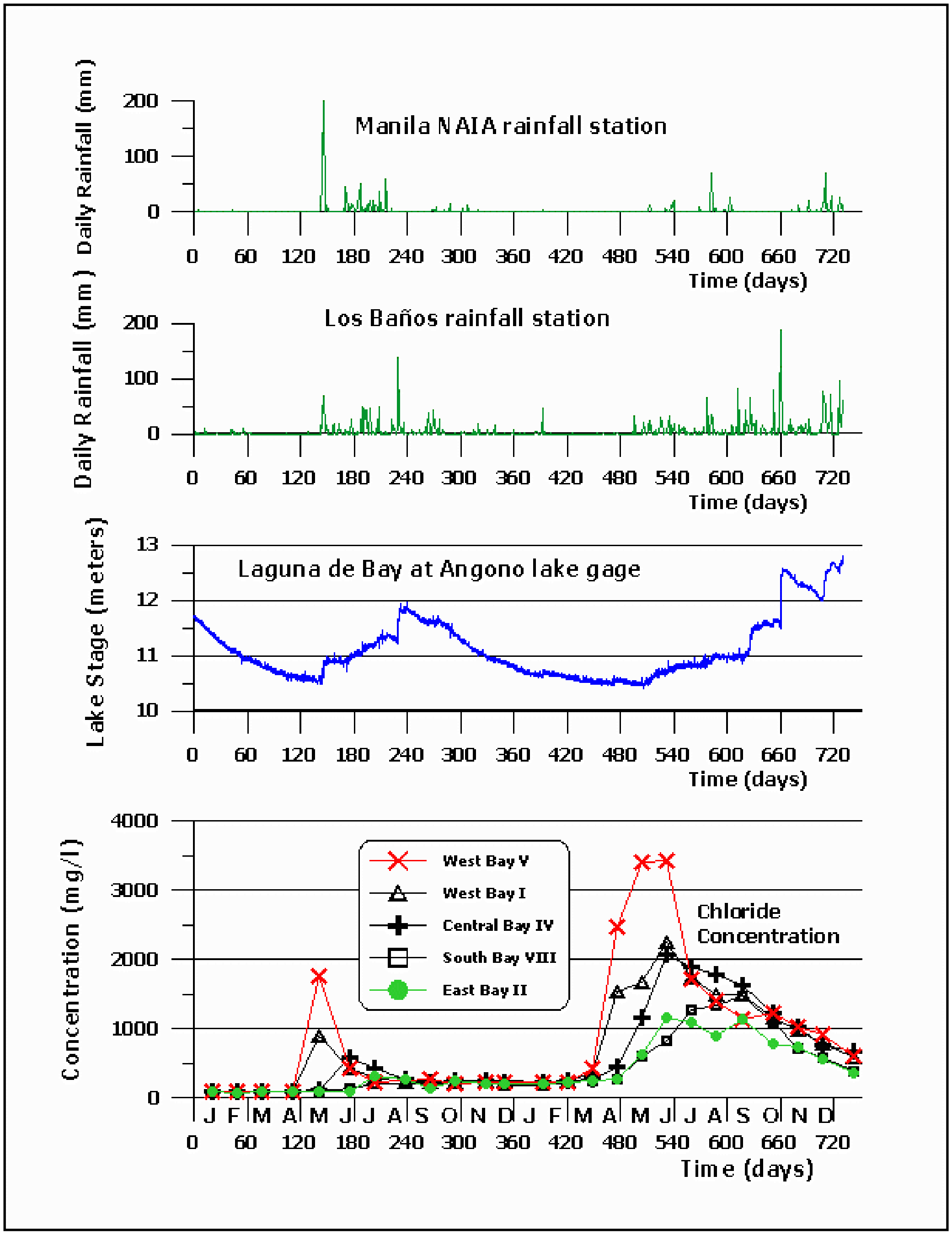

Figure 2.3. Rainfall, lake stage, and salinity during the El Niño months of 1997-1998 (Liongson 2003).

References

De las Alas, J and A.M. Marzan, 1982: Modelling the Circulation of Laguna de Bay. University of the Philippines, Quezon City, Metro Manila.

LLDA, 1984 1988, 1996-1999: *Water Quality Data on the Laguna de Bay and Tributary Rivers*. Annual Reports. Laguna Lake Development Authority, Pasig City, MM.

LLDA, 1996: *Laguna de Bay Master Plan*. Laguna Lake Development Authority, Pasig City, MM.

LLDA-DENR. Philippine Environmental Quality Report, 1990-1995.

LLDA-NIGS, 1999: *Sedimentation Patterns, Sediment Quality, and Bathymetry of Laguna de Bay: Establishing Environmental Baselines for Lake Management using the Sediment Record*. University of the Philippines, Quezon City, Metro Manila.

Morel-Seytoux, H.J., S.A. Alhassoun, G.Q. Tabios III, L.Q. Liongson and D.S. Rojas, Jr., 1999: SWATCH – A distributed hydrologic watershed model. In: *Proc 19th Annual Hydrology Days*, American Geophysical Union, Colorado State University, Fort Collins.

SOGREAH, 1974: *Laguna de Bay Water Resources Development Study*. United Nations Development Programme and Asian Development Bank. Manila.

Tabios, G.Q. III and C.C. David, 2004: Competing Uses of Water: Cases of Angat Reservoir, Laguna Lake and Groundwater Systems of Batangas City and Cebu City. In: *Winning the Water War*, A. Rola, H.A. Francisco and J.P.T. Liguton (eds.), Philippine Institute of Development Studies, NEDA, Makati City, pp. 105-131.

Tabios, G.Q. III, 2003: Modelling Imperatives of Manila Bay/ Laguna Lake System. *In: Proc Symposium on Environmental Issues related to Infrastructure Development*. Japan Society for the Promotion of Science-Philippine Department of Science and Technology, Manila Peninsula, Makati City, 2003 August 8-9, pp. 43-52.

Tachikawa, Y., R. James, K. Abdullah, and Mohd. Desa, 2004: *Catalogue of Rivers for Southeast Asian and the Pacific*, Volume V. UNESCO-IHP Publication.

3

Water Resources

MACRINA T. ZAFARALLA, CARLITO R. BARRIL, ADELINA C. SANTOS-BORJA,
EDUARDO V. MANALILI, JOSEFINA T. DIZON, JOCELYN G. STA. ANA,
NORMA O. AGUILAR†

CONTENTS

3.1 Lake Water Quality

3.1.1 Sources of Pollution and Eutrophying Nutrients

3.1.1.1 Sources of pollution

The strategic location of Laguna de Bay makes it an ideal sink for all kinds of water pollutants that impair water quality. The lake's major sources of pollution and their percentage contributions are: domestic, 68.5 percent; industry, 19 percent; and agriculture, 11.5 percent (Figure 3.1). From these, solid and liquid wastes enter the lake by way of the 22 major and the more than 100 minor tributaries including the periodically back-flowing outlet, the Pasig River.

As of 2000, the base population of the domestic sector was around 6.6 million or about 9 percent of the country's total population (NSO 2000). About 60 percent of the total solid and liquid waste inputs came from this sector, while industry contributed 30 percent, and the other sectors, 10 percent.

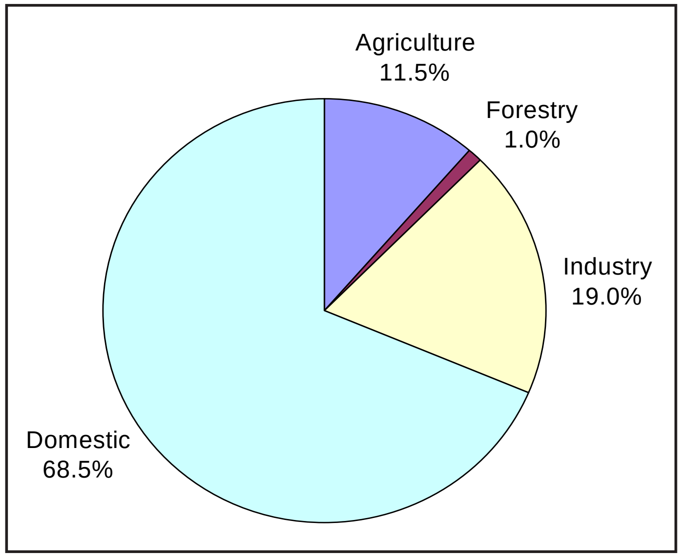

Figure 3.1. The percentage contribution of the major sources of pollutants in Laguna de Bay (LLDA 2002).

3.1.1.2 Nutrient level and eutrophication

Eutrophication. This is a process of over-enrichment of a body of water with the nutrients, nitrogen (N), phosphorus (P), and carbon (C). It manifests through the preponderant growth of algae called "algal bloom". Of the three causal elements of a bloom, the often emphasized are N and P. Lakes being inland water bodies go through the following successive stages of trophic development: oligotrophic, mesotrophic, eutrophic, and dystrophic. An oligotrophic lake is relatively pristine with a very low productivity. As its nutrient load increases with time, primary production is stimulated and secondary production follows - the lake graduates to the mesotrophic status. Lake fertility is further raised as autochthonous (internally derived) nutrients pile up at the same time that the allocthonous (extremely derived) inputs continue. The increased fertility further stimulates production evident in the development of an algal blom, at which point the lake is said to be eutrophic. There are a number of parameters used in combination to arrive at the trophic classification of lakes (Tables 3.1 and 3.2).

Nutrient levels in Laguna de Bay have been extremely high as early as 1973 (SOGREAH 1974). The lake was considered hypertrophic way back in the early 1970s (SOGREAH 1974), or even earlier (Villadolid 1933) - a valid reason for its high fish production at the time.

Hypertrophication in the 1970s was the result of high nutrient inputs from the watershed. Of the estimated 5,000 t of N entering the lake at that time, 26 percent came from domestic sources, 36 percent from livestock and poultry, 5 percent from industrial sources, 11 percent from fertilizers, and 22 percent from the Pasig River backflow. Nitrate-N averaged around 150 $\mu g\ l^{-1}$ while the total nitrogen (TN) was assumed to range from 900 to 1,000 $\mu g\ l^{-1}$. Inorganic phosphate was below 40 $\mu g\ l^{-1}$, and the total phosphate (TP) was below 100 $\mu g\ l^{-1}$. In 2000, the use of a Laguna de Bay waste load model put the total N input at around 13,800 t yr^{-1}. Of this, 79 percent came from domestic sources, 16.5 percent from agricultural activities, 4.5 percent from industrial effluent, and 0.5 percent from other sources.

Today, with the burgeoned watershed population of around 6.6 million (LLDA 2003), and with the croplands around the lake having been converted to subdivisions, the estimated contribution of domestic wastes to lake pollution would be higher, while that of agriculture in the form of fertilizers, lower. Supporting evidences for the primacy of domestic wastes in the process of cultural eutrophication in lake are many: the high density of domiciles in the human settlements around the lake; the absence of decent latrines to contain sewage; the heaps of garbage, floating refuse and debris; etc. The problem of eutrophication in Laguna de Bay is exacerbated and perpetuated by the lack of a centralized sewage system. Domiciles are located near the level of high water, at the water's edge, or over the water itself. Early in the 1970s, the SOGREAH (1974) observed that at least half of the sample populations in Rizal and Laguna had unsanitary latrines or none at all. An estimated 17 percent of the total N coming from sewage flowed into runoff. The estimated total N contribution of runoff water at the time was 1,258 t.

Agriculture also contributes to lake pollution through runoff water from the fertilized crop lands and from livestock and poultry farms. Some 39 percent of the lake's total N input

Table 3.1. Some trophic state indicators for lakes and values for Laguna de Bay.

Period/Indicators	Oligotrophic	Mesotrophic	Eutrophic	Hypertrophic	Laguna de Bay****
Primary Productivity*					
Mean daily rates in a growing season,					
mg C m^{-2} day^{-1}	30-100	100-300	300-3,000	>3,000	8,000 (1970s) ~1,000 (1990s)
g C m^{-2} day^{-1}	0.03-0.10	0.1-0.3	0.3-3.0	>3.0	0.65 (EB) 1.35 (WB) 1990s
Total annual rates, g C m^{-2} yr^{-1}	10.95-36.5; 7-75	36.5-109.5	109.5-1,095; 75-700	>1,000	2,922 (1970s) 365 (1990s)
t C ha^{-1} yr^{-1}	0.1-0.365; 0.07-0.74	0.365-1.095	1.1-10.95; 0.75-7	>11	2.86 (1996) 3.06 (1997) 4.38 (1998) 4.66 (1999)
Biomass					
Chlorophyll *a*,** mg m^{-3}	0-4	5-9	10-100		29.9 (1998) 33.8 (1999) 3.5 (SB, 1999)
Annual mean chlorophyll,*** mg m^{-3}	2.5	2.5-8	8-25	25+	
Nutrients					
Total P,*** mg l^{-1}	0.01	0.01-0.035	0.035-0.10	>0.10	0.25 (WB, 1990s) 0.23 (EB, 1990s) 0.28 (LDB, 1996)
Total N, mg l^{-1}			0.3		1.78 (LDB, 1996)
Annual mean Secchi disk transparency,*** m	6.0	6-3	3-1.5	1.5	0.42 (WB, 1990s) 0.40 (EB, 1990s)
Secchi disc transparency Minima,*** m	3.0	3-1.5	1.5-0.7	<0.7	0.10 (WB) 0.05 (EB)

* Rodhe (1969). Cited in US EPA. Water Quality Criteria, 1972
** APHA-AWWA-WPCF (1971); Edmondson (1970). Cited in US EPA. Water Quality Criteria, 1972
*** Sources: Hakanson, 1980; Hakanson and Jansson, 1983; Meybeck et al. 1989.
**** LLDA (1996-1999).

came from this sector in 1973. The figure would be higher today because of the increased demand for pig and poultry products.

Finally, there are the N and P contributions of aquaculture. Decomposing supplemental feeds given in excessive amounts along with fecal matter from fish exacerbate the eutrophication problem. Decomposing algal blooms and fish excretions replenish the nutrient pool that lies very close to its surface favoring algal growth. Cariaso (1982) took note of the abandoned fishpen and fish cage materials as slow-release sources of nutrients enhancing lake eutrophication.

The most recent estimates of nitrogen supply in Laguna de Bay reflect the failed effort to significantly reduce lake eutrophication. Barril (2003) observes that the nitrogen supply from 1990 to 1999 averaged 1.10-1.27 mg l^{-1} in East and West bays, respectively (Tables 3.3a and 3.3b). These values are higher than the critical level of 0.30 mg l^{-1} N in algal bloom development.

But notwithstanding the high levels of plant nutrients in the lake, algal blooms have become a rare occurrence in the late 1980s to the 1990s (Santiago 2003). In June-July 1973, a lake-wide algal bloom of *Microcystis* brought the density of

Table 3.2. Some characteristics of lake types (Anderson 1981).

Period/Indicators	Oligotrophic	Mesotrophic	Eutrophic	Dystrophic
NPP (g C m^{-2} yr^{-1})	15-50	50-150	150-500	10-100
Phytoplankton Biomass (mg C m^{-3})	20-200	200-600	600-1,000	20-400
Total organic matter	1.0-5.0	1.0-5.0	10-100	20-400
Chlorophyll *a* (mg l^{-1})	0.0003-0.003	0.002-0.015	0.010-0.5	0.00001-0.002
Light penetration (m)	20-200	5.0-40	3.0-20	0.00001-0.002
Total P (mg l^{-1})	0.001-0.005	0.005-0.010	0.010-0.030	0.001-0.010
Inorganic N (mg l^{-1})	<0.001-0.20	0.20-0.40	0.30-0.65	0.001-0.20
Total inorganic solutes (mg l^{-1})	2.0-20	10-200	100-500	5-100

algae to a million a millimeter. Consequent to this was the blooms' most damaging effect on aquaculture when an estimated 5 million milkfish died during a massive fish kill following the collapse of the algal bloom.

Nutrient supply is one of three primary factors that could possibly limit algal photosynthesis or primary productivity in the lake. Between N and P, the former has often been identified as limiting, which probably explains why researchers address this concern. The other factors are water temperature and turbidity or the ability of the water to allow sunlight to pass through. Water temperature was the first identified limiting factor based on 1973-1977 data (LLDA-WHO 1978). Then followed the designation of nutrient supply, particularly N (BCEOM 1984). The idea of a light-limited photosynthesis was brought up in 1981 (Nielsen 1981; Nielsen and Santiago 1981) For the decade 1990-1999, nitrogen again surfaced as the limiting factor based on the N/P ratio of 5-6.4 (Tables 3.3a, 3.3b, and 3.7). A ratio above 7, would make P the limiting element (Meybeck et al 1989).

3.1.2 Status and Trends of Chemical Water Quality Parameters

Laguna de Bay is a Class C inland water (DENR 1990) suitable for domestic water use, contact recreation, and for fishery. This classification is based on its intended use but not on its trophic status. In the present assessment, emphasis is given to both the degree of compliance with water quality standards contained in DAO 34, and trophic status. Trend analysis is done to show how parameters behaved through time.

The principal data used came from the results of water quality monitoring studies conducted by the Institute of Chemistry, UPLB (IC-UPLB) from 1985 to 1997 (Barril 2000), and by the LLDA from 1996 to 1999. Other data include those of LLDA (1988), Borja (1990), Zafaralla (1990), Barril (1993),

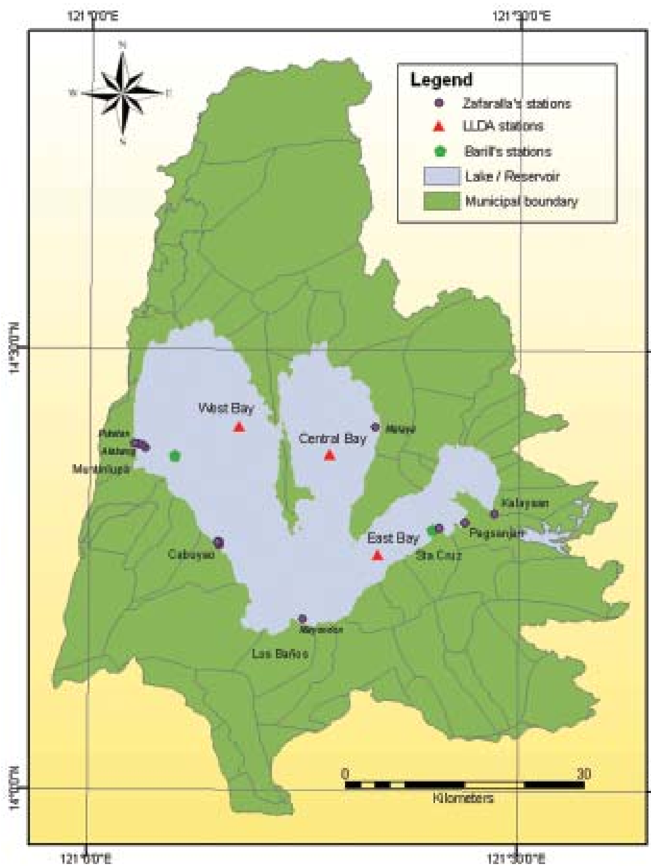

Figure 3.2. Sampling stations of Zafaralla, Barril, and LLDA.

and the unpublished data of Zafaralla and Santos for 1984-1985. Station locations are presented in Figure 3.2.

The combined water quality data for the period 1990 to 1999 are summarized in Tables 3.3a and 3.3b to show the annual means and standard deviations of the different water quality parameters for East and West bays. Tables 3.4, 3.5, and 3.6 present a summary of LLDA data for the decade 1990 to 1999 for East bay, Central bay, and West bay, respectively.

Table 3.7 shows the annual means and ranges for the entire lake in 1996. The variations of key parameters for the past 12 or so years from 1986 to 1999, are depicted using a three year moving trend analysis based on annual means (Figures 3.3 to 3.16).

Nitrogen. The available forms of this element are ammonium (NH_4^+), nitrate (NO_3^-), nitrite (NO_2^{2-}). The total nitrogen (TN or TKN) combines all ionic forms and those fixed in the tissues of living organisms and organic debris. It is a measure of how much N was incorporated in organic biomass.

The earliest monitoring by the LLDA from 1973 to 1977 focused on two available forms. Nitrate ranged from 20 to 500 µg l^{-1}, the peak values developing in the cooler season, while the lower in the dry. Of the four bays, Central bay had the highest N values. In relation to eutrophic criterion, the internationally recognized desirable limit for nitrate-N is <0.3 mg l^{-1} (Sawyer 1947). This limit was exceeded from 1974 to the 1990s in many parts of the lake (Barril 2003; Zafaralla 1990; Baluyot and Sacro 1981).

The combined NH_3-N data of the UPLB (Barril 2000) and LLDA for the decade 1990-1999 gave an average mean of around 0.27 mg l^{-1} for both the West and East bays (Tables 3.3a and 3.3b). This exceeds the Class C criterion of <0.016 mg l^{-1}. The higher concentration of ammonia relative to nitrates indicates increasing anaerobiosis due to the accumulated decomposable organic materials in the lake. This condition may lead to low DO levels near the bottom sediments where most of the anaerobic decomposition process occurs (Barril 2002).

The LLDA did not include total N among its baseline parameters. For the decade 1990-1999, the TKN averaged 1.27 and 1.10 mg l^{-1} in West and East bays, respectively. These are excessive of the minimum level for eutrophication (Tables 3.3a and 3.3b).

Ammonia and nitrate levels followed an upward course toward 1995 then declined thereafter. Total N, on the other hand, showed a sustained upward trend throughout the 12-year period between 1986 to 1999 (Figures 3.3a, 3.3b, 3.4a, 3.4b, 3.5a, and 3.5b). Increasing levels of the available N forms until 1995 may indicate reduced uptake by a reduced phytoplankton population. An increasing total N implies an enlarged store of potentially available N.

Phosphorous. Two forms of phosphorus (P) have been studied, the available form or orthophosphate (ortho-P) and total P (TP). The former includes a number of ionic forms of P that are available for uptake by autotrophs. Total P pertains to the combined available P and fixed P in the bodies of living and dead organisms, animal excreta, organic exudates and debris, and the P fixed by inorganic substances. The recommended levels of available P are 0.10 mg l^{-1} for flowing waters, and 0.05 mg l^{-1} for the protection of lakes and reservoirs (LLDA 1987). A more stringent standard of 0.025 for lakes and reservoirs is shared by the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA). The class C water quality criterion is 0.01 mg l^{-1}. TP is not a water quality criterion, but this rather than ortho-P is quantified in classifying the trophic status of waters.

The baseline data for ortho-P in Laguna de Bay range from 10 µg l^{-1} to over 100 µg l^{-1} (LLDA-WHO 1978). For the decade 1990-1999, the average means in West bay and East bay were 12 times the Class C criterion of 0.01 mg l^{-1} (Table 3.3a and 3.3b). In terms of TP, the average of the means in West and East bays were 0.25 mg l^{-1} and 0.23 mg l^{-1}, respectively, implying that these places were eutrophic at the time. At the local level in South bay, the unpublished data of Zafaralla and Santos obtained in 1984-1985 in Mayondon, Los Baños and Sta. Cruz, Laguna relegates the lake under the hypereutrophic category. This is the earlier recognized trophic status of the lake in the early days of aquaculture and possibly, as early as the 1960s (Table 2.2).

Both ortho-P and TP have been on an upward course in the lake (Figures 3.6a, 3.6b, 3.7a and 3.7b). Oscillations of ortho-P have been irregular with the standard deviation at times equal to the mean. The intensity of algal blooms, surges of releases from anthropogenic sources, and the stirring up of sediments are some of the strong influences on P dynamics in the lake (Zafaralla and Mercado 2005, in press).

Dissolved Oxygen The baseline DO range is 5-11 mg l^{-1}. For the decade 1990-1999, the average means were 7.6 and 7.4 mg l^{-1} in West bay and East bay, respectively. The year 1996, which preceded an El Niño year, was marked by the lowest DO readings (Table 3.7). It was the year of a most turbid lake whose mean annual secchi depth was a low of 21.7 cm for the entire lake. Except for this unusual year, the rest of the time gave steady concentrations (Figures 3.8a and 3.8b).

Different places in the lake exhibited different DO means during the same time of day, implying a horizontal differentiation into high and low DO areas. This is expected because different parts of the lake have different water uses. In the area of Putatan in Muntinlupa City, where water is presently abstracted for domestic use, there stands an active abattoir, whose presence could very well be one of the causes for DO to dip down to as low as 1.3 mg l^{-1} in the daytime (Zafaralla and Mercado 2005, in press).

Table 3.3a. Water quality of West bay of Laguna de Bay [annual means and standard deviation (SD)].

Parameters	1990	1991	1992	1993	1994	1995	1996	1997*	1998*	1999*	Ave**
NH_3-N (mg l^{-1})	0.20	0.42	0.34	0.58	0.16	0.59	0.15	0.04	0.17	0.04	0.27
SD	0.34	0.32	0.28	0.41	0.11	0.58	0.15	0.03	0.46	0.06	0.27
NO_3-N (mg l^{-1})	0.19	0.19	0.61	0.51	0.79	0.73	0.32	0.14	0.02	0.084	0.36
SD	0.17	0.17	0.60	0.58	0.61	0.52	0.28	0.17	0.02	0.083	0.32
TKN (mg l^{-1})	1.04	1.44	1.26	1.01	1.04	0.19	2.19		1.25	1.04	1.27
SD	0.73	1.00	0.37	0.48	0.58	0.52	1.44		1.12	0.54	0.75
Chloride (mg l^{-1})	126	383	486	710	358	288	184	263	1,165	403	437
SD	161	337	242	299	96	157	81	224	650	145	239
E.C. (mS cm^{-1})	1.87	1.86	2.10	2.34	1.14	0.28	0.38			1.42	1.42
SD	1.21	1.22	0.98	0.86	0.31	0.29	0.24			0.64	0.72
Hardness (mg l^{-1})	160	161	189	290	144	137	116	128	572	166	206
SD	117	96	96	135	35	49	38	88	363	49	107
Total P (mg l^{-1})	0.50	0.25	0.20	0.11	0.16	0.21	0.19		0.39	0.27	0.25
SD	0.61	0.10	0.18	0.06	0.11	0.16	0.11		0.44	0.13	0.21
Ortho-P (mg l^{-1})	0.26	0.09	0.12	0.04	0.11	0.11	0.11	0.23	0.03		0.12
SD	0.27	0.05	0.11	0.03	0.09	0.13	0.09	0.16	0.02		0.11
DO (mg l^{-1})	7.97	6.98	7.96	8.25	7.32	7.40	7.12	8.05	7.86	7.54	7.64
SD	1.08	1.17	0.97	0.78	0.75	0.71	1.40	0.90	0.99	0.59	0.93
COD (mg l^{-1})	18.6	19.7	34.7	42.2	25.4	48.0	41.3	43.0	62.0	54.7	39.0
SD	7.6	16.7	22.2	14.7	6.4	16.7	27.0	40.9	44.0	35.6	23.2
Clarity (Secchi depth in cm)	47	30	38	47	36	32	22	42	78	46	42
SD	30	11	19	19	21	23	12	26	27	13	20
Temperature (^{o}C)	29.00	27.00	26.80	29.60	28.30	29.00	28.30	29.00	31.00	28.8	28.7
SD	2.20	1.40	1.70	1.80	2.00	2.10	2.10	1.90	2.60	2.6	2.0
pH	8.4	8.2	8.4	8.9	7.9	8.2	8.2	8.3	8.5	8.0	8.3
SD	0.6	0.5	0.7	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.6
Alkalinity (mg l^{-1} $CaCO_3$)	70.00	51.00	56.00	32.00	47.00	68.00	70.00	75.00	35.00	25	53
SD	17.00	11.00	15.00	8.00	7.00	13.00	9.00	11	14	8	11
Oil and grease								1.65	1.50	2.60	1.92
TDS							473	612	2,514	878	1,119
TSS							158	100	43	45	87
Turbidity								58	20	32	37
NPP (g C m^{-2} day^{-1})							0.83*	1.00	1.5	1.5	1.30

* LLDA data
** Average of annual means and standard deviations.

Seasonal differences in DO are common. The wet season is characterized by better aerated waters than the dry. A gap in the knowledge about DO dynamics concerns its behavior at nighttime and in the early morning. Filling this gap will help shed light on the role of DO in the lake's fish kill phenomenon. Of late, fish kills seem to have diminished in frequency of occurrence.

Table 3.3b. Water quality of East bay of Laguna de Bay [annual means and standard deviation (SD)].

Parameters	1990	1991	1992	1993	1994	1995	1996	1997*	1998*	1999*	Ave**
NH_3-N (mg l^{-1})	0.33	0.36	0.37	0.53	0.14	0.72	0.15	0.05	0.02	0.02	0.27
SD	0.42	0.37	0.39	0.35	0.09	0.47	0.15	0.05	0.02	0.04	0.23
NO_3-N (mg l^{-1})	0.17	0.20	0.21	0.38	0.43	0.47	0.19	0.14	0.02	0.05	0.23
SD	0.13	0.16	0.12	0.22	0.37	0.26	0.14	0.13	0.02	0.05	0.16
TKN (mg l^{-1})	0.95	0.84	1.08	0.89	1.11	1.12	1.63		1.00	1.27	1.10
SD	0.71	0.35	0.43	0.51	0.66	0.56	0.80		0.87	0.92	0.65
Chloride (mg l^{-1})	126	145	167	275	166	193	107	159	664	266	227
SD	161	77	101	126	75	83	55	85	366	107	124
E.C. (mS cm^{-1})	0.42	0.55	0.73	0.97	0.48	0.12	0.19			1.19	0.58
SD	0.35	0.29	0.40	0.45	0.25	0.09	0.15			0.60	0.32
Hardness (mg l^{-1})	57	65	65	106	68	85	83	110	387	130	115.6
SD	36	20	39	47	27	26	34	107	209	34	58
Total P (mg l^{-1})	0.48	0.16	0.17	0.10	0.14	0.16	0.25		0.39	0.26	0.23
SD	0.51	0.08	0.10	0.03	0.09	0.12			0.58	0.09	0.20
Ortho-P (mg l^{-1})	0.32	0.08	0.09	0.06	0.10	0.09	0.07	0.21	0.01		0.11
SD	0.36	0.04	0.05	0.02	0.07	0.07	0.04	0.19	0.02		0.09
DO (mg l^{-1})	7.50	6.50	7.10	720	7.60	7.30	7.20	8.20	7.60	7.6	7.4
SD	1.00	0.90	0.60	0.40	0.70	0.60	0.60	0.80	1.00	0.4	0.7
COD (mg l^{-1})	13.5	10.6	16.5	23.8	18.7	27.1	33.4	23.0	34.0	44.4	24.5
SD	5.70	6.00	9.10	8.70	8.20	5.90	18.00	17.40	17.35	18.3	11.5
Clarity (Secchi depth in cm)	27.0	41.0	31.0	34.0	32.0	28.0	21.6	41.0	90.0	51.0	40
SD	19.0	14.0	15.0	12.0	13.0	20.0	15.0	29.0	35.0	19.0	19.1
Temperature (°C)	28.6	27.3	25.5	29.0	28.2	27.4	27.7	28.0	30.0	28.3	28.0
SD	2.3	1.8	1.7	2.4	1.7	3.1	3.1	1.7	2.2	2.4	2.2
pH	8.0	7.8	7.8	8.0	7.6	7.9	7.8	8.1	8.0	7.9	7.9
SD	0.4	0.6	0.7	0.4	0.3	0.2	0.2	0.5	0.3	0.4	0.4
Alkalinity (mg l^{-1} $CaCO_3$)	55.00	42.00	45.00	27.00	40.00	56.00	56.90	70.00	31.00	26	45
SD	21.00	12.00	14.00	6.00	8.00	12.00	17.00	12	14	6	12
Oil and grease								1.25	1.40	2.50	1.33
TDS							384	434	1,421	625	716
TSS							162	71	39	38	78
Turbidity								58.0	24.0	32.0	38
NPP (g C m^{-2} day^{-1})							0.53*	0.56	0.79	0.71	0.65

* LLDA data
** Average of annual means and standard deviations.

Table 3.4. Water quality of East bay of Laguna de Bay (annual means of LLDA data).

Parameters	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Ave.
NH_3 (mg l^{-1})	0.0240	0.0346	0.0453	0.0465	0.1396	0.0768	0.0822	0.0491	0.0306	0.0046	0.0533
NO_3 (mg l^{-1})	0.1434	0.0626	0.1536	0.0234	0.1408	0.2232	0.0393	0.1441	0.0301	0.0414	0.1002
TN (mg l^{-1})	no data	no data	no data	no data	no data	no data	no data	no data	1.01	0.90	0.95
Chloride (mg l^{-1})	231	270	435	654	257	211	127	159	664	266	327
E.C. (µS)	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	
TH (mg $CaCO_3$ l^{-1})	175	118	149	186	105	133	80	110	387	130	157
TP (mg P l^{-1})	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	
PO_4 (mg P l^{-1})	0.1287	0.0644	0.0627	0.0554	0.0582	0.1189	0.0563	0.2142	0.0134	0.0032	0.0775
DO (mg l^{-1})	8.0	8.3	7.9	7.5	6.3	8.8	8.2	8.2	7.6	7.6	7.8
COD mg l^{-1}	22	34	29	18	21	23	23	23	34	38	26
SD (cm)	64.1	58.8	64.6	67.9	46.9	47.5	49.2	41.3	90.0	50.8	58.1
T (°C)	28.0	28.0	28.7	28.5	29.5	29.2	28.5	28.2	30.4	28.3	28.7
pH	8.0	7.7	8.4	8.0	7.8	8.3	8.1	8.1	8.0	7.9	8.0
Alkalinity (mg $CaCO_3$ l^{-1})	63	46	61	43	58	78	66	70	31	26	54
Oil and grease (mg l^{-1})	0.66	7.24	8.96	3.82	50.15	2.89	1.44	1.67	1.36	2.54	8.07
TDS (mg l^{-1})	602	612	816	1,044	591	583	318	434	1,421	625	705
TSS (mg l^{-1})	51	32	46	36	54	70	39	71	39	38	48
TRS (mg l^{-1})	42.6	27.8	36.6	24.4	66.1	39.9	27.0	58.0	23.8	31.5	37.8
NPP (g C m^{-2} day^{-1})	1.00	1.55	1.08	0.45	0.27	0.69	0.53	0.56	0.79	0.70	0.76
TC (MPN/100 ml)	1,548	1,128	1,709	455	1,752	2,070	4,061	860	128	283	1,399

Table 3.5. Water quality of Central bay of Laguna de Bay (annual means of LLDA data).

Parameters	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Ave.
NH_3 (mg l^{-1})	0.0320	0.0482	0.0799	0.0393	0.0694	0.0750	0.0379	0.0318	0.0296	0.0057	0.0449
NO_3 (mg l^{-1})	0.1632	0.0781	0.1677	0.0213	0.2582	0.2663	0.0630	0.1557	0.0359	0.0427	0.1252
TN (mg l^{-1})	no data	no data	no data	no data	no data	no data	no data	no data	0.75	0.69	0.72
Chloride (mg l^{-1})	514	350	674	1,077	369	392	166	229	1,066	438	527
E.C. (µS)	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	
TH (mg $CaCO_3$ l^{-1})	254	158	245	272	139	249	92	117	481	174	218
TP (mg P l^{-1})	no data	no data	no data	no data	no data	no data	no data	no data	0.39	0.22	0.30
PO_4 (mg P l^{-1})	0.1499	0.0369	0.0896	0.0310	0.1045	0.1560	0.0761	0.2718	0.0247	0.0118	0.0952
DO (mg l^{-1})	8.3	8.4	8.2	8.1	6.8	8.8	8.5	8.2	7.9	8.2	8.1
COD (mg l^{-1})	30	40	36	22	27	20	18	22	34	46	30
SD (cm)	81.8	65.0	692	88.6	49.7	57.9	53.3	58.3	86.7	70.0	68.0
T (°C)	28.1	28.1	28.8	28.9	29.3	29.4	28.1	28.4	30.3	28.5	28.8
pH	8.4	8.0	8.7	8.3	8.1	8.4	8.3	8.3	8.2	8.2	8.3
Alkalinity (mg $CaCO_3$ l^{-1})	70	48	67	50	61	80	71	71	31	28	58

Table 3.5. *Continued...*

Parameters	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Ave.
Oil and grease (mg l^{-1})	58.45	58.03	26.53	7.83	14.68	5.67	1.73	1.07	1.57	3.09	17.86
TDS (mg l^{-1})	1,164	793	1,289	1,846	815	1,102	402	564	2,317	950	1,124
TSS (mg l^{-1})	47	33	48	20	45	55	29	75	37	24	41
TRS (mg l^{-1})	36.6	25.8	32.1	15.6	65.9	27.2	20.1	52.0	17.7	20.4	31.3
NPP (g C m^{-2} day^{-1})	1.76	1.79	1.46	1.00	0.48	0.72	0.59	0.90	1.13	1.37	1.12
TC (MPN/100 ml)	2,743	1,706	2,396	1,071	588	1,409	2,605	946	334	766	1,456

Table 3.6. Water quality of West bay of Laguna de Bay (annual means of LLDA data).

Parameters	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Ave.
NH_3 (mg l^{-1})	0.0707	0.0663	0.0686	0.0869	0.1420	0.0733	0.0837	0.0380	0.0812	0.0369	0.0748
NO_3 (mg l^{-1})	0.1637	0.0745	01591	0.0255	0.2624	0.2298	0.0333	0.1435	0.0220	0.0498	0.1164
TN (mg l^{-1})	No data	No data	No data	No data	No data	No data	No data	No data	1.25	0.78	1.01
Chloride (mg l^{-1})	548	355	706	1,007	339	547	160	263	1,165	403	549
E.C. (µS)	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	
TH (mg $CaCO_3$ l^{-1})	269	153	238	265	142	266	90	128	533	166	225
TP (mg P l^{-1})	No data	No data	No data	No data	No data	No data	No data	No data	0.39	0.25	0.32
PO_4 (mg P l^{-1})	0.1287	0.0442	0.1087	0.1059	0.0769	0.1435	0.0686	0.2303	0.0278	0.0091	0.0944
DO (mg l^{-1})	7.9	7.6	7.7	7.2	6.8	8.9	8.3	8.4	8.9	7.9	8.0
COD (mg l^{-1})	48	43	55	22	23	25	35	43	62	51	41
SD (cm)	88.2	54.0	66.3	78.5	43.5	45.9	44.2	42.1	78.3	49.2	59.0
T (°C)	27.7	27.5	28.7	28.1	29.5	29.4	28.6	28.7	31.0	28.8	28.8
pH	8.3	7.6	8.5	8.0	7.9	8.4	8.2	8.3	8.5	8.0	8.2
Alkalinity (mg $CaCO_3$ l^{-1})	76	49	69	47	64	83	76	75	35	26	60
Oil and grease (mg l^{-1})	38.21	24.84	7.61	78.92	436.73	4.41	0.95	1.80	1.52	2.63	59.76
TDS (mg l^{-1})	1,157	904	1,427	1,897	769	1,300	389	612	2,514	878	1,185
TSS (mg l^{-1})	60	54	65	27	81	65	60	100	43	45	60
TRS (mg l^{-1})	35.5	30.0	36.3	19.2	74.8	35.5	43.5	58.1	20.2	31.8	38.5
NPP (g C m^{-2} day^{-1})	1.24	1.74	1.88	2.21	0.90	1.44	0.83	1.01	1.88	1.51	1.46
TC (MPN/100 ml)	2,521	769	3,366	3,276	968	2,718	3,414	1,609	131	496	1,927

COD and BOD. Chemical oxygen demand indicates the amount of oxidizable substances both organic and inorganic present in water. Thus, the value of COD theoretically includes the BOD load.

For the decade in review, COD registered average means of 39 and 24 mg l^{-1} for West and East bays, respectively. The highest annual means in 1998 were 62 and 34 mg l^{-1}, respectively (Tables 3.3a and 3.3b). These values exceeded the criteria for Class C waters (i.e., BOD level of 9 mg l^{-1}). Trend-wise, the increase in COD levels is alarming particularly towards the end of the last millennium (Figures 3.9a and 3.9b). It implies increasing amounts of oxygen demanding substances, both organic and inorganic.

BOD is the amount of oxygen required in the biological decomposition of organic wastes. The kinds and amounts of effluent dumped, the season of the year, and the place where

Table 3.7. Annual means and ranges of the different water quality parameters of Laguna de Bay (1996).

Parameter		East Bay		West Bay		Central Bay		South Bay		Average of Means
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	
Temperature (°C)	s	27.8	23.6-32.6	28.6	24.5-32.0	28.4	24.0-31.3	28.1	24.2-30.9	28.2
	b	27.5	23.6-30.0	28.0	24.2-30.1	27.9	24.1-30.3	27.7	24.2-29.9	27.8
pH	s	7.7	6.8-8.5	8.1	7.5-8.9	8.2	7.5-9.0	8.1	7.2-9.1	8.0
	b	7.8	7.4-8.7	8.1	7.4-9.7	8.1	7.5-9.0	8.1	7.5-8.9	8.0
Conductivity (mS cm^{-1})	s	214	38.3-489	388	75.2-717	330	50.8-771	292	77.5-730	306
	b	228	35.7-488	395	67.7-714	325	47.7-770	295	68.5-726	311
Clarity (cm)		21.6	5.0-58	22.0	7.5-51.7	21.3	5.0-46.7	22.1	7.0-55	21.7
Hardness (mg l^{-1})		83.2	7.83-156	113	38.8-201	116	28.5-223	100	22.0-228	103
Alkalinity (mg l^{-1})		56.9	11.6-75.0	67.0	29.7-84.0	71.3	34.7-153	83.4	43.5-155	69.7
Chloride (mg l^{-1})		107	15.8-239	152	43.6-312	150	60.6-277	134	37.2-250	136
TSS (mg l^{-1})		162	19.0-344	158	29.0-426	129	49.0-294	137	16.0-384	146
TDS (mg l^{-1})		384	201-679	473	210-809	374	52.0-651	371	55.0-788	400
DO (mg l^{-1})	s	7.8	6.4-8.7	7.9	6.3-9.1	7.4	6.1-8.0	7.6	6.4-8.6	7.7
(Daytime levels)	b	6.7	4.7-8.3	7.1	5.3-9.7	6.8	5.0-7.8	7.0	4.4-7.6	6.9
COD (mg O_2 l^{-1})		33.4	7.17-70.5	35.4	6.33-87.5	35.1	6.25-93.4	32.6	6.70-69.36	34.1
Ortho-P (mg l^{-1})		0.067	0.023-0.172	0.124	0.034-0.38	0.076	0.023-0.122	0.101	0.18-0.450	0.092
Total P (mg l^{-1})		0.251	0.093-1.08	0.318	0.054-1.24	0.268	0.041-1.20	0.276	0.041-1.310	0.28
NH_3-N (mg l^{-1})		0.135	0.048-0.594	0.228	0.025-0.563	0.157	0.017-0.72	0.132	0.035-0.239	0.16
TKN (mg l^{-1})		1.63	0.560-3.78	2.20	0.79-5.230	2.06	0.597-5.78	1.21	0.478-4.560	1.78
Nitrate-N (mg l^{-1})		0.188	0.104-0.546	0.338	0.074-0.882	0.226	0.080-0.372	0.154	0.081-0.267	0.23

s = surface
b = bottom

measurement is done, are the factors influencing the levels of BOD in the lake. Water treatment facilities address the BOD load of liquid effluents coming from industries.

Industry is a major contributor of pollutants in Laguna de Bay. It contributes about 30.4 percent of the total pollution load being disgorged into the lake. There are now some 4,000 industrial establishments in the basin, most of which are located in West bay area.

The BOD production by the industry sector is shown in Table 3.8. Based on the estimates of Orbeta and Indab (1994), industry is the highest generator of BOD in the watershed, exceeding the contribution of the domestic sector by at lease 55 percent. Zafaralla, in her examination of the records of industrial establishments, observed that of the 897 industries monitored in 1994, only 31 firms (3.5 percent) had pollution control devices or water treatment facilities (WTF). The rated BOD removal efficiency of the then-existing WTFs was 88.5 percent. LLDA (2004) put out recent information showing that industries discharging wastewater effluents into the lake represent 70 percent of the total BOD loading. Only 29 percent of this portion has water treatment facilities.

The lake suffers from the highest loading of high-BOD materials mostly during the rainy season. This unexpected situation may be due to the increased scale of production, and therefore wastewater generation, by manufacturing firms in the wet season. BOD from these sources is conveyed by tributary streams and rivers. Remaining to be uncovered in relation to lake BOD increases in the wet season is the role of algal bloom die-off that generally occurs at this time.

Water Clarity. A measure of water clarity is called secchi disk (SD) transparency. At the depth where the disk just disappears, only 1 percent of the incident solar radiation at the surface of the water remains. There would be a net gain in the amount of organic materials produced in photosynthesis above secchi depth called the photic zone. Below it, or within the aphotic zone, no gain results because the products of the light-limited photosynthesis there would not compensate for the metabolic cost of respiration. Baseline monthly SD readings generated by the LLDA-WHO (1978) range from 0.08 to 1.3 m. Cooler months are more turbid at 0.4 m SD, while summer months have improved clarity with SD equal to 2 m.

Based on water clarity, Laguna de Bay is a highly disturbed lake. It has been on an increasingly turbid state until mid-1997 with the year 1996 registering a low annual mean of 21.7 cm for the entire lake. The dry season level was as low as 10 cm from 1986 to 1997. This is quite disturbing because SD is an intensity parameter whose impact depends more on its temporal or ambient level than on the annual mean.

The water quality criterion specifies that SD should not be less than 100 cm for Class C waters (Table 3.7, Figures 3.10a and 3.10b). The range for eutrophic lakes is 0.8-7.0 with a mean of 2.45 (Vollenweider 1968). Others give very similar values (Table 3.2). In 1989, the SD readings in some areas in East and West bays fell below the indicated lower limit, i.e., these had a range of 0.05 to 0.4 m and a mean of 18.5 cm (Zafaralla et al. 1990). Other data sets show 1989 as one with the worst SD readings (Barril 1990; 1994; 2002). This could be a sign that at the physical level, the lake was already becoming dystrophic as early as before the 1990s (Figures 3.10a and 3.10b).

In 1998, the annual mean improved to 78 cm (Tables 3.3a and 3.3b), a consequence of the high salinity water that entered the lake in that year (Cl^- mean = 1165 mg l^{-1}). By 1999, the mean SD of the lake again bordered around 0.46 m (LLDA 1999).

The growing murkiness of the water in Laguna de Bay implies that the deposition of turbidity-causing materials has been continuous and unabated. Consequently, the shoaling or shallowing process continues. When the sediments are closer to the water's surface, the lake's bottom sediments are facilely re-suspended, rendering the overlying water turbid. Laguna de Bay is wind-stirred from around 10:00 o'clock in the morning to 3:00 o'clock in the afternoon. This makes for its high turbidity development on a daily basis. Because of this condition, even the statistically significant differences between seasons are even smaller than the lower limit of the secchi disk transparency of eutrophic lakes (Table 3.1).

Laguna de Bay is critically turbid. Algae do not grow very well in its waters anymore. An improvement of this condition is not anticipated in the near future because the lake is getting shallower with time. The bottom sediments are already as

Table 3.8. The computed and predicted BOD production by sector in the Laguna de Bay watershed.

Sector	BOD Production (t yr^{-1})				Source
	1976-1985	1985-2000	1990-1995	1990-2000	
Domestic	2,151	2,784			SOGREAH 1974
	477	506	-	-	LLDA 1993
	-	-	1,856	2,269	Orbeta and Indab 1994
Industry	-	-	-	1,360	SOGREAH 1974
	744	1,346	-	-	LLDA 1993
	-	-	2,816	3,520	Orbeta and Indab 1994
Agribusiness	222	360	-	-	LLDA 1993
	-	-	339	595	Orbeta and Indab 1994
Pasig inflow	457	752	-	-	LLDA 1993
	-	-	700	790	Orbeta and Indab 1994

much as three meters thick, thus their contribution to the development of lake turbidity will continue to be higher and higher than that of rivers. Rivers, however, ensure the ready supply of loose materials to be re-suspended. Reduction of lake turbidity is a most pressing problem in managing this body of water to restore its former level of primary production for the benefit of the open fisheries.

While re-suspension of bottom sediments was already the recognized cause of the loss of lake clarity in the 1970s or earlier, this condition is even worse today in terms of expanse and duration. Seasonal differences are small, and the seasonal ranges are below the lower limit of SD water transparency in eutrophic lakes (Table 3.1).

Chloride. In 1998, the chloride annual means in West and East bays were 1,165 and 664 mg l^{-1}, respectively. These concentrations are way above the criterion of 350 mg l^{-1} for Class C Inland Waters. For the last decade, 1990-1999, the means for the two bays were 437 and 227 mg l^{-1}, respectively. It is alarming that the average means in West bay for the last decade has already exceeded the water quality criterion. For while saline water may bring about lake clarification, its high sodium and chloride contents diminish the lake water's suitability for domestic, irrigation, and industrial purposes. The trend of the fluctuating chloride levels during the last 14 years is definitely upward (Figures 3.11a and 3.11b).

The LLDA used a modeling tool, the Delft3D-Flow, to study the dispersion of saltwater entering the lake from the Pasig River. Taking 1995 as a characteristic year with seawater backflow, this government agency established that as early as mid-January, portions of West bay in the vicinity of the Napindan channel already registered salinity levels exceeding the Class C chloride criterion of 350 mg l^{-1}. By February, saline water with chloride higher than the criterion, had dispersed southwards in West bay. In early May, this had already reached the bay's southernmost part fronting Talim Point. At about this time also, slightly saline water from West bay would have entered Central bay via the Diablo Pass. By the end of May, the whole of Central bay had developed higher salinity. The model also showed that seawater backflow reached the sourthernmost part of the lake in June, and a small portion of East bay by the month of August. Salinity levels diminished from September to December. Transport of saline water in the lake was found to be under the influence of the volume of seawater backflow and the intensity of wind-induced water current.

Conductivity. Electrical conductivity (EC) is a relative measure of a natural body of water's richness in ionic species. Different parts of the lake expectedly reflect varied EC levels. In the area of Putatan in West bay, some 10 km away from the mouth of the Pasig or Napindan River, the EC ranged from 350 to 1,100 µS cm^{-1} (Mercado 1999). In the vicinity of the mouth of the Sta. Cruz River, the EC was 65 to 337 µS cm^{-1} (Zafaralla and Valmonte 1990). Salts and heavy metals are the primary influences on the variation of this parameter.

For the decade, 1990-1999 the average means for EC were 1.42 and 0.58 mS cm^{-1} in West bay and East bay, respectively (Tables 3.3a and 3.3b). Trend-wise, both are fluctuating but definitely on the upward trend (Figures 3.12a and 3.12b).

Hardness. This has effects on the toxicity of metals. Depending upon the heavy metal under consideration, toxicity may be enhanced in both soft (20 mg l^{-1} as $CaCO_3$) and hard water (330 mg l^{-1} as $CaCO_3$) (Bunison et al. 1975).

For the decade 1990-1999, hardness ranged from an average mean of 116 mg $CaCO_3$ l^{-1} in East bay to 206 mg $CaCO_3$ l^{-1} in West bay (Tables 3.3a and 3.3b). The trends in hardness are similar to those of conductivity which are both fluctuating but on the uptrend.

Temperature. Laguna de Bay is just like any other tropical lake that cools in the wet season and warms up in the dry season. The mean seasonal difference is about 6-9ºC, while bottom temperature is about 0.5 ºC lower than the surface water temperature (Table 3.7). Thus, there is hardly any thermal stratification because the lake is shallow with an average depth of 2.5 m.

For the period 1986 to 1999, the average mean temperatures for West bay and East bay were the same at 28.7 ± 2.0ºC and 28.0 ± 2.0ºC, respectively (Tables 3.3a and 3.3b). The trends show that over the years, the difference between the minimum and maximum levels had widened (Figures 3.14a and 3.14b). Temperature is an intensity parameter. Its ambient levels during dry and hot months could affect the fish directly physiologically, and indirectly through natural food quality. In the summer months, the diatoms would be at the base of the food chain, while in the wet season, the blue-green algae (BGA) take their turn (Charlton 1993). This biological differentiation shows that the lake temperature interacts with other environmental factors in subtle ways that translate into seasonal changes in the structure of algal communities.

pH and Alkalinity. The range of values of pH for the past decade implies a well buffered body of water with average means of pH 9 ± 0.4 in East bay and pH 8.3± 0.6 in West bay (Tables 3.3a and 3.3b). These pH variations are within the range reported by Gipps and Coller (1980) as favoring a reduced toxicity of Cd to *Chlorella pyrenoidosa.* The latter is also a ubiquitous alga of the lake. The lake's pH is also within the range (pH 6.5-8.5) in which the toxicity of a metal mixture to *Selenastrum capricornutum* was reduced. In 1997-1999, the prescribed upper limit of 8.5 was exceeded as shown in Figures 3.15a and 3.15b (Rosana et al. 1997; LLDA 1997-1999). There is a need to study the effect of pH on heavy metal toxicity in the lake because this body of water is receiving an unknown variety of toxic metals in quantities that could affect the health and well-being of people who depend on it especially for fish.

Alkalinity has an erratic behavior, but its levels appear to be on the downtrend (Figures 3.16a and 3.17b). This parameter is a measure of the buffering capacity of the lake water for incoming acids. An extreme reduction in alkalinity could potentially be ecologically disastrous in the light of increasing acid fluxes.

3.1.3 Assessing the Trophic Condition of the Lake Based on Chemical Properties

Two bases were used to assess the trophic status of the lake utilizing the data gathered by Barril and associates. One set utilized some of the parameters used in determining trophic status classification, while the other comprised of selected criteria for Class C water resources (DAO 34 1990). Many of the water quality parameters have exceeded the prescribed criteria and were still on an upward course during the last decade of the past millennium. Others have fallen to levels indicative of the stressed state of the resource. In terms of the parameters for trophic status determination, TN and TP projected a hypereutrophic state. Ortho-P, chlorides, hardness, and electrical conductivity (not included in the water quality criteria), and COD have, at one time or another, exceeded the criteria for Class C water resources. Those that showed decreasing or erratic trends were clarity, DO, pH and alkalinity.

The LLDA also generated its own set of data within the last decade of year 2000. It regularly undertakes a monthly monitoring of West, Central and East bays. Water quality criteria for Class C water resources were met based on the BOD, NO_3, and DO (Figure 3.17). The maximum limit was exceeded by the ortho-P levels alone in 1997 which was an El Niño year.

The above findings indicate of the existence of some discrepancy in the values of parameters when different sets of data generated by different investigators are examined. Apparently, the place of sampling, the time of sampling, the methods of analysis used, and the handling of the samples, would be a source of differences in the results of physico-chemical determinations done. The issue here is not about which data set is correct. Both are correct. Each set reflects the physico-chemical conditions obtaining around the time where they were collected. The existence of an entire data set showing that the lake conditions appear to be fine should not be a cause for the managers and stakeholders of the resource to rest contented. Rather, it is the existence of cases where the recommended desirable levels are surpassed that should invite attention, and further probing, in order to obtain clues on what could be wrong on the ecosystem. To do this is to prevent perpetuation of the stressed state over a longer period, and the furtherance of its consequences, especially on people.

3.1.4 Toxic and Hazardous Substances

Industrial firms and agriculture are the primary sources of toxic and hazardous substances (THS) that find their way in the lake where they could affect the aquatic food chain all the way up to man.

In 1994, the Environmental Management Bureau (EMB) (Amador 2003) recorded 1,481 industrial establishments in the basin. Recent data show that this has increased to 4,000 establishments. Most of the industries were involved in chemical production, food processing, and chemical manufacture. The agricultural sector lies primarily in the southeastern part of the lake. Agricultural chemicals are a source of heavy metals, like Hg, Cd, Cr, and Pb; along with persistent organic pollutants (POPs) like polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), and pesticides such as insecticides and fungicides. If these find their way in the aquatic food chain, they may undergo a process called biomagnification or bioaccumulation which could lead to carcinogenic effects, mental disorders, hormonal dysfunction, reproductive abnormalities, birth defects, etc. Organic pollutants in waters may produce synergistic, antagonistic or additive effects with heavy metals, (Rhee 1988; Munawar, Wong and Rhee 1988), dichlorodiphenyl ethene (DDE), and PCBs (Mosser et al. 1974).

Levels of heavy metals in water. The reports of various investigators (Barril 1998; Madamba et al. 1994, 1995, 1997) tend to show that there are varying levels of Pb, Cr, Cd, Cu, As, and Hg in the lake. However, all of them have, at one time or another, been found to exceed the prescribed criteria for Class C waters (Table 2.10). Barril and his group observed from 1991 to 1997, Cu, Zn, and Pb, in that order, were highest in concentration (Table 3.10).

Among the bays, West bay has been consistently exhibiting higher levels than East Bay. Central Bay was lowest in terms of Cd and Cu. The data in Table 3.10 show that in general,

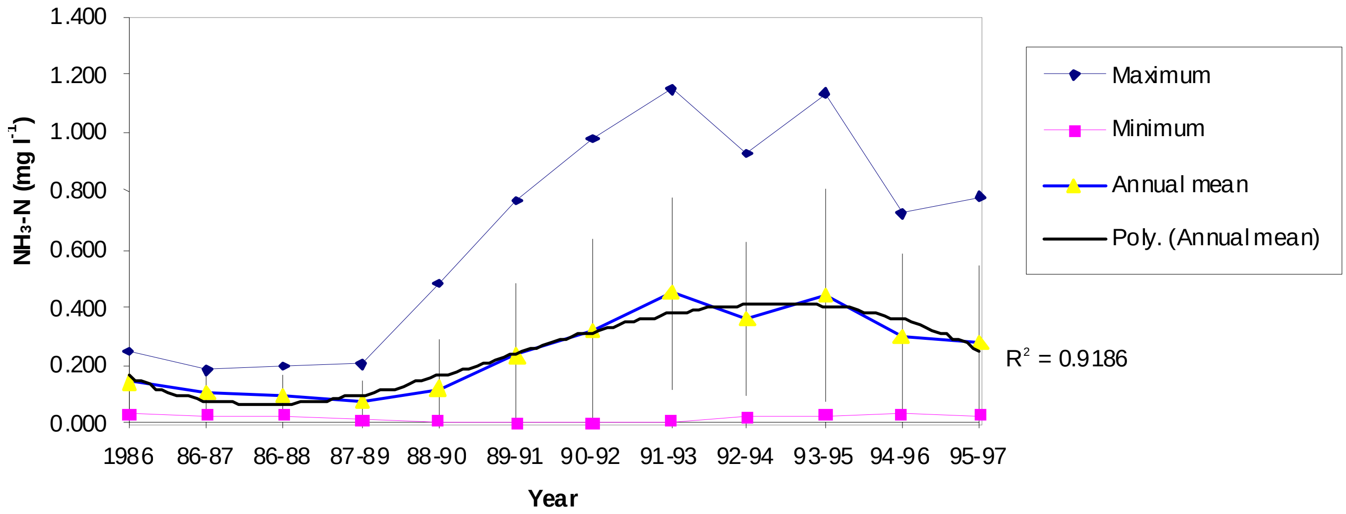

Figure 3.3a. Three-year trend of NH_3-N in West bay of Laguna de Bay.

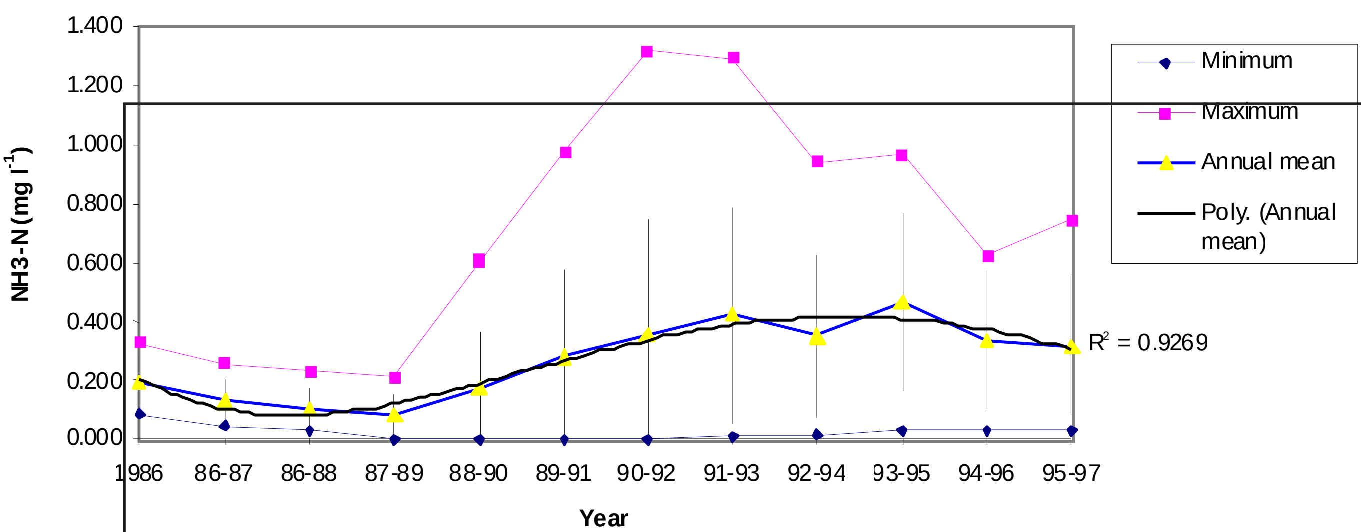

Figure 2.6b. Three-year trend of NH_3-N levels in East bay of Laguna de Bay

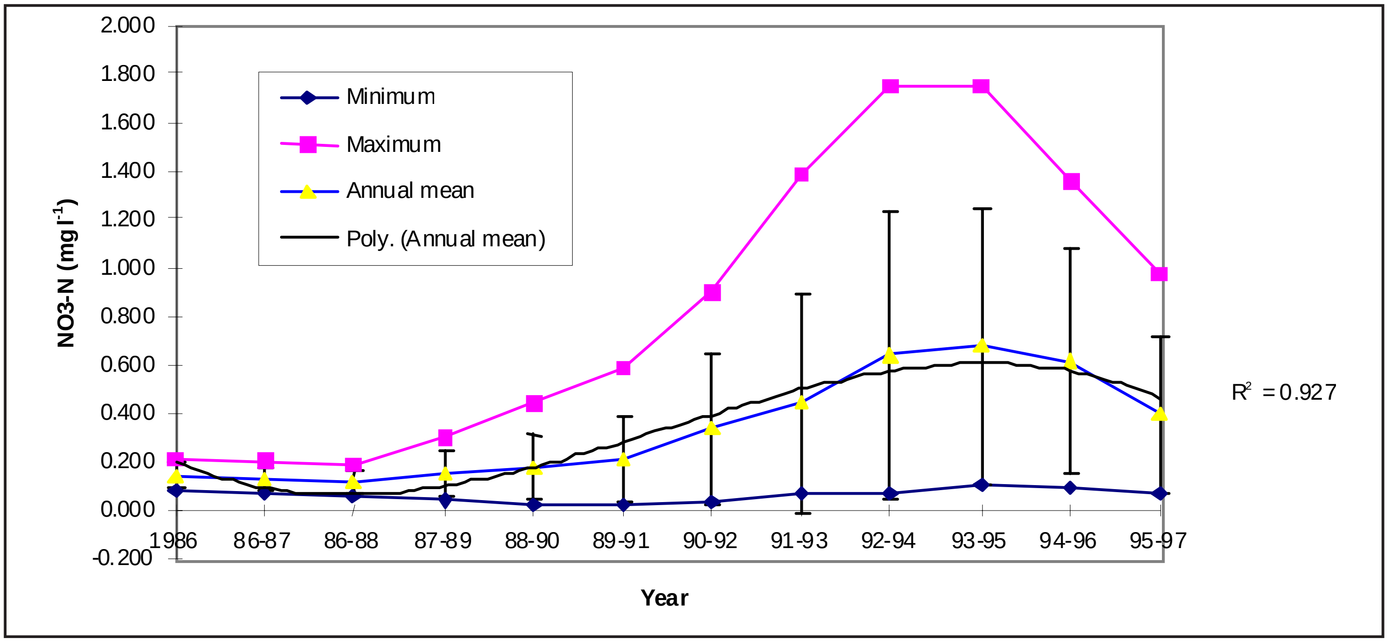

Figure 3.4a. Three-year trend of NO_3-N levels in West bay of Laguna de Bay.

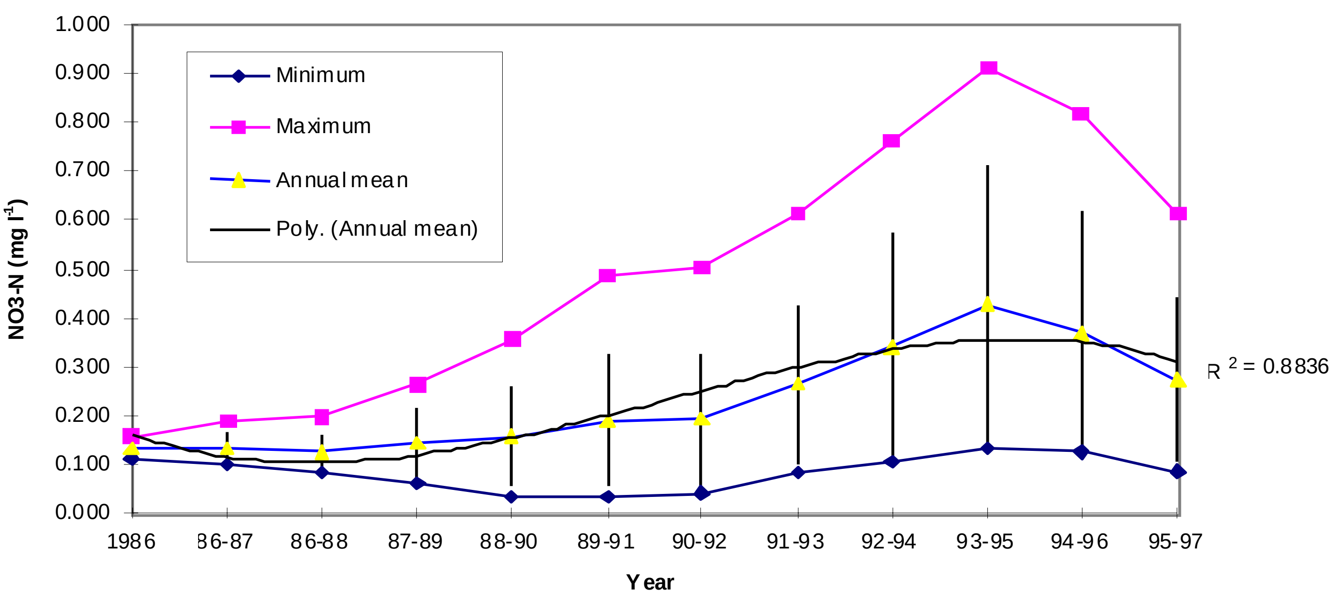

Figure 2.7b. Three-year trend of NO_3 -N levels in East bay of Laguna de Bay.

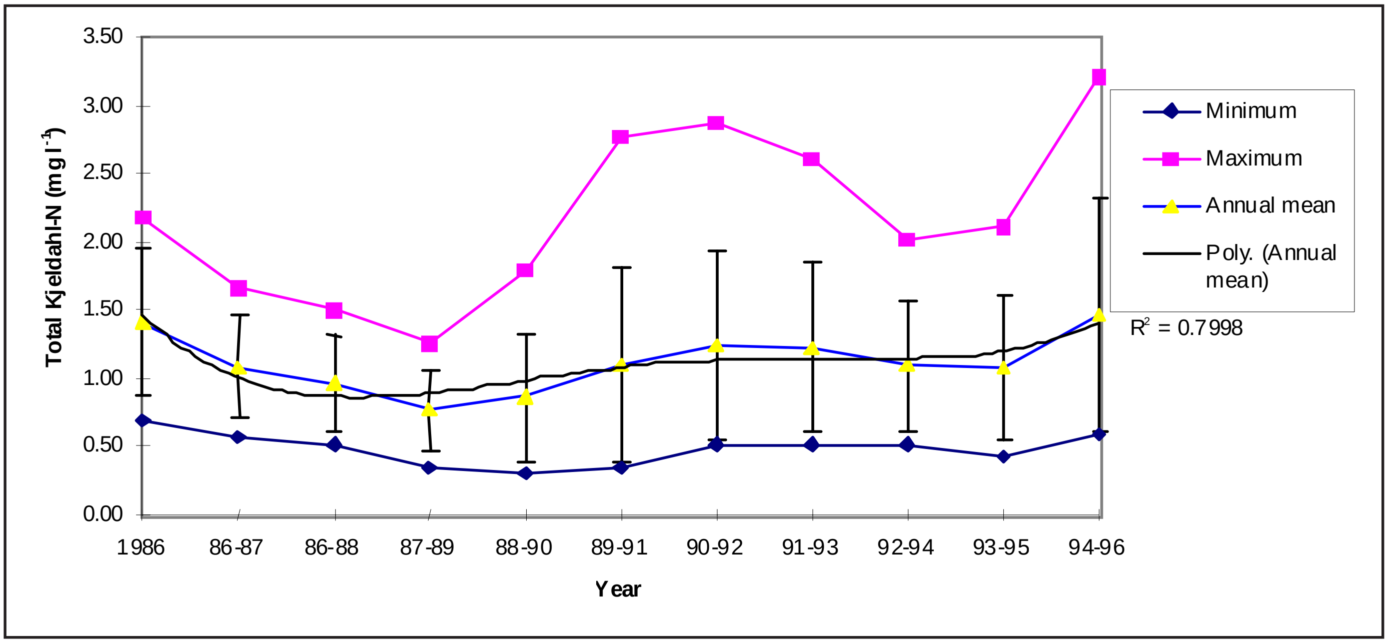

Figure 3.5a. Three-year trend of total Kjeldahl-N levels in West bay of Laguna de Bay.

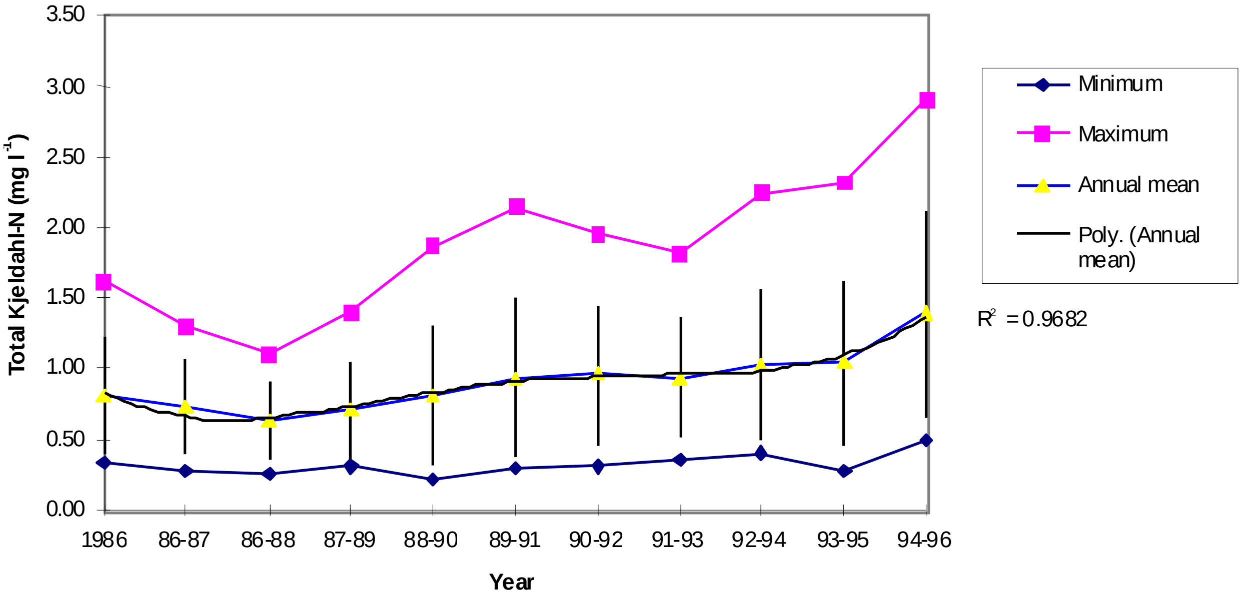

Figure 2.8b. Three-year trend of total Kjeldahl-N levels in East bay of Laguna de Bay.

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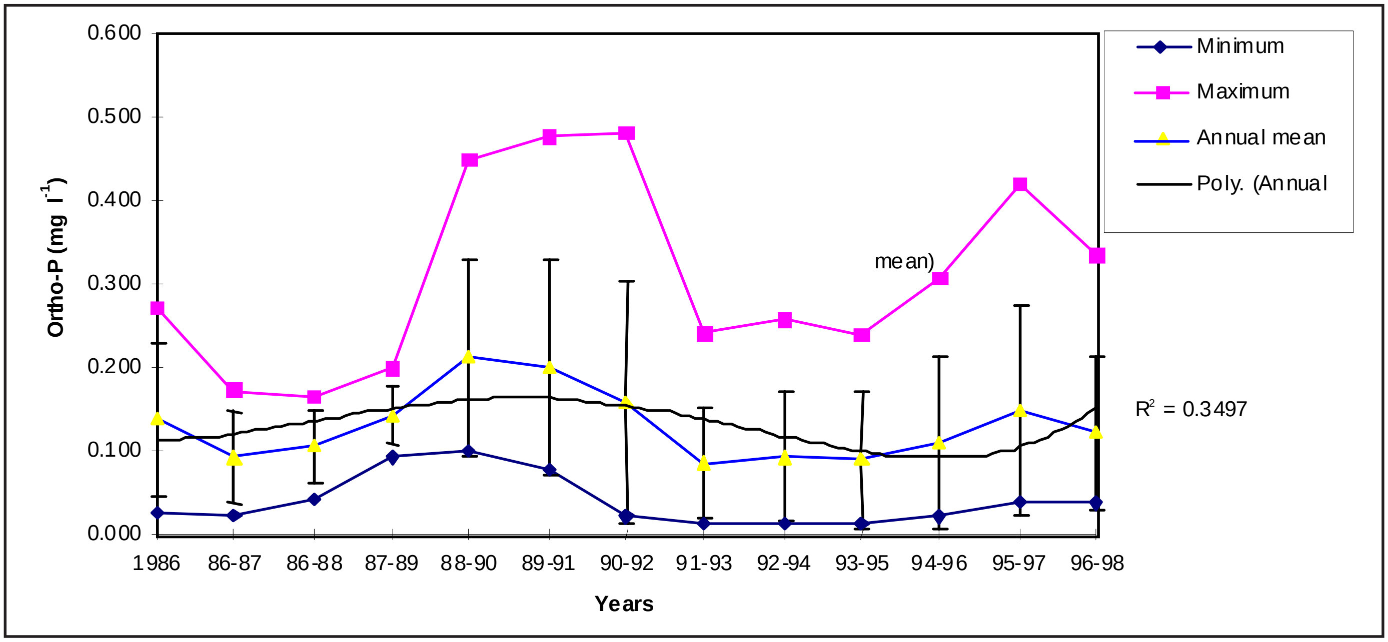


Figure 3.6a. Three-year trend of ortho-P levels in West bay of Laguna de Bay.

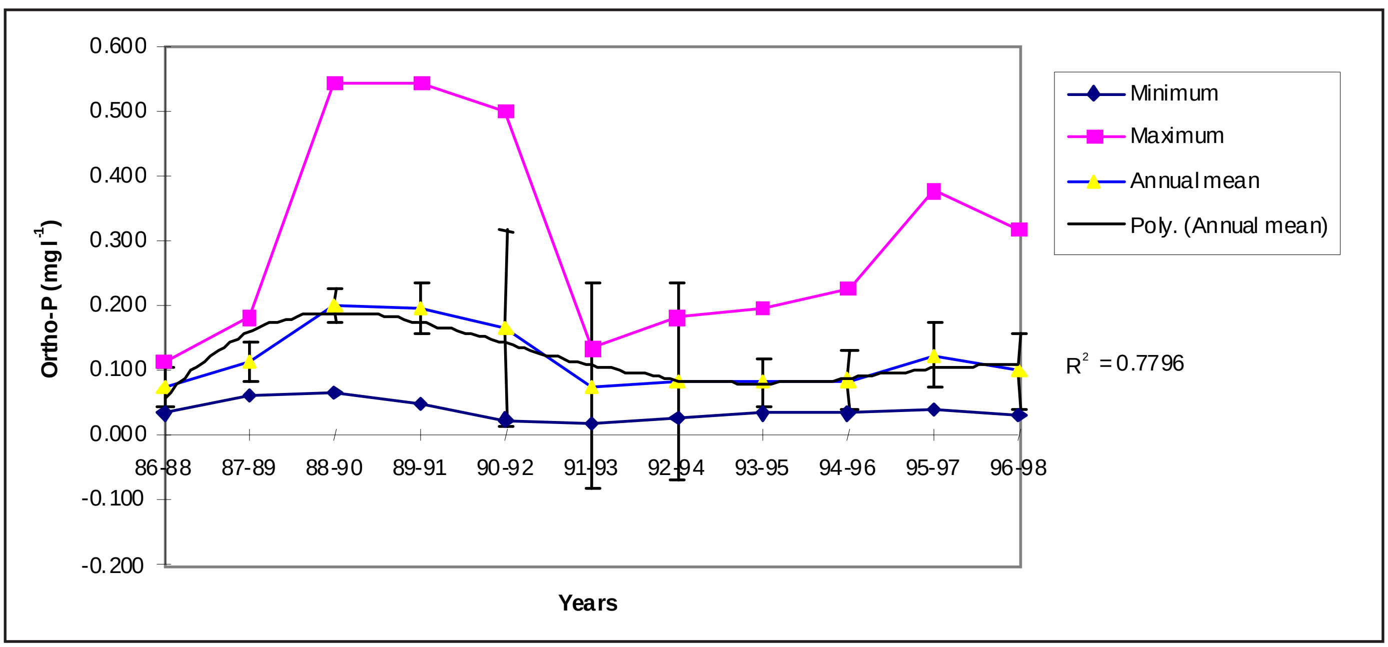


Figure 3.6b. Three-year trend of ortho-P levels in East bay of Laguna de Bay.

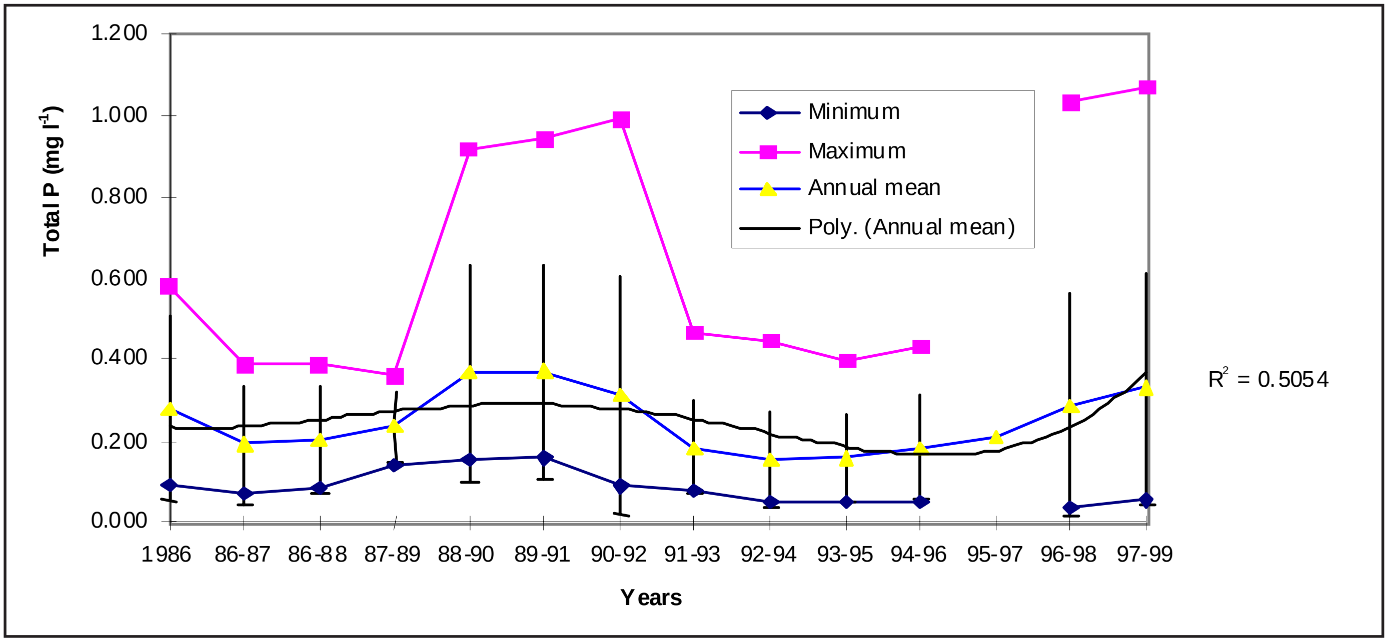


Figure 3.7a. Three-year trend of total P levels in West bay of Laguna de Bay.

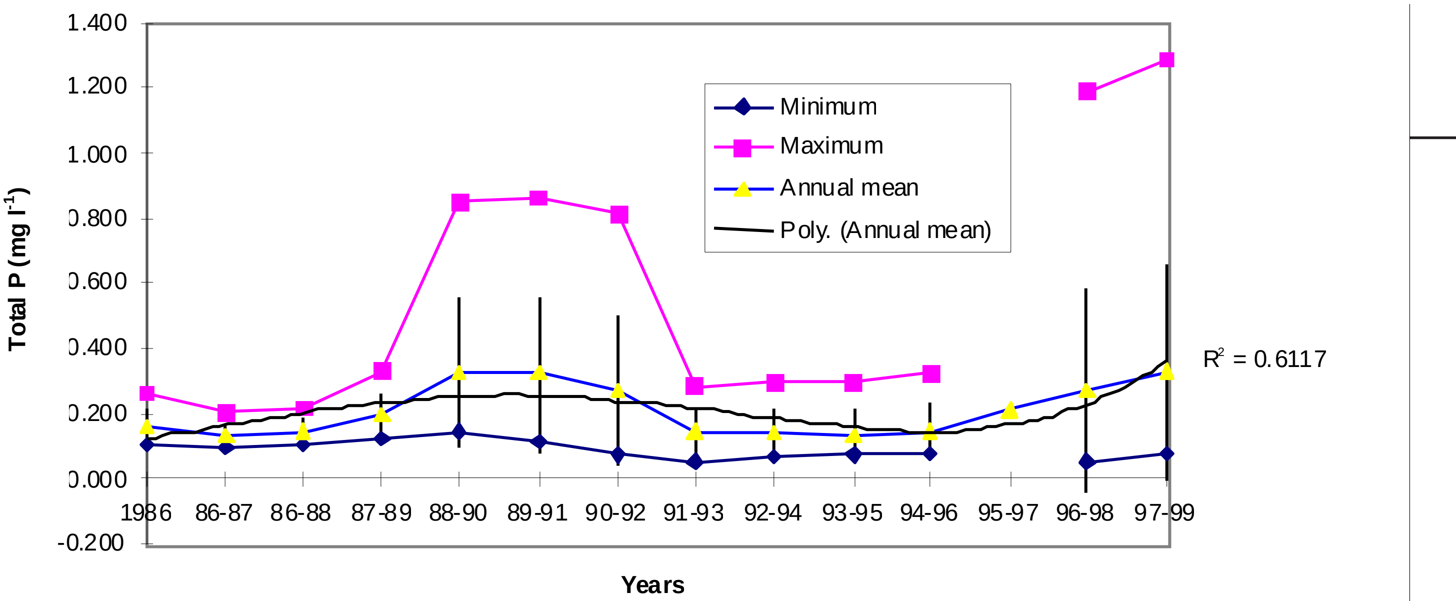


Figure 2.10b. Three-year trend of total-P levels in East bay of Laguna de Bay.

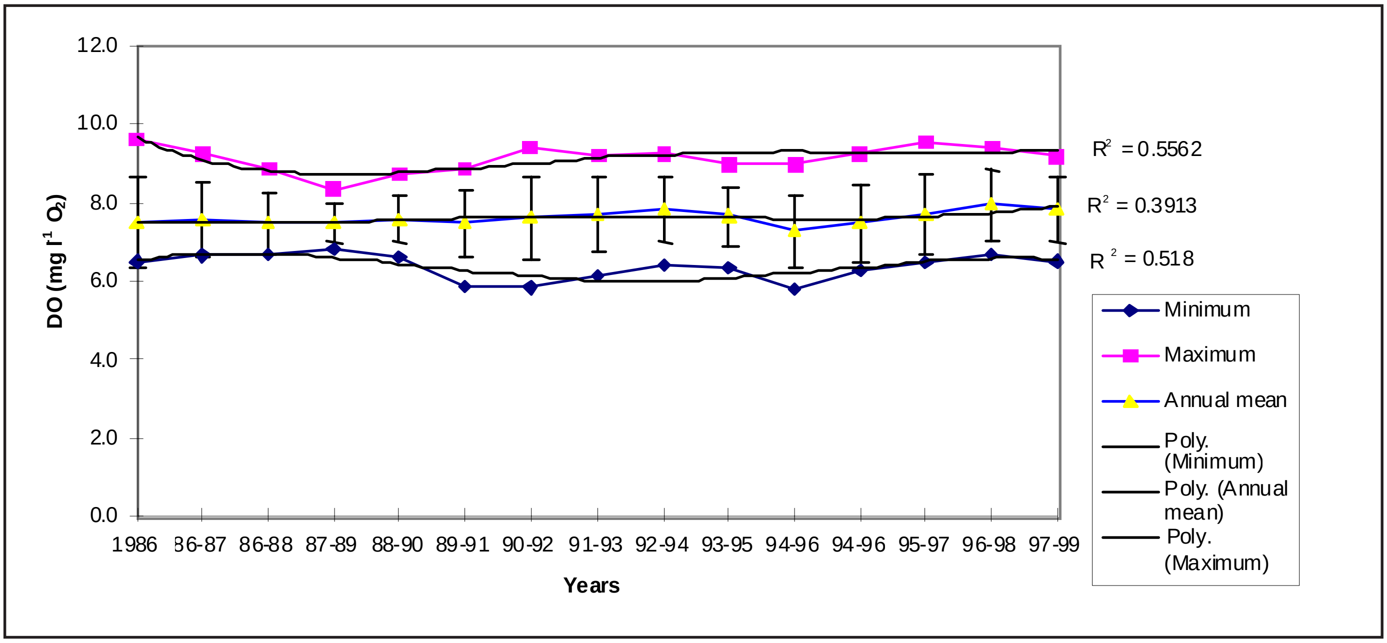


Figure 3.8a. Three-year trend of dissolved oxygen levels in West Bay of Laguna de Bay

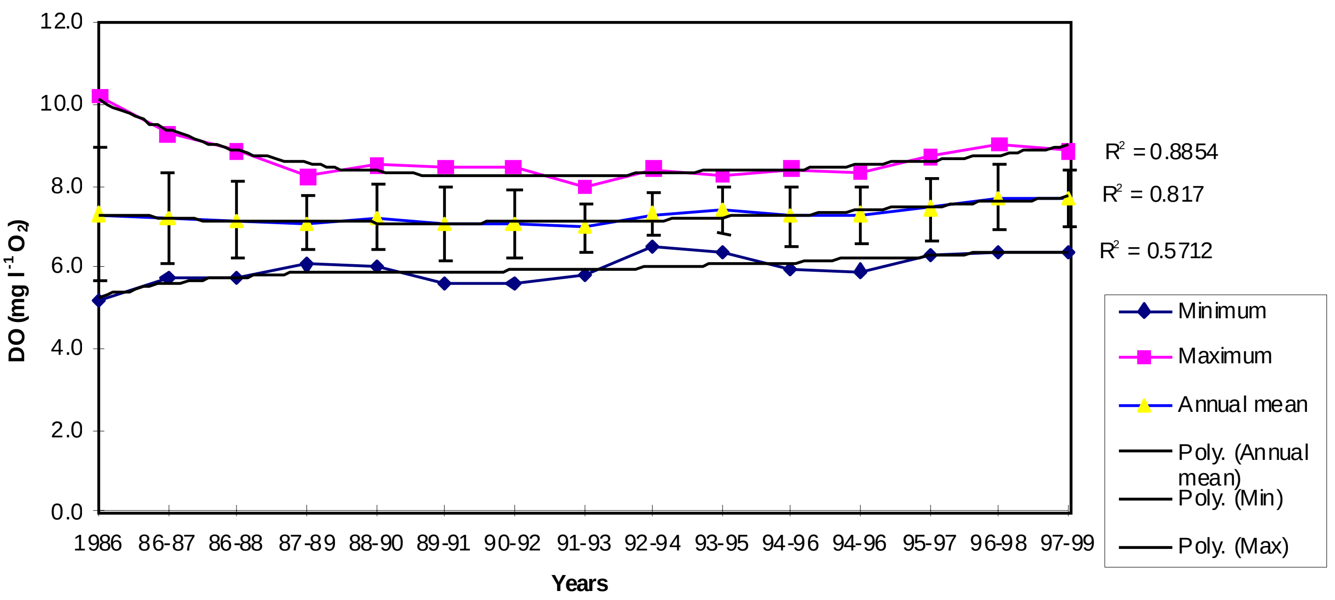


Figure 2.11b. Three-Year Trend of Dissolved Oxygen levels in East Bay of Laguna de Bay

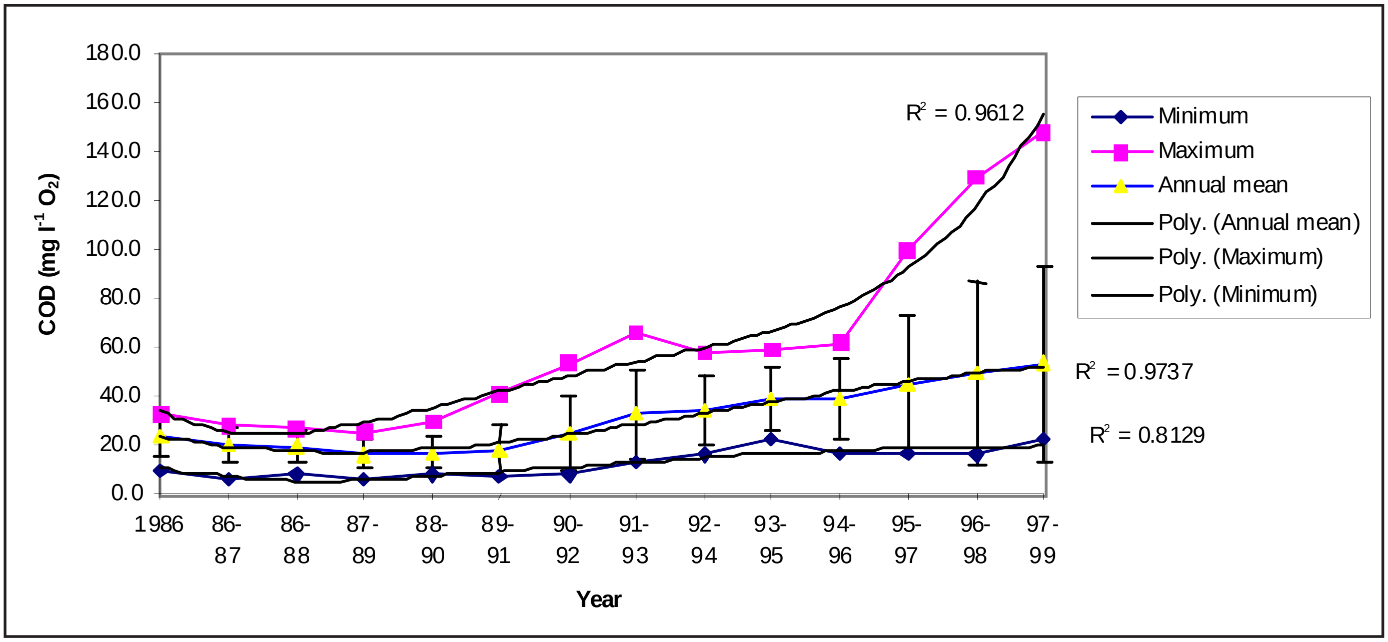


Figure 3.9a. Three-year trend of COD levels in West bay of Laguna de Bay.

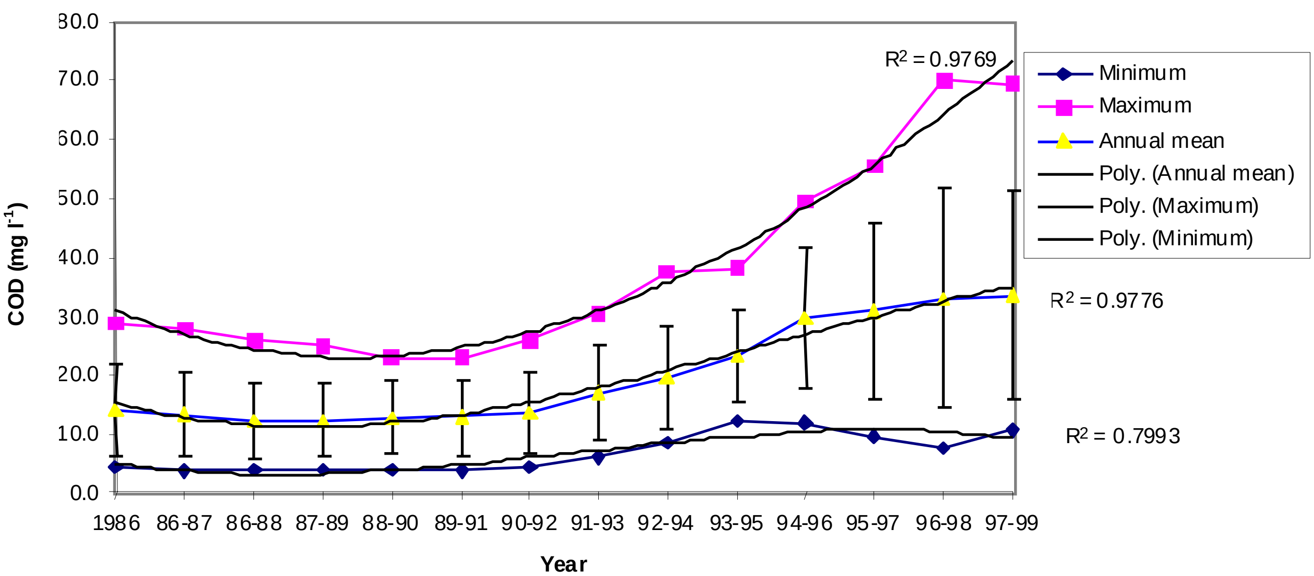


Figure 2.12b. Three-year trend of COD levels in East bay of Laguna de Bay

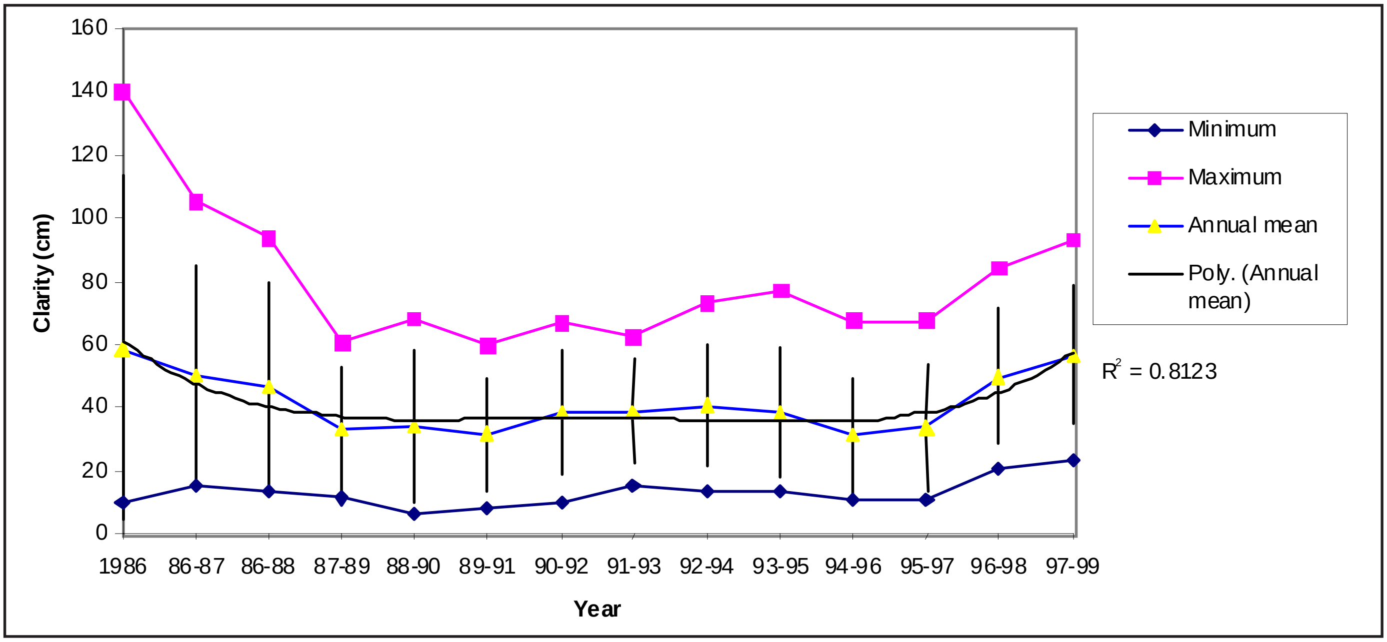


Figure 3.10a. Three-year trend of clarity levels in West bay of Laguna de Bay.

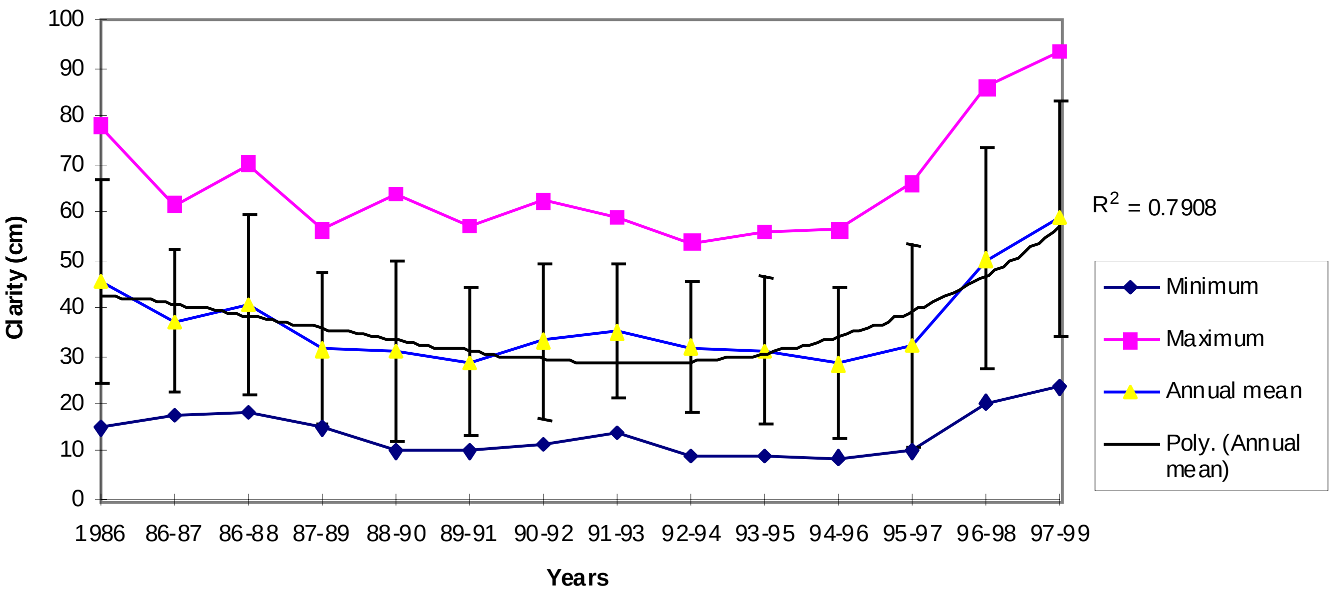


Figure 2.13b. Three-year trend of clarity levels in East bay of Laguna de Bay

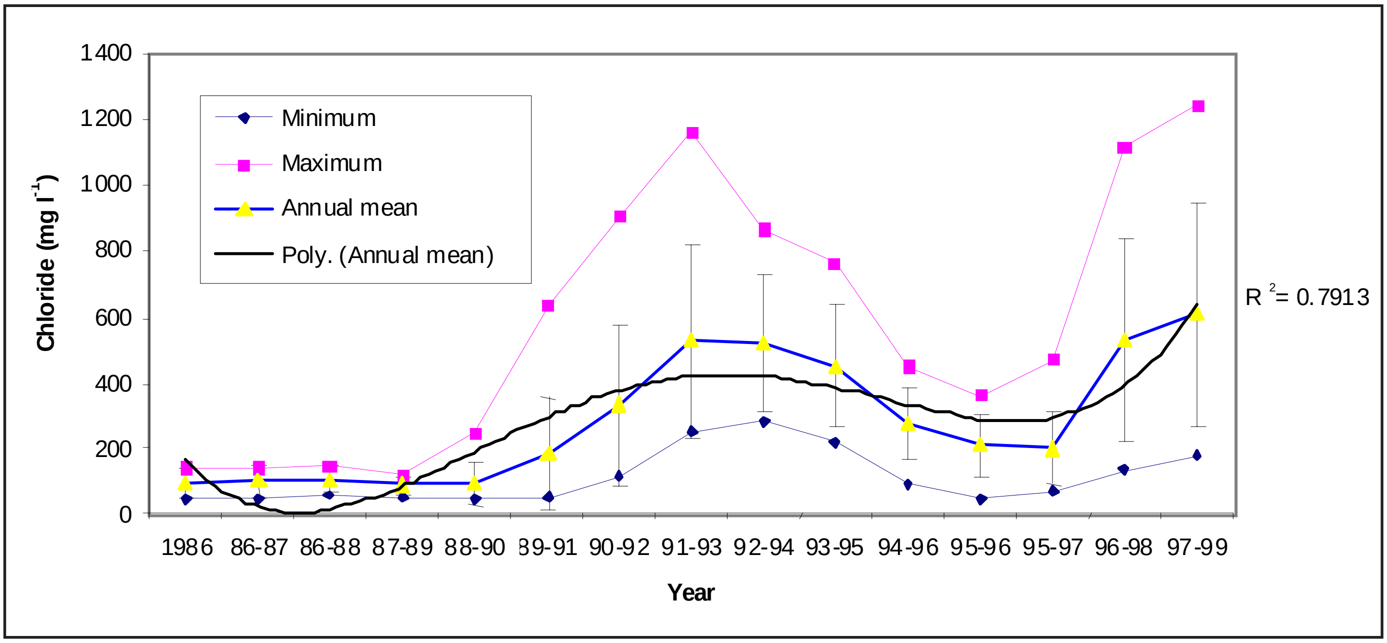


Figure 3.11a. Three-year trend of chloride levels in West bay of Laguna de Bay.

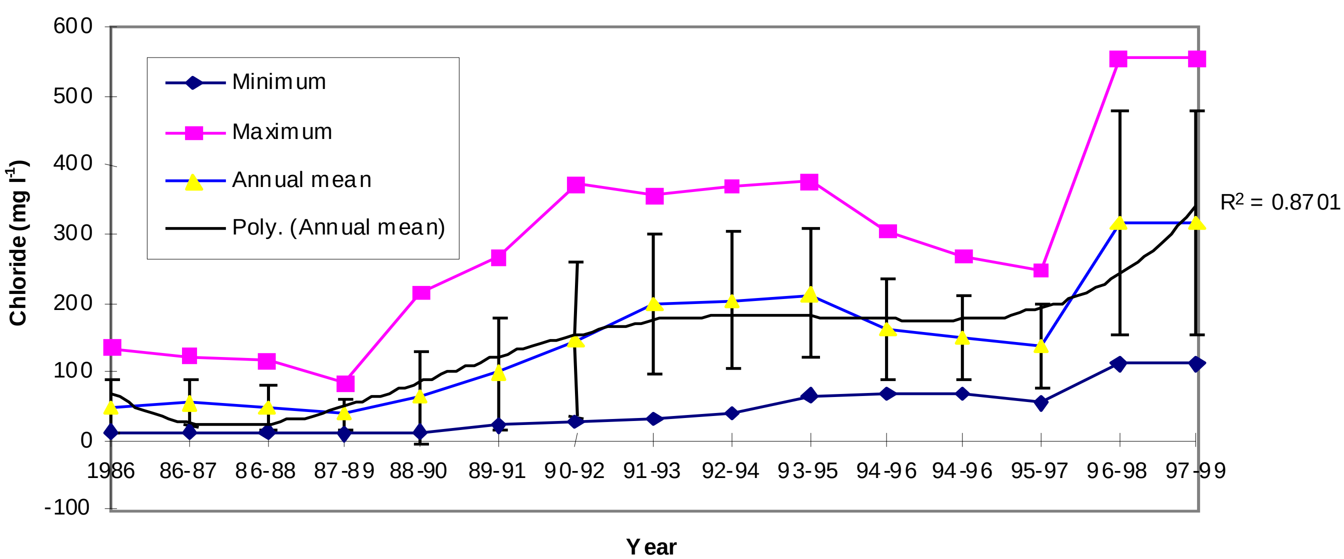


Figure 2.14b. Three-year trend of chloride levels in East bay of Laguna de Bay.

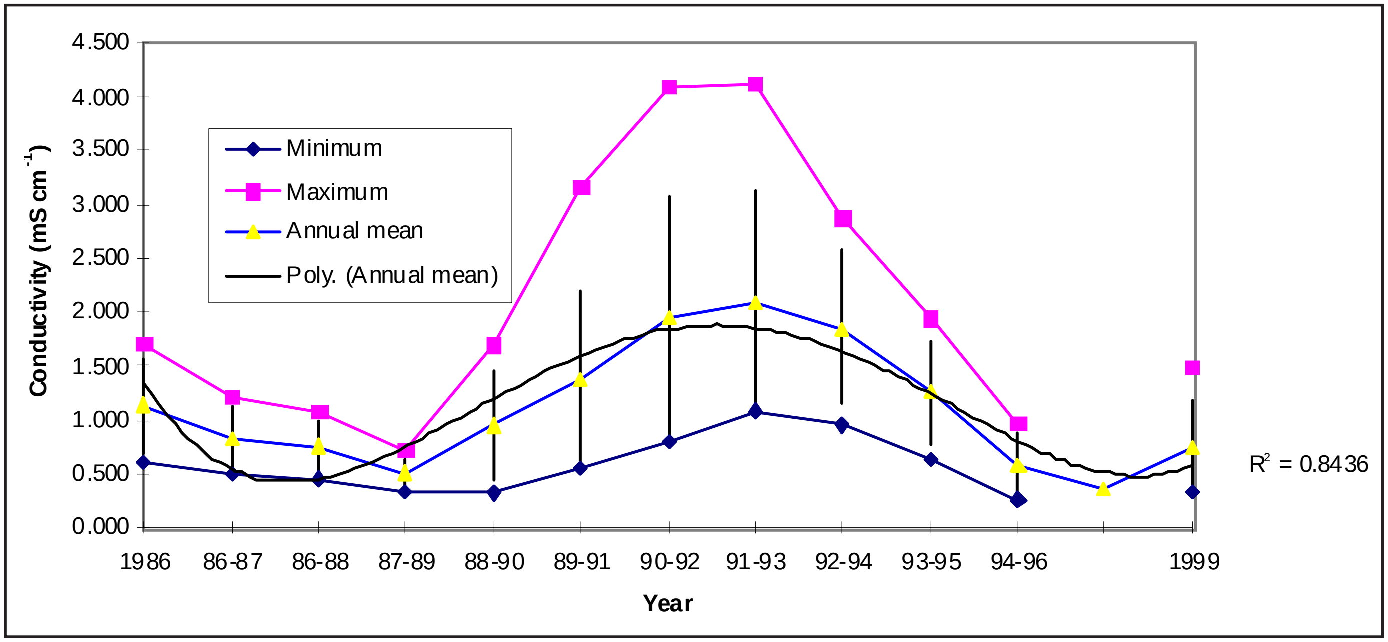


Figure 3.12a. Three-year trend of conductivity levels in West bay of Laguna de Bay.

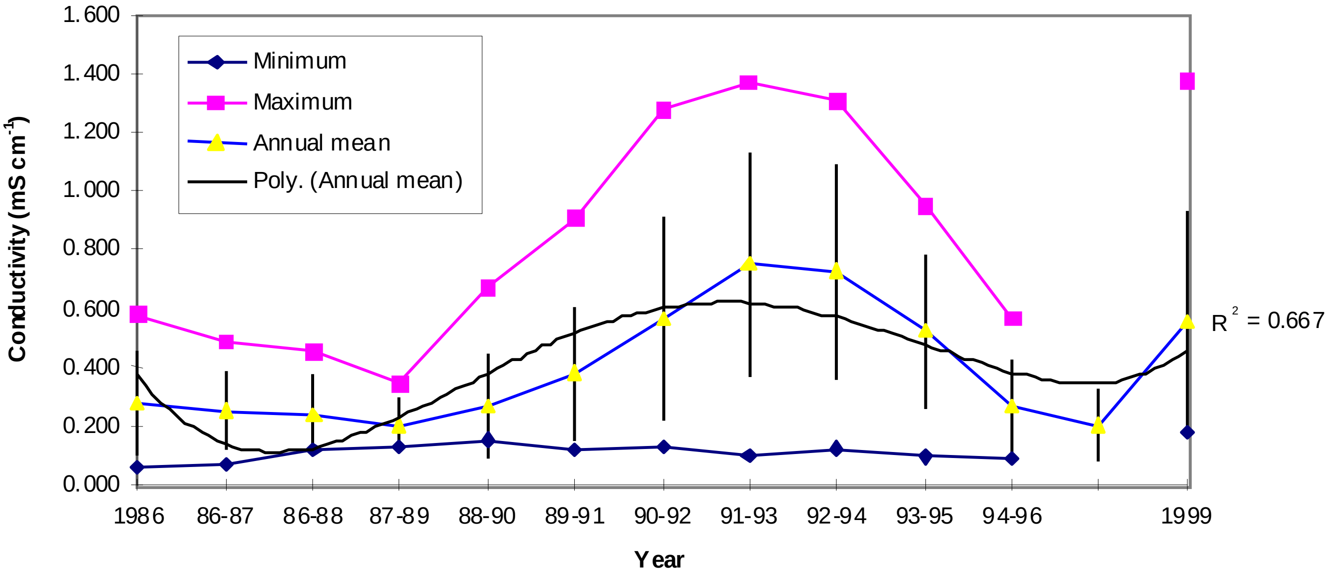


Figure 2.15b. Three-year trend of conductivity levels in East bay of Laguna de Bay.

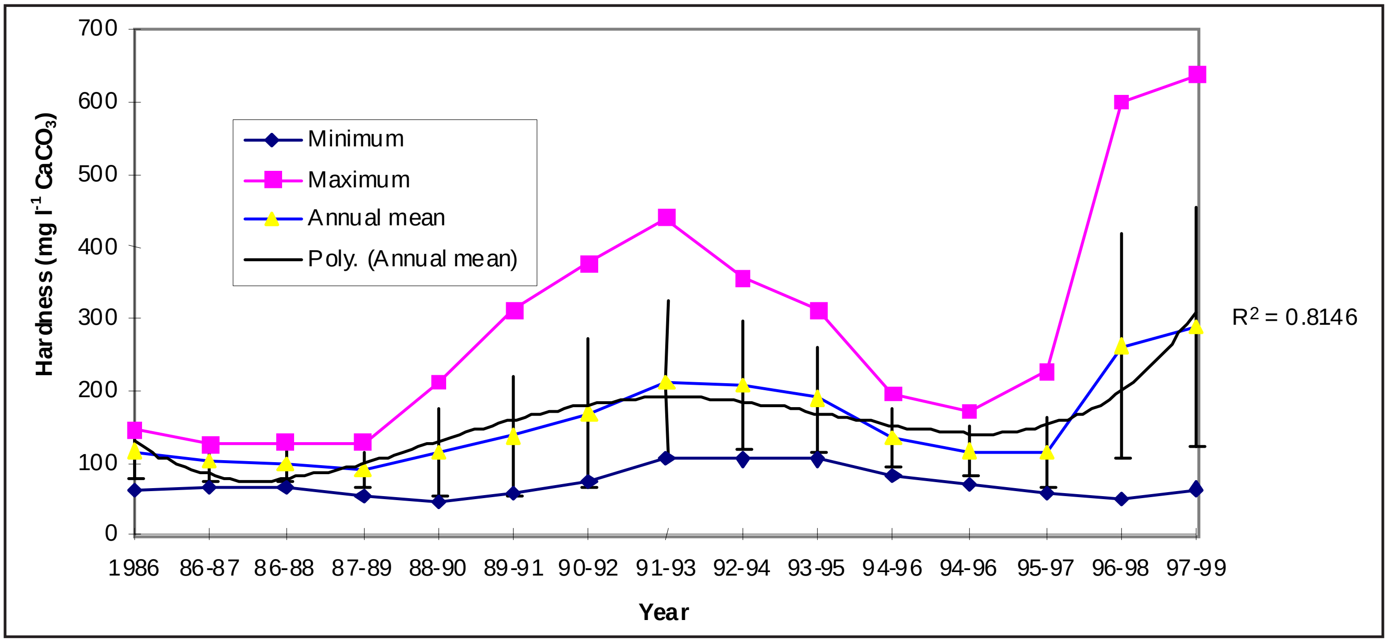


Figure 3.13a. Three-year trend of hardness levels in West bay of Laguna de Bay.

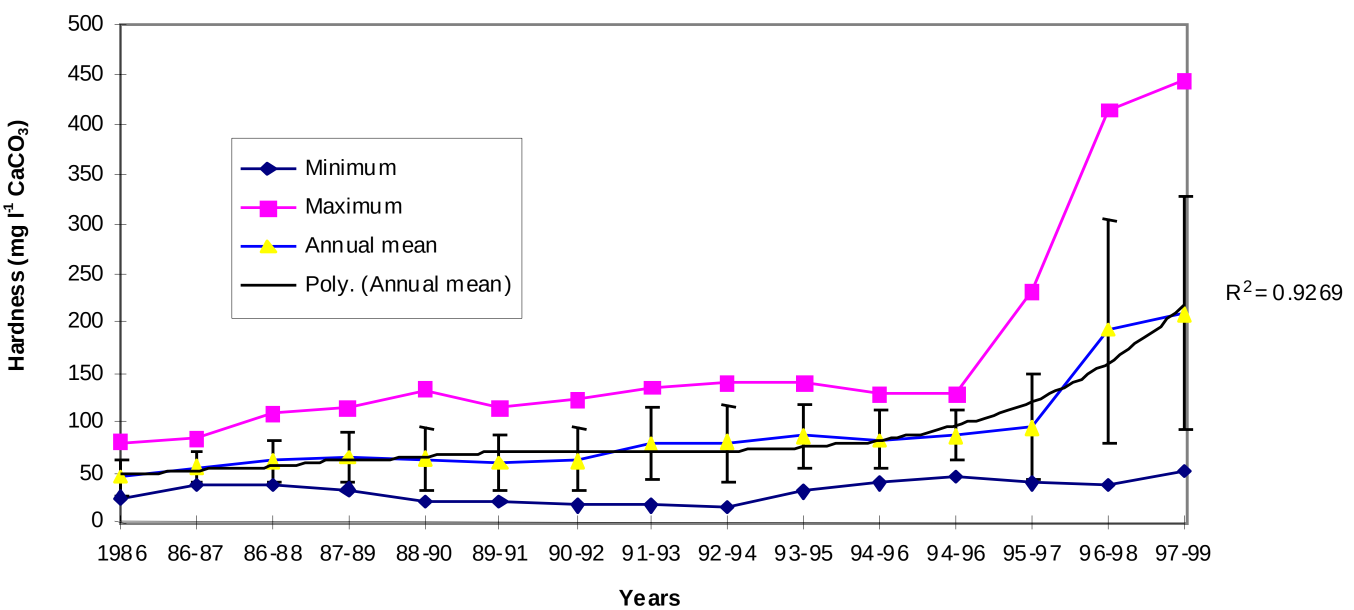


Figure 2.16b. Three-year trend of hardness levels in East bay of

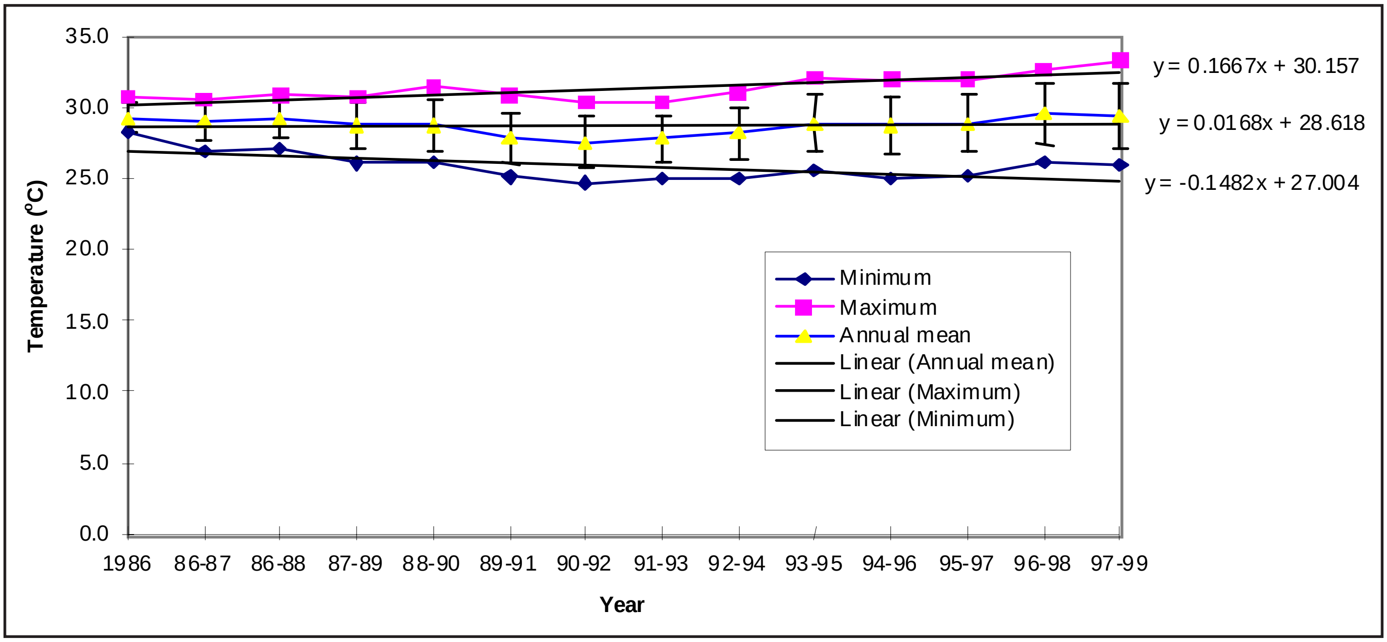


Figure 3.14a. Three-year trend of temperature levels in the West bay of Laguna de Bay.

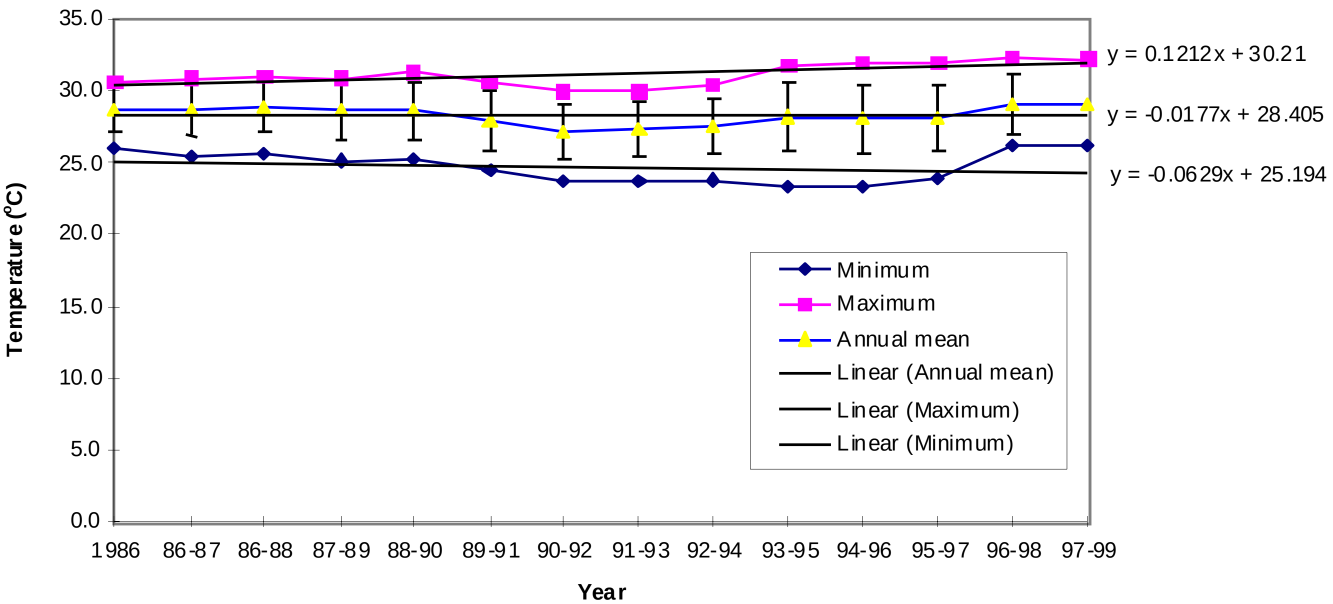


Figure 2.17b. Three-year trend of temperature levels in the East bay of Laguna de Bay

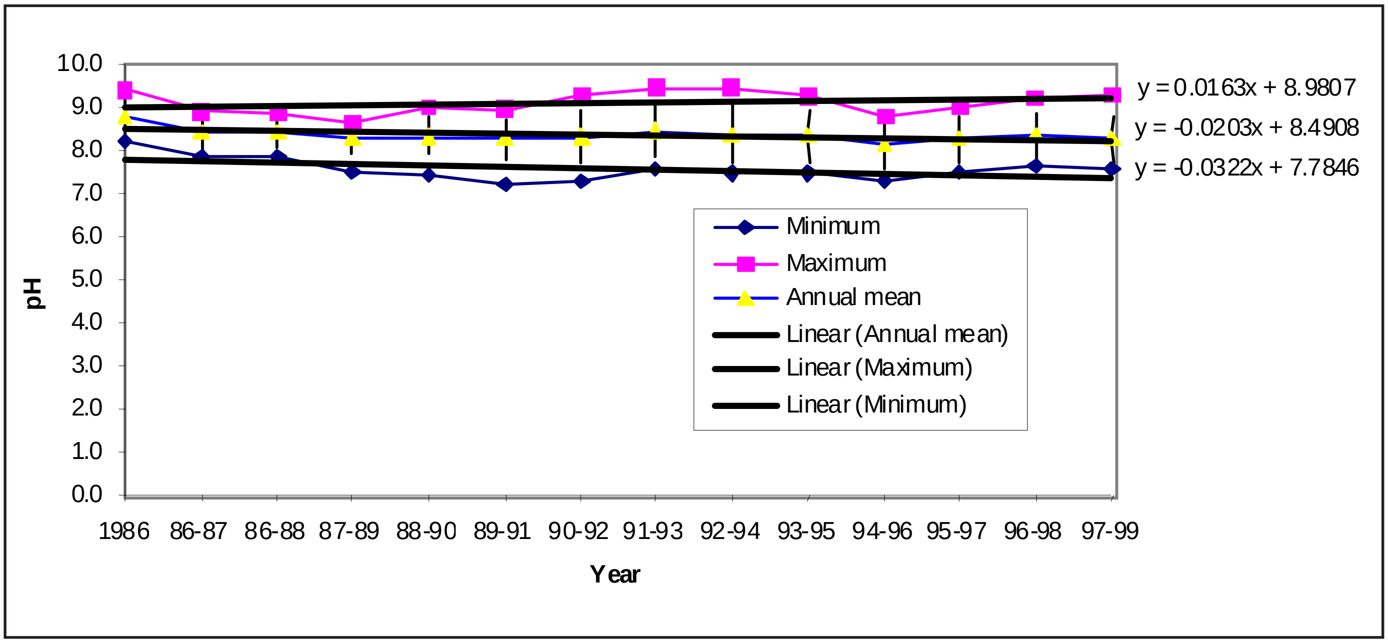


Figure 3.15a. Three-year trend of pH levels in West bay of Laguna de Bay.

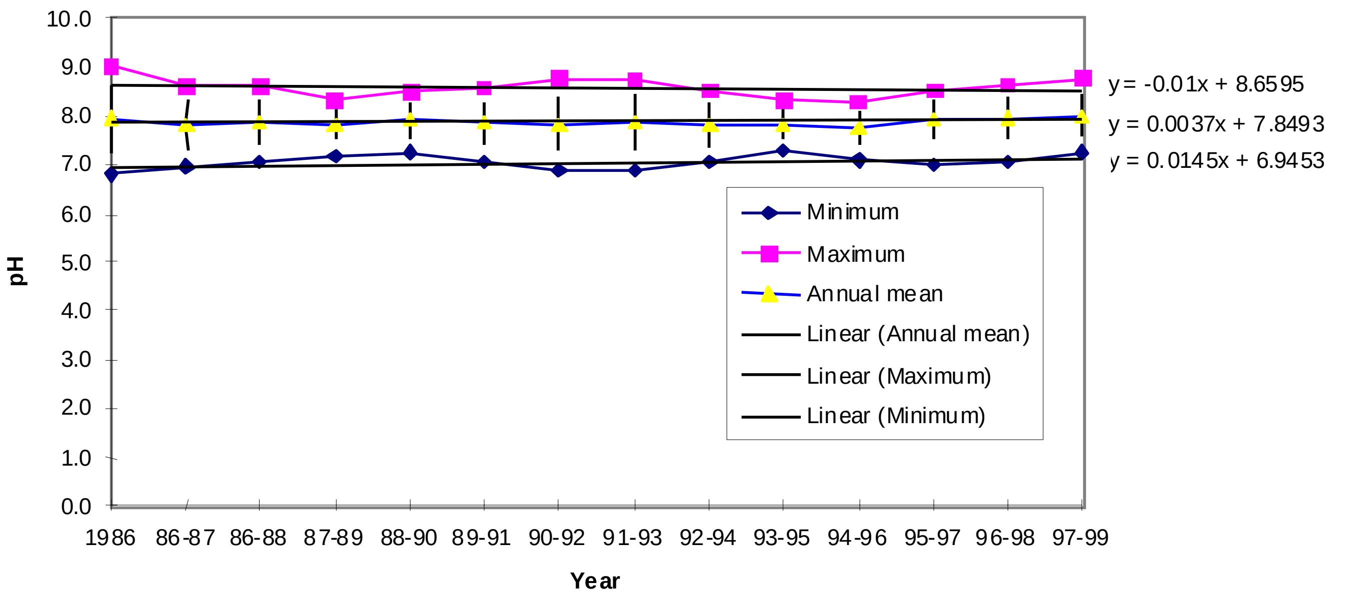


Figure 2.18b. Three-year trend of pH levels in East bay of Laguna de Bay.

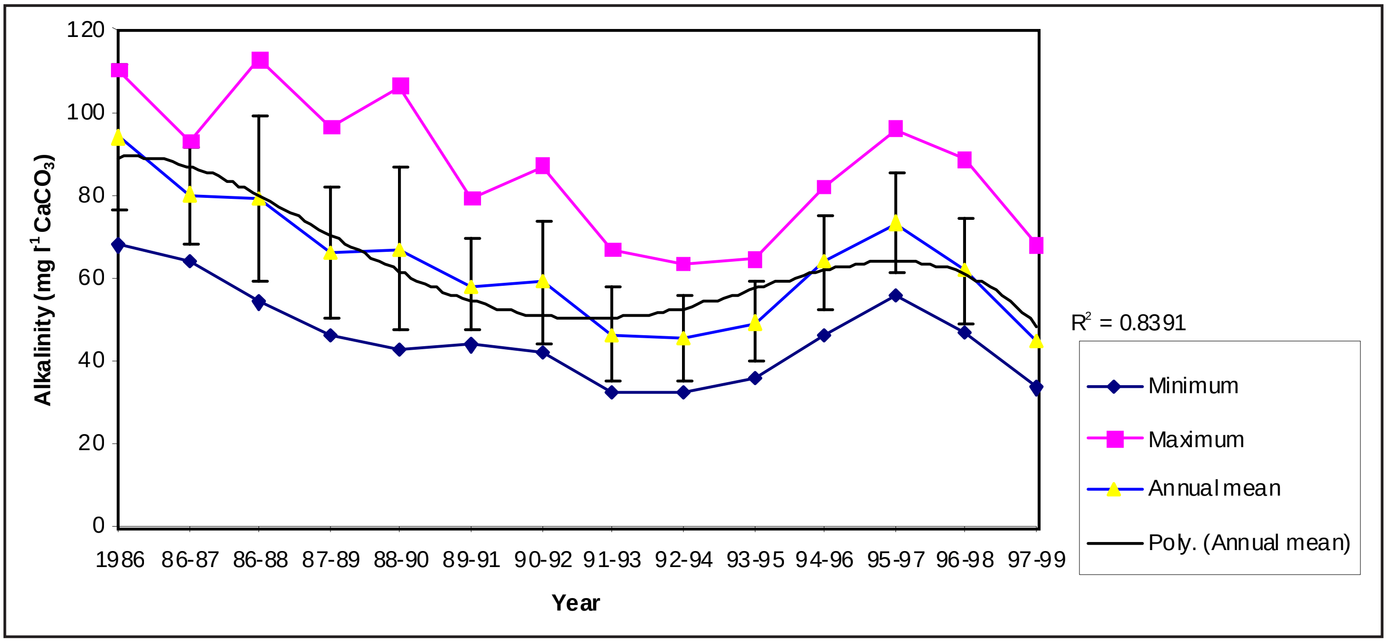


Figure 3.16a. Three-year trend of alkalinity levels in West bay of Laguna de Bay.

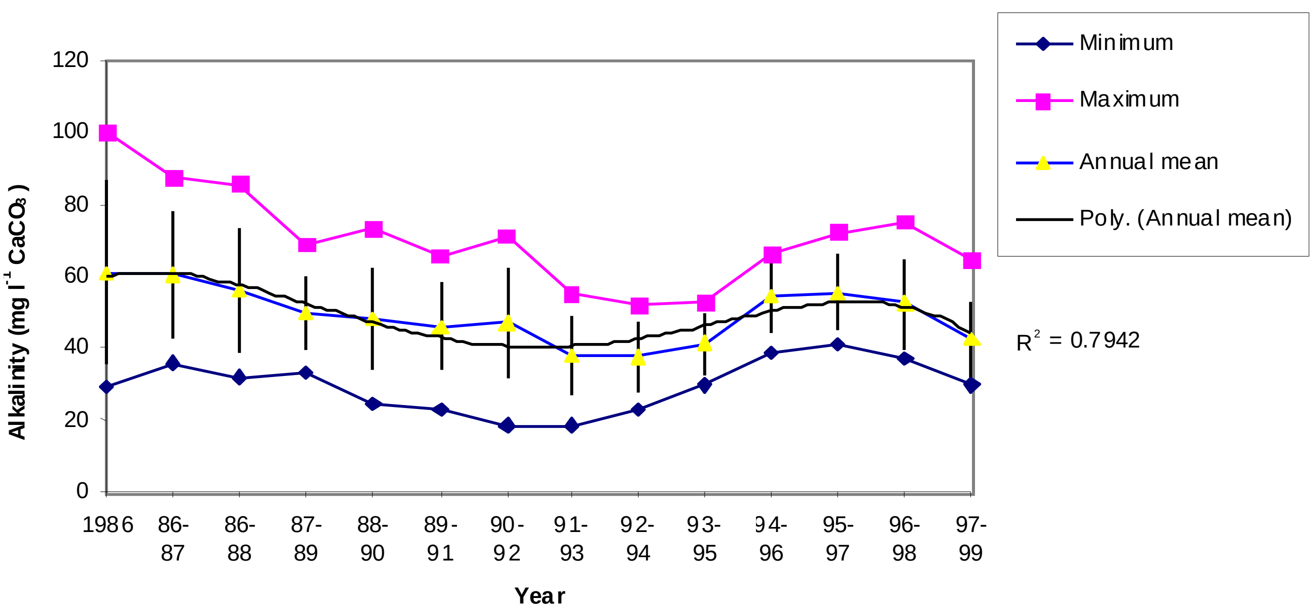


Figure 2.19b. Three-year trend of alkalinity levels in East bay of Laguna de Bay

there is no definable trend for the studied heavy metals. This can be attributed to the limited data and the differences in the stations of investigators. Even the analytical procedures used could be a source of variation.

The latest data of the LLDA (1999) surprisingly indicates improvement in water quality based on some of the heavy metals. It reported that Cd, Cr, and Pb levels were lower than the set criteria of 0.01, 0.05 and 0.05g mg l^{-1}, respectively. Pb and Ni were below the detection limit, while Zn concentration ranged from 0.10 to 0.3 mg l^{-1}. Iron (Fe) was reportedly high with an average of 1.986 mg l^{-1}. Preliminary studies (NEDO, LLDA, JEMAI 2000) showed that As in the lake ranged from 0.022 to 0.030 mg l^{-1}. The criterion is 0.05 mg l^{-1}.

Levels of heavy metals in sediments. Sediment samples taken from different parts of Laguna de Bay generally contained about 1,000 times higher concentrations than that of water samples (Table 3.11) according to the findings of researchers from the IC-UPLB (Madamba et al. UPLB, 1994, 1995, 1997; Barril 1998 unpublished). Sediment enrichment with heavy metals may arise from their adsorption on suspended particulates or colloids which eventually settle in the bottom sediments. There are indications of incremental levels with time.

Parallel to its findings regarding heavy metals in the lake water, the LLDA also obtained data indicating that the sediment concentrations are very low. Except for Ni whose concentration range is 2 to 12 times the average shale values, many were up to twice the average shale values. According to the National Institute of Geological Sciences (1999), lake pollution based on heavy metal levels in the sediments is very low, corresponding to I_{geo} 0 to 2 which is interpreted as unpolluted to moderately polluted.

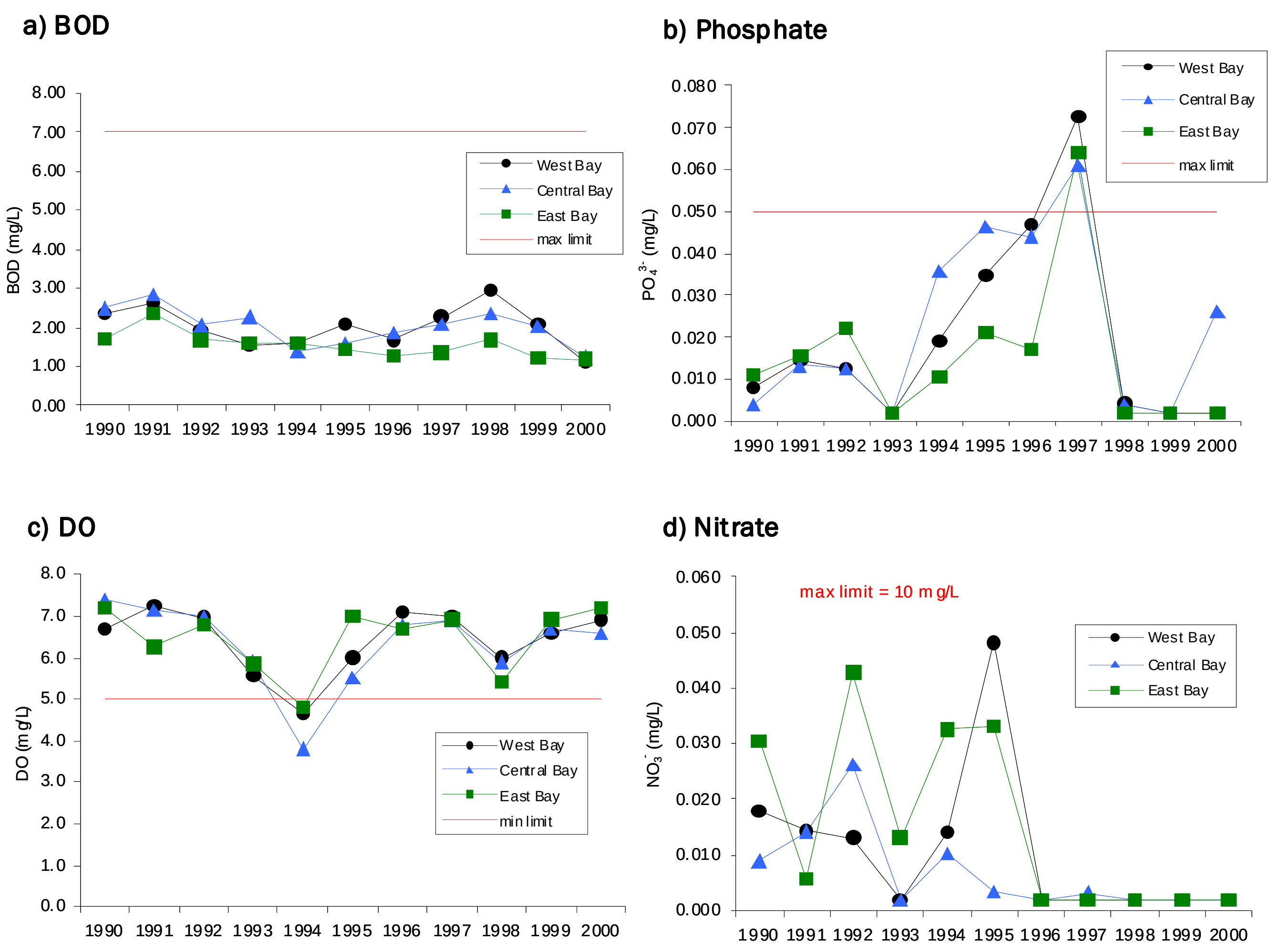


Figure 3.17. BOD, phosphate, DO, and nitrate concentrations in Laguna Lake from 1990 to 2000. These water quality parameters met the criteria for Class C water (Source: LLDA).

Levels of heavy metals in biota. A study done by Relon in 1989-1990 indicated that the mercury levels in fish samples (i.e., dalag, kanduli, biya, and tilapia) collected between Taguig and Binangonan were below the WHO maximum tolerable consumption in food which is equivalent to 0.3 mg of total mercury per week (Table 3.12). Barril's (1998) analyses on fish over a period of seven years, i.e., from 1990 to 1997, showed that different species had varied abilities to accumulate heavy metals (Table 3.13). Focusing on the heavy metal contents of the edible portions of fish, the results showed that among the three species collected in 1990-1991, *Oreochromis sp.* (tilapia), an omnivore, exhibited the highest Cu (5.42 ± 0.31 µg g^{-1}) and Zn (35.4 ± 0.7 µg g^{-1}) concentrations. Pb and Cd were not detected in the flesh or edible portions of all samples. In 1997, *M. lacustris* (dulong) had the highest concentration of Cr (4.62 ± 0.03 µg g^{-1}), Cu (6.85 ± 0.07 µg g^{-1}), and Zn (158 ± 5 ìg g^{-1}), while *C. carpio* (carp) had the highest Cd concentration (2.55 ± 0.02 µg g^{-1}). Mudfish (*O. striatus*) collected in 1990-1991 had a higher concentration of Cu (2.18 ± 0.08 µg g^{-1}) compared to the 1997 samples with Cu concentration of 1.54 ± 0.11 ìg g^{-1}. On the other hand, *C. manilensis* (tulya) had higher levels of Cr (3.36 ± 0.20 µg g^{-1}), Cd (3.38 ± 0.07 µg g^{-1}), Pb (13.6 ± 0.6 µg g^{-1}), Cu (103 ± 1 µg g^{-1}), and Zn (135 ± 0 µg g^{-1}) than the 1990-1991 samples. Observations on the inedible portions indicated high levels of Cr, Cd and Pb, while Cu and Zn were highest in the entrails.

The concentration factors (CF) were calculated from the ratio of the metal concentration in the edible fish tissue (fresh basis) to that in water. The CF for Zn (258-1254) and Pb (121-351) were highest in all the fish species. The mollusk, *Corbicula manilensis*, gave a higher figure for Cu than for Zn (391 vs. 173). Inedible portions and entrails gave much higher values than the above.

Organic Pollutants. The studies done on organic pollutants are very few. Barril's unpublished 1998 data show that organic pollutants were higher in terms of some PAHs (Table 3.14). The detected COD in water, oil and grease in sediments evinced the presence of some harbingers of organic pollutants. Toxic and hazardous organic chemicals, such as pesticides and other industrial persistent organic chemicals, have been found in fish and other biota. Due to the limited data on organic pollutants in the lake, a satisfactory assessment of its ecological condition based on these cannot as yet be done.

3.1.5 Thermal Pollution

Thermal pollution occurs in the form of the heated wastewaters dumped into the lake primarily by power plants. Four such plants now exist, namely, the National Power Corporation (for the Malaya and Sucat Thermal Power Plants and Kalayaan Hydropower Plant); Philippine Petroleum Corporation Refinery in Pililla, Rizal; and Shell Philippines, Inc. Their effluents have been observed to cause a 4ºC rise in the temperature of surrounding waters, thereby enhancing the growth of the phytoplankton. This physiological response relates to the Q_{10} principle which states that living organisms theoretically double their metabolic rates with every 10ºC rise in temperature. Thermal pollution effects on lake biota have not been adequately explored.

Table 3.9. Reported concentrations of heavy metals in the waters of Laguna de Bay (mg l^{-1}).

Heavy Metals	Class C Water Quality Criteria	Reyes 1986	LLDA data 1987*	URSI 1989	PNOC 1994	NPC 1996	Zafaralla 1997 (unpublished data)	LLDA 1997*	Zafaralla 1997 (unpublished data)	LLDA 1997*	LLDA 1998*	LLDA 1999*
Pb	0.05	0.15	0.0118	0.28	<0.02	<0.02	0.02-0.05	0.07	<0.050	0.0636	0.0225	<0.04
Cr	0.05	-	0.006	nil	<0.02	<0.02	nil	0.0098	-	-	0.0003	0.0030
Cd	0.01	-	0.0051	0.004	<0.02	<0.003	0.0015-0.004	-	<0.025	0.025	0.022	0.0052
Cu	0.02		0.005				0.0022-0.021	0.018	0.049	0.0258	0.011	0.0115
As	0.05								-			
Hg	0.002						0.0032		<0.005			

*LLDA data – annual mean

Table 3.10. Mean levels of heavy metals (µg l^{-1}) in water samples from Laguna de Bay.

Location	Cr	Cd	Pb	Cu	Zn	Ni
1991-1992[1/]						
Central bay	-	-	-	-	-	-
East bay	1.6	0.54	6.84	8.15	-	2.74
West bay	2.58	0.88	9.59	9	-	3.74
South bay	-	-	-	-	-	
1996[2/]						
Central bay	4.28 ± 1.19	0.92 ± 0.07	10.81 ± 1.42	17.92 ± 0.93	18.44 ± 1.50	
East bay	3.39 ± 0.93	1.29 ± 0.25	6.79 ± 1.10	21.57 ± 1.89	16.41 ± 1.65	
West bay	5.04 ± 0.85	2.01 ± 0.14	10.40 ± 0.52	24.55 ± 1.96	17.95 ± 1.24	
South bay	4.08 ± 0.81	2.02 ± 0.21	8.21 ± 0.08	21.42 ± 0.19	17.04 ± 0.42	
1997[2/]						
Bay River mouth	4.68 ± 0.10	1.45 ± 0.08	7.30 ± 0.53	9.36 ± 0.99	7.92 ± 1.21	
San Pedro River mouth	10.42 ± 0.40	1.20 ± 0.01	105.0 ± 8.51	67.96 ± 1.31	87.50 ± 1.29	
Tunasan River mouth	5.74 ± 0.15	1.28 ± 0.02	15.85 ± 0.33	23.54 ± 0.13	27.39 ± 1.38	
San Juan River mouth	4.58 ± 0.20	0.88 ± 0.02	14.54 ± 1.01	7.79 ± 0.99	7.42 ± 1.20	
Napindan River mouth - s	17.81 ± 0.39	1.62 ± 0.04	65.10 ± 4.09	79.90 ± 4.54	67.12 ± 4.91	
Napindan River mouth - b	19.52 ± 0.99	2.02 ± 0.08	65.20 ± 0.38	90.23 ± 15.16	77.50 ± 12.67	
Sta. Rosa offshore - s	10.77 ± 0.18	1.02 ± 0.03	19.44 ± 0.67	33.57 ± 0.96	32.55 ± 1.76	
Sta. Rosa offshore - b	11.60 ± 0.39	1.28 ± 0.07	22.68 ± 1.19	48.62 ± 8.09	42.98 ± 5.17	
Sucat offshore - s	11.70 ± 0.20	1.62 ± 0.03	21.14 ± 1.98	70.69 ± 1.10	64.49 ± 4.44	
Sucat offshore - b	12.24 ± 0.68	1.72 ± 0.07	22.74 ± 2.06	76.82 ± 4.73	76.82 ± 4.68	
San Cristobal River mouth	4.72 ± 0.08	0.90 ± 0.05	11.59 ± 0.40	6.30 ± 0.28	7.00 ± 1.54	
Morong River mouth - s	13.50 ± 0.26	1.72 ± 0.01	15.83 ± 2.46	43.25 ± 3.57	46.66 ± 5.79	
Morong River mouth - b	19.96 ± 1.54	2.00 ± 0.12	49.82 ± 2.30	86.40 ± 12.28	100.71 ± 15.06	
Sta. Cruz River mouth - s	6.10 ± 0.06	1.74 ± 0.03	8.82 ± 1.21	26.16 ± 1.24	23.70 ± 2.19	
Sta. Cruz River mouth - b	9.04 ± 0.07	1.73 ± 0.02	17.50 ± 2.32	52.36 ± 7.60	50.90 ± 6.69	

s = surface
b = bottom
[1/] Reyes and Lapie (1991)
[2/] Madamba et al. (1997)

Table 3.11. Mean levels of heavy metals [mg kg^{-1} methyl formyl benzoate (MFB)] in sediment samples from Laguna de Bay.

Location	Cr	Cd	Pb	Cu	Zn	Mn
1989-1991[1/]						
Central bay	-	-	-	-	-	-
East bay	4.33	0.238	8.97	44.9	45	405
West bay	1.83	0.152	5.22	36.7	31.1	276
South bay	-	-	-	-	-	-
1996[2/]						
Central bay	2.95 ± 0.16	0.52 ± 0.06	17.0 ± 1.4	26.2 ± 3.6	45 ± 6	
East bay	3.08 ± 0.45	0.63 ± 0.02	19.3 ± 1.5	38 ± 2	51 ± 4	
West bay	2.52 ± 0.28	0.70 ± 0.04	19.7 ± 0.8	37 ± 3	49 ± 2	
South bay	2.72 ± 0.01	0.67 ± 0.02	20.9 ± 0.5	30.0 ± 2.6	51 ± 1	
1997[2/]						
Bay River mouth	3.57 ± 0.02	0.32 ± 0.01	6.82 ± 0.04	22.97 ± 0.46	16.18 ± 0.37	
San Pedro River mouth	3.61 ± 0.16	0.46 ± 0.02	13.88 ± 0.80	43.57 ± 1.59	44.58 ± 2.69	
Tunasan River mouth	9.49 ± 1.45	0.64 ± 0.16	25.72 ± 0.60	49.62 ± 12.06	67.70 ± 8.88	
San Juan River mouth	3.56 ± 0.14	0.33 ± 0.00	12.70 ± 0.23	42.28 ± 0.99	16.96 ± 0.60	
Napindan River mouth	11.40 ± 0.14	0.50 ± 0.03	20.01 ± 0.99	24.56 ± 3.46	32.32 ± 1.83	
Sta. Rosa offshore	3.12 ± 0.20	0.40 ± 0.04	10.14 ± 0.81	24.82 ± 4.02	17.20 ± 2.98	
Sucat offshore	5.78 ± 0.58	0.50 ± 0.05	10.62 ± 2.02	39.45 ± 7.29	28.55 ± 3.39	
San Cristobal River mouth	2.16 ± 0.01	0.35 ± 0.02	13.56 ± 0.27	46.84 ± 6.96	11.83 ± 1.07	
Morong River mouth	7.33 ± 0.05	0.54 ± 0.03	9.05 ± 0.85	23.94 ± 1.59	30.47 ± 1.92	
Sta. Cruz River mouth	3.94 ± 0.02	0.46 ± 0.04	22.54 ± 1.69	37.00 ± 2.64	28.52 ± 2.25	

[1/] Baes, A.U. and A.D. Lapie (1993)

[2/] Madamba et. al. (1997)

3.1.6 Microbiological Status

Coliform counts of 1.25 million MPN/100 ml have been observed in 1985 (Zamora 1986; Table 3.15). The DENR-LLDA, in its Philippine Environmental Quality Report for 1990-1995, gave counts of up to 44 million MPN/100 ml in 1993. Lately, however, the LLDA (1996-1999) noted in its annual water quality reports on the lake and its tributaries that the "Total Coliform levels in the lake are within the criterion set for Class C Inland Waters at 5,000 MPN/100 ml" (Table 3.16). In another part of this chapter, the coliform counts cited from secondary sources are in the tens of million counts MPN/100 ml.

If indeed, in recent times, there has been a seeming thinning down of coliform populations in the main lake, what could be the implication of this phenomenon? There are three possibilities. First, this may be due to dilution, assuming that the conditions of water in the tributaries and in the main lake are the same. Second, it is possible that water in the main lake has a limited amount of the substances necessary for coliform proliferation. Third, it is possible that even though the necessary conditions

Table 3.12. Mean total mercury (μg g^{-1}) of different fish samples for 12 months.

Fish Samples	Month of Collection												Over Mean
	Aug. '89	Sept.	Oct.	Nov.	Dec.	Jan. '90	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Std. Dev
Dalag	0.0103	0.0069	0.0102	0.0120	0.0139	0.0088	0.0063	0.0021	0.0670	0.0180	0.0180	0.0320	0.021A ±0.0023
Kanduli	0.0215	0.0267	0.0081	0.0142	0.0209	0.0060	0.0083	0.0000	0.0500	0.0109	0.0109	0.0092	0.020A ±0.016
Biya	0.0115	0.0119	0.0086	0.0071	0.0144	0.0031	0.0092	0.0000	0.0291	0.0141	0.0141	0.0098	0.013B ±0.009
Tilapia	0.0110	0.0083	0.0090	0.0079	0.0074	0.0062	0.0087	0.0024	0.0000	0.0153	0.0153	0.0113	0.008C ±0.005

Table 3.13. Mean levels of heavy metals (mg kg^{-1} MFB) in the flesh of fish from Laguna de Bay.

Sample	Cr	Cu	Zn	Cd	Pb
1990-1991[1/]					
Milkfish *Chanos chanos*	-	3.29 ± 0.31	23.2 ± 1.2	nd	nd
Tilapia *Oreochromis mosambica*	-	5.42 ± 0.31	35.4 ± 0.7	nd	nd
Mudfish *Ophicephalus striatus*	-	2.18 ± 0.08	22.1 ± 0.3	nd	nd
1992-1993[2/]					
Tulya *Corbicula manilensis*	nd	24.35 ± 0.69	132 ± 3	0.44 ± 0.04	nd
Shrimps *Macrobrachium sp.*	0.18 ± 0.06	15.3 ± 0.5	66 ± 2	0.25 ± 0.02	nd
1997[3/]					
Carp *Cyprinus carpio*	2.55 ± 0.02	4.68 ± 0.11	20.9 ± 1.2	2.55 ± 0.02	9.73 ± 0.88
Mudfish *Ophicephalus striatus*	2.86 ± 0.12	1.54 ± 0.11	23.0 ± 0.5	1.66 ± 0.02	12.18 ± 0.04
Kanduli *Arius manilensis*	4.30 ± 0.07	2.28 ± 0.18	39.8 ± 1.0	1.76 ± 0.01	11.88 ± 0.53
Gouramy *Trichogaster pectoralis*	4.56 ± 0.22	4.82 ± 0.03	31.0 ± 1.2	2.05 ± 0.15	12.0 ± 0.9
Hito *Clarias batrachus*	3.76 ± 0.06	4.02 ± 0.92	38.5 ± 2.4	2.18 ± 0.10	14.48 ± 0.92
Dulong *M. lacustris*	4.62 ± 0.03	6.85 ± 0.07	158 ± 5	1.80 ± 0.02	16.7 ± 0.3
Tulya *Corbicula manilensis*	3.36 ± 0.20	103 ± 1	135 ± 0	3.38 ± 0.07	13.6 ± 0.6

[1/] Madamba et. al. (1994)
[2/] Madamba et. al. (1995)
[3/] Madamba et. al. (1997)
nd = no data

Table 3.14. Analysis of organic pollutants in water and sediments in Laguna de Bay (1997).

Location	COD (mg l^{-1}) in Water		Oil and Grease in Sediments ($g\ kg^{-1}$)		Organic Pollutants
	April	July	April	July	March
Bay River	7.50	6.50	4.76	on	n.a.
Sta. Cruz River	13.50	12.50	31.03	on	*(1, 4, 5)
Morong River	21.00	15.00	10.30	4.95	n.a.
Napindan River	18.50	7.50	13.32	21.24	*(1, 4, 5)
San Juan River	6.50	13.38	11.28	on	n.a.
San Cristobal River	4.00	37.99	6.77	on	*(1, 2, 3, 4, 5, 6, 7)
San Pedro River	19.50	15.50	11.81	on	*(1, 2, 3, 4, 5)
Tunasan River	10.50	18.73	19.31	on	n.a.
Sta. Rosa offshore	6.00	14.98	7.81	5.09	n.a.
Sucat offshore	16.00	18.73	6.80	7.22	n.a.
South bay	-	11.50	-	on	n.a.
Victoria	-	10.00	-	on	n.a.
Lumban	-	6.00	-	on	n.a.
Kalayaan	-	6.50	-	4.47	n.a.
Jala-jala	-	48.00	-	6.16	n.a.
Cardona	-	8.50	-	on	n.a.
Binangonan	-	36.00	-	on	n.a.

*Number in parenthesis indicates the following organic pollutants:
(1) Ibuprofen
(2) Bezafibrate
(3) Tetrachlorophthalic acid
(4) 2,4-dichlorobenzoic acid
(5) Tris-2-chloroethyl phosphate
(6) Anthracene
(7) Phenanthrene
on - on-going analysis
n. a. - not analyzed.
- symbol means no sampling done

for growth are there, coliforms fail to thrive because of toxicants. According to Prof. Noel Sabino, professor of microbiology at the Institute of Biological Sciences, UPLB, his study shows that there is less of the heterotrophic bacteria in the main lake than in the tributaries, possibly due to the presence of inhospitable conditions (e.g. varied toxicants) in the latter.

3.1.7 Trends in Phytoplankton Biomass and Productivity

Chlorophyll a (Chl a). This is utilized in the estimation of one of the parameters for determining the trophic status of a body of water. It may be used to stand for the amount of algal biomass at the time of determination. The range for eutrophic lakes is 10-500 ìg l^{-1} (Table 3.2).

The LLDA used the wet weight of phytoplankton to represent algal biomass from 1974 to 1988. The method is inaccurate, and so a process of conversion was followed using the LLDA data from 1974 to 1988. The method used assumptions concerning the water content of algal cells, their ash-free dry weight, to arrive at the estimated amount of chl a. The results are presented in graphical form in Figure 3.18.

Within the period 1974-1988, the range in concentration of algal biomass expressed as chl a was from around 2 ìg l^{-1} to 68 ìg l^{-1}. The period mean indicates a eutrophic state for the most part of the period. However, towards the late 1980s, algal biomass production deteriorated. The separate trends in the West and Central bays illustrate this point.

In West bay, chl a increased from 1974 to 1975. By 1976, this diminished below the lower limit of eutrophic water bodies. This is indicative of a progression to a worse state, a deterioration rather than reversion to an earlier more welcome stage of trophic development which is the mesotrophic state.

Table 3.15. Total coliform count and percent population of *E. coli* in Laguna de Bay waters.

Location	Coliform Count (MPN/100 ml)		% *E. coli* in Coliform Population	
	1984 (Wet)	**1985 (Dry)**	**1984 (Wet)**	**1985 (Dry)**
Mayondon (South bay)	450,000	1,300,000	53.6	18.8
Kalayaan (East bay)	273,000	2,050,000	55.3	15.0
Jala-jala (Central bay)	227,000	1,000,000	58.3	31.1
Alabang (West bay)	475,000	1,120,000	54.1	36.0
Pasig, Parolan	216,000	820,000	54.8	35.0
Average	**329,000**	**1,258,000**	**55.2**	**27.2**

Note: Permissible Coliform Count (Class C): 5,000 MPN/100 ml.
Source: Dr. Agnes F. Zamora, Institute of Biological Sciences, UPLB.

Table 3.16. Total coliform count in Laguna de Bay (annual averages of LLDA data).

Year	West bay	Central bay	East bay
1990	2,561	2,743	1,548
1991	769	1,706	1,128
1992	3,366	2,396	1,709
1993	3,276	1,071	455
1994	968	588	1,752
1995	2,718	1,409	2,070
1996	3,414	2,605	4,061
1997	1,609	946	860
1998	131	334	128
1999	496	766	283
Average	1,927	1,456	1,399
Class C		5,000 (maximum)	

Table 3.17. Annual mean concentration ranges of chl a (ìg l^{-1}) in East and West bays, 1987-1988.

Year	East bay	West bay
1987	16.8 (nil - 98.7)	37.8 (nil - 150.5)
1988	9.9 (3.3 - 13.8)	13.9 (3.8 - 41.1)
Average	13.4	25.9

Indicator levels: 100 ìg l^{-1} chl a – 50 percent probability of fish kill
200 ìg l^{-1} chl a – 100 percent probability of fish kill

A sudden and steep climb ensued in 1980 before biomass crashed to its historic lows over the entire lake between 1984 and 1988. Better conditions were indicated by the values obtained by Barril (1993) of 13.4 ìg l^{-1} and 25.9 ìg l^{-1} for East and West bays, respectively, for the period 1987-1988 (Table 3.17). Some nil readings, however, were indicated for the period implying over-grazing by herbivores or impeded biomass production. Overall, the conditions of West bay from 1984 to 1988 were not too favorable for algal growth in the lake.

Findings in Central bay tend to show that the lake was worse-off in that area than in West bay. Even as algal biomass values were higher than in West bay, this bay's production potential was more readily impaired. The fall in biomass from 1973 to 1974 was catastrophic, but the bay remained eutrophic until 1983, after which it gave hints of becoming dystrophic based on pigments alone. This lasted until 1988.

The unpublished data of Zafaralla and Santos in their monitoring work in the Mayondon area of South bay from 1986 to 1987 showed the range to be from 2.48 ìg l^{-1} to 14.24 ìg l^{-1} with levels below 10 ìg l^{-1} being more frequent than those above it (Figure 3.19).

Overall, the above indicates of a worsening condition of the lake's biological resources in the 1980s. The lake was overly fertilized but the algae did not respond through increased biomass production.

Anthropogenic developments and algal biomass production. Two major anthropogenic developments in the lake basin emerged in the ecological context of the falling algal biomass of the late 1970s to the 1980s. On one hand is the continued growth of fishpen areas. On the other is the construction of and eventual operation of the NHCS.

As stated in another sub-section, the fishpen areas have been growing unimpeded since the early 1970s. In 1981 when the algal biomass collapsed from the major peak formed in 1980, the total area allocated to fishpens was 1.5 times that of the past year. And when algal biomass reached its historic low in 1983, the area hit its historic high of 350 km^2. Short of a competitive advantage for fast diminishing natural food, the open fisheries area naturally shrank but remained a potent force to decimate algal biomass at twice its size in 1973. Thus, the crash in algal biomass production, the peak in fishpen areas, the peak in lake fish production all converge in the years 1983 and 1984 (see Tables 4.4 and 4.6). The base of the food chain weakened under the stress of heavy grazing. This is consistent with the ecological principle that variance in the biomass of consumers evokes substantial variance in primary production (Carpenter and Kitchell 1987).

To remedy the poor performance of the aquaculture sector when this reached maximum area, the LLDA demolished fishpens from 1984 to 1988. Ironically, what area was freed the catch fishermen claimed. And so the following years saw a dismal slump in fish production. Apparently, due to a severe stress applied on the resource, the self-restoring ability of the lake had been impaired.

Construction of the NHCS began in 1977. Its short-lived full operation began in 1983, but was terminated in 1984. Termination was a response to widespread opposition from the lake's fishermen and fishpen operators who blamed the structure for the dwindling fish production.

Far removed in time from those developments in the past, there is no way now to measure the parts of the disturbance caused by damming and aquaculture in the near-demise of fish production in the lake. But the convergence of maximum fishpen area, full operation of the NHCS, and a first time 99,000-t total fish production, a lower fish productivity, and a first historic low in algal biomass are proofs that the lake's carrying capacity had been exceeded.

The most recent chl a data available from the LLDA for the present assessment are for the years 1998 and 1999 (Figures 3.20 and 3.21). Overall, these indicate the lake is hypertrophic. Zafaralla, Mercado, and Datu (unpublished data) found the algal biommas to be higher in 1998 than in 1997 (67.44 ìg l^{-1} vs. 59.71 ìg l^{-1}). However, this diminished by 43 percent in 1999. There are many conceivable factors at the local level that lead to variance from the general trend of primary production in the lake.

Biomass production in the lake is seasonal. The most recent data show that the dry season tends to have a higher production.

The four bays are spatially differentiated with Central bay consistently exhibiting relatively higher biomass per season and per year. West bay tended to equal the primary production of Central bay only in the dry season. On an annual basis, however, West bay is slightly less productive (11 percent). South bay had the lowest primary production (Figure 3.22).

Table 3.18. Chlorophyll a levels in the dry and wet season. (Source: LLDA)

Time Observed	Chlorophyll a (g m^{-2} day^{-1})	
	1998	1999
Dry Season	29.9	41.8
Wet Season	29.9	26.3

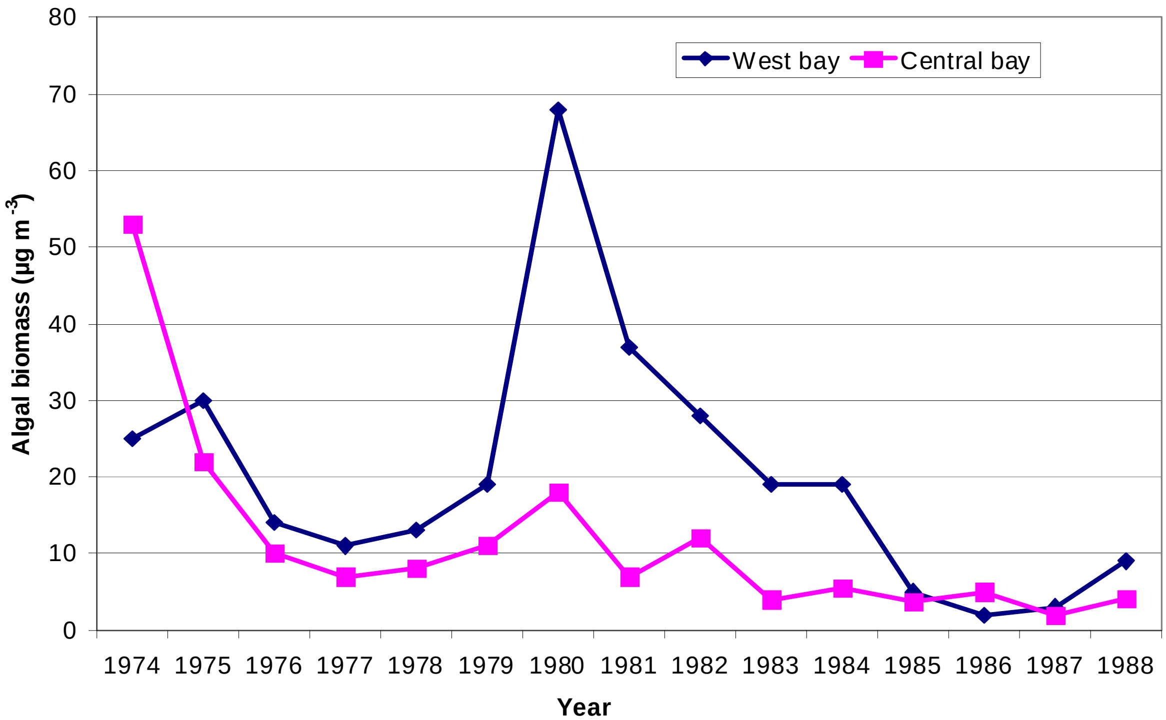


Figure 3.18. Laguna Lake average annual algal biomass in terms of chlorophyll a (1974-1988).

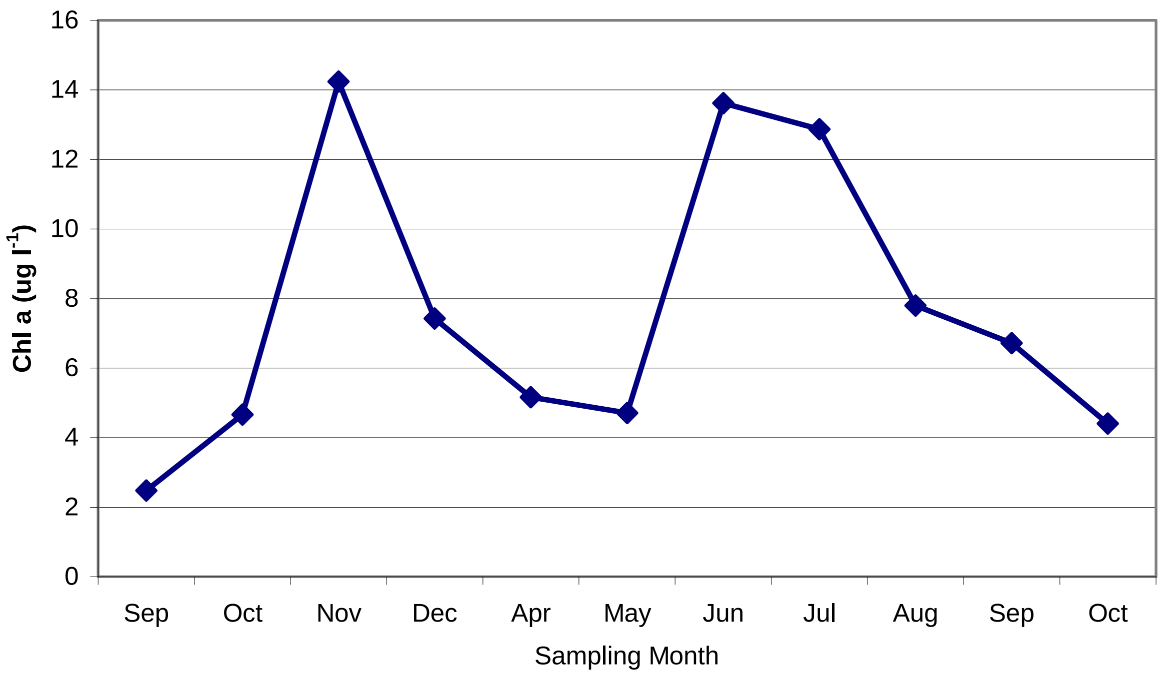


Figure 3.19. Chlorophyll a levels in Mayodon, Los Baños area of South bay, September 1986 - October 1987.

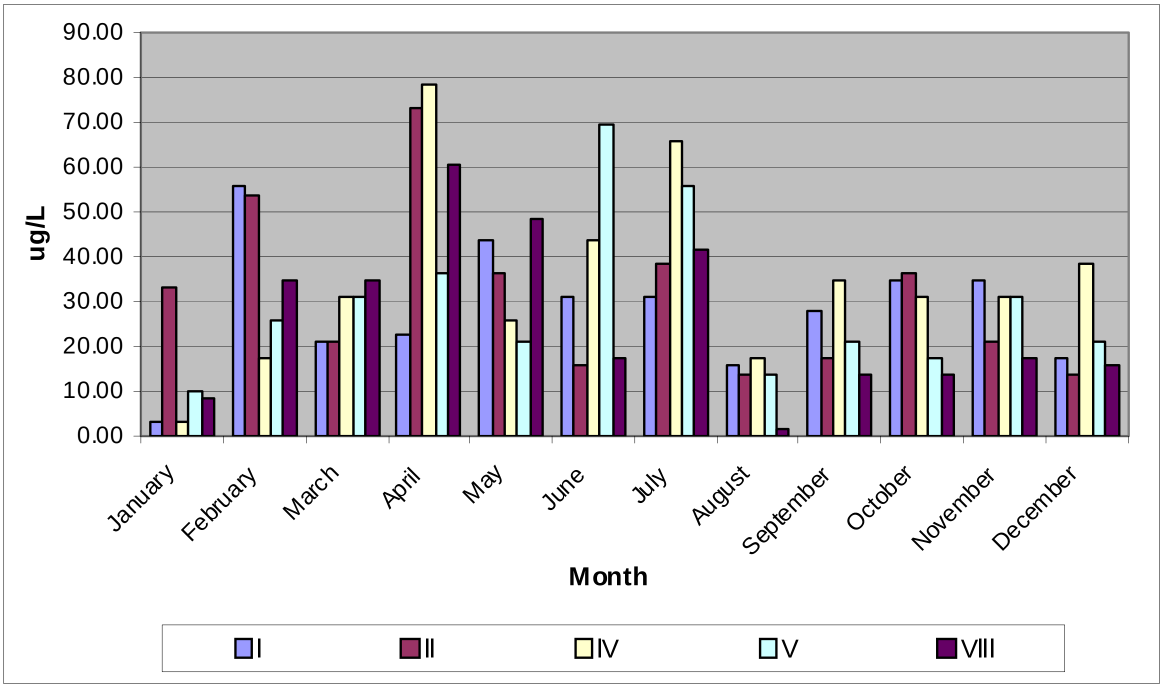


Figure 3.20. Chlorophyll a (ìg l-1) in Laguna de Bay, 1998 (Source: LLDA).

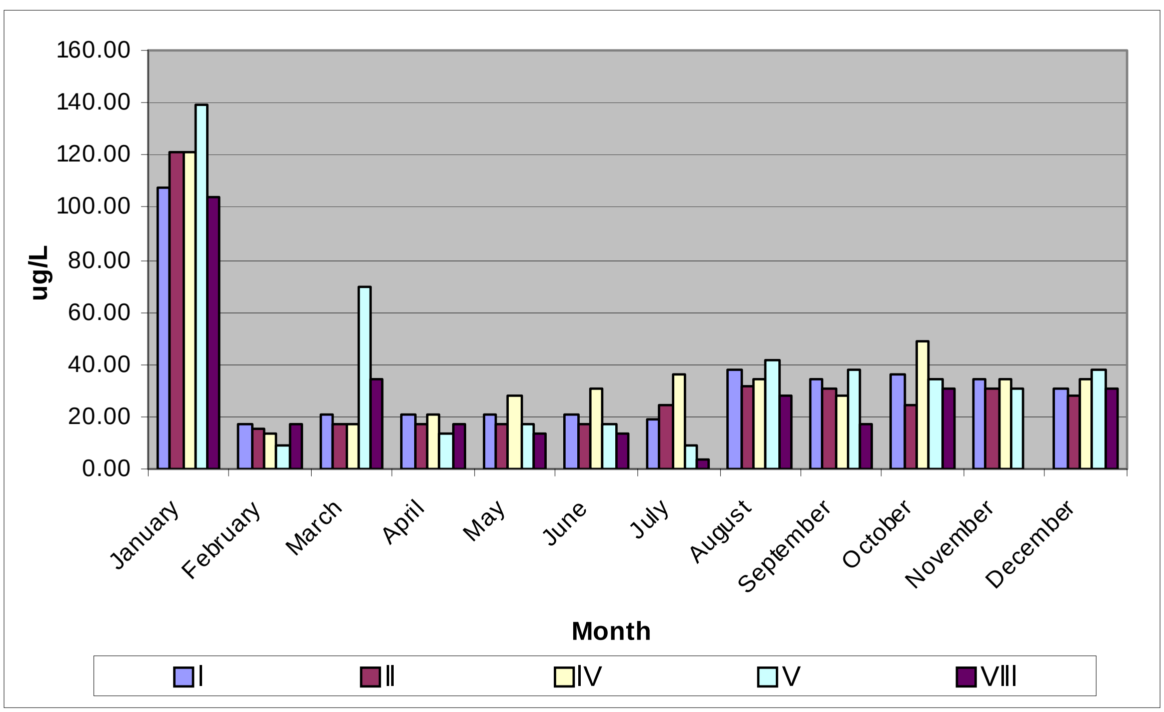


Figure 3.21. Chlorophyll a (ìg l-1) in Laguna de Bay, 1999 (Source: LLDA).

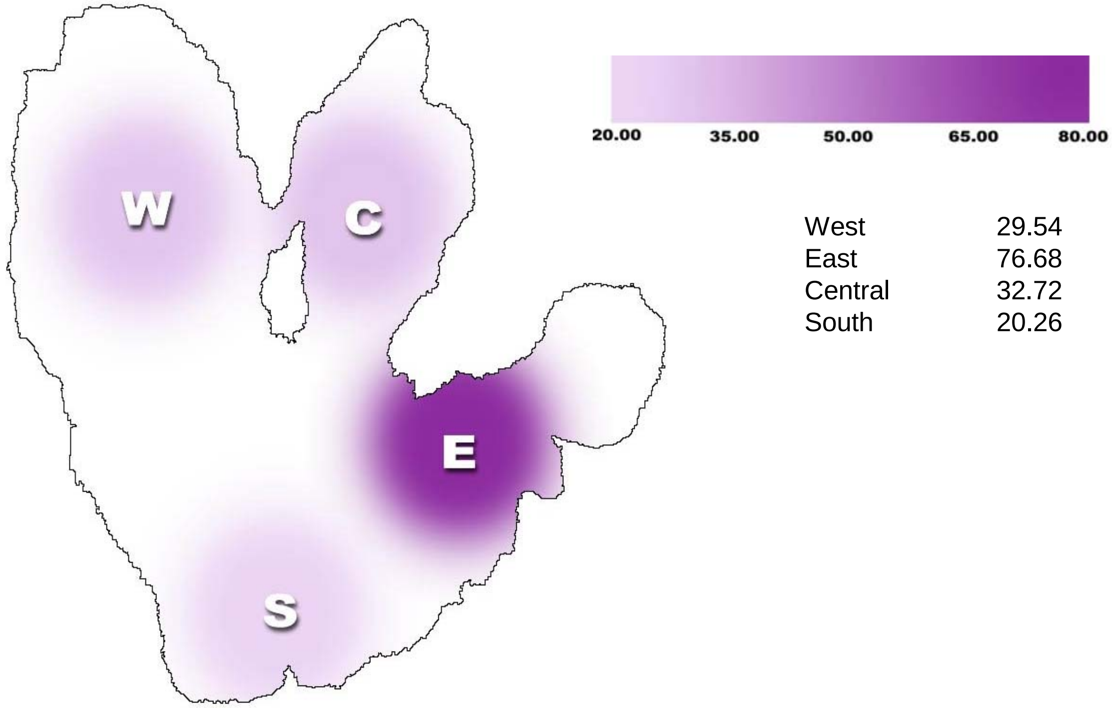


Figure 3.22. Chlorophyll a levels (ì g l^{-1}) in Laguna de Bay, 1999.

Net Primary Productivity. This is included along with chlorophyll a in trophic state determination. Literature gives a range of 0.3-3.0 g m^{-2} day^{-1} for eutrophic lakes and >3.0 for hypertrophic (Table 3.1). The results of the determinations done by the LLDA are presented in Figures 3.23 to 3.25.

Light-and-dark bottles yielded 0.53 g C m^{-2} day^{-1} in the mid-1970s (SOGREAH 1976), while the ^{14}C method gave a range of 3 to 8 g C m^{-2} day^{-1}, with average of 2.1 g C m^{-2} day^{-1} at the end of the 1980s (Nielsen et al. 1981). The latter brings Laguna de Bay slightly above the reported productivities of lakes Lanao (1.75) and Mainit (1.7) in Mindanao. A SOGREAH update in 1991 exceeded its 1976 estimate at 1 g C m^{-2} day^{-1}.

The LLDA also had data from 1973 to 1988. Since the method used did not conform with international standards, they are considered as not truly representative (Charlton 1993), and could be underestimated. Be that as it may, it is notable that the range of the values tends to be wide and reflects a eutrophic to hypertrophic lake.

Monitoring of NPP was resumed by the LLDA in 1996-1997. It observed a small yet evident difference between the two seasons with the wet being the more productive than the dry (Figure 3.26).

The group of Zafaralla used rainfall and temperature data to divide the year into four parts and found that the no backflow year of 1997 had a mean NPP of 2.402 g C m^{-2} day^{-1}. That of 1998 was lower 0.91 g C m^{-2} day^{-1}. Mean transparency in 1997 and 1998 in the area was between 35 to 40 cm. The NPP dynamics in the lake are influenced by a set of complex factors not solely dependent on water clarity changes in the present highly turbid lake.

The question of whether or not the lakeshore fishermen were right in their claim that saltwater intrusion from Manila Bay was essential to the improvement of lake primary productivity was a subject of conjecture for sometime. In one analysis of the mid 1973-1988 LLDA data, a correlation did not clearly emerge between primary production and salt intrusion on one hand and turbidity and salt intrusion on the other (Charlton 1993). The net primary productivity as a variable is corroborated by the absence of correlation between the two in all of the monitoring work undertaken in the laboratory of Zafaralla in 1984-1985, 1987-1988, and 1998-1999. It is evident that there is a host of interactions influencing the level of NPP.

The chemical mechanism for lake clearing has been described in an earlier section. Turbid water develops daily around 10 o'clock in the morning till 3 o'clock in the afternoon. It increases in intensity in the dry season when the northeast monsoon winds blow. The result is a tremendous reduction in light penetration that registers at zero. Rain alleviates this condition; consequently algal growth is improved. But algal growth no longer becomes as massive as it used to be beginning in the late 1980s. Conditions have greatly

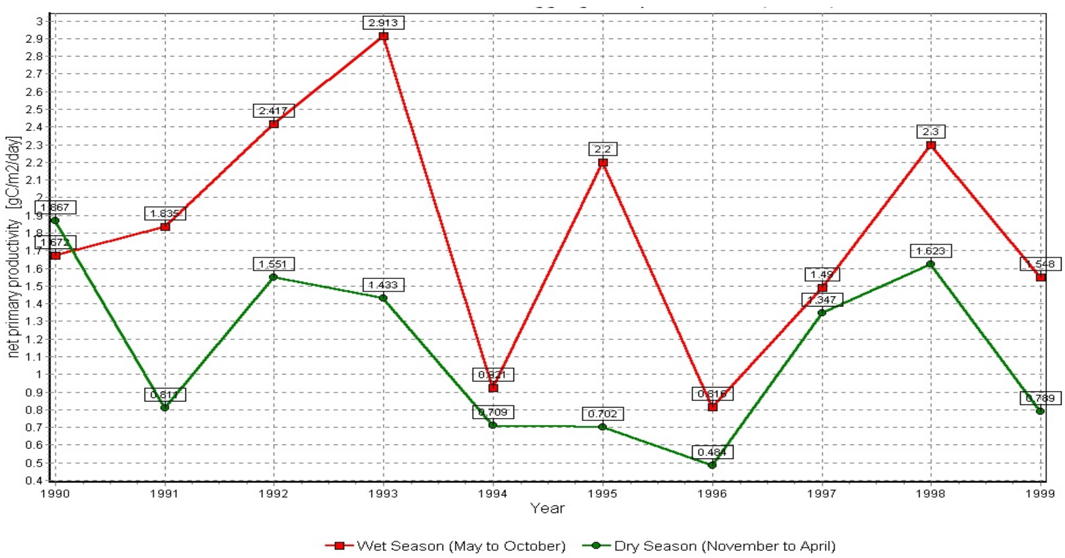


Figure 3.23. Lake primary productivity at West bay, aggregated values per season, 1990-1999 (mean).

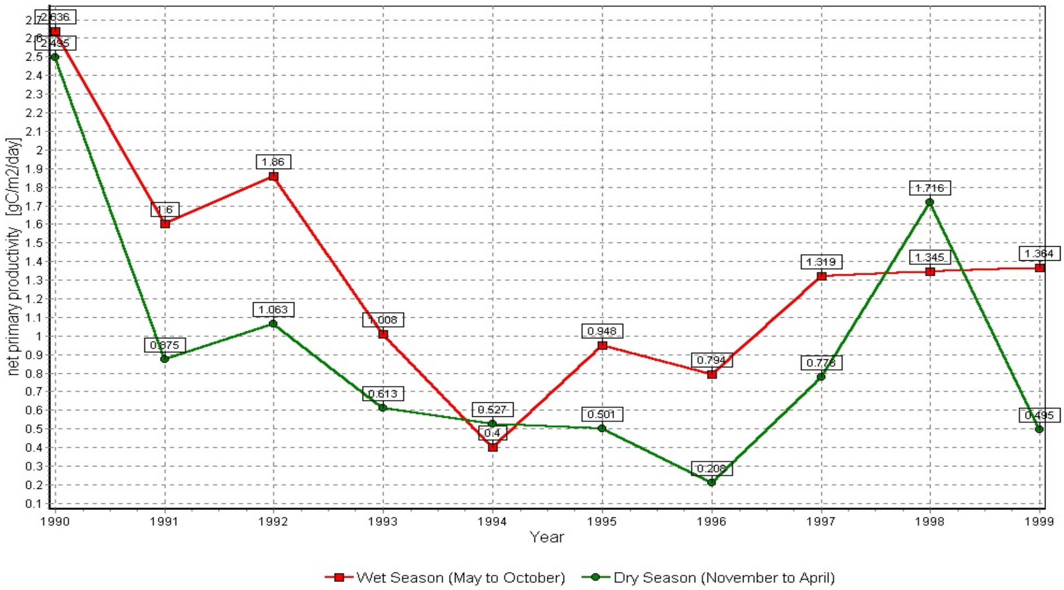


Figure 3.24. Lake primary productivity at Central bay, aggregated values per season, 1990-1999 (mean).

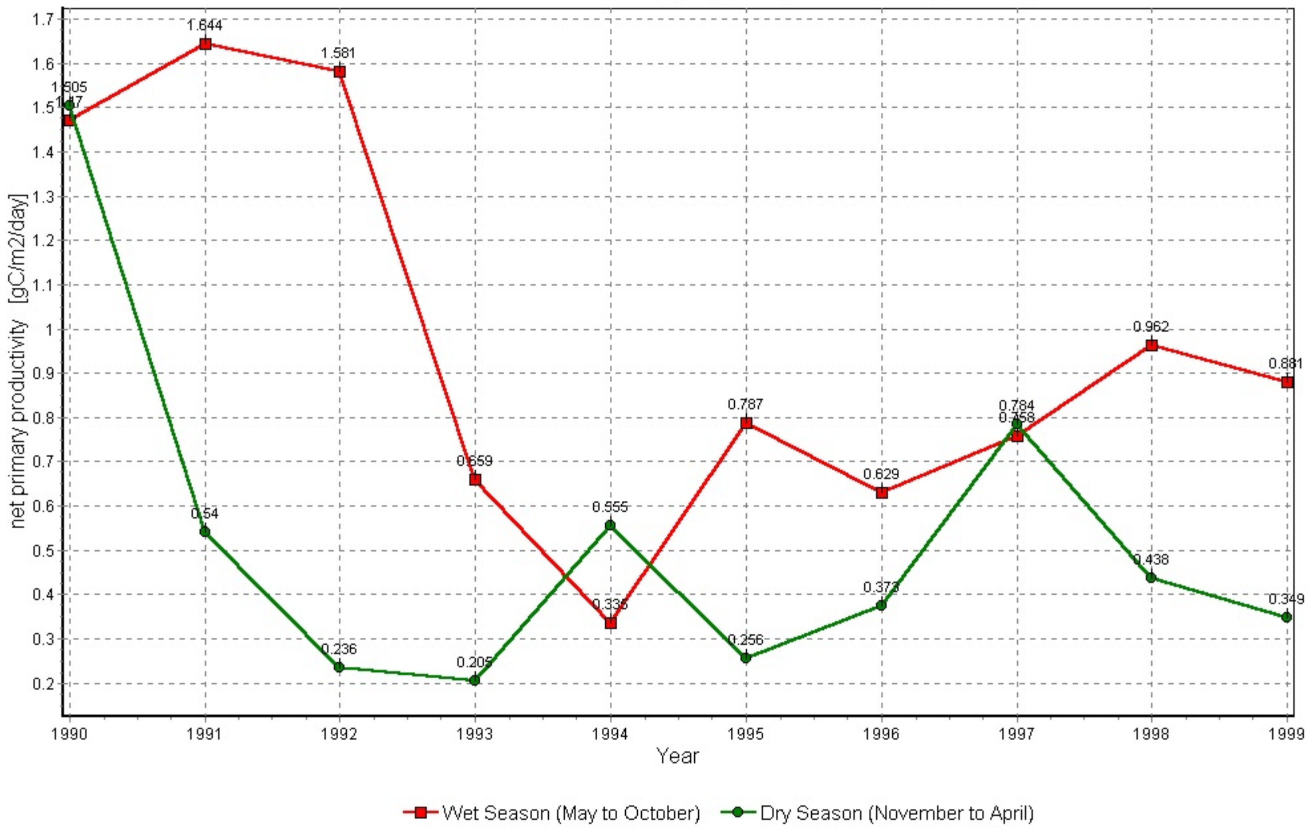
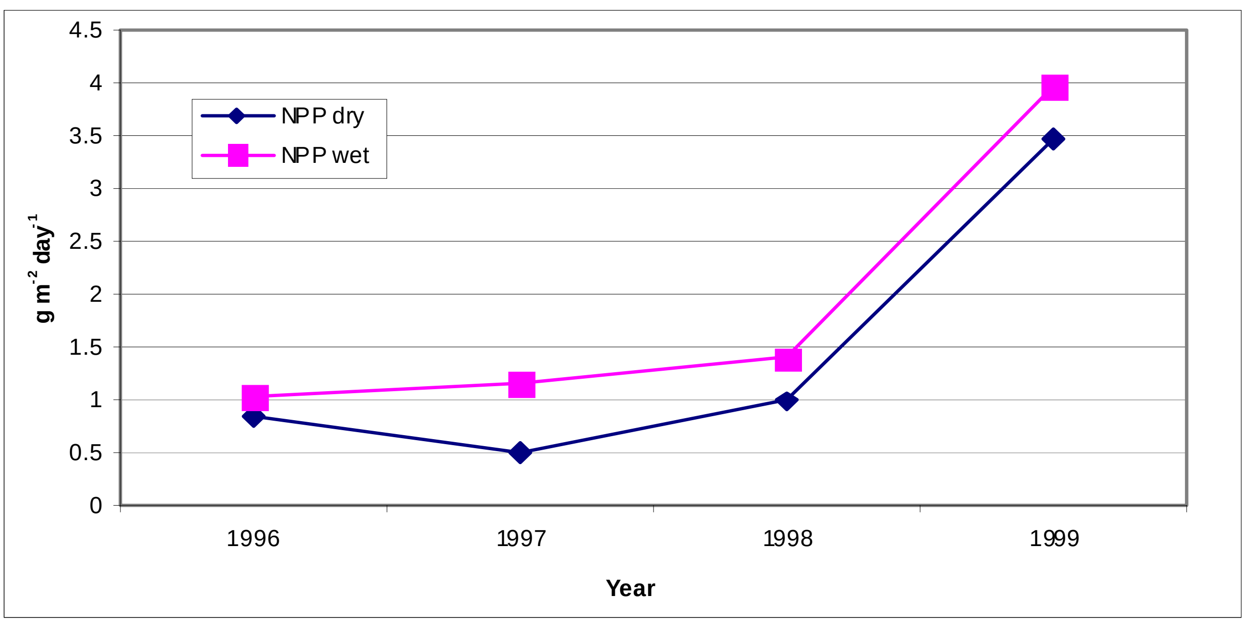


Figure 3.25. Lake primary productivity at East bay, aggregated values per season, 1990-1999 (mean).



ons, 1996-1999.

deteriorated in the lake; even the algae have lost their responsiveness to the high nutrient levels.

Finally NPP and algal biomass are not expected to correlate. The former is a physiological process influenced by the physiological state of algal cells, amount of pigments present, maturity of cells, nutrients, and pollutants present. Chlorophyll a is also determined by biochemical processes, but physical processes, like transport by the water medium and grazing by consumers, produces larger scale alterations that cannot be accounted for by the changed ability of cells to produce pigments or biomass.

Phytoplankton Community Structure. Baseline data for the period 1973-1977, as contained in the 1978 report of the LLDA-WHO, include 62 genera of phytoplankton representing the algal classes Cyanophyceae (BGA); Chlorophyceae (green algae); Bacillariophyceae (diatoms); and Dinophyceae (dinoflagellates). The dominant species were the blue-greens *Microcystis*, *Anabaena*, and *Oscillatoria*. Except for the latter, the others are two of the top three noxious algae of water supplies. The other cyanophytes with irregular presence and low numbers were: *Raphidiopsis, Anabaenopsis, Lyngbya, Spirulina, Aphanocapsa, Aphanothece, Chroococcus, Synechococcus,* and *Agmenellum*.

The green algae had the highest number of represented genera numbering 27. The most common were *Scenedesmus* and *Closterium*, a desmid. *Scenedesmus* increased significantly until the second half of the 1970s. As the fishpen areas grew, two other desmid genera increased their populations, namely, *Staurastrum* and *Cosmarium*. Desmids are known to frequent dystrophic waters. Their increasing number of representatives and density is interpreted as a possible concurrence with the observations at the physico-chemical levels indicative of some areas becoming dystrophic.

There were 22 diatom genera which are almost twice the number of blue-green algal genera. The dominants were *Melosira* and *Stephanodiscus*. Species densities in the group increased two-fold towards 1977. Only two dinoflagellate genera appear in the baseline.

The densities of the three main algal groups revealed the blue-greens undergoing diminishing densities, from 400,000 in 1973 to 120,000 in 1977. By contrast the green algal species increased their populations from 70 to 3,000. The diatoms had no definite trend over the years.

From the LLDA data of 1973-1988 that he analyzed, Charlton (1993) concluded that algal shift had taken place in the past. Where before the blue-greens dominated, the diatoms seemed to have taken over in recent years. Pinnate diatoms tended to dominate in the dry and BGA in the wet.

In a survey of five different areas from South bay to East bay (Cabuyao, Mayondon,Victoria, Kalayaan, Pililla) including Talim Island (Figure 3.27), it was found out that *Microcystis* was the dominant in places impacted by industrial effluents (Cabuyao and Pililla) (Zafaralla et al. 1990). The centric diatom *Melosira* dominated in places with fishpen aquaculture, duck- and hog-raising, and in the vicinity of the Kalayaan Pump-Up Storage Power Plant. *Coscinodiscus* was frequently the second dominant in most places, while the blue-greens *Anabaenopsis* and *Spirulina* took over when the cell density of *Coscinodiscus* dwindled.

A comparison of the observations of Zafaralla in 1984 with the baseline shows that some changes in the structure of algal communities had occurred. The big-celled diatom, *Stephanodiscus*, common in the early years of fish caging, is now rarely encountered. This implies that the increasing intensity of water use on the one hand, and the changing lake water quality on the other, may have eliminated some algal species.

The 1984 data also hint of a spatial differentiation based on the proportions of the different algal groups (Figure 3.28). In any locality, the dominants could be either the green algae (chlorophytes), or the diatoms (bacillariophytes).

Zafaralla and Mercado (2005, in press) obtained the following proportions of algal groups in the Putatan area of Laguna de Bay: blue-green algae, 39 percent; chlorophytes, 31 percent; diatoms, 26 percent; and the euglenoids and dinoflagellates, each with 2 percent.

The unpublished data collected by Zafaralla and her students in the Putatan area from 1996 to 1999 indicated increasing density of algae. This parallels the LLDA's findings of an increasing trend in biomass for the period 1998-1999. Figure 2.32 shows that algal densities increased from 1996, the time of no saline water backflow, to 1998, the second year of the El Niño. It appeared to undergo further improvement up to 1999. They further established that algae increased in density from 1996 to 1999 (Figure 3.29). The recent annual maximum of 7,404 units ml^{-1} is way below the 4,000-unit maximum formed by the most prolific blue-green algal class of the 1970s.

The above data have a number of implications. Over the years, the ability of algae to form large populations has weakened possibly as an offshoot of the drastic changes in water quality. In Putatan, this has affected primarily the bloom-forming cyanophytan group. In the fish chapter of

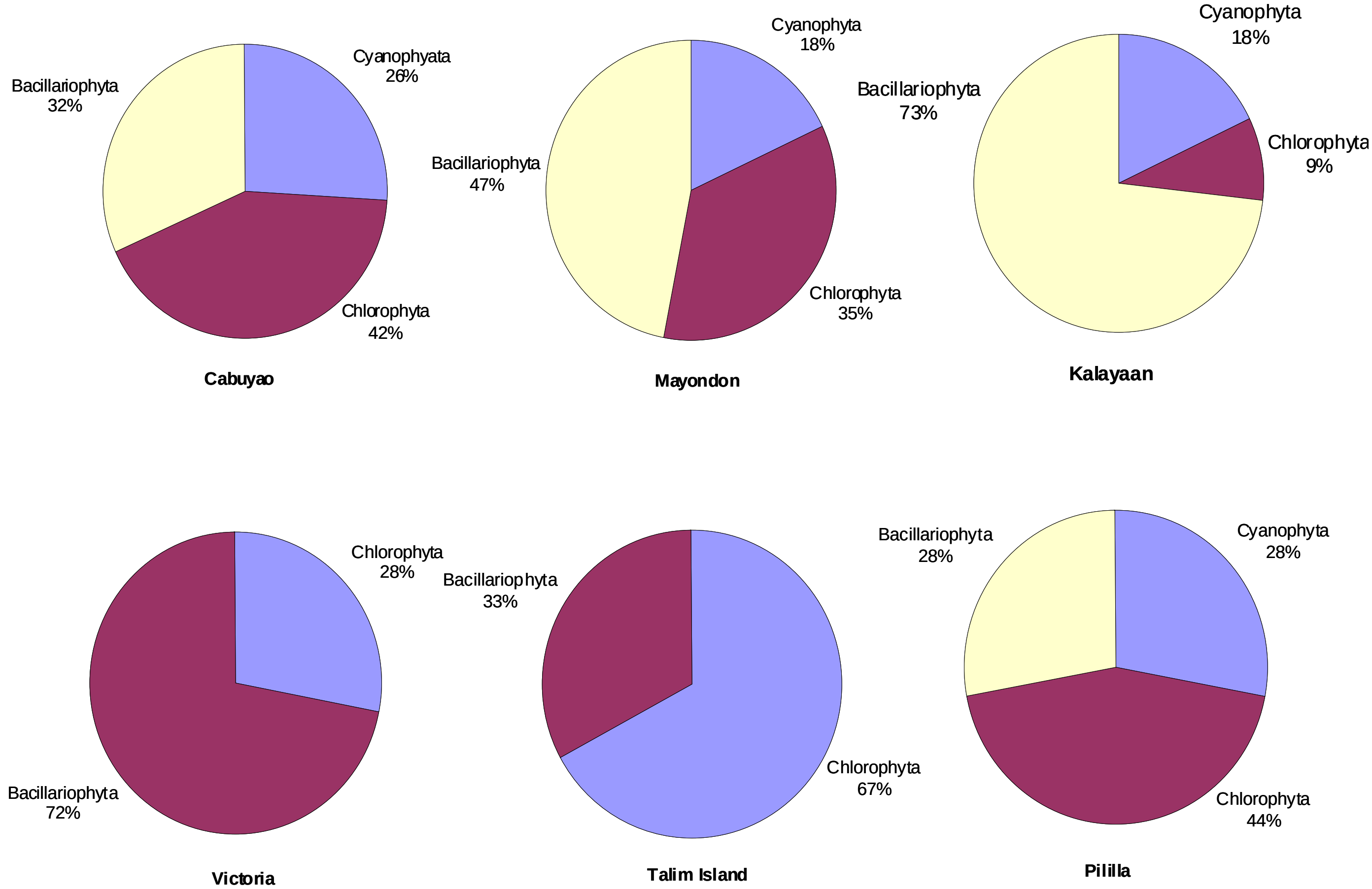


Figure 3.27. The proportions of the different algal groups observed in Laguna de Bay, February-May 1984.

this book, a parallel finding is a dwindling fish production over the years.

Latest data on algal community structure from the LLDA (Figure 3.30) show the blue-green algae and the green algae having a balanced number of generic representations.

Zooplankton. The baseline data on the zooplankton communities are found in the report of the LLDA-WHO (1978) which cover the period 1973-1977. The primary groups present are the copepods, cladocerans, and rotifers. Their pooled densities underwent an abrupt decline from about 1,000 ipl (individuals per liter) in 1973 to a mere 300 ipl in 1977. The fishpen area grew from 48 km^2 in 1973 to 26 km^2 in 1977. The rotifers were seemingly the hardest hit, their density declining from around 300 ipl to near zero. Cladocerans with an overall average of approximately 300 per liter, and copepods whose overall average was approximately 100 per liter, similarly suffered a close to 50 percent diminution. Coincident with this near-wipe-out of zooplankton groups was the increased density of cultured

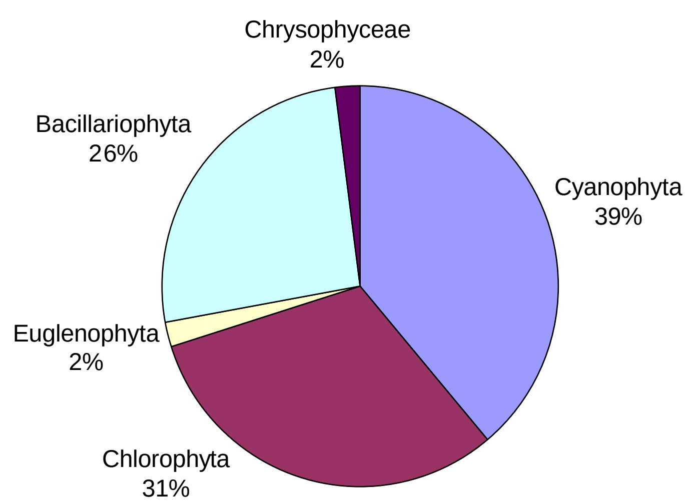


Figure 3.28. The proportions of different classes of algae represented in the Putatan area of Laguna de Bay, September 1996-February 1998.

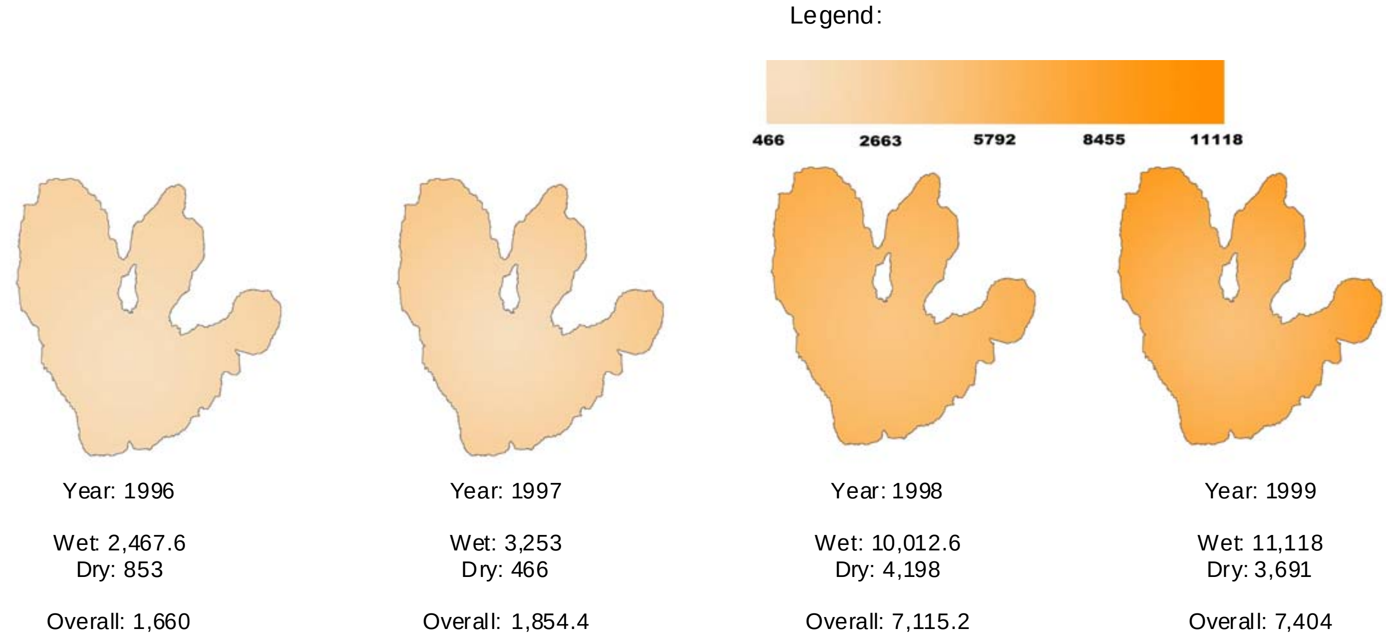


Figure 3.29. The densities of phytoplankton in Laguna de Bay, 1996-1999.

fish. Thus, an increased grazing pressure is a strong factor that trims down zooplankton populations.

Zooplankton in the lake manifest a seasonal abundance. During the time of their peak performance between 1973 to 1977, their densities reached as high as 2,850 ipl in summer. Dense populations however, were short-lived because of heavy predation by fish. According to the LLDA, the summer communities at that time comprised of the Copepoda, primarily *Cyclops* and *Diaptomus*; and the cladocerans, *Bosmina, Diasphanosoma, Moina, Bosminopsis,* and *Alona*. The yearly means for the entire lake from 1996 to 1999 are depicted in Figure 3.31.

The zooplankton data of the LLDA for the 1990s show a total of 36 species belonging to 23 genera. Of the three most commonly represented groups found, the Rotifera was the most diverse with 17 species. These, however, generally had small populations. Cladocerans with nine species ranked second to the rotifers. This group manifested sporadic high densities in 1990, 1991, 1995, and 1996. Copepods had only four species but ranked first in terms of density and persistence. The group comprised of the juvenile stages (nauplii), and copepodids of *Arctodiaptomus, Thermocyclops,* and *Mesocyclops*.

In 1990, a maximum of 1,616 ipl was recorded in West bay around the mouth of the Pasig River. Of this, 98 percent were rotifers. In the next year, a decline was evident that reached its lowest point in 1992. The density of zooplankters was reduced by almost 50 percent. In West bay where the count dwindled down to 830 ipl, the most adversely affected were the copepods which represented 49 percent of what was lost.

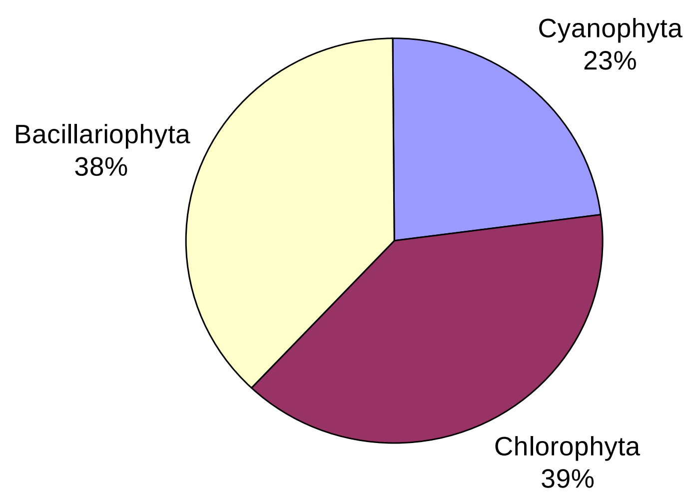


Figure 3.30. The proportions of algal groups in Laguna de Bay, 2002 (Source: LLDA).

The collapse of the lake's zooplankton community in 1992 continued unimpeded through the years (Figure 3.32). There was a brief recovery in 1998 but this did not prosper. In the succeeding years, a continuous retrogression of zooplankton populations evinced in all bays. The area around the mouth of the Pasig River, however, seems relatively more hospitable. Because of the clearer water in the area consequent to autoflocculation, phytoplankton exhibit better growth.

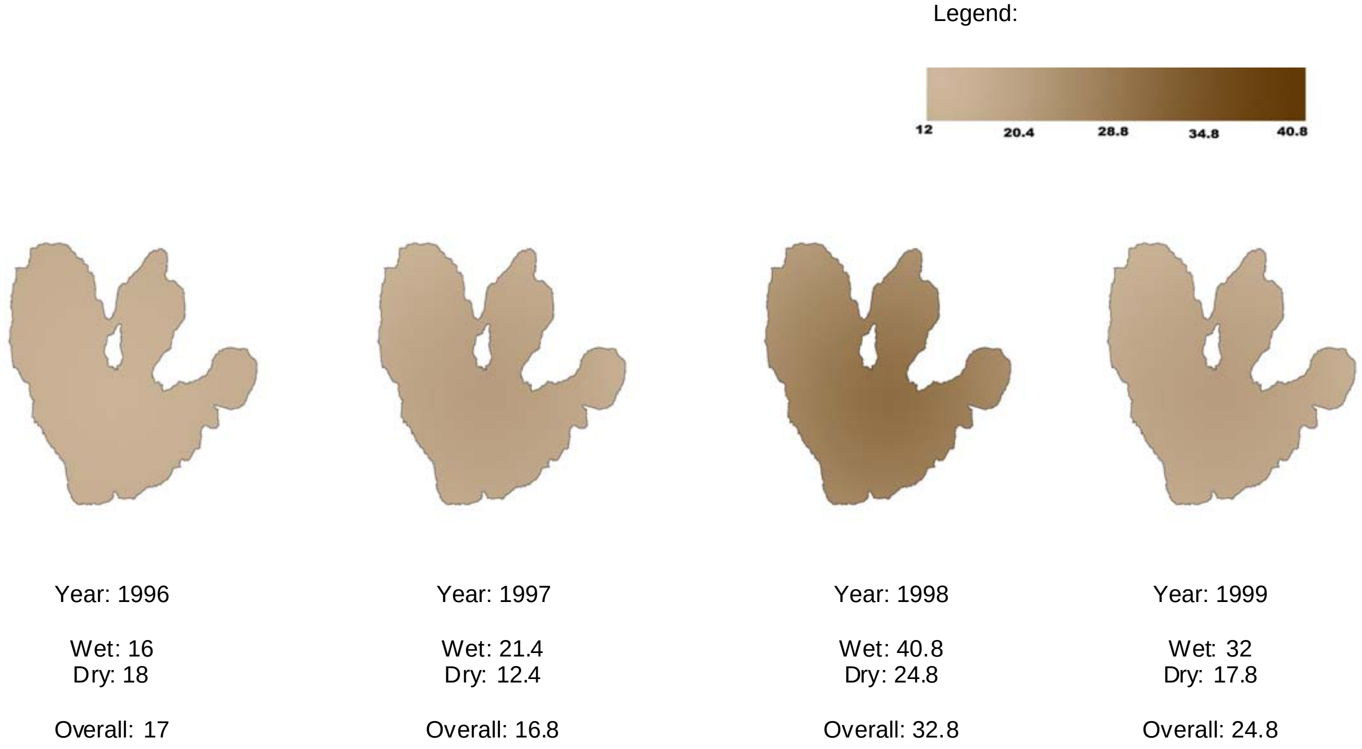


Figure 3.31. Zooplankton densities in Laguna de Bay, 1996-1999.

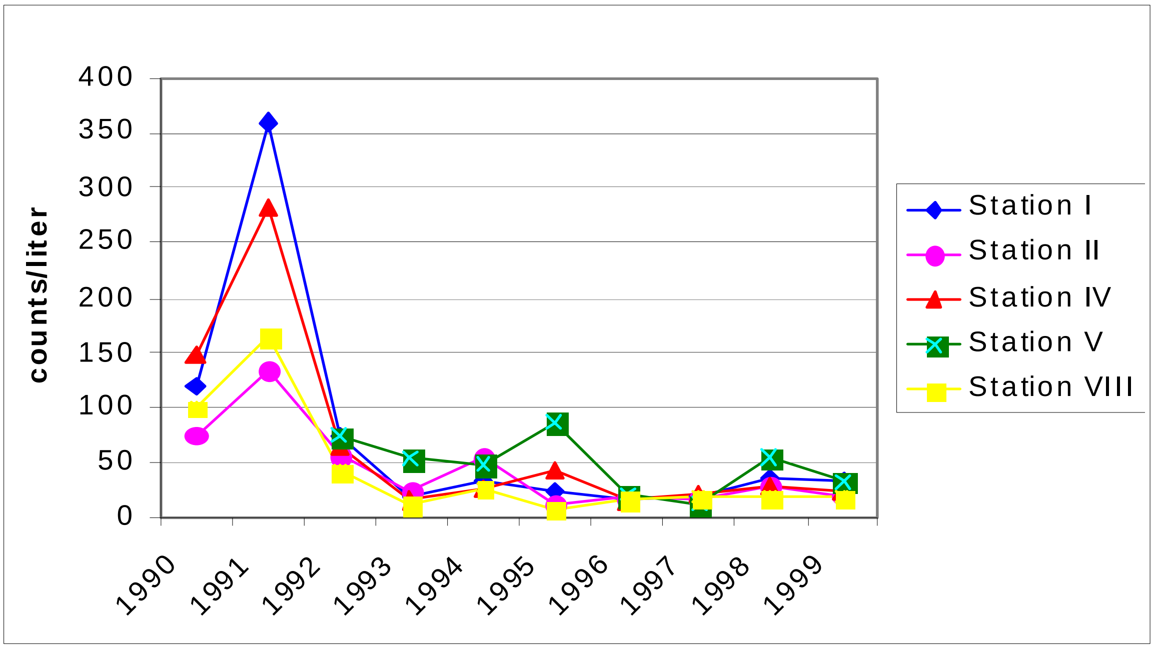


Figure 3.32. Annual average of zooplankton whole lake, 1990-1999

Apparently, the greater abundance of better quality food helps the zooplankton to flourish there.

Zooplankton species that populate in the lake are characteristically small-bodied. Large bodied forms are uncommon. The LLDA attributes this to the common proliferation and periodic blooms of colonial algae, particularly of *Microcystis aeruginosa*. Reportedly this blue-green alga exerts mechanical feeding pressure to big-sized cladocerans.

Fish predation is a strong pressure that reduces zooplankton populations, especially the large-sized species. Juvenile fish probably account for the decreasing zooplankton density. Gut analysis of *Leiopotherapon plumbeus* (ayungin) from the lake, revealed that 72 percent of the gut content was composed of cladocerans, copepods, ostracods, and *Rotatoria* (Kock et al. 1999).

The zooplankton as a group has not received the attention that it deserves in terms of scientific research. Knowledge of the dynamics of the zooplankton community would help elucidate on the oscillating populations of primary producers in the lake.

Benthic Fauna. These organisms are found attached or resting at the bottom or living in the bottom sediments. They are recognized as good indicators of aquatic pollution particularly organic contamination and eutrophication. The benthic community is composed of about 22 genera consisting of mollusks, oligochaetes, ostracods, nematodes, insect larvae, water arachnids, crustaceans, and juveniles of fish. *Thiara sp.* and *Cypricercus sp.* are the most common. According to the LLDA-WHO (1978), these are cosmopolitan in distribution. They also show seasonality with peaks common during the dry season. In 1998, the peak was observed in July around the mouth of the Pasig River. This seemingly delayed peak abundance could be due to the El Niño that hit the country in1997-1998.

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A downward trend was observed from 1990 to 1997. Benthos counts however increased in 1998. The annual average for benthic fauna is presented in Figure 3.33.

Benthic fauna of the lake comprise of the following in decreasing abundance: Oligochaetes, Ostracods, Molluscans, and Dipterans. The Nematoda and Chordata are practically negligible. Their density over the entire lake from 1975 to 1977 averaged approximately 3,000 indiv m^{-2}. At that time, West bay exhibited higher densities than Central bay (4,000 m^{-2} vs. 2,000 indiv m^{-2}).

Oligochaetes were represented by the genera, *Branchuira*, *Limnodrilus*, and *Tubifex*. Their populations reached their peak in the summer months. *Limnodrilus* and *Tubifex* were common inhabitants of the West bay. Ostracods consisted primarily of the genus *Cypicernus*. Peak population densities generally occurred during the cool months.

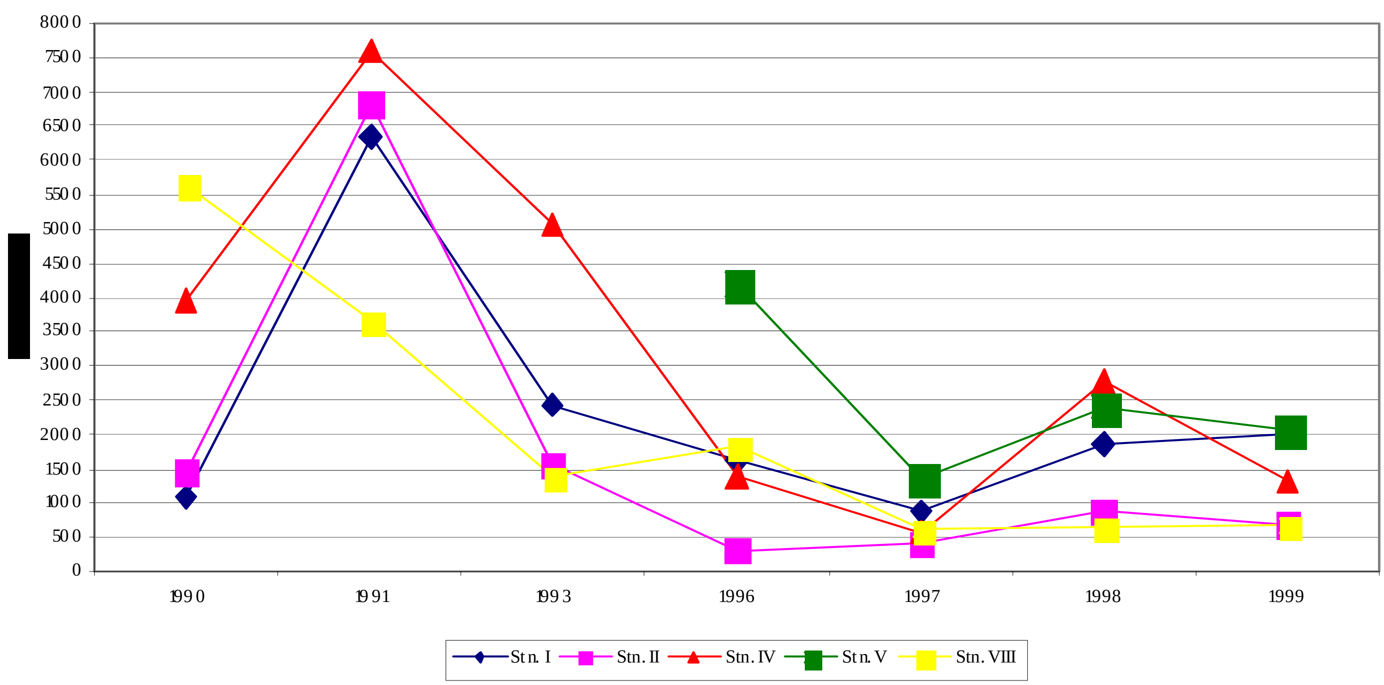

Figure 3.33. Annual average of benthic fauna in Laguna Lake, 1990-1999.

The Molluscans reported are *Corbicula*, *Lymnaea*, *Pleurocea*, *Promenetus*, *Tarebia*, and *Amnicola*. Their populations usually grew in the second half of the year, with *Lymnaea* and *Amnicola* dominating. Dipteran representatives were mainly of Chironomid and Midge larvae. None of the information accessed revealed the season in which their populations increased. The yearly means from 1996 to 1999 are shown in Figure 3.34.

Aquatic Macrophytes. Aquatic macrophytes in the lake range from the submersed, floating to the emergent species. These serve as a homing ground or shelter, a place for egg deposition, and as a source of food to many larval forms of aquatic fauna. Both the floating and benthic rooted forms help cleanse the water of its pollutants. An overgrowth of floating macrophytes may control the density of phytoplankton. Rooted macrophytes absorb minerals and heavy metals from the sediments and stabilize the substratum (Aguilar 2003). They form a part of the transition zone between the aquatic and the terretrial ecosystem. When aquatic macrophytes decay they contribute to soil formation, a cause for the rapid shoaling of the lake especially where *Eichhornia crassipes* grows luxuriantly.

Around the mid-1980s, a tremendous decrease in their population occurred. *E. crassipes* and *Hydrilla verticillata* were strongly decimated. The former used to threaten the economic gains of fishpen owners during the monsoon season because of the losses incurred when fishpens were knocked down by the wind-blown thickets of the plant. Today, one no longer finds this type of a threat, because floating macrophytes are virtually gone except in the outskirts, primarily of South bay and East bay. Such a diminution in a usual component of the aquatic biota could have tremendous impact on associated fauna, but this has not been investigated.

Submersed macrophytes are not an exception. These used to cover the bottom of the shallow lake to the extent that plants' parts are among the materials that entangle the rudder of motorized boats along with plastic and the like. Today, this kind of a problem no longer causes as much nuisance.

The taxonomy of aquatic macrophytes in the lake is well explored. They are included in the book of Pancho (1972) entitled *World's Worst Weeds*. Studies done in 1984-1985 (Aguilar et al. 1984-1985; Pitargue 1991-1992) showed that there has been a six-fold increase from seven to 32 species of emergent species in South bay. The common emergent species are *Typha angustifolila* L., *Phragmites karka* (Retz) Trin. Ex Steud., and *Schoenoplectus grossus* (L.f.).

The area covered with aquatic macrophytes in 1977 is presented in Figure 3.35. This map needs updating

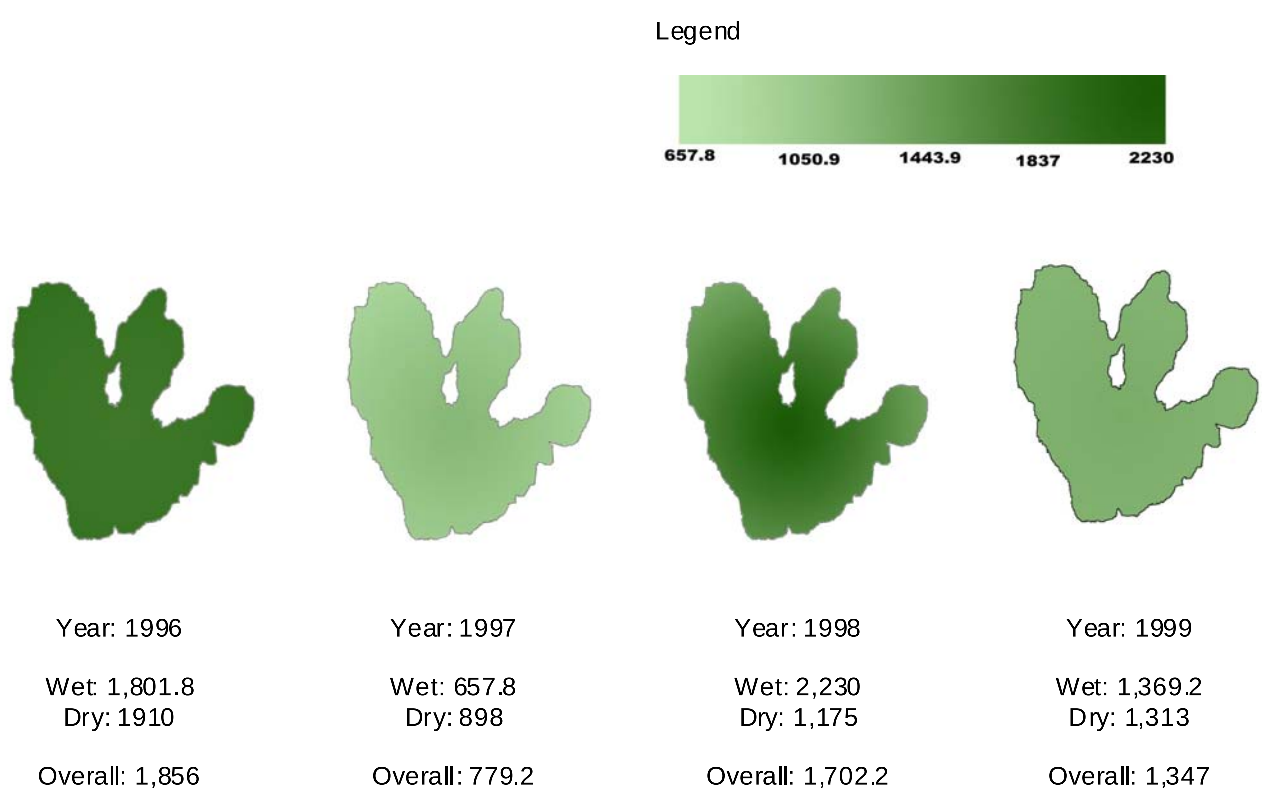

Figure 3.34. Benthos densities in Laguna de Bay, 1996-1999.

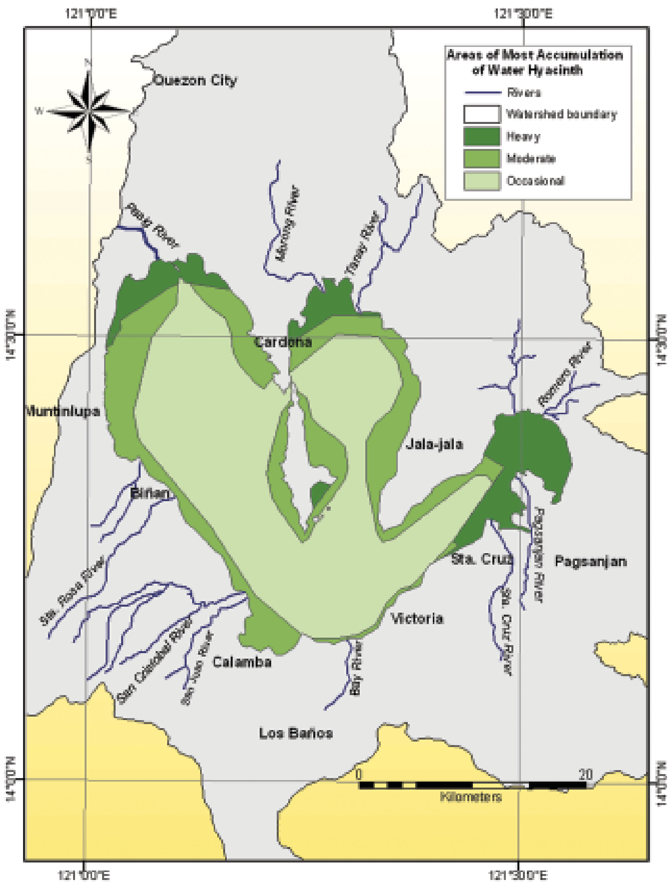

Figure 3.35. Density of aquatic macrophytes in Laguna de Bay, 1977.

considering that around 27 years have already passed since the map was constructed.

3.2 Factors Affecting Water Quality and Their Impacts on the Lake Ecosystem

The different factors (or drivers of change) that affect the water quality of Laguna de Bay, either directly or indirectly, basically relate to human population and the need to meet demands for food, shelter, basic utilities, and other amenities. These include food production in terms of crops, livestock and fish, industrialization including plants' operations, land use change, devegetation, and urbanization. All of these activities invariably generate wastes and residuals that when disposed in the lake watershed ultimately end up in the lake.

Figure 3.36 shows the different sources of wastes and effluents and the type of pollutants they contain that contribute to the pollution and water quality degradation of the lake. Domestic wastes and livestock production both contribute oxygen-demanding wastes (such as biodegradable organic wastes) and disease-causing agents (pathogenic bacteria, fungi, viruses, etc.). Industrial wastes also contribute oxygen-demanding wastes in addition to synthetic organic and inorganic chemicals (detergents, pesticides, industrial organic compounds, heavy metals, mineral acids, etc.) heat and oil which are also generated by power plants operating in the lake area. The impacts of these pollutants include build-up of toxicants and pathogens which pose health hazards to plants and animals including man, increase in BOD/COD load which leads to DO depletion, destruction of fish habitats which leads to lowered fish production. On the other hand, crop production contributes plant nutrients (N and P) and pesticides through runoffs, while aquaculture (fishpen and fishcage) contributes plant nutrients and organic wastes directly through excess supplemental feeding. All these nutrients including those from domestic and industrial sources contribute to cultural eutrophication and occurrence of "algal blooms" from time to time leading to accelerated aging of the lake.

At this point, the lake already shows the signs of advanced state of eutrophication (hypertrophic or dystrophic state) characterized by high turbidity and low primary and fish productivity, among others. One of the pollutants that increases the turbidity and siltation of the lake is sediments coming from the watershed caused by deforestation and land conversion (logging, slash and burn farming, urbanization, etc.). Through the years, the uncontrolled run-off of silt and sediments from the tributaries and watershed has led to the shallowing of the lake and increase in its water turbidity. Today the transparency or secchi disc reading of the lake is way below the criteria for Class C waters (the designated classification of the lake). This limits light penetration and algal photosynthesis, and thus, primary productivity of the lake. The deterioration in water quality and destruction of fish habitats also affect wildlife and the aesthetic and recreational values of the lake. Added to this is the impact of fish culture operations which does not only contribute to the pollution of the lake, but also limits the fishing area of open fishermen - leading to the conflict between the fishpen owners and the fishermen.

Another factor that affects the water quality and characteristics of the lake is the MF which diverts floodwaters from the Marikina River into the lake whenever necessary. This floodwater does not only release water pollutants into the lake, but also causes flooding and inundation of the lakeshore areas including municipalities and crop production areas. Thus, it also affects both food production, and the health and general well-being of the people.

By and large, such is the interaction of the drivers of change with the water quality of the lake and their consequent impacts upon the ecological integrity and environmental services of this important body of water. In a nutshell, the culprit is human population and its unbridled exploitation, use and abuse of the lake's resources.

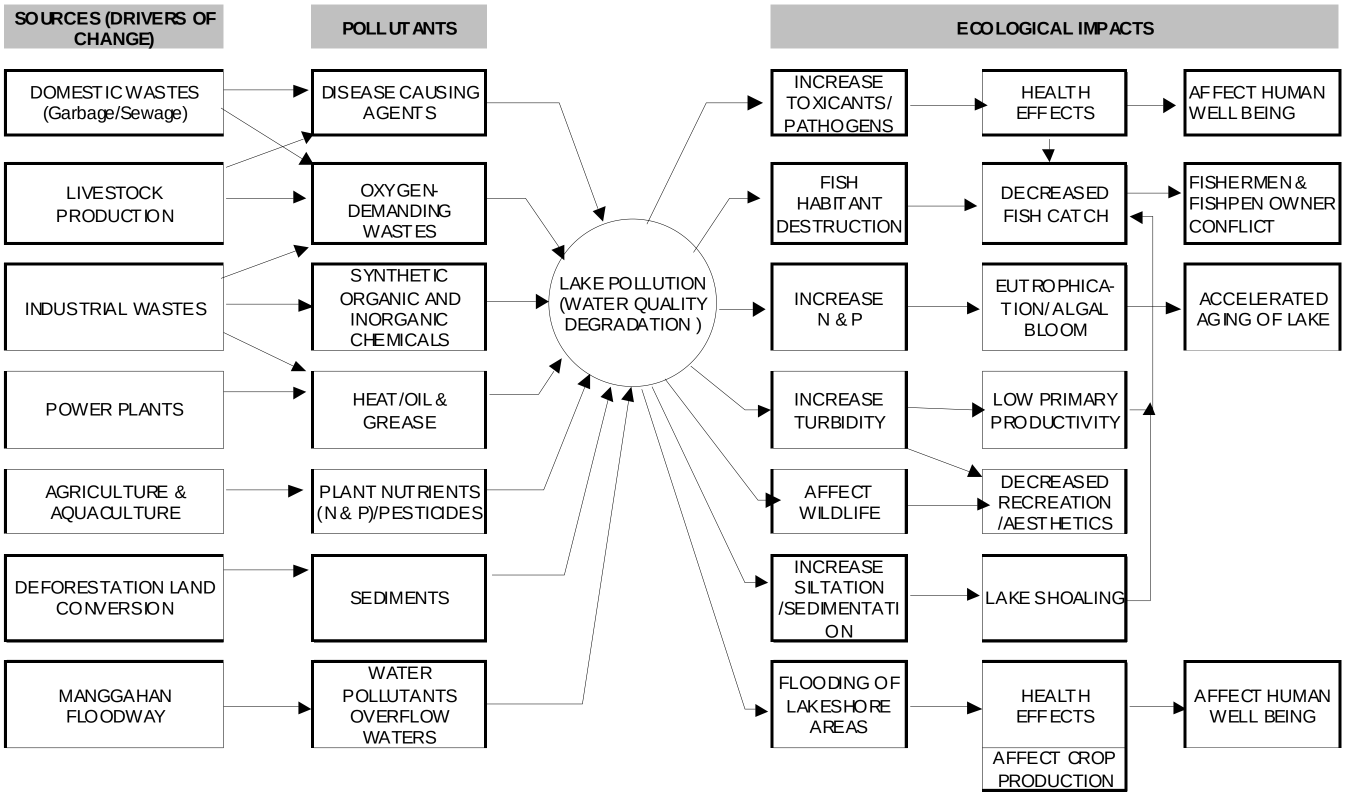

Figure 3.36. Factors (drivers of change) affecting water quality and their impacts on the lake ecosystem.

3.3 Conclusions

The results of this assessment of the water quality of Laguna de Bay lead to the conclusion that ecologically the lake is severely degraded. An earlier view is reiterated: it is an “extremely stressed ecosystem needing restoration” (Tamayo-Zafaralla 2002).

Evidences to the lake’s present state are many. Physically, it is perennially turbid with a brownish-gray tinge. The turbidity-causing materials largely come from the bottom sediments. The latter’s volume is replenished on a sustained basis by 22 major lake tributaries and more than 100 smaller streams.

This body of water is overly enriched with plant nutrients, but the algae are no longer responding as they should gauged from their photosynthetic (NPP) rates and biomass / chl a production. The reasons for this can be sourced to the water medium in which they live.

Data and information concerning the amounts of toxic and hazardous chemicals, especially of heavy metals and agricultural pesticides, indicate inconsistent results. Moreover, these are considered too few. Some give levels that are excessive, others indicate these are nil. The danger here is when managers miss the message or the cue from the inconsistent results. Take the case of the heavy metals, some of which the LLDA claims are sometimes present in some species only. It is best to take the safe side, and stand guard on the possibility of biomagnification to dangerously high levels especially in those species which people commonly consume.

The LLDA data show that coliform counts have decreased over the years. Let us not be quick in interpreting this as improvement in lake water quality. Even bacteria perish under adverse conditions of their habitat. Furthermore, the observed high bacterial populations in many studied tributaries put the lake at the receiving end as though it were a sink for the transported microbes.

Standing guard against the possibility of misreading of the implications of scientific results also concern those parameters that seemingly have no direct impact on human health. The LLDA observes that BOD levels are within acceptable bounds, to the consternation of other investigators. Its being entered among the Living Lakes of the world should NEVER be a reason NOT to treat this lake as though it is at the brink of crisis ecological conditions. On the contrary, to treat it as such strengthens the resolve to effectively fend off realization of a worse-case scenario.

While it is true that statistical procedures do give the impression of non-significance of results, this should not deter lake managers from taking cues about the lake’s true state from its living components. This chapter of the assessment combined with the fish chapter reveals some simple relationships that must be taken as bases for sound management of the lake's resources. Lake water is clearer in some parts, but the fish's growing period to marketable size is no longer four months but 12! Species composition in biological communities have changed and so have fish communities. Algal production is lower, the volume of fish yield is dismal. Algal blooms have become a rare phenomenon, now the tainted taste of fish is lessened. Fishpen and fish cage operators are investing bigger capital to reap their desired gains; the marginalized lakeshore fishermen invest longer hours fishing and get rewarded with a minimal catch.

The Laguna de Bay is an extremely stressed freshwater ecosystem. It is critically in need of restoration. New and drastic measures towards lake restoration are in order.

References

American Public Health Association, American Water Works Association, and Water Pollution Control Federation, 1993: *Standard Methods for the Examination of Water and Wastewater*. APHA. Washington, DC.

Baluyot, E.A. and N.Q. Sacro, 1981: The Physico-Chemical Environment of Laguna de Bay. *The Philippines Biota* ***15,*** 92-105.

Barril, C.R. and E. T. Tumlos, 2002: Water quality trends and trophic state assessment of Laguna de Bay, Philippines. *Aquatic Ecosystem Health & Management J.* **5(2)**, 115-126.

Barril, C.R. and E.T. Tumlos, 1997: Key water quality parameters for sustainable development of Laguna de Bay. Proceedings of a Seminar-Workshop on "Microbial-based Technologies for Pollution Abatement of Laguna de Bay. Feb. 25-27, 1997. Hotel Inter-Continental, Manila.

Barril, C.R., 1990: Water quality assessment and management of Laguna de Bay: concepts, problems and strategies. In: *Laguna Lake Basin, Philippines: Problems and Opportunities*, P. Sly, (ed.), (1993) ERMP Report #7, UPLB DALHOUSIE U, pp. 115 142.

Barril, C.R., 1993: Water quality management of Laguna de Bay, Philippines: ecological and political barriers. Proceedings of Stockholm Water Symposium, 10 14 August, Stockholm, Sweden, pp. 173 180.

Barril, C.R., E.T. Tumlos, R.C. Bato and L.SP. Madamba, 1995: Water quality assessment and management of a hypertrophic lake, Laguna de Bay, Philippines: problems and strategies. Proceedings of the 6th International Conference on the Conservation and Management of Lakes. 23 27 October, Tsukuba, Japan.

Barril, C.R., L.SP. Madamba and E.T. Tumlos, 1994: Water quality of Laguna de Bay: status and trends. *Kimika*, **10**, 25 33.

Basiao, Z.U.**,** 1988. Effects of Initial Stocking Size of Nile tilapia Fingerlings in Cages Without Supplemental Feeding in Laguna Lake. Natural and Applied Science Bulletin 40(3):171-175

BCEOM. 1984. Laguna de Bay Environmental Reassessment Study. Report for Laguna Lake Development Authority. Manila.

Carlson, R.E., 1977" A trophic state index for lakes. *Limnol. Oceanography,* **22**, 361 369.

Carpenter, S.R. and J.F. Kitchell (eds.), 1993: *The Trophic Cascade in Lakes*. Cambridge University Press, London.

Charlton, M. N., 1993: Laguna Lake (Philippines) Water quality trend analysis study. In: *Laguna Lake Basin, Philippines: Problems and Opportunities,* P. Sly, (ed.), (1993) ERMP Report #7, UPLB DALHOUSIE U, pp. 115-142.

Darvin, L.C., 1998: *Biophysicochemical Characterization of Laguna de Bay Waters at Putatan, Muntinlupa City.* Unpublished M.S. Thesis, School of Environmental Science and Management, University of the Philippines Los Baños.

De las Alas, J and A.M. Marzan, 1982: Modelling the Circulation of Laguna de Bay. University of the Philippines, Quezon City, Metro Manila.

Delmendo, M.N., 1966: An evaluation of the fishery resources of Laguna de Bay. *Philippine Journal of Fisheries,* **14(2)**, 213-225, 1976.

Delos Reyes, M., 1995: Eco history of Laguna de Bay. Presented at the Laguna de Bay Workshop. March 6 12. CEC, UPLB. College, Laguna.

Edmondson, W.T., 1970: Phosphorus, nitrogen and algae in Lake Washington after diversion of sewage. *Science,* **169**, 690-691.

Hakanson, L. and M. Jansson, 1983: *Principles of Lakes Sedimentology*. Springer-Verlag, New York.

Henderson Sellers, B. and H. R. Markland, 1989: *Decaying Lakes: The Origin and Control of Cultural Eutrophication*. Chap. 8. John Wiley & Sons, New York.

Jin Xiangcan, Liu Hongliang, Tu Qingying, Zhang Zongshe, and Zhu Kuan. 1990. Eutrophication of Lakes in China. The Fourth International Conference on the Conservation and Management of Lakes "Hangzhou 1990."

Liu Hongliang, 1990: Classification of Trophic Types of Lakes in China. In: *Proceedings of the 4th International Conference on the Conservation and Management of Lakes*, "Hangzhou '90", Liu Honglian, Zhang Yutian & Li Haisheng (eds.), Chinese Research Academy of Enviornmental Sciences (CRAES), ILEC & UNEP publication.

LLDA. 2004. Fish Disease Monitoring Program Report (1994-2000).

LLDA, 1984 1988, 1996-1999: *Water Quality Data on the Laguna de Bay and Tributary Rivers*. Annual Reports. Laguna Lake Development Authority, Pasig City, MM.

LLDA, 1996: *Laguna de Bay Master Plan*. Laguna Lake Development Authority, Pasig City, MM.

LLDA-DENR. Philippine Environmental Quality Report, 1990-1995.

LLDA-NIGS, 1999: *Sedimentation Patterns, Sediment Quality, and Bathymetry of Laguna de Bay: Establishing Environmental Baselines for Lake Management using the Sediment Record*. University of the Philippines, Quezon City, Metro Manila.

LLDA-WHO (Laguna Lake Development Authority – World Health Organization), 1978: *Comprehensive Water Quality Management Program, Laguna de Bay*. Vol. 1, Summary Report. Laguna Lake Development Authority, MetroManila.

Madamba, L.SP., Q.C. Bariring and C.R. Barril, 1998: *Heavy metals in the Laguna de Bay Ecosystem*. Progress reports on Assessment and Control of Toxic and Hazardous Substances in Laguna de Bay. Institute of Chemistry, UPLB. College, Laguna (Unpublished).

Martinez, M. R. and T. W. Eakle, 1977: Fluctuations in algal population densities in fishpens and fishponds, Laguna de Bay, Philippines. *Kalikasan Philipp J. Biol.*, **6(2)**, 123-124.

Mercado, F.L., 1998: *Biophysicochemical Characterization of Laguna de Bay Waters at Putatan, Muntinlupa City*. Unpublished BSc. Thesis, University of the Philippines Los Baños.

National Academy of Sciences, 1969: *Eutrophication: Causes, Consequences, Correctives*. The Academy, Washington, D.C.

Nielsen, B.H., 1981: The Hydraulic Control Structure – A threat to the fishpen industries of Laguna de Bay. *Likas-Yaman,* **3(5),** 9-28.

Nielsen, B.H., 1983: *Limnological Studies in Laguna de Bay, 1908-1983*. Submitted as part of a terminal report to SEAFDEC, Aquaculture Division, April 1993.

Nielsen, B.H., A.E. Santiago and F. Petersen, 1981: The Hydraulic Control Structure: A Threat to the Fishpen Industry in Laguna de Bay. Paper presented at a forum on March 19, 1981, Asian Institute of Tourism, University of the Philippines, Diliman, Quezon City.

Overbeck, J., 1989: Qualitative and Quantitative Assessment of the Problem. In: *Guidelines of Lake Management Vol. 1: Principles of Lake Management*, S.E. Jorgensen and R.A. Vollenweider (eds.). Chap. 4, ILEC and UNEP

Palma, A.L., A.S. Diamante and R.M. Pol, 2002: An assessment of the fishery resources of Laguna de Bay. *Aquatic Ecosystem Health and Management*, **5(2)**, 139-146.

Reyes, M. and R. Martens, 1994: Geoecology of Laguna de Bay, Philippines I. Techno-commercial impact on the trophic level structure of the Laguna de Bay aquatic ecosystem 1968-1980. *Ecological Modelling*, **75/76**, 497-509.

Rodhe, W., 1969: Crystallization of eutrophication concepts in northern Europe. In: *Eutrophication: Causes, Consequences, Correctives*. The Academy, Washington, D.C. pp. 50-64.

Rosana, M.R., V.D. Panisales, A.A. Carandang and J.R. Tolentino, 1997: Primary productivity and production of Tilapia in cages in the South bay area of Laguna de Bay. Paper presented in the Zonal Center for Inland Water, Marine and Aquaculture Seminar-Workshop. Los Baños, Laguna, Philippines, Dec. 1-2.

Santiago, A.E., 1990: Limnological behavior of Laguna de Bay: review and evaluation of ecological status. In: *Laguna Lake Basin, Philippines: Problems and Opportunities*, P. Sly, (ed.), (1993) ERMP Report #7, UPLB DALHOUSIE U, pp. 115 142.

Santos-Borja, A.C. 1994. The control of saltwater intrusion into Laguna de Bay: socio-economic and ecological significance. Lake and Reserv. Manage. 10(2):213-219.

Sawyer, C.N., 1947: Fertilization of lakes by agricultural and urban drainage. *J. N. Engl. Water Works Assoc.*,**61**, 109-127. Cited in Water Quality Criteria 1972.

Sly, P.G., M.N. Charlton and S.R. Joshi, 1993: Results of exploratory coring in Laguna Lake, Philippines. In: *Laguna Lake Basin, Philippines: Problems and Opportunities*. ERMP, Philippines. pp 224-237.

SOGREAH, 1974: *Laguna de Bay Water Resources Development Study.* United Nations Development Programme and Asian Development Bank. Manila.

Tamayo-Zafaralla, M., R.A.V. Santos, R.P. Orozco, and G.P.C. Elegado, 2002: The ecological status of lake Laguna de Bay, Philippines. *Aquatic Ecosystem Health and Management*, **5 (2)**, 127-138.

URS International Inc., 1989: *Laguna Lake Toxic and Hazardous Waste Management Feasibility Study*. Report for Laguna Lake Development Authority, Manila. LLDA

Valerio, A.T., 1990: *Determinants of Fishery Exploitation in Laguna Lake*. Ph.D. Dissertation, U.P. Los Baños, College, Laguna.

Vallejo, A.N. Jr., 1985: Fishes of Laguna de Bay. *Natural and Applied Science Bulletin*, **37**, 4.

Villadolid, D.V., 1933: Some causes of depletion of certain fishery resources of Laguna de Bay. *Natural and Applied Science Bulletin*, **2(3/3)**, 251 256.

Vollenweider, R.A., 1968: Scientific Fundamentals of the Eutrophication of Lakes and Flowing Waters, with Particular Reference to Nitrogen and Phosphorus as Factors in Eutrophication. OCED Rept. DAS/CSI/68.27, Paris, OCED.

Vollenweider, R.A. (ed.), 1969: *A Manual on Methods for Measuring Primary Production in Aquatic Environments*. IBP Handbook 12, Blackwell Sci. Pubs, Oxford, England.

Vollenweider, R.A. (ed.), 1974: *A Manual on Methods for Measuring Primary Productivity in Aquatic Environments*. IBP Handbook 12. Blackwell, Oxford. 255 pp.

Zafaralla, M.T., E.A. Corcolon, and R.A.D. Valmonte, 1990: Phytoplankton Community Dynamics in Relation to Meteorological and Physico-chemical Conditions in Laguna de Bay. *UPLos Baños Journal* **1(9)**, 27-52.

Zafaralla, M.T. and F.A. Mercado, 2005. Trophic state descriptors of water quality in the abstraction area for water treatment in Laguna de Bay, Philippines. *Philipp. Agric. Sci.* (in press).

Zamora, A.F., 1986: Levels of coliform bacteria in Laguna de Bay. Personal communication.

4

Fish

ADELAIDA L. PALMA, ELIADORA C. MERCENE, MILAGROSA R. GOSS

CONTENTS

4.1 Overview of Fisheries in Laguna de Bay

Laguna de Bay is a multi-purpose resource, and fisheries is its most important traditional resource use. Guerrero (1982) has cited its fisheries as one of the richest in the world. However, there is paucity of information regarding the natural fish population of the lake since most of the early studies conducted on the lake fisheries delved on the biology of major species like *Glossogobius giurus* (Manacop and Capco 1953; Felix and San Antonio 1959; Marquez 1960; Juliano 1960; Velasquez 1961; Garcia et al. 1962; Delmendo 1970; Velasquez 1976; and Lopez 1978); *Arius manilensis* (Manacop and Capco 1953; Felix and San Antonio 1959; Delmendo 1979) and *Leiopotherapon plumbeus* (Enriquez 1960; Delmendo 1970).

The existing record on the lake fishery resources varied. Francisco (1959) described the fishery resources of the lake as consisting of 17 species of finfishes, 5 species of native crabs and shrimps, and 6 species of clams and snails. The first in-depth study of the fishes in the lake done by Parson (1960) identified 23 species of fish belonging to 16 families and 19 genera. Davies (n.d.) also mentioned 23 species belonging also to 16 families but only 16 genera with *Glossogobius giurus*, *Leiopotherapon plumbeus*, *Cyprinus carpio*, *Clarias sp.*, *Arius manilensis*, *Ophicephalus striatus*, and *Oreochromis sp*. as the dominant species. Rabanal (1964) listed 24 species comprising the fish fauna of the lake with eight indigenous, four introduced species which have established their population in the lake, and the rest are migratory saltwater species. Twenty years later, Vallejo (1985) reported 25 to 26 species including 5 new species. Mercene (1987) listed 26 fish species of which 9 are indigenous, 5 migratory, and 13 exotic or introduced, but noted the occurrence of only eight indigenous species in 1990.

The indigenous fishes of the lake include Silver perch or ayungin (*Leiopotherapon plumbeus*); White goby or biyang puti (*Glossogobius giurus*); Manila catfish or kanduli (*Arius manilensis*); Manila catfish (*Arius dispar*); Mudfish/ snakehead or dalag (*Chana striata*); Catfish or hito (*Clarias macrocephalus*); Climbing perch or martiniko (*Anabas testudineus*); Goby fry or dulong (*Gobiopterus lacustris*), and Ornate sleeper (*Ophiocara aporos*).

The lake is also endowed with ten species of univalve mollusks or snails and one species of bivalve, the *Corbicula manilensis* or “tulya”. These are economically important feed for the flourishing duck industry around the lake. There are also three crustacean shrimp species: the *Macrobrachium lanceifrons*, *Caridina gracilirostris*, and *Penaeus affinis.*

Fishery activities in the lake consist of open water capture fisheries and aquaculture. Production from capture fisheries comes mainly from the operation of seven important fishing gears (gill net, fish corrals, motorized-push net, push net, fyke net, fish trap, fish pot, long line/manual seine fish shelter, brush shelter, drag seine, and snail dredge); while aquaculture production comes from fishpens and fish cages. The combined fisheries production from open water capture fisheries and aquaculture used to provide more than two third of the freshwater fish requirement of Metro Manila and adjoining provinces (Borja 1993), but present production could only supply 18 percent of the total fish requirement of the basin population.

4.2 Fish Production in Laguna de Bay

4.2.1 Capture Fisheries

4.2.1.1 Fishermen

A socioeconomic survey conducted in 1996 (Palma 1997) showed that there are 3,055 fishermen. The Bureau of Agricultural Statistics (BAS) in 1991 reported a total of 6,833 fishermen operating in the lake, showing 50.4 percent decline in the fishermen population within the five-year period (Figure 4.1). This decreasing trend in the number of fishermen has been observed over the 37 years when the first major fisheries assessment was conducted. From the 13,000 fishermen operating in the lake in the study of Delmendo in 1963, Delos Reyes (1995) noted a 60 percent decline in 1973, two years after the establishment of fishpen in the lake. The number of fishermen operating in the lake again decreased to 8,620 in 1983 primarily due to the decrease in the lake productivity (Pacardo 1993).

Fishery production despite variations among data sources (BFAR, BAS, LLDA) showed decreasing trends. The overall fish production has declined from about 90,000 t in 1980 to about 38,000 t in 1996, with increasing points from 1982-1984, and between 1988-1993. After 1993, a continued downward trend is apparent (Figures 4.6-4.8).

The increase of fish production between 1982-1984 was attributed to increasing number of fishponds during the period. It was argued by BFAR that the drastic decline of fish production from 1961 to 1973 (83,000 t to 20,700 t) has already occurred even before the introduction of fishpen; and the corresponding increase in fish production in the 1980s was made possible by the introduction of fishpen technology.

At the basin scale, the decreasing productivity of the lake and the need to produce fish for consumption of the basin population are two major issues that the resource manager, the LLDA has to contend with. To respond to these issues, research and development aimed at generating approaches and technologies (e.g., fishpen, fish cage, fingerling

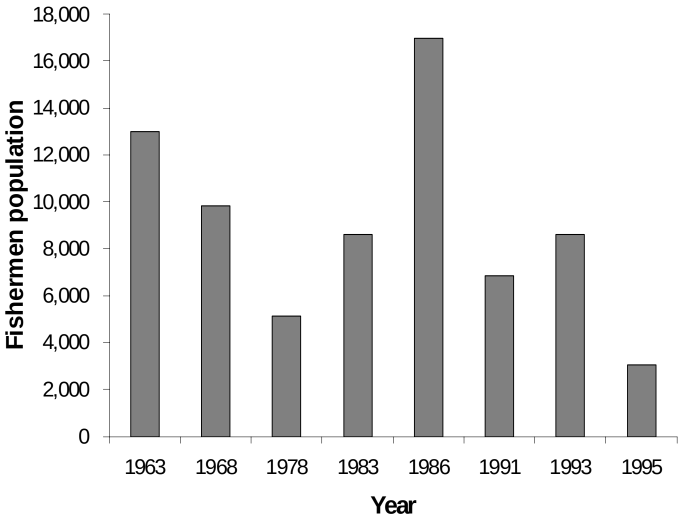

Figure 4.1. Fishermen population in the Laguna Lake Basin, 1963-2000. Sources: Delmendo 1996, Shimura and Delmendo 1969, Mercene 1980 (unpublished report), LLDA Survey 1983, COMELEC list of registered votes, BAS 1991, Pacardo 1993, and Palma 1997.

production). However, among fisherfolks, use of traditional fishing gears remains to be the major means of fishing which render them economically vulnerable to competition with fishpen over space and to the deteriorating water lake quality. This inequity in access to the fishpen technology has been the source of widespread conflict between the small fisherfolks and large fishpen operators in the 1980s. Conflicts subsided when the state through the LLDA instituted and fully implemented the Laguna Lake Zoning in the 1990s precisely to delineate areas for fishpens, navigational lanes and areas for open fishing. This policy commonly known as zoning map or ZOMAP allowed the multiple fishery use of the lake to open fishing and aquaculture.

Full time fishermen comprised 51.4 percent while 48.6 percent are part time fishermen in 1995 (Palma 1997). Fishing is a traditional occupation which most fishermen practiced for 20 years to support a family with an average household size of five. Part time fishermen are also engaged in other economic activities like farming (35 percent), construction work (29.4 percent), and tricycle operation (8.5 percent).

4.2.1.2 Fishing gears

Twenty types of fishing gears operate in Laguna de Bay. Sixty-five percent (65%) are categorized as active (non-stationary), and thirty-five percent (35%) are classified as passive (stationary) gears (Table 4.1).

The highly productive or major gears are gill net, fish corral, motorized push net, fyke net, fish traps, fish pots, and long line (Mercene 1987). However, in the 1996 survey (Palma 1997), the longline was replaced by manual seine/fish shelter as a major fishing gear. A comparison of the efficiency of selected fishing gear is shown in Table 4.2. The motorized push net, motorized drive-in net, and the manual push net were found to be the most efficient gears. Most of the gears are operated throughout the year while others are seasonal in use. Specific type of gear is required for different species and fishing season. The operation of multiple gears, which included the combination of gill net and fish corral; gill net and fish pot; gill net and fyke net; gill net and fish trap; gill net and longline; gill net and spear; gill net, fish corral, and fish pot; gill net, fyke net, and fish pot; and gill net, scissor net, and fish trap was noted in 18.6 percent of the fishermen.

Description of major gears

1. Gill net - a selective gear and its catch depends on its mesh size and the kind of material which is either a nylon multi-filament or monofilament. The catch composition was composed of tilapia (38 percent), Bighead carp (20 percent), Manila catfish (15 percent), Silver perch (10 percent), Common carp (7 percent), Milkfish (7 percent), and White goby (3 percent).

2. Fish corral - stationary gear made of either nets or bamboos. The size and shape of the gear varies depending on the type of species to be caught. The catch composition consisted of tilapia (27 percent), Bighead carp (27 percent), Common carp (13 percent), Silver perch (9 percent), Manila catfish (7 percent), shrimp (5 percent), White goby (5 percent), Milkfish (3 percent), Snakehead (3 percent), and Gouramy (1 percent).

3. Motorized push net (Suro) - a non-selective and stationary gear. It catches all kinds of fishes depending upon the engine type and horsepower used. The catch composition consisted mainly of shrimp (36 percent), goby fry (34 percent), tilapia (7 percent), Silver perch (17 percent), Manila catfish (1 percent), and White goby (5 percent).

4. Fyke net - a passive gear made up of bamboo rings and netting materials with mesh size of 22 mm. The catch composition consisted of shrimp (38 percent), tilapia (35 percent), Silver perch (3 percent), Manila catfish (6 percent), White goby (6 percent), Milkfish (3 percent), and Snakehead (5 percent).

5. Fish trap - a passive gear made up of wooden or metal frame box enclosed with chicken wire. The catch composition consisted mainly of Tilapia (59 percent), Snakehead (11 percent), Gouramy (6 percent), Bighead carp (5 percent), Manila catfish (4 percent), Silver perch (6 percent), Common

Table 4.1. Types of fishing gears operating in Laguna de Bay.

Type of Gear	English Name	Local Name
Active (non-stationary) gear	Cast net	Dala
	Cover pot	Sukob, salakab
	Drag seine	Pukot
	Dredge	Kaladkad, pangahig
	Gill net	Pante
	Harpoon, spear	Salapang, pana
	Lift net	Salambaw
	Manual drive-in net	Dayakos, Biyakos
	Manual push net	Sakag
	Motorized drive-in net	Harikit
	Motorized push net	Suro
	Pole and line	Biwas
	Scissors net	Salap
Passive (stationary) gear	Drift long line	Kitang
	Fish corral	Baklad
	Fish pot	Bubo, saklet
	Fyke net	Skylab
	Manual seine, fish shelter	Sapyaw, Takibo, bumbon
	Fish trap	Roborat, patanga
	Shrimp brush shelter	Gatang-gatang

carp (1 percent), Milkfish (5 percent), White goby (2 percent), and shrimp (1 percent).

6. Fish pot - a baited gear of different shapes and sizes made of woven bamboo splints or net provided with a one-way valve for entrance of fish and a trap door for removing the catch. The catch composition includes shrimp (91 percent), Silver perch (5 percent), White goby (2 percent), and tilapia (2 percent).

7.a. Long line - a passive and selective gear that catches only few fish species compared to other major gear. The catch composition includes Goby (biya) and Manila catfish (kanduli).

7.b. Manual seine/fish shelter - This is a combination of fish shelter consisting of water hyacinth which serves as the fish aggregating device; and the manual seine used to enclose the shelter and catch the fish. The catch composition includes Snakehead (75 percent), tilapia (10 percent), Gouramy (7 percent), Catfish (4 percent), Common carp (2 percent), Manila catfish (1 percent), and shrimp (1 percent).

4.2.1.3 Boats

In 1978, 80 percent of the fishermen owned boats while 12 percent had no boats. The boats are either motorized or non-motorized. The motorized boats range from 1.83 m to 17.37 m (6 ft. to 57 ft.) using from one piston engine of Briggs Stratton or Kohler to six piston of Isuzu or Toyota engines. The 2,863 motorized boats and 1,624 non-motorized boats are listed by municipalities in Table 4.3. Increases in the number of boat owners (99.5 percent) and in the number of motorized boat were noted in 1995 which added to the fishing pressures in the lake.

There was an observed change in the species composition and relative abundance of fishes in the open water (Delmendo 1979; Mercene 1987; Palma 2002). In the early 1960s up to the 1970s, the main bulk of the catch from the lake is composed of Silver perch and White goby, comprising more than 30 percent of the total fish catch. In the 1990s, tilapia comprised the major catch from the lake. In 1995-1996, tilapia and Bighead carp dominated the fish yield while only Manila catfish, Silver perch, and Snakehead, among the indigenous species can be considered part of the major catch. In the year 2000, there has been an alarming increase in the

Table 4.2. Efficiency of selected fishing gear, 1995-1997.

Fishing Gear	Total # of Units	Total # of Fishing (hr yr^{-1})	No. Fishermen Engaged	Fishing Effort (hr)	Annual Production (t)	Catch per Unit Effort (kg hr^{-1})
Gill net	2,033	3,780	1,386	7,684,740	3,803.00	0.50
Fish corral	405	3,832	405	1,551,960	1,638.60	1.06
Fish trap	80	3,780	80	302,400	156.74	0.52
Drift long line	79	2,880	79	227,520	159.38	0.70
Fyke net	77	3,780	77	291,060	251.34	0.86
Fish pot	3,830	3,780	2,611	14,477,400	360.70	0.03
Drag seine	136	2,880	136	391,680	253.79	0.65
Manual seine/Fish shelter	91	3,780	91	343,980	310.07	0.90
Manual push net	10	2,880	10	28,800	90.14	3.13
Lift net	0	0	0	0	0.00	0.00
Manual drive-in net	24	2,880	24	69,120	156.00	2.26
Dredge	0	0	0	0	0.00	0.00
Harpoon/Spear	28	2,880	28	80,640	48.47	0.60
Motorized push net	51	2,880	51	146,880	534.00	3.64
Pole and line	7	3,780	7	26,460	26.18	0.90
Motorized drive-in net	10	2,880	10	28,800	95.81	3.33
Cast net	3	2,880	3	8,640	6.07	0.70
Cover pot	0	0	0	0	0.00	0.00
Scissor net	10	2,880	10	28,800	40.42	1.40
Shrimp brush net	0	0	0	0	0.00	0.00

number of Janitor fish (*Hypostomus plecostomus*) in the catch composition from open waters.

The total fishers' effort exerted in the open water of Laguna de Bay in 1996 was 10,653,220 hours with an average catch per unit effort of 0.25 kg hr^{-1} indicating the marginal condition of the fishermen in the lake. Although the number of fishermen has decreased, fishing pressure remained high due to the operation of non-selective and highly efficient fishing gears.

4.2.1.4 Aquaculture

Laguna de Bay is extensively used for aquaculture in the form of fishpen and fish cages. Fishpen culture was first introduced in Laguna de Bay in 1965 by the Philippine Fisheries Commission with the culture of carps and goby. However, it was the establishment of the 0.38-km^2 fishpen in Looc, Cardona in 1970 by the LLDA for the culture of milkfish that started the fishpen industry. Its development was propelled by the implementation of the Laguna Bay Fishpen Development Program (LBFDP) jointly funded by the Asian Development Bank (ADB) and the Organization of Petroleum Exporting Countries (OPEC) special fund.

The fishpen structure consists of framework for the barrier and pen enclosure. This is made up of bamboo (*Bambusa spinosa)* and anahaw *(Livistonia rotundifolia*) posts driven vertically and reinforced with transverse or longitudinal bracings; net enclosure with sizes ranging from 0.05 km^2 (for individual) and 0.50 km^2 (for corporations); and shapes varying from square, rectangular, or circular (Figure 4.2).

The fishpens are stocked at a density of 30,000 to 60,000 milkfish fingerlings per hectare. The fingerlings are purchased from the nursery growers in nearby provinces, acclimated to freshwater, and transported in live fishing boat (locally called *pituya*). Stocking and harvesting operations were year round. The best time to stock is between March to June which coincides with the high production of natural food in the lake. Partial harvesting (20-30 percent of the stocks) is done in October to November followed by restocking. The culture relies mainly on natural food although in cases where there is a decline in primary productivity, supplemental feed consisting of rice bran, rice bran and fishmeal, and

Table 4.3. Number and type of fishing boats by municipality.

Municipality	Type of Boat	
	Non-Motorized	Motorized
Jalajala	51	177
Pililla	94	114
Tanay	21	32
Baras	3	24
Morong	58	55
Cardona	218	413
Binangonan	274	152
Angono	10	36
Taguig	41	49
Muntinlupa	19	25
Rizal Province	**789**	**1,077**
San Pedro	43	40
Biñan	17	11
Sta. Rosa	40	142
Cabuyao	59	123
Calamba	85	289
Los Baños	48	88
Bay	38	148
Victoria	11	25
Pila	23	24
Sta. Cruz	142	203
Pagsanjan	11	3
Lumban	73	48
Kalayaan	64	44
Paete	12	24
Pakil	73	49
Pangil	70	52
Siniloan	20	110
Mabitac	6	2
Laguna Provice	**835**	**1,425**
Total	**1,624**	**2,502**

breadcrumbs are given. Culture period lasts for 3-4 months with harvestable size ranging from 170 to 200 g fish.

Santiago (1982) cited the abundance of natural food (primary productivity of 0.5-9 g C m^{-3} day^{-1}), the absence of true plankton feeder among the indigenous economic species of the lake, and the then favorable water quality for the success of the early operation of the milkfish fishpen culture. Annual yield from the fishpen during this time ranged from 4-10 t ha^{-1} (400-1,000 t km^{-2}). Milkfish production relies primarily on natural food consisting of phytoplankton, zooplankton, benthos, and filamentous algae. The high profitability of the fishpen culture has led to the unregulated proliferation of the fishpens in all parts of the lake (Figure 4.3) reaching its peak in 1984 with a total area of 510 km^2 (51,000 ha; Figure 4.4). The fishpen area was drastically reduced beginning 1989; and was sustained to the present 100 km^2 within the 150 km^2 fishpen belt (Figure 4.5) designated by the LLDA, with 99.27 km^2 presently occupied by 212 corporations, 28 cooperatives, and 123 individuals (LLDA Fishpen Registration 2003).

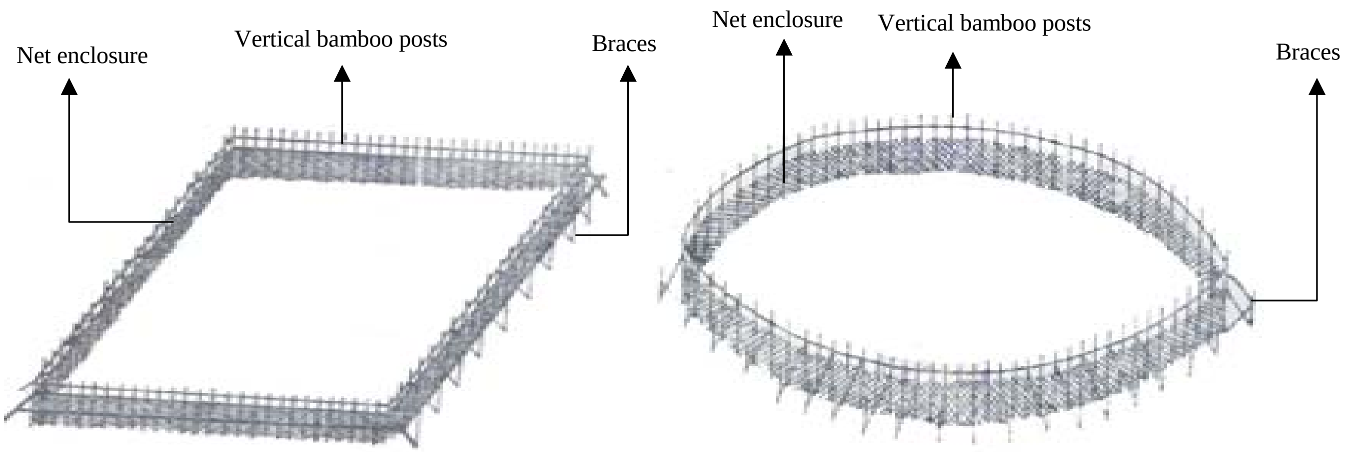

Figure 4.2. Fishpen structure in Laguna Lake.

The decreasing trend in fish production per unit area after the peak of fishpen production in 1984 (Tabbu et al. 1986) led to the launching of the Program UNLAD by the LLDA, BFAR, and SEAFDEC on the polyculture of tilapia, Bighead carp, Silver carp, and Common carp in fishpens. The program diversified the species cultured in fishpens with tilapia and Bighead carp presently being polycultured or intercropped with milkfish.

Cage culture started in 1974 when LLDA experimented on small-scale net cages using Tilapia (*Oreochromis niloticus*). The culture also relies mainly on natural food. The fingerlings used for stocking are produced from breeding cages and small lakeside ponds. There are 1,453 registered tilapia fish cage operators in Laguna de Bay occupying a total area of 7.78 km^2 (LLDA Fish Cage Registration 2002).

Delos Reyes (1992) also noted significant changes in fisheries production in Laguna de Bay within 1961-1973 when production from capture fisheries declined from 83,000 t in 1961 to 20,700 t in 1973 showing a declining trend in capture fisheries even before the introduction of the fishpen. Aquaculture contributed significantly to the overall fish production in 1980.

Open water capture fisheries contributed to the main bulk of production from the lake prior to the establishment of aquaculture. The highest production was 86,282 t recorded in 1963. Fish production from open water fluctuated between 1963 to 1996, but showed an overall declining trend at an annual average rate of 2.93 percent over the 33-year period.

4.3 Fish Production Trends

There is neither sustained monitoring system nor standard procedure for data gathering on the fish production in Laguna de Bay. Discrepancies in production data from different agencies make it difficult to compare fish production from year to year.

An estimate of the total fish production was made by combining the production data for open water capture fisheries from BFAR, the agency conducting the actual fisheries assessment survey, and the production data from aquaculture from LLDA. Generally, the total fish production from Laguna de Bay has declined by 64 percent from 1980 to 1996, although the highest production was noted in 1984 at 115,891 t. The high production coincided with the peak of the fishpen operation (Figure 4.6).

Figure 4.3. Map of Laguna de Bay showing fishpen area, 1984.

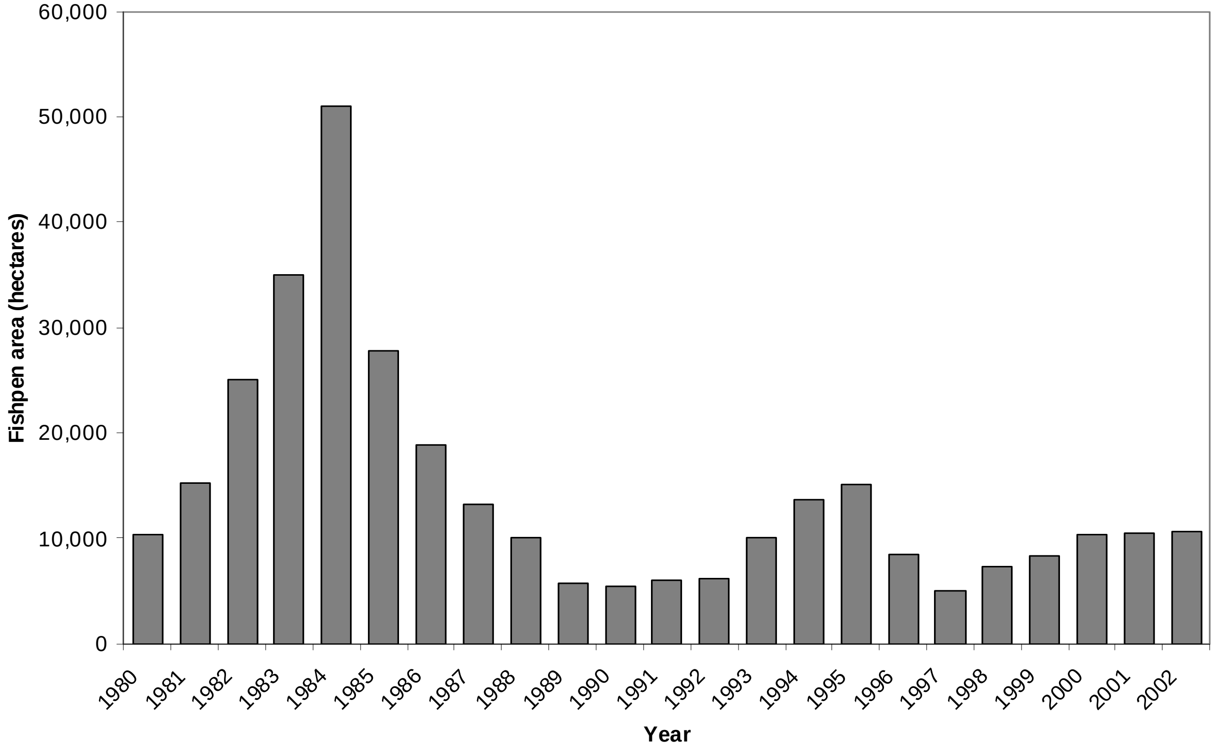

Figure 4.4. Area occupied by fishpen.

The lowest production was 1,691 t noted in 1994 (Figure 4.7).

Similarly, production from aquaculture has fluctuated within the 23-year period (1980-2002). LLDA recorded the highest production of 86,300 t in 1984 during the peak of the fishpen operation and lowest production of 30,800 t in 1988. There was no available aquaculture production data from BAS before 1995. Available production data for aquaculture from BAS from 1995 to 2002 showed similar trend in the corresponding years with LLDA, with the highest production recorded in 2000 at 33,843 t and lowest in 1996 at 19,359 t. Production from fishpen appeared to stabilize at 37,000 t. In the year 2002, fishpen and fish cage culture systems contributed equal share in the aquaculture production (Figure 4.8).

4.4 Species Diversity

A total of 33 species consisting of 14 indigenous, 5 of which are migratory, and 19 exotic or introduced (Table 4.4) have been reported by various authors to have thrived in the lake at different times. Of the 9 non-migratory indigenous species, only 5 are presently caught in significant quantities. These are *Arius manilensis*, *Leiopotherapon plumbeus*, *Glossogobius giurus*, *Chana striata*, and *Gobiopterus lacustris*. *Arius dispar* and *Ophiocara aporos* have

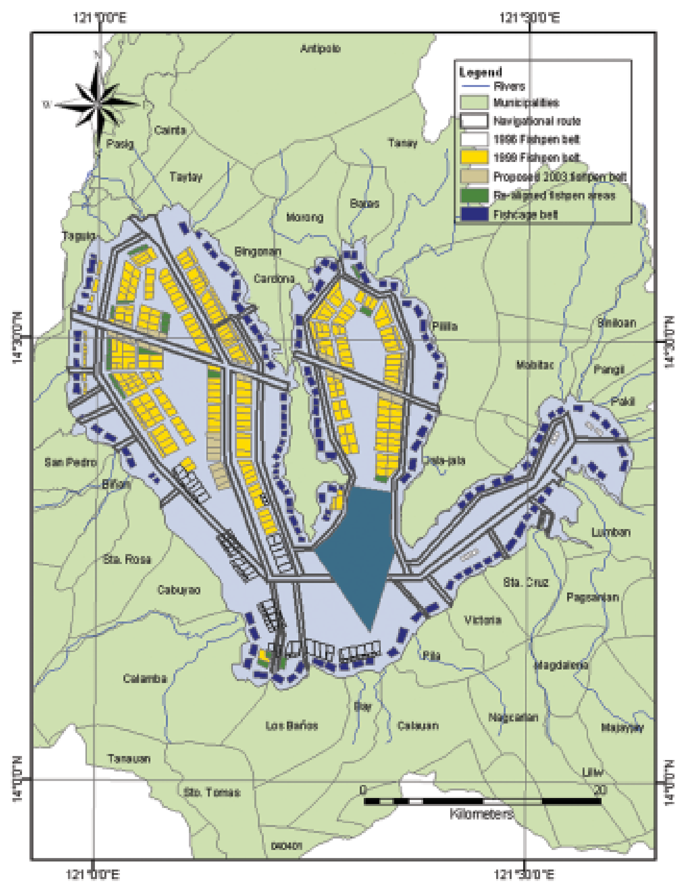

Figure 4.5. Zone map of Laguna Lake Basin designating the fishpen belt.

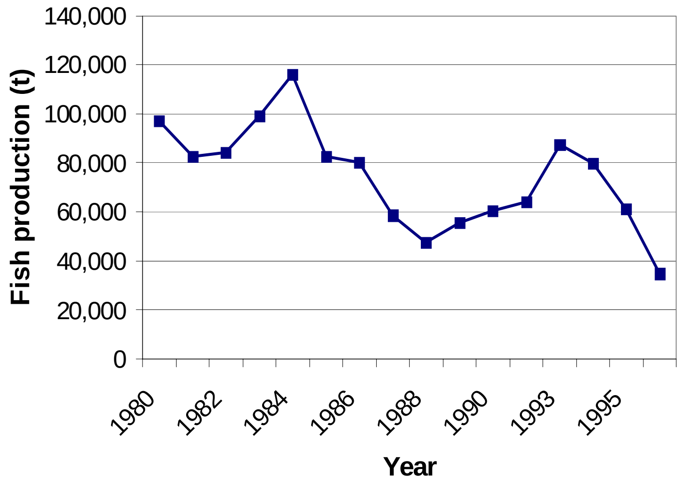

Figure 4.6. Total fish production, 1980-1996.

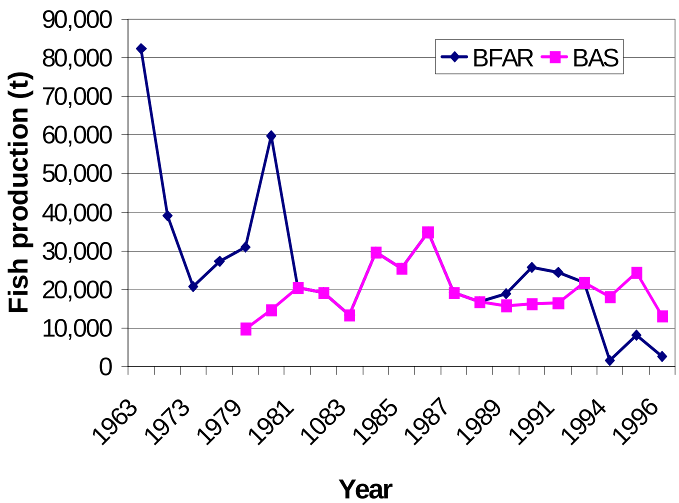

Figure 4.7. Fish production from open waters, 1963-1996.

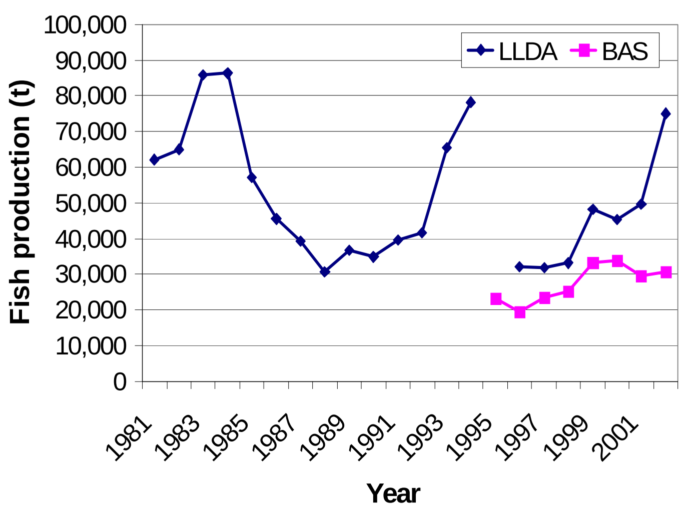

Figure 4.8. Fish production from aquaculture, 1981-2002.

disappeared, and *C. macrocephalus* has been totally replaced by *C. batrachus.*

The changes in species diversity of Laguna Lake is affected by the transitory nature of the migratory species; human intervention through intentional species introduction and stocking for fishery enhancement; and escapement from aquaculture. The migratory species in the lake has disappeared in the 1990 fish catch survey mainly due to the blocking of the migration path by NHCS and the pollution of the Pasig River.

Nineteen exotic species have been introduced in the lake through direct stocking (milkfish, 4 species of tilapia, 4 species of carps, 3 species of Gouramy, and Mosquito fish); or escapement from aquaculture (milkfish, tilapia, 3 species of Catfish, Bighead carp, and Janitor fish). Among the exotic species, *Clarias batrachus*, *Oreochromis sp.*, *Cyprinus carpio*, *Gambusia sp.*, *Hypostomus plecostomus*, *Osphronemus gouramy*, and *Trichogaster pectoralis* were able to establish their population in the lake.

4.5 Drivers of Change in Open Water Capture Fisheries and Aquaculture

4.5.1 Napindan Hydraulic Control Structure

This control structure consists of a gated dam, lock, and navigation facilities across the Napindan channel. The purpose is to stop the backflow of saline and polluted water from the Pasig River, control the lake level for the storage of water needed to ensure an adequate discharge for irrigation and other purposes, and facilitate the reduction of water during floods.

The operation of the hydraulic control structure in 1983 prevented the inflow of seawater which played a vital role in the natural primary productivity of Laguna de Bay. Seawater intrusion can cause clearing effect due to the flocculation of suspended colloidal matters. This results to increase in plankton biomass and higher fish production. Primary productivity of the lake ranged from 2 g C m^{-2} day^{-1} (BRS-SEAFDEC AQD 1986 as cited in Tabbu et al. 1986) to 8 g C m^{-2} day^{-1} (Nielsen 1983) prior to the operation of the hydraulic control structure and dropped to 0.79 g C m^{-2} day^{-1} after its operation. This adversely affected the catch of the sustenance fishermen as shown in the marked decline in the production from open water capture fisheries (Figure 4.6). The high production for aquaculture in 1984 was due to the extensive area occupied by the fishpen, but production per unit area has declined.

Table 4.4. Fishes of Laguna de Bay.

English Name	Common Name	Scientific Name
A. Indigenous		
1. White goby	Biya	*Glossogobius giurus*
2. Silver perch/Theraponid	Ayungin	*Leiopotherapon plumbeus*
3. Snakehead/Murrel/Mudfish	Dalag	*Ophicephalus striatus*
4. Climbing perch	Martiniko/Tinikan	*Anabas testudenius*
5. Ornate sleeper	Papalo	*Ophiocara aporos*
6. Goby fry	Dulong	*Mirogobius lacustris*
7. Catfish	Hito	*Clarias macrocephalus*
8. Manila/Sea Catfish	Kanduli	*Arius manilensis*
9. Manila Catfish	Kanduli	*Arius dispar*
B. Migratory		
1. Mullet	Talilong	*Mugil sp.*
2. Eel	Palos/Igat	*Anguilla sp.*
3. Spadefish	Kitang	*Scatophagus argus*
4. Ten pounder	Bid-bid	*Megalops hawaiensis*
5. Tarpon	Buan-buan	*Megalops cyprinoides*
C. Exotic or Introduced		
1. Milkfish	Bangus	*Chanos chanos*
2. Catfish	Hito	*Clarias batrachus*
3. Catfish	Hito	*Clarias gariepinus*
4. Tilapia	Tilapia	*Oreochromis niloticus*
5. Tilapia	Tilapia	*O. mossambicus*
6. Tilapia	Tilapia	*O. aurea*
7. Tilapia	Tilapia	*Tilapia zilii*
8. Carp	Carpa	*Cyprinus carpio*
9. Gouramy	Goramy	*Osphronemus gouramy*
10. Bighead carp	Mamaling	*Aristichthys nobilis*
11. Indian carp	Rohu	*Labeo rohita*
12. Silver carp	Mamaling	*Hypothalmicthys molitrix*
13. Gold fish		*Carassius auratus*
14. Tawis	Tawis	*Barbonymus gonionotus*
15. Perch	Tilapia	*Tilapia sp.*
16. Spotted gouramy	Pla-salit	*Trichogaster pectoralis*
17. Janitor fish		*Hypostomus plecostomus*
18. Mosquito fish		*Gambusia sp.*
19. River Catfish		*Pangasius sutchi*

The hydraulic control structure also served as a physical barrier in the migration route of marine species entering the lake, hence the reduction of migratory fishes in the lake after its full operation.

4.5.2 Primary Productivity

Primary productivity, often referred to as phytoplankton productivity, is the rate of carbon fixed or potential energy, in the form of organic compounds, stored by the algae in the process of oxygenic photosynthesis. Phytoplankton productivity is the common and important factor being considered in determining the overall status of a given body of water since phytoplankters are found at the base of an energy chain or food web and the basic source of primary food in the aquatic ecosystem. Rabanal et al. (1964) recognized four trophic levels in the lake. The primary producers are mainly phytoplankter and an assortment of macrophytes concentrated along the 220 km shoreline. The Ecopath II model done by delos Reyes (1995) identified three trophic levels in the 1990s for Laguna de Bay with 34 pathways leading from the phytoplankter to the apex predator, the snake. Hence, there seems to be a good correlation between primary production and fish yield in tropical waters (Marten and Polovina 1982).

The most complete data on NPP for Laguna de Bay were taken from 1985 to 1999 (Table 4.5). This was determined by measuring the oxygenic photosynthetic activity. Estimates of algal productivity, through biomass or chlorophyll analyses, were determined from 1820 to 1983 (Table 4.6) which showed that there was higher algal productivity rate during the early period of 1820, 1920, and 1950.

There was a high positive correlation between algal productivity, whether based on NPP (r=0.862) or algal biomass or chlorophyll analysis (r = 0.9), and fish production in the open waters. Fish productions were comparatively higher from 1990 to 1993 which coincided also with the higher rate of algal biomass production in the lake (Figure 4.9).

The highest algal productivity was recorded in 1980 at 153.30 t ha^{-1} yr^{-1} which was associated with the bloom of the BGA, *Microcystis aeruginosa*. However, the occurrence of algal blooms with concomitant fish kills was noted in earlier years than 1980 (1972,1973, 1975, and 1977).

4.5.3 Species Introduction

As shown in Table 3.4, there were 19 species introduced in the lake. Of these species, two catfish species, *Clarias batrachus* and *Hypostomus plecostomus*, which were accidentally introduced to the lake through escapement from aquaculture, have adversely affected the lake fisheries.

At the peak of catfish culture in the 1972, the Thai catfish (*Clarias batrachus*) was introduced in the Philippines from Thailand and was stocked in the fishponds adjoining the lake. The flooding of these ponds has resulted to the escape of Thai catfish to the Laguna de Bay where it was able to breed naturally and establish its population resulting to the

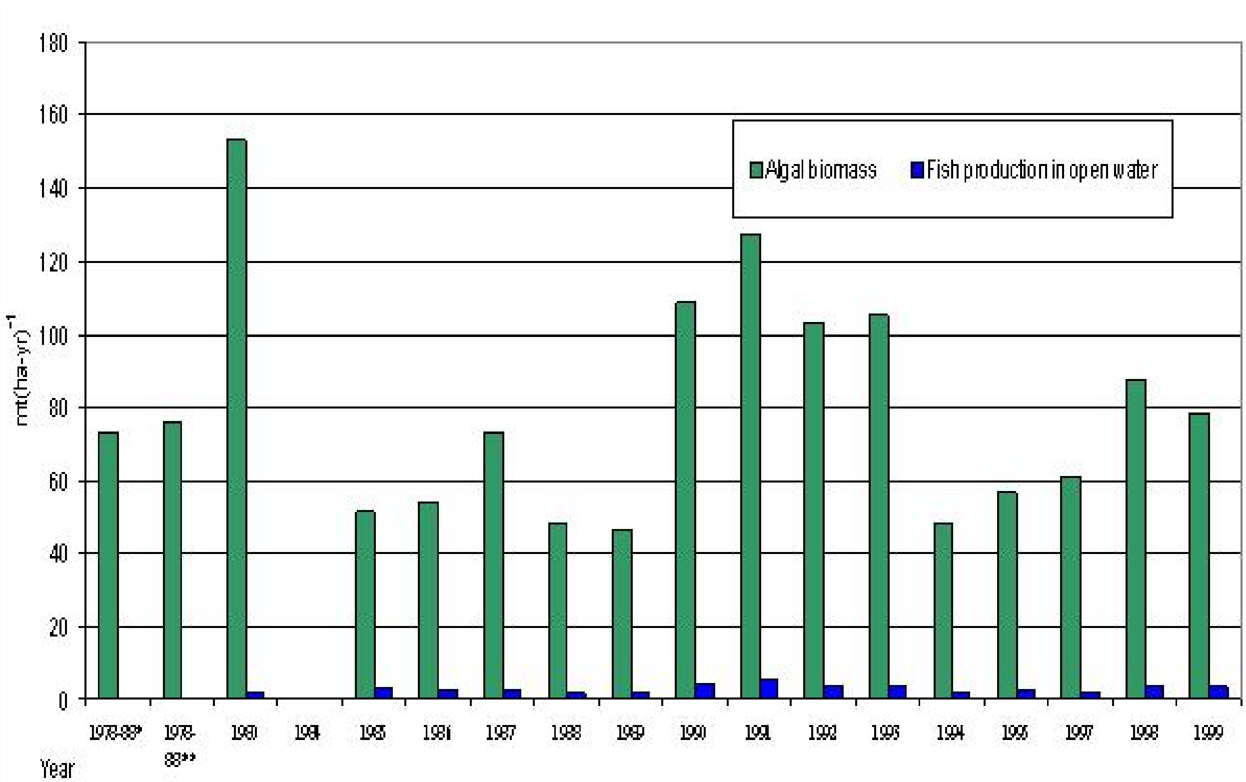

Figure 4.9. Comparison of algal biomass (in t ha^{-1} yr^{-1}) and fish productivity in the open water (t ha^{-1} yr^{-1}) in Laguna de Bay, 1978-1999.

Table 4.5. A comparison of the algal productivity to fish productivity in fishpens, fish cages, and in the open water of Laguna de Bay, Philippines from 1978 to 1999.

		A	B	C	D[3]	E[3]	F[3]
Year	**Bays**	**Net Primary Productivity (NPP)[1] (g C m^{-2} day^{-1})**	**Carbon Production B=Ax3.65 (C ha^{-1} yr^{-1})**	**Algal Biomass Production Rate C=Bx20 (t ha^{-1} yr^{-1})**	**Fish Production in Fishpens (t ha^{-1} yr^{-1})**	**Fish Production in Fish Cages (t ha^{-1} yr^{-1})**	**Fish Production in Open Water (t ha^{-1} yr^{-1})**
1978-88*		1.000	3.650	73.00			
1978-88*		1.040	3.796	75.92			
1980		2.100	7.665	153.30	3.576		2.248
1984						45	
1985	WB[2]	0.576					
	CB	0.626					
	EB	0.925					
	SB						
	LOOC	0.662					
	Ave.	0.700	2.555	51.40	1.856	27.5	3.196
1986	WB	0.770					
	CB	0.640					
	EB	0.670					
	SB						
	LOOC	0.860					
	Ave.	0.740	2.701	54.02	2.169	6.428	2.845
1987	WB	0.900					
	CB	0.980					
	EB	0.880					
	SB						
	LOOC	1.230					
	Ave.	1.000	3.650	73.00	2.143	15.857	2.492
1988	WB	0.600					
	CB	0.690					
	EB	0.670					
	SB						
	LOOC	0.660					
	Ave.	0.660	2.409	48.18	1.940	16	1.936
1989	WB	0.440					
	CB	0.760					
	EB	0.720					
	SB						
	LOOC	0.630					
	Ave.	0.640	2.336	46.72	6.250	10	1.84
1990	WB	1.260					
	CB	1.830					
	EB	0.970					
	SB						
	LOOC	1.900					
	Ave.	1.490	5.438	108.76	6.25	10	4.350

Table 4.5. *Continued...*

Year	Bays	A Net Primary Productivity (NPP)[1] (g C m^{-2} day^{-1})	B Carbon Production B=Ax3.65 (C ha^{-1} yr^{-1})	C Algal Biomass Production Rate C=Bx20 (t ha^{-1} yr^{-1})	D[3] Fish Production in Fishpens (t ha^{-1} yr^{-1})	E[3] Fish Production in Fish Cages (t ha^{-1} yr^{-1})	F[3] Fish Production in Open Water (t ha^{-1} yr^{-1})
1991	WB	1.710					
	CB	1.740					
	EB	1.500					
	SB						
	LOOC	2.050					
	Ave.	1.750	6.387	127.74	6.250	10	5.108
1992	WB	1.810					
	CB	1.410					
	EB	1.040					
	SB						
	LOOC	1.390					
	Ave.	1.410	5.146	102.92	6.25	10	4.115
1993	WB	1.920					
	CB	1.060					
	EB	0.360					
	SB						
	LOOC	2.410					
	Ave.	1.440	5.256	105.12	6.25	10	4.035
1994	WB	0.930					
	CB	0.420					
	EB	0.260					
	SB						
	LOOC	1.020					
	Ave.	0.660	2.409	48.18	5.246	10	1.901
1995	WB	1.350					
	CB	0.660					
	EB	0.580					
	SB						
	LOOC	0.820					
	Ave.	0.780	2.847	56.94	3.5		2.470
1996	WB	0.826					
	CB	0.588					
	EB	0.531					
	SB						
	LOOC	1.190					
	Ave.	0.780	2.847	56.94	3.5	20.04	4.973

Table 4.5. *Continued...*

Year	Bays	A Net Primary Productivity (NPP)[1] (g C m^{-2} day^{-1})	B Carbon Production B=Ax3.65 (C ha^{-1} yr^{-1})	C Algal Biomass Production Rate C=Bx20 (t ha^{-1} yr^{-1})	D[3] Fish Production in Fishpens (t ha^{-1} yr^{-1})	E[3] Fish Production in Fish Cages (t ha^{-1} yr^{-1})	F[3] Fish Production in Open Water (t ha^{-1} yr^{-1})
1997	WB	1.005					
	CB	0.899					
	EB	0.565					
	SB						
	LOOC	0.883					
	Ave.	0.836	3.0514	61.028	3.5	20.008	2.409
1998	WB	1.883					
	CB	1.128					
	EB	0.794					
	SB						
	LOOC	1.002					
	Ave.	1.202	4.386	87.72	3.5	0.005	3.479
1999	WB	1.507					
	CB	1.367					
	EB	0.712					
	SB						
	LOOC	1.526					
	Ave.	1.075	3.922	78.445	3.5	20.007	3.729

[1]NPP (net primary productivity) data from LLDA except 1978-1984; 1978-1984* derived from BCEOM, 1984; 1978-1984** data derived from LLDA-WHO, 1984; 1980 derived from C14 study of Nielsen (1981).
[2]WB=West Bay; CB=Central Bay; EB=East Bay; SB=South Bay; Looc, Cardona, Rizal.
[3] Data from Aida Palma, April 23, 2003.

subsequent disappearance of the native *Clarias macrocephalus* either due to niche displacement or introgression.

Similarly the Janitor fish (*Hypostomus plecostomus*) has accidentally escaped to the lake from the ponds of ornamental fish breeders at the height of the flood in 1995; and its occurrence in the East bay was first reported by Palma in 1996. It has since proliferated and spread out from the East bay to the West bay. The janitor fish has also invaded the Marikina River system where it has destroyed the physical environment due to its boring breeding behavior, and is now a threat to the food web because of its benthic foraging habit. It has become a dominant catch in the fish corral where fishermen reported that 9 out of 10 fishes caught are janitor fish.

The rest of the exotic fishes, particularly carps and tilapia, have contributed significantly to the lake's fish population.

4.5.4 Fishing gear

The use of high-powered motor greatly affected the fish population in the open waters. The motorized push net or "suro" is the most destructive fishing gear. It is made of fine mesh net, non-selective and catches all kinds and sizes of fishes. Records of BFAR in 1997 showed 51 units of push net operating in the West and South bays of the lake. When operated in shallow areas, this gear can destroy breeding and feeding areas of fish. Other non-selective gears are the drag seine or "pukot" and drive-in net or "seket".

Table 4.6. A comparison of the algal productivity based on algal biomass and chlorophyll analysis to fish productivity in fishpens, fish cages, and open water from Laguna de Bay, 1820-1997[1]

Year	A Algal Biomass ($t\ ha^{-1}\ yr^{-1}$)	B P/B Production/ Biomass	C Algal Productivity C=AxB ($t\ ha^{-1}\ yr^{-1}$)	D[4] Fish Production in Fishpens ($t\ ha^{-1}\ yr^{-1}$)	E[4] Fish Production in Fish Cages ($t\ ha^{-1}\ yr^{-1}$)	F[4] Fish Production in Open Water ($t\ ha^{-1}\ yr^{-1}$)
1820	0.9075	268.36	243.54			
1920	0.8250	268.36	243.54			
1950	0.8250	268.36	221.40			0.8095[5]
1968	0.8250	268.36	221.40			599.36[5]
1973	0.8250	268.36	221.40			
1974	0.8250	268.36	221.40			
1974*	1.5122	146.90	405.81			
1975*	0.3996	146.90	58.10			
1976	0.8250	146.90	121.19			
1980	0.6055	146.90	88.95	3.576		2.248
						731.81[5]
1982*	0.4577	146.90	67.24			
1983*	0.4255	146.90	62.83			
1990	0.6688	146.90	98.25	6.25	10	4.350
1996[2]	1.1650	146.90	171.14	3.5	20.04	4.973
1997[3]	1.3490	146.90	198.17	3.5	20.008	2.409

[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 based from delos Reyes 1995.
[2] Based on chlorophyll analysis of LLDA.
[3] Based on chlorophyll analysis from one sampling per bay, data from Martinez-Goss, 1999.
[4] Data from Aida Palma.
[5] Data from delos Reyes 1995.

4.5.5 Fishpen/Cage Structures

The establishment of fishpens and fish cages has both positive and negative impacts on the lake fisheries. Pen and cage cultures have increased production from aquaculture; while the escapement of fishes from the net enclosures provide indirect stocking which has greatly enhanced open water fisheries. The pen structure has also provided sanctuary for the Manila catfish, *Arius manilensis*, which led to the recovery of its natural population.

However, the establishment of these permanent structures in the lake has significantly reduced the area for open water capture fisheries resulting to conflicts between fishpen operators and sustenance fishermen which reached its peak in 1982-1983. Furthermore, the structures also blocked navigation routes and served as trap for silt particles and macrophytes thus hindering water circulation.

4.5.6 Water Quality

Laguna de Bay was naturally eutrophic as early as the 1930s with high biological productivity (delos Reyes 1995). Later anthropogenic activities further added to the lake's nutrient loading, causing further increase in eutrophication

(SOGREAH 1991). Domestic and industrial pollution had contributed to the rapid deterioration of the quality of the lake water. The fishpen and fish cages have also contributed to self-pollution through direct nutrient loading of unassimilated food and metabolic wastes. The high levels of phosphate and nitrogen influenced the occurrence of algal bloom. The bloom forming algae in the lake, consisting of the blue-green algae *Microcystis, Oscillatoria,* and *Anabaena* species, can cause localized oxygen depletion during die-offs resulting to fish kills. Massive fish kills associated with algal blooms have occurred in the lake in 1972, 1973, 1975, and 1977 causing severe losses in the fishpen industry (Martinez and Eakle 1977). Fish kills have become more pronounced since the introduction of fishpens. *Microsystis* bloom can also result to the accumulation of geosmin in fish flesh which render the fish unpalatable for human consumption.

4.5.7 Typhoons

Bad weather conditions and the occurrence of typhoons pose direct threats to aquaculture. The unregulated growth of the fishpen in the early 70s was controlled by the occurrence of strong typhoons in 1976 while 95 percent of the fishpen structures have been leveled by typhoon in 1995. Escapement from pens and cages due to typhoons increases production from capture fisheries.

Strong winds during typhoons also stirred up the lake bottom resulting to the release of nutrients in the water. This eventually led to the occurrence of algal blooms particularly in the area of the South bay (Martinez and Eakle 1977).

References

Alferes, V., 1982: Fish pen design and construction. In: *Report of the Training Course on Small-scale Pen and Cage Culture for Finfish*. 26-31 October 1981, Laguna Philippines and 1-13 November 1981 Hongkong. Workplan Implementation (General) FAO. South China Sea Fisheries Development and Coordinating Programme Manila Philippines, pp. 23-51.

BAS, 1979-1996: *Fishery-Production Statistics for Laguna Lake*. Bureau of Agricultural Statistics. Quezon City, Philippines.

BFAR, 1997: *Philippine Fisheries Profile*. Bureau of Fisheries and Aquatic Resources. Quezon City, Philippines.

BFAR, 1999: *Philippine Fisheries Profile*. Bureau Fisheries and Aquatic Resources. Quezon City, Philippines.

BFAR, 2000: *Philippine Fisheries Profile*. Bureau Fisheries and Aquatic Resources. Quezon City, Philippines.

Borja, A.S., 1993: Water quality management of Laguna de Bay. In: *Laguna Lake Basin, Philippines: Problems and Opportunities*. Environmental and Resource Management Project (ERMP) Philippines. ERMP Report 7. pp. 143-167.

Davies, J., F. Lacanilao and A. Santiago, n.d.: *Laguna de Bay Problem and Option*. Haribon Foundation for the Conservation of Natural Resources.

Darvin, L. C., C. Dela Cruz, and H. L. Bolivar, n.d.: A survey of lakes and reservoirs in Luzon. *Fisheries Research Journal of the Philippines*, Research Notes, 91-99.

Delmendo, M. N., 1977: An evaluation of the fishery resource of Laguna de Bay. *The Philippine Journal of Fisheries*, **14(2)**, 213-225.

FAO, 1982: *Fishpen and Cage Culture Development Project in Laguna de Bay*. South China Sea Fisheries Development and Coordinating Programme. Manila, Philippines.

Felix, S., 1982: Selection of site for fish pen farming. In: *Report of the Training Course in Small-scale Pen and Cage Culture for Finfish*. 26-31 October 1981, Laguna, Philippines.

Felix, S., 1973: *Bangus Culture in Fish Pens*. Bureau of Fisheries Manila, Philippines. May 1973.

Fortes, R. D., 1993: Management Option for Sustainable Development of Laguna de Bay. In: *Proceedings of the National Symposium-Workshop on Lake Fisheries Management*, R.B. Edra, E.V. Manalili and R.D. Guerrero III (eds.). PCAMRD Los Baños Laguna Book Series No. 19.

Goss, M. R., 1999: *Estimation of Fish Biomass in Laguna de Bay Based on Primary Productivity*. Environmental and Natural Resource Accounting Program (Phase III). NCSO, Makati, City.

Herre, A.W., 1953: *Checklist of Philippine Fishes*. US Fish and Wildlife Service Research Report 20.

J. R. S., 1970: Age and Size at Sexual Maturity of White Goby (*Glossogobius giurus*). A Common Species of Fish of Laguna de Bay, with notes on its Food Habits. *Philippine Journal of Fisheries*, **8**, 71-100.

LLDA, 1999: *Fish pen/Fish cage, Fish Production in Laguna de Bay*. Laguna Lake Development Authority Laguna, Philippines.

LLDA, 1996: *The Laguna de Bay Master Plan (Final Report)*. Laguna Lake Development Authority Laguna, Philippines.

LLDA, 2003: Raw data of Fish cage and Fish pen operators in Laguna Lake.

Mane, A. 1981: Management and Maintenance of Fish pens in Laguna de Bay. In: *Report of the Training Course of Small-scale Pen and Cage Culture for Finfish*. 26-31 October 1981 Laguna, Philippines. South China Sea Fisheries Development and Coordinating Programme Manila, Philippines, p. 5-63

Martinez, M. R. and T. W. Eakle, 1977: Fluctuations in algal population densities in fishpens and fishponds, Laguna de Bay, Philippines. *Kalikasan Philipp J. Biol.*, **6(2)**, 123-124.

Mercene, E.C., 1989: A survey of Laguna de Bay open water fishery. *Fisheries Journal of the Philippines*, **12(1 and 2)**, 17-28.

Mercene E. C., 1990: Studies Conducted on Selected Endemic Fish in Laguna de Bay. In: *Development of Low-cost Proven Feed Update on Philippine Endemic Fishes*. TLRC, Book Series No. 6, pp. 35-41.

Mercene, E.C., 1983: Assessment of the Capture Fisheries and Biology of some financially important species. In: *Summary proceedings of Seminar/workshop on the State Development of Laguna de Bay Area*. PCARRD, Los Baños, Laguna, p. 7.

Mercene, E.C., 1987: A survey of Laguna de Bay open water fishery. *Fisheries Research Journal of the Philippines*, **12(1-2)**, 17-27.

Mercene, E.C. and M.P. Nasino, 1991: Survey of shrimp catch distribution by fishing gear in Laguna de Bay. *The Philippine Agriculturist*, **72(2)**, 265-274.

Mercene, E.C. and M.P. Nasino, 1994: An assessment of the Goby fishing in Laguna de Bay. *Philippine Asia Life Sciences*, **3(1)**, 25-34.

Mercene, E.C. and L.P Cabrera, 1991: Contribution to the biology of Ayungin, *Therapon plumbeus* (Kner). *Philippine Journal of Fisheries*, **22**, 79-85.

Mercene, E.C., 1997: Freshwater fishes of the Philippines. In: *Proceedings of the First National Symposium-Workshop on Aquatic Biology R & D*, Book Series No. 20/1997, pp. 81-106.

Montemayor, Jr., 1985: Updated information, data on limnological characteristics of the Philippine Lakes. *Fisheries Newsletter*, **13**, 59-77.

Marquez, J., 1970: Age and size at sexual maturity of White Goby (*Glossogobius Giurus*), a common species of fish on Laguna de Bay, with notes on its habits. *The Philippine Journal of Fisheries*, **8**, 71-199.

NSCB, March 1998: A case study on the compilation of natural resource accounts in the Philippines In: *Accounting for Philippine Freshwater Fishing Resource*. Environmental and Natural Resource Accounting Sub-programme Integrated Environmental Management for Sustainable Development Program.

Palma, A.L., 1997: The socioeconomic aspects of capture fisheries in Laguna de Bay with emphasis on the operation of major fishing gears. *Journal of Agricultural Economics and Development*, **25(1-2)**, 117-129.

Palma, A.L., A.S. Diamante and R.M. Pol, 2002: An assessment of fishery resources of Laguna de Bay. *Aquatic Ecosystem Health and Management*, **5**, 139-146.

PCARRD, 1980: *State of the Art Lakes and Reservoirs Research*. Fisheries Research Division, Philippine Council for Agriculture and Resource Research. Fisheries Series No. 1/1981.

Pullin, R., 1981: Fish pen of Laguna de Bay, Philippine. *ICLARM Newsletter*, pp. 11-13.

Ronquillo, I. A. and P. Caces-Borja. 1960: Notes on the infestation of *Chanos chanos* by a parasitic isopod. *Philippine Journal of Fisheries*, **8(January 1960-December 1970)**, 113-115.

Santiago, A., 1991: *Turbidity and Sea Water Intrusion on Laguna de Bay*. SEAFDEC, Binangonan, Rizal.

Santiago, A., 1982: Lake water quality and productivity assessment. In: *Report of the Training Course on Small-scale Pen and Cage Culture for Fish*.

SAEP, 2002: Carp displacing Milkfish in Laguna fish pens. *SAEP News Letter Special*. Quezon City, Manila, Philippines.

Vallejo, A., 1985: Fishes of Laguna de Bay. *Natural and Applied Science Bulletin*, **37(4)**, 285-321.

Tabbu, M. et al., 1986: Polyculture of Bighead, Common carp and Nile Tilapia in Cages in Laguna Lake. *Fisheries Research Journal of the Phiippinesl*. **XI (1 & 2)**. 5-12.

5

Rice

BENITO S. VERGARA, MA. VICTORIA O. ESPALDON,
MERLYN CARMELITA N. RIVERA, DOLORA N. NEPOMUCENO

Contributing Authors: *Alice E. Bongco, Grace L. Chua, Oliver B. Barbosa*

CONTENTS

5.1 Description of the Basin and Rice Production Area

Agricultural areas of LLB extend upstream towards the uplands of the watershed. The northern side is dominated by the Marikina Watershed with patches of hilly shrublands and denuded forest and some cultivated to fruits and trees and/or used for pastures. The western side of the lake towards Metro Manila is urbanized with very minimal agricultural activities.

The provinces of Laguna (1,758.46 km^2) and Rizal (1,308.92 km^2) comprise the main basin area of 3,067.38 km^2 or 80 percent of the total basin. The combined farm area in these provinces is 1,224.64 km^2 with Laguna having the bigger share at 859.98 km^2, representing 70 percent of the total and Rizal with 364.66 km^2 of farmlands representing 30 percent.

Rice is the major agricultural product of LLB covering 380 km^2 of land. It is cultivated on the mountain slopes as "upland rice". This type of cultivation occupies small spotty areas and the harvest is mainly for home consumption. Rice is also cultivated along the river tributaries and these are mostly irrigated. These irrigated paddies found at a higher topographic level along the lakeshore area are concentrated in Laguna and some areas in Rizal. The source of water is the river. These ricefields are not affected by the water level of the lake.

The shoreline of LLB is 220 km. Ricefields on the lakeshore particularly on the southern and eastern sides of Laguna de Bay consist of 136.37 km^2, of which 68.75 km^2 or 50 percent is in the province of Laguna. The shoreland areas are the major areas affected by the water level of the lake. The area of the ricefields varies from year to year depending on the pattern of water withdrawal and the water level. These areas are also irrigated usually by damming the small rivers flowing into the lake.

This discussion on rice is centered on the ricefields along the lakeshore affected by the water level of the lake, particularly in the Laguna province.

5.2 Rice Production in the Lakeshore Area

Rice production areas in the basin source water for irrigation either from the ground, springs, or tributaries of the lake. However, some areas are rainfed, and most of the lakeshore areas directly source water from the lake.

The lakeshore land is located in different areas along the Laguna de Bay. The shoreland area is estimated to be around 139 km^2 which are cultivated during the summer season when lake water level decrease from the regular 12.5 m elevation in the rainy season to 10.5 m during the dry months of the year. Sixty-six percent or a total of 92 km^2 is found in Laguna, 26 percent in Rizal (36.7 km^2), and 8 percent in Metro Manila (11.3 km^2). Of the total lakeshore lands, 41 percent (estimated to be around 57 km^2) is classified as ricelands, 49 percent (69 km^2) is marsh and mudflats, and about 10 percent (13 km^2) is built up area.

Shoreland provides vital economic and social benefits to the people living around the lake. It serves as buffer zone and habitat for ecologically and economically important aquatic species. As a buffer zone, it has environmental significance since it contributes to the present state of the lake environment. More significantly for small farmers, it is utilized for short-term or seasonal agricultural crops, primarily rice.

5.2.1 Rice Production

The ricefields on the lakeshore are almost contiguous to each other stretching from the East bay to Central (South) bay and the West bay. The larger rice farms are found in the province of Laguna and Rizal. In 1997 the annual rice production of irrigated rice in Laguna is 117,017 t, with an average yield of 4.26 t ha^{-1} (426 t km^{-2}) in the dry season and 3.94 t ha^{-1} (394 t km^{-2}) during the wet season. The area harvested to rice is 283.86 km^2, larger in the dry than the wet season planting. Most of the harvests are consumed within the province, and Laguna is actually deficit in rice supply (110,234 t deficit in 1997).

The ricefields on the shoreland are submerged when the water level rises from 10.5 to 12.5 m (Bongco et al. 2003). Rice, however, can be cultivated in flooded conditions with water up to 20 cm from the soil level. Rice production in this area is therefore variable since the land planted every year is variable.

Traditional farmers have tilled the lands without the formal land titles. Each farmer, however, has established ownership by village consensus. There was no formal cadastral survey undertaken, but each farming household knows who owns the rice paddies next to theirs. This system of informal ownership has been in effect from as far as the people can remember. This has created conflict of use and management with the state regulatory mechanism. The recent efforts by the LLDA to manage the lake involves physically delineating lake boundary. Republic Act (RA) 4850 noted that drawdown areas or the shoreland between 10.5-12.5 masl is part of the lake and hence part of the public domain, and its use should be regulated by the LLDA. This has been strengthened by the DAO 27-95 that places a moratorium on the acceptance and processing of all public land applications covering areas immediately adjacent to the lake. This is a current bone of contention between the local community and the LLDA.

5.2.2 Rice Culture (Irrigated and Lakeshore Areas)

Rice was generally planted once a year before the introduction of the modern rice varieties. Present areas usually have two rice crops per year. January to June is considered the dry season and July to December the wet season.

Rice is transplanted in puddled soil using a modified *dapog* system. The system uses a wet bed where the pre-germinated seeds are grown for 14 or more days as opposed to the 11 days in *dapog* system. The seedlings are not uprooted but scraped from the top layer of the soil using a *bolo* (long knife).

Dry season transplanting of seedlings starts in January at the upper level of the shoreland and moves toward the lake as the water recedes. Transplanting may last up to April on the water edge while harvesting starts in April and ends in June or July. By then the lake water starts to rise. The upper lakeshore is transplanted by July while the lower part of the lakeshore is usually not transplanted as the water level becomes too deep for the survival of the rice plant.

Many tropical areas near the lake or land depressions where water accumulate during the rainy season have similar pattern of rice transplanting which is entirely dependent on the water pattern.

Rice is transplanted in a puddled soil with water drained before transplanting to prevent the golden snails from eating the seedlings. Older seedlings are used also for this reason, hence the modified seedbed.

Farmers use straight row planting. Transplanting of the seedlings needs several people. Hand or manual weeding is the common practice. Different arrangements for transplanting of seedlings, weeding, and harvesting of the grains are made by the farmers with farm groups from the community.

Fertilizer is generally applied only if the crop is well established. The rate of fertilizer application in the irrigated ricefields of Laguna is 4.68 bags ha^{-1} (50-kg bags; 468 bags km^{-2}) for the dry season and 4.42 bags ha^{-1} (442 bags km^{-2}) for the wet season. The 1997 data showed that the majority of the fertilizer applied during the dry season is urea (3.07 bags ha^{-1} or 307 bags km^{-2}) followed by complete fertilizer (0.90 bags ha^{-1} or 90 bags km^{-2}). Trends in level of application of urea fertilizer have remained the same from 1988 to 1997 (PPDO 1998).

Pesticides are also used although integrated pest management is now being practiced. Leaf roller and stem borer are common but the golden apple snail is the most serious pest. During dry season cropping, the greatest damage to the rice crop is brought about by the golden snails. During the rainy season cropping, flooding at the transplanting-tillering and harvesting stages exact damage to the crop. The lost from rats can be considerable, but large scale planting at the same time can diminish the damage from rats. Poison baits are the popular method of controlling the rats.

At transplanting and young stage of the plant, the drifting, floating water lilies can over run the ricefields. Farmers normally install a fence around the ricefields fronting the water line using twigs. Such fencing, however, is not effective when the winds are strong.

Irrigation using shallow pumps to lift the water from the canal is practiced but damming the small rivers flowing into the lake is the usual practice.

Threshing is done on the ricefield while the paved streets and highways are often used for drying.

5.2.3 Variety

Modern high yielding varieties were used by 1992. Currently the popular rice varieties are IR74 and IR52 for both cropping seasons. Traditional rice varieties were no longer planted in this area by 1997.

5.2.4 Historical Trends in Rice Production

Rice is the only crop that can be planted in submerged conditions, hence this area has been planted to rice for centuries. The assured water supply, food supply, and security in these areas resulted in the rapid development of the towns associated with the rice land areas such as Biñan, Sta. Rosa, and Bay of the Laguna province. They have been established during the Spanish occupation more than 400 years ago. Most of the ricefields along the shore of Laguna de Bay are in the province of Laguna.

In 1970 the harvested area for rice in Laguna was around 540 km^2. This area decreased below 450 km^2 in 1983 and stayed at 260-380 km^2 in 1992. Rice production decreased parallel to the decrease in area. In 2002, the area was around 263.19 km^2, the lowest area recorded since 1970. The decrease is most likely the result of real estate development and industrial park establishment. Fishponds have also been established in many ricefields.

The area used during the dry crop season (January to June) is higher than the wet season from 1983 to 1997. Grain yields per hectare were also higher during the dry season compared to the wet season as reported in many parts of the Philippines and other tropical areas. By 1992 almost all the rice varieties used were modern varieties. In 1997 no plantings of traditional varieties were reported in Laguna.

5.2.5 Irrigation Water for Agriculture

Within the Laguna Lake watershed, an estimated 12,361 farmers benefit from the irrigation systems by tilling a total service area of 206.19 km^2 (Rivera et al. 2001).

As of 1998, there are 12 national irrigation systems (NIS) which are divided into three irrigation system offices (ISOs), namely: Laguna Friar Lands Irrigation System (LFLIS) which manages four gravity and one pump irrigation systems irrigating a total of 28.87 km^2 in the first and second congressional districts, Sta. Maria-Mayor River Irrigation System (SMMRIS) which manages two gravity pump irrigation systems irrigating a total of 13.17 km^2 in the fourth congressional district, and Laguna Irrigation System Office (LISO) which manages five NIS irrigating a total of 49.60 km^2 in the third and fourth congressional districts.

The total land area being irrigated by NIS is 91.64 km^2 with 6,683 farmer-beneficiaries. Other provinces like Rizal, Batangas, Cavite, and Quezon have no NIS.

There are 153 communal irrigators' associations within the Laguna Lake watershed irrigating a total area of 100.15 km^2 with 5,569 farmer-beneficiaries. Laguna has the highest number with 85 communal irrigation systems (CIS) followed by Rizal with 48 CIS.

There are 109 private irrigators within the watershed. Rizal has the highest number at 70 followed by Laguna at 30 (Appendix A16).

Apparently, Batangas, Cavite, and Quezon have four irrigators' associations – be it communal or private – because only four towns each in Batangas and Cavite and one in Quezon are considered part of the Laguna Lake watershed.

5.2.6 Alternative Livelihood

Land along the lakeshore is planted mainly to rice. Rice is the main livelihood of the farmers along the lakeshore. The rice crop needs high labor during land preparation, transplanting, occasional weeding, and harvesting. Most rice crops take around 110 to 130 days. While the rice crop is growing, the rice farmers usually seek alternative livelihood. In the South bay area, cottage industries such as woodcarving and papier mache are common alternatives. Some farmers usually have farms on the mountainside and these are cultivated with cash crops or fruit trees. Duck raising is another alternative to rice farming.

In the East bay area where larger towns have grown, driving a tricycle, carpentry, and fishing are some of the alternative livelihood.

As early as 1975, census already showed that the population in the basin depended on various sources of livelihood to include rice farming, fishery, farming, livestock and duck raising, manufacturing, and employment in private and government institutions. The dual nature of the basin, that of being located at the heart of Southern Tagalog and the hub of economic activities, offers its communities both the opportunities of employment in the industrial as well as in the agricultural sectors. In 1991, varied crops were observed to be grown and livestock raised as sources of livelihood of the population (Table 5.1).

5.3 Drivers of Change/Factors Affecting Rice Yields

Rice production system is affected by a multitude of factors. This section examines the factors influencing the rice production in the lakeshore areas as shown in Figure 4.1.

5.3.1 Water Level of the Lake

Rice production in the lakeshore is primarily affected by various factors such as crop yield, area for cropping, nutrient and pesticide management, occurrence of typhoons, and timing of planting. Crop yield is affected by lakewater pollution as irrigation water mainly comes from the lake. Area for cropping however is a serious concern as more and more lakeshore lands are converted to uses other than rice growing. For example, drawdown areas are cultivated with vegetables and other cash crops, like cutflowers. Other areas are also converted to settlement or resettlement areas, or even illegal dumpsites. Occasional flooding which consequently affect water level is also decreasing the area for rice. Lake level modification which is expected to occur with the construction of infrastructures along the lakeshore is estimated to adversely affect the areas traditionally cultivated with rice. This is especially in the areas in Laguna where farmers fear that the construction of viaduct will cause the lake water to rise above the normal level. While there is an expected decline of rice production along the lakeshores, the development of industries around the area and the growing population increase the demand for rice. To meet this demand and to secure availability of rice for domestic consumption, there is a need to find ways to increase crop yield through efficient nutrient and pest management and

Table 5.1. Registered farmers, cultivated lakeshore farming areas, and other production data, 1991 (NCSO 1992).

Item	Palay	Corn	Vegetable	Other Crops
Registered farmers	863	36	155	9
Laguna	588	21	107	4
Rizal	247	13	14	4
Muntinlupa	0	0	30	0
Taguig	28	2	4	1
Lakeshore farming area (m^2)	39,443.62	38,569.14	39,176.77	21,375
Laguna	11,734.33	9,100.25	10,303.81	12,725
Rizal	8,245	11,968.89	7,495.83	33,366.67
Muntinlupa	0	0	6,877.13	0
Taguig	19,464.29	17,500	14,500.00	20.000.00
Average no. of cropping per year	1.32	1.29	1.99	2.57
Laguna	1.35	1.40	1.42	2.25
Rizal	1.3	1.08	2.08	4.00
Muntinlupa	0	0	4.68	0
Taguig	1.07	1.50	1.00	1.00
Animal production (cavan)	82.28	74.11	1,450.28	1,783.75
Laguna	91.42	59.42	1,846.94	3,050
Rizal	53.05	85.15	178.71	517.50
Muntinlupa	0	0	55.17	0
Taguig	151.67	112.50	2,500.00	0
Average expenses per cropping (PhP)	5,012.26	785.83	2,315.08	9,640
Laguna	5,448.84	1,235.00	3,085.78	12,750
Rizal	3,674.18	336.67	922.50	1,350
Muntinlupa	0	0	700.62	0
Taguig	7,058.54	0	1,750	20,000
Net income per cropping per farmer (PhP)	7,500.76	1,243.33	2,849.69	17,740
Laguna	7,378.54	1,756.67	3,776.10	8,000
Rizal	6,934.03	730.00	809.58	1,350
Muntinlupa	0	0	796.67	0
Taguig	13,260.65	0	5,750.00	70,000

use of improved variety of rice at the farm level, as well as to find alternative livelihood for the traditional farming communities.

The most critical factor that determines rice production in lakeshore lands is the water level of the lake. Laguna Lake is defined as that "area covered by the lake water when it is at the average annual maximum lake level elevation of 12.50 m, as referred to a datum 10.00 m below mean lower low water (MLLW)". Lands located at and below such elevation are public lands that form part of the bed of said lake. Being a flat land, a rise of 200 cm in the average water level of 10.5 m can submerge most of the 136.37 km^2 of shoreland which is mostly riceland. The average lake level in the dry season is 10.5 m (msl) and 12.5 m in the wet season. Records of extreme water levels based on different studies conducted in the lake are as follows (PEA 1991):

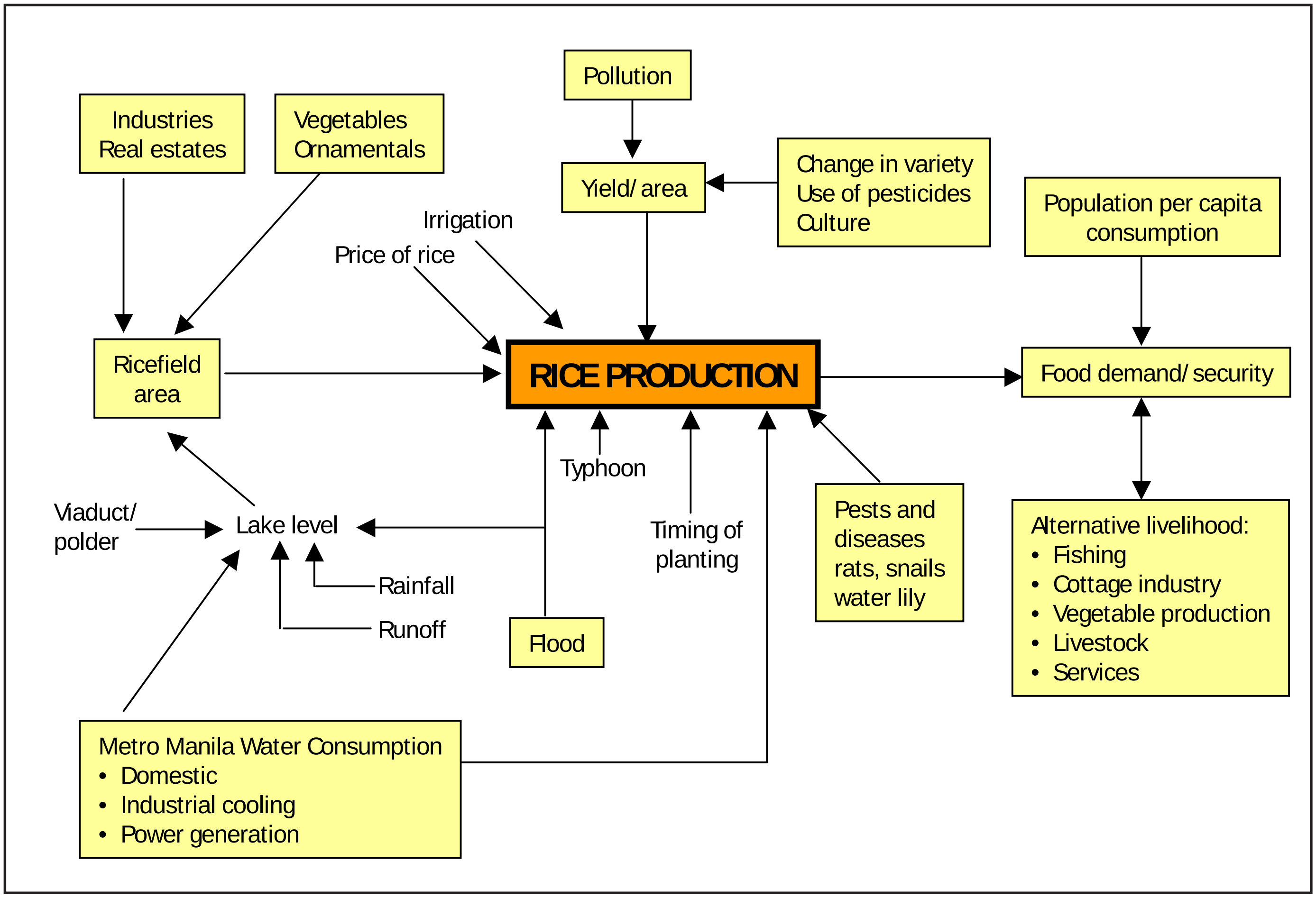

Figure 5.1. Factors influencing the rice production in the lakeshore areas.

Year	Water level (m elevation)
1914	14.62
1943	14.35
1972	14.03
1978	13.58
1986	13.34

Historical water levels are being gathered at different monitoring sites which represent different parts of the lake, namely the Angono station located in West bay, Looc station in Central bay, Los Baños station in South bay, and the Kalayaan station in the East bay. From the digitized contours 10.5 m and 12.5 m elevation from 1:10,000 National Mapping and Resource Information Authority (NAMRIA) municipal maps, other contours were delineated, like the 15 m contour line as shown in Figure 5.2. Based on this projection, the lakeshore lands exposed to cultivation vary depending on the lake level. This was the basis for estimating the average shoreland areas of about 139 km^2 as shown below.

Water Lakeshore Elevation	Area (m^2)	Perimeter (m)	Hectares	Estimated Areas (km^2)
15	1,196,932,259.33	318,416.25	119,693.23	
10.5	870,820,043.78	279,005.80	87,028.00	
12.5	1,009,877,533.36	335,623.40	100,987.75	139

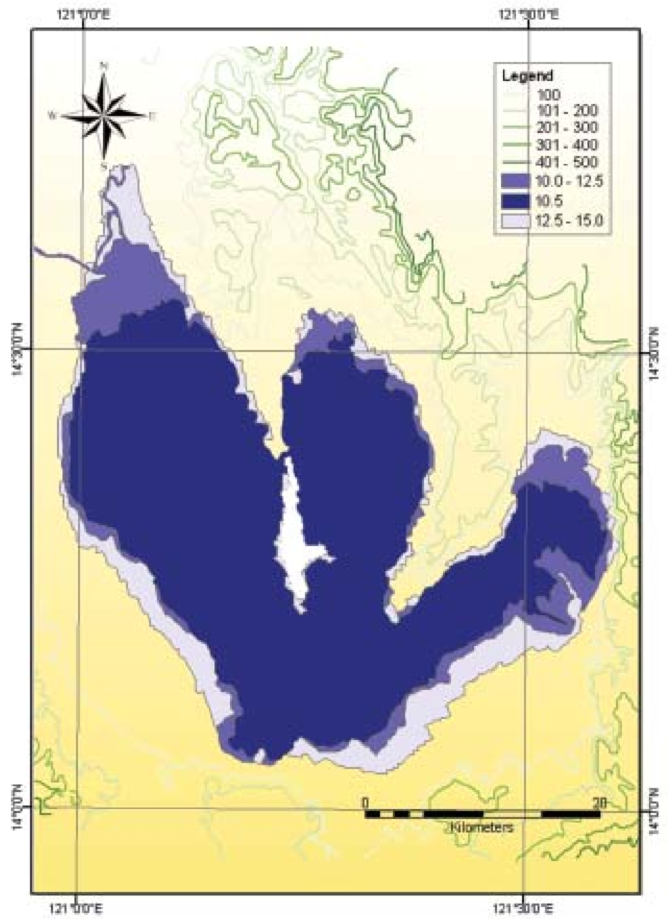

Figure 5.2. Interpolated water levels and digitized contour map. Source: LLDA IWRM Division.

Table 5.2 also indicates the municipalities in the region which are affected by the lake level water rise from 10.5 m to 12.5 m. For instance, the municipality of Victoria in Laguna Province has a total area of 24.85 million m^2, and about 3 million m^2 are affected by the water rise. The affected agricultural area by the 12.5 m lake level rise by municipality is being estimated by the LLDA Integrated Water Resource Management Division (IWRMD) – Geographic Information System (GIS) Laboratory as of June 2003.

5.3.2 Rainfall and Typhoon

Since the amount of precipitation varies from year to year, the water level of the lake also varies and heavily depends on the rainfall in the LLB as a whole. In years when typhoons bring unusually heavy precipitation and concurrent with the high tide in the Manila Bay, the water level can reach 14.62 m as in 1914, 14.35 m in 1943, 14.03 m in 1972. Figure 5.3 shows the annual fluctuation of the water level in Laguna de Bay.

5.3.3 Flood and Runoff

Floodwaters coming from the 22 tributary rivers draining into the lake can affect the water level of the lake. Ricelands along the rivers usually release their excess water. Since drainage through the Pasig River is not that rapid, water level of the lake can increase up to 14.60 m.

5.3.4 Pests and Diseases

Damage from rats has been reported to be extreme along lakeshore lands. Farmers reported that they experience heavy losses from rat infestation. There is some security if the rice crop matures at the same time; hence late planting is a disincentive for farmers.

Water lily is also a problem because areas, which are heavily infested by water lily, may not be cleared for planting rice in some cases. Farmers also believe that thick water lily clusters harbor the rodents that damage their crop. Water lily invasion of the rice field can be prevented to some extent by putting twigs at the border of the rice field fronting the lake.

Birds are a problem only at maturity of the rice crop and are easily mitigated by different devices. The devices, however, usually need the presence of a person to maintain. The most serious pests of the ricefields along the lakeshore are the golden apple snails which are of recent origin in the area. The snails can wipe out a hectare of newly transplanted rice overnight. Farmers have adapted to this problem by changing their seedbed and water management.

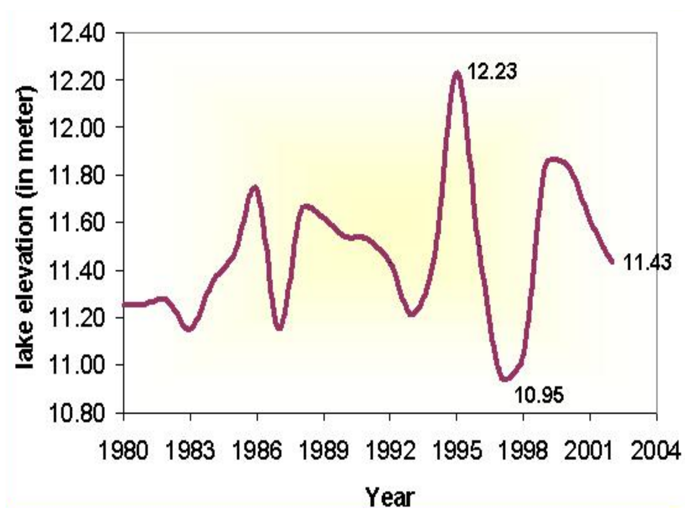

Figure 5.3. Annual water level fluctuation, 1980-2002.

Table 5.2. Municipalities affected by lake level water rise and their total area and shoreland area.

Municipality	Province	Area (m^2)	Shoreland (m^2)
Pasig	Metro Manila	24,793,864.31	7,988,776.93
Pateros	Metro Manila	4,364,220.51	1,457,692.21
Marikina	Metro Manila	36,575,759.60	195,611.64
Cainta	Rizal	16,907,480.77	5,848,058.96
Taguig	Metro Manila	24,910,689.87	18,184,044.40
Taytay	Rizal	31,770,115.47	11,248,404.34
Angono	Rizal	18,523,565.49	886,314.73
Morong	Rizal	42,423,099.75	5,649,755.18
Baras	Rizal	26,195,615.96	2,569,921.43
Tanay	Rizal	123,158,074.72	1,557,501.23
Pililla	Rizal	79,073,610.37	3,676,336.51
Jala-Jala	Rizal	50,086,047.33	3,000,010.90
Mabitac	Laguna	57,751,245.26	4,958,476.59
Siniloan	Laguna	17,598,479.44	7,603,975.13
Paete	Laguna	13,840,398.20	1,132,403.56
Kalayaan	Laguna	47,725,074.96	2,279,626.10
Lumban	Laguna	74,914,972.91	17,091,438.51
Sta. Cruz	Laguna	34,439,831.16	5,837,230.13
Pagsanjan	Laguna	36,381,942.96	825,676.77
Pila	Laguna	34,281,013.75	2,985,280.66
Victoria	Laguna	24,854,621.86	3,314,135.53
Calauan	Laguna	65,242,238.09	1,987,125.42
Bay	Laguna	46,683,984.63	831,624.05
Los Baños	Laguna	57,856,743.77	1,337,628.41
San Pedro	Laguna	24,715,699.56	1,749,878.93
Biñan	Laguna	48,118,167.82	2,147,397.13
Sta. Rosa	Laguna	41,953,288.04	850,701.42
Cabuyao	Laguna	53,684,920.78	1,307,884.86
Calamba	Laguna	147,577,186.39	5,268,843.45
Binangonan	Rizal	49,700,479.45	112,270.11
Binangonan	Rizal	49,700,479.45	145,009.50
Cardona	Rizal	26,949,531.88	842,046.06
Cardona	Rizal	26,949,531.88	138,030.39
Quezon City	Metro Manila	27,219,746.47	189,495.87
Pakil	Laguna	18,789,778.50	2,212,721.87
Pakil	Laguna	18,789,778.50	489,747.01
Pangil	Laguna	40,914,958.29	149,177.39
Pangil	Laguna	40,914,958.29	4,379,532.78
Paranaque	Metro Manila	47,119,643.51	3,914,509.39
Total			**136,344,295.47**

5.3.5 Land Use Change

The use of the ricelands for other purposes such as housing or industrial areas and the lake water for household use will affect rice production.

Over the last decades, the growth of industrial parks has been brought about by the development of CALABARZON. An industrial park is "a tract of land subdivided and developed accordingly to a comprehensive plan under a unified continuous management and with provisions for basic infrastructure and utilities, with or without pre-built standard factory buildings and community facilities for the use of community of industries" (LLDA BR 106 s 1999).

The rise of industrial parks or industrial estates has been pronounced in the urbanized municipalities and cities of Laguna specifically Calamba City, Sta. Rosa, and Cabuyao as well as in Batangas and Cavite. The establishments of these industrial parks, which at times are several hundreds of hectares in several municipalities surrounding the lake, deprive society of an equivalent area supposedly for rice production (Table 5.3).

Table 5.3. Number and classification of industrial and other establishments in LLB.

Category	Wet/Both		Unclassified	Dry	Total
	w/ WTF	w/o WTF			
Housing subdivision, commercial establishment, institution, recreation	157	641	97	131	1,026
Metal	91	75	48	149	363
Gasoline station, LPG, and refilling station, distribution/depot	91	189	6	24	310
Minerals and non-metals	69	111	21	90	291
Piggeries, poultry, livestocks	84	112	4	59	259
Semiconductor, Electrical, Electronics, Appliances	69	54	35	77	235
Chemicals, Pharmaceuticals	63	52	22	75	212
Food Manufacturing	87	81	13	20	201
Dry, textile, garments, sewing	43	43	22	81	189
Plastic, films, foam	12	27	17	90	146
Fast food restaurant	11	137			148
Unclassified	2	15	88	10	115
Pulp and paper manufacturing, printing services, paper related	21	33	12	27	93
Rubber and leather (Tannery)	4	11	5	57	77
Wood	1	5	3	57	66
Agricultural	11	11	3	28	53
Hospital services	10	42			52
Industrial estate	10	6	9	6	31
Transportation services, car sales, and service center	6	21	5	8	40
Beverages	21	16		2	39
Laundry	17	14		4	35
Slaughterhouse, dressing plant, hatchery	17	14	3		34
Miscellaneous, services	4	6	12	8	30
Power plant	6	10		4	20
Dumpsite		16			16
Total	**907**	**1,742**	**425**	**1,007**	**4,081**

As of 2002, there were 3,881 industrial and other establishments in the LLDA database broken down into 2,649 with wet processing, 1,007 with dry process, and 425 unclassified. Among those with wet processing, 907 have established wastewater treatment facilities, while 1,742 have yet to install their treatment systems.

Out of 3,881 establishments which are on LLDA record (included in the database), 1,481 have been monitored but they have not yet complied with the requirements for registration with LLDA. On the other hand, 2,353 are registered with LLDA. A total of 47 establishments closed their operation since 1999.

As a response to the rapid conversion of lands to other uses in the basin, the LLDA implements Board Resolution (BR) 106, series of 1999 to govern the application of the Environmental User Fee System (EUFS) to all industrial parks within LLB. Under these guidelines, every industrial park is expected to observe due diligence in protecting the environment thus, they are required to put up a central treatment plant (CTP) for liquid wastes discharged by its individual locators. Locators of industrial estates may discharge their wastes provided they are inter-connected to the CTP of the park.

5.4 Socioeconomic Conditions

5.4.1 Demographic Characteristics and Rice Requirements in LLB

The Laguna Lake Basin includes the provinces of Laguna and Rizal and some municipalities of Cavite and Batangas, and one municipality of Quezon – Lucban. The basin has a combined population of 6,601,514 (NSO 2000) or roughly about 9 percent of the total population of the country (Table 1.2). The population is unevenly distributed between the industrial and the agricultural sectors, notably the Metro Manila areas (of combined population of 2,078,794 as of 2000) and the Quezon, Cavite, and parts of Laguna and Rizal as the agricultural sector. The average household size in the basin is almost similar with the national average of 4.99, with Batangas having the biggest household size of 5.07.

The 2000 population of this area increased by almost 1.9 million over the 1995 census figure of 9.9 million (with September 1, 1995 as reference date) and 3.5 million over the 1990 census figure of 8.3 million. The population is growing at the rate of 3.72 percent in the second half of the nineties. This means that during this period, the population increased by about 370,000 persons per year on the average, or 42 persons per hour.

If the average annual growth rate of the population continues at 3.72 percent, then the population of this region is expected to double in 19 years. The number of households increased to 2.41 million from the 1995 figure of 1.99 million. The average household size decreased slightly to 4.88 from the 1995 figure of 4.98 persons. This means that for every 100 households, the number of members decreased by 10 persons.

Among the 5 provinces comprising the basin, Cavite registered the largest population at 2.06 million persons, followed closely by Laguna with 1.97 million persons. Rizal was the fastest growing province in the region with an average annual growth rate of 5.79 percent, followed closely by Cavite with 5.45 percent. Table 5.4 shows the changes in the population in 1990, 1995, and 2000. The total population is shown to be steadily increasing, although the annual growth rate (AGR) shows that between 1990-1995, there were decreasing AGR in most of the municipalities in the basin. Most striking was the negative growth exhibited by the cities of Mandaluyong and Muntinlupa under the National Capital Region (NCR). Between 1995 and 2000, however, there was a general increase in the AGR of most municipalities, although much lower that the AGR between 1980 and 1990.

The census however does not provide available information at the municipality levels for Batangas, Cavite and Quezon. Hence, there are gaps in the table, while the AGR at the provincial level were taken for comparison purposes.

5.4.2 Rice Requirements of the Basin Population

Table 5.5 shows estimated food requirements in terms of rice for the year 2000, using 96 kg per capita consumption (NEDA 1999). Based on this estimate, about 63,000 t of rice was required by the total basin population. This represents about 8.6 percent of the total estimated demand for rice. The ricelands along the lakeshore is about 57 km^2. Based on an empirical study of lakeshore rice farming in Laguna (Espaldon et al. 2002), farmers harvest about 40-75 cavans per ha a year (4,000-7,500 cavans km^{-2}; with only one cropping) and assuming a low yield of 40 cavans per ha (4,000 cavans km^{-2}), the total yield of lakeshore ricelands is about 228,000 cavans per year or 11,400 t of palay. This translates to about PhP 91.2 M revenue generated at a farm gate price of PhP 8 per kilogram. In terms of rice production, assuming a full grains production and effective milling, it can provide about 9 percent of total rice requirement for the basin.

5.4.3 Institutional Arrangements

The 253-km long shoreland areas provide vital economic and social benefits to the people living around the lake. It

Table 5.4. Total population and annual growth rate in the Laguna Lake Basin, 1990, 1995, 2000 (NSO 2000).

Provinces/ Municipalities	Total Population			Annual Growth Rate		
	May 1, 1990	Sept. 1, 1995	May 1, 2000	1980-1990	1990-1995	1995-2000
Philippines	60,703,206	68,616,536	76,503,333	2.32	2.36	2.34
Laguna de Bay Basin						
1. Laguna	1,370,232	1,631,082	1,965,872	3.32	4.08	3.67
2. Rizal	977,448	1,312,489	1,707,218	5.67	5.79	5.73
3. Batangas				2.20	3.02	2.58
Sto. Tomas						
Tanauan						
Malvar						
Lipa						
4. Quezon				2.15	1.90	2.03
Lucban						
5. Cavite				6.46	5.45	5.99
Carmona						
GMA						
Tagaytay						
Silang						
6. Metro Manila						
Mandaluyong	248,143	286,870	278,474	2.75	-0.63	1.16
Pasig	397,679	471,075	505,058	3.22	1.50	2.42
Pateros	51,409	55,286	57,407	1.37	0.81	1.11
Muntinlupa	278,411	399,846	379,310	7.01	-1.12	3.13
Taguig	266,637	381,350	467,375	6.93	4.45	5.77
Marikina	310,227	357,231	391,170	2.68	1.96	2.34

serves as buffer zone and habitat for ecologically and economically important aquatic species. It is utilized by small farmers for short-term or seasonal agricultural crops including rice. As a buffer zone, it has environmental significance since it contributes to the present state of the lake environment.

Due to the development activities taking place within the basin, LLB has been continuously threatened by population growth, increasing and changing demands in resources, and development activities. The lakeshore area has become a sanctuary for people displaced from various areas in Metro Manila and other provinces. Significant portions of lakeshore areas have already been and continually being lost or degraded due to pollution, reclamation, inappropriate farming practices as well a aquaculture systems. Oftentimes, this area is also the site of social clashes because of land tenurial problems of various origins since this is thickly inhabited in certain areas. Some of these occupants are holder of land titles, tax declaration, or other documents.

In view of this, the DENR and the LLDA Board of Directors issued a series of administrative orders and resolutions to govern the management and development of shoreland areas of Laguna de Bay (Table 5.6 and Appendix A17). Implementation of shoreland management rules and regulations by the LLDA is undertaken in coordination with LGUs.

For untitled shoreland, LLDA processes applications for lease filed by qualified users/occupants.

Shoreland Occupancy Permit is the legal authorization granted by the LLDA to qualified lease applicant for the use/ occupancy of certain portion of the untitled shoreland areas for a specific period of time subject to the lease regulations, terms, and conditions as prescribed under BR 113, series of 1999.

Nonetheless, the LLDA is looking into the effectiveness of the current policy instruments for shoreland management and

Table 5.5. Estimated rice requirement of the basin population at 96 kg per capita, 2000.

Provinces/ Municipalities	Total Population	Rice Requirement Using 96 kg per Capita	In Tons
Philippines	76,498,000	7,343,808,000	7,343,808
Laguna de Bay Basin	6,601,514	633,745,344	633,745.34
1. Laguna	1,965,872	18,8723,712	188,723.71
2. Rizal	1,707,218	163,892,928	163,892.92
3. Batangas	449,070	43,110,720	43,110.72
Sto. Tomas	80,393	7,717,728	7,717.73
Tanauan	117,539	11,283,744	11,283.74
Malvar	32,691	3,138,336	3,138.34
Lipa	218,447	20,970,912	20,970.91
4. Quezon	38,834	3,728,064	3,728.06
Lucban	38,834	3,728,064	3,728.06
5. Cavite	361,726	34,725,696	34,725.70
Carmona	47,856	4,594,176	4,594.18
GMA	112,446	10,794,816	10,794.82
Tagaytay	45,287	4,347,552	4,347.55
Silang	156,137	14,989,152	14,989.15
6. Metro Manila	2,078,794	199,564,224	199,564.22
Marikina	391,170	37,552,320	37,552.32
Pasig	505,058	48,485,568	48,485.57
Pateros	57,407	5,511,072	5,511.07
Muntinlupa	379,310	36,413,760	36,413.76
Taguig	467,375	44,868,000	44,868.00
Mandaluyong	278,474	26,733,504	26,733.50

control (BR 23 of 1996 and related issuances). In January 2001, a consultative meeting was held as part of the review process with an end in view of amending BR 23 due to implementation/enforcement issues, namely:

- Development projects/activities have overtaken regulation and control, i.e., the law defining the shoreland [Presidential Decree (PD) 813] was enacted in 1975 while the policy guidelines were issued in 1996.
- While the policy tools exist (Shoreland Occupancy Permits, Notice of Violations, Ex-parte and closure orders), they are ineffective for the purpose of shoreland restoration and environmental regulation.
- Lack of resources to monitor shoreland activities and enforce the rules and regulations.
- Indifferent lakeshore local government units (LGUs) manifested in citing of illegal open dumpsites on shoreland and river banks; proceeding with local development projects without the needed environmental clearances and permits from DENR/LLDA.

5.5 Scenarios

5.5.1 Laguna Lake Basin as a Source of Domestic Supply for Metro Manila

With a rapidly increasing population coupled by inadequate surface water production in the Angat Region and the declining groundwater resources, the lake water will be a major source of potable water. A memorandum of agreement already exists with Ayala Land to use 300,000 m^3 per month of water from the lake. Already, additional water is being requested.

The LLDA has a proposed plan to help ensure future sustainable development of the lake resources. The Polder Island Development Plan (PIDP) was conceived to provide raw water for drinking water supply, address the problem of wastewater treatment, and improve water quality and ecology of LLB, among others. A component of the PIDP is a raw water storage reservoir that addresses the development of LLB as an alternative raw water source. This is proposed to

Table 5.6. Rules and regulations on shoreland management.

Rules and Regulations	Title	Date of Issue
LLDA Board Resolution 10	Asserting LLDA's Authority and Exclusive Jurisdiction in Laguna de Bay Concerning Issuance of Permits for Reclamation Projects and Disallowing Any Non-environmentally Feasible Activities in the Lake	June 29, 1995
DENR Administrative Order 27-95	Moratorium on the Acceptance and Processing of All Public Land Applications Covering Areas Immediately Adjacent to the Laguna De Bay Basi	
LLDA Board Resolution 23	Approving the Rules and Regulations Implementing Section 41 (11) of RA 4850, As Amended, Defining and Regulating the Use/Occupancy of Laguna de Bay Shoreland Areas	September 26, 1996
LLDA Board Resolution 39	Approving the Increase of Rates for the Survey of Shorelands Within the Laguna de Bay Region and Areas for Aquaculture Operation	February 27, 1997
LLDA Board Resolution 110	Amending the Administrative Fine for Violation of LLDA Rules on Reclamation/Landfilling of Any Portion of the Laguna de Bay and Its Shoreland	August 26, 1999
LLDA Board Resolution 113	Amending BR 23 by Adding the Implementing Guideline Governing the Lease of the Laguna de Bay Shoreland Areas	September 30, 1999

bridge the gap from 2006 when the present sources in the northern end of the Metropolitan Waterworks and Sewerage System (MWSS) service area will be fully used up until the time when the new drinking water reservoir in the hills north of Metro Manila could be operational.

The 400 million liters per day (MLD) capacity water storage reservoir component of PIDP will allow the salinity levels to be maintained in the lake for the benefit of fisheries and at the same time makes the water in the polder water reservoir suitable as drinking water source. Salinity levels in the South bay of water entering the lake via the Pasig River/Napindan channel have been measured up to 1,500 mg l^{-1} (TDS). It is proposed that freshwater could be stored in the reservoir when salinity levels are low. When it exceeds 600 mg l^{-1} (TDS), direct intake raw water from the lake is closed and supply flow from the polder reservoir begins to continue until lake water salinity reaches acceptable level again. By operating the NHCS, the duration salinity concentrations can be controlled to suit both fisheries and water supply (LLDA 2002).

The PIDP, specifically the wastewater treatment/sanitation component, will provide practical solutions to liquid waste pollution. It is proposed to consist of:

- a proper wastewater treatment plant;
- sludge handling and disposal;
- gravity sewers in the western catchment;
- interceptor sewers need to be constructed along the coastline and in the polders; and
- industrial wastewater treatment plant.

Wastewater calculations indicated a total flow of more than 500,000 m^3 day^{-1} to be phased over 10 years. The initial capacity of the treatment plant is about 150,000 m^3 day^{-1} (assumed to be operational by 2011), and additional 350,000 m^3 day^{-1} by 2016.

Shoreline restoration is proposed under the PIDP to consist of:

- introduction of fishponds for endemic species;
- establishment of green buffer zone;
- integration of recreation activities nature development/ ecologic embankment; and
- establishment of LLB ecology museum.

If Laguna de Bay will be a source of domestic water supply of Metro Manila in the near future, there will be an urgent need to minimize pollution in the lake. Agricultural activities contribute to pollution loading of Laguna de Bay mainly through chemical residues from pesticides and other agro-chemicals and animal wastes that wash down to the water systems, irrigation canals, and through surface run-off during rainy season. The use of pesticide in the ricefields not only along the lakeshore but also the irrigated rice along the river tributaries contributes to the pollutants of the lake. Nitrogen from agricultural sources comprises about 60 percent of the total nitrogen-based pollutants in the mid-1970s (see Section 3.1.1 for a fuller discussion of water chemistry).

More waste from fertilizer and pesticide use will end up in Laguna Lake considering that most of the region's prime agricultural lands and irrigated paddies are found along the lakeshore areas.

There are other factors contributing to the pollution of the lake water and probably more serious than those coming form the ricefields such as the almost 4,000 industries around the lake that discharge their wastewater to the lake; pollution from households which accounts for a great majority (about 70 percent) of organic wastes discharged into the lake; and pollution from more than 5,000 motorized watercrafts and 23 oil barges.

5.5.2 Decrease in Water Level

With the decrease in the water level, more shorelands will be available for rice production. The LLB has a shallow, gentle sloping topography. A decrease in water level will expose more land that can be planted to rice. Conversion of land area into organic farming is possible. The upper part of the lakeshore that will be permanently dry as a result of lower lake water level can be planted to vegetables. Organic gardening would be ideal to lessen pollution.

5.5.3 Construction of Circumferential Road Using Areas Occupied by Ricefields

The construction of a 9.8-km road dike in Rizal, Taguig, and parts of Laguna has already been proposed and construction is ongoing. A 10-m wide road will occupy a 20-m wide dike, perhaps even more. Soil to build up the dike will most likely come from the ricefields. This 9.8-km road dike will decrease the ricefields by 0.196 km^2. An estimate of 4 t ha^{-1} (400 t km^{-2}) for two crops a year will mean a decrease in 80 t of rice with the building of the 9.8-km dike.

Another road construction in Laguna has produced similar effect. When a by-pass road was built for the towns of Paete and Pakil on the ricefields which measured 20-m wide and 4-km long, it occupied 0.08 km^2 of rice lands. What is even more significant is that both sides of the highway are now being occupied by houses, areas which are used for rice farming before.

To investigate the effect of the proposed dike on the hydrology of the lake, the dike was included in the Delft3D-Flow model set-up under the LLDA- Sustainable Development of Laguna de Bay Environment (SDLBE) Project. The model was then run in depth-averaged computation mode using the dike in operational. Output of this run was compared to the result of the model without the dike in place but having all other inputs and model coefficients unchanged.

The results of the model calculations show an important effect of the proposed dike on the water level of the lake particularly in periods of rainy season. It was shown in the model that during high water stage, when the water level reaches the long year averaged maximum lake level of 12.50 m up to an extreme water level of 14.50 m, the average water level is computed at 13.47 m when the dike is not yet present; and an average of 13.49 m or an increase of 2 cm in water depth if the dike is operational. Inundation of floodplain areas lying above the 11.5-m elevation along the project will be prevented. However, floodplain areas along the municipality of Taytay will suffer an increase in lakewater level especially during storm if this area will not be included in the dike protection work. During the storm, the model predicted a maximum water level of 14.57 m in Taytay area with the dike in place as against the elevation 14.50 m when the dike is not present.

The storm event which occurred last November 1995 was reconstructed to simulate the impact of the dike on water circulation. Results of this run show minor changes on the movement of lake water near the mouth of Napindan River. Without the dike, the model predicts higher flow velocities on the flooded shoreland areas. With the dike in place, the shoreland area is protected from flooding and the flow direction near the dike follows more or less the alignment of the dike. In general, the dike will not cause considerable alteration in water movement of the lake.

5.5.4 Use of Lake Water for Industrial Cooling

Four power plants are located in the region, two of which have closed, the Sucat and Manila Thermal Plants. These caused an increase in lakewater temperature by about 2°C near the discharge points of the thermal power plants. The Shell Refinery by the Shell Philippines Petroleum Corporation located in Barangay Malaya, Pililla Rizal extracts water from Laguna Lake for thermal cooling. Approximately 45,000 gallons or 170.32 m^3 min^{-1} of water is extracted from the lake, while KEPHILCO also located in Pililla, Rizal uses water from Laguna Lake as coolant and generates a total of 124,000 m^3 $hour^{-1}$. The same amount of water is returned to the lake at the speed of 2-3 minutes with an increased temperature of 1.67°C. Accordingly, the increased water temperature does not have any detrimental effect on the aquatic resources. Prior to its closure, the Sucat Thermal Power Plant, formerly known as the Gardner Synder Thermal Plant and owned by Manila Electric Company, extracted water from Laguna Lake. A total of 1,272.36 M m^3 per hour per annum of the lake water was used for cooling. The water went through chemical treatment due to high level of salinity during summer season when the Mangahan gate is open.

Increase in temperature may have slight influence to rice cultivation, but its oil and grease content from industrial machineries and cooling towers may affect water quality, hence the planktons population in the immediate area.

5.5.5 Use of Lake Water for Power Generation

The Kalayaan Pumped Storage Power Plant (KPSPP) pumps lake water up to Caliraya Lake for storage during off-peak demand. It generates 300 MW of hydroelectric power by releasing stored water during peak demand period, supplying the Luzon Power Grid. Under the KPSPP Rehabilitation, Upgrading and Expansion Project (KPSPP-RUEP), a component of the Caliraya-Botocan-Kalayaan (CBK) Project under the CBK Power Corporation and NPC, KPSPP shall be expanded to generate an additional 355 MW, aside from improving the existing capacity by an additional capacity of 4 MW (CBK Power Company-NPC 2003). An increase in lake water temperature near the discharge point of KPSPP has been noted. This may have little bearing to rice cultivation but may affect plankton growth in the area.

5.5.6 Uncontrolled Land Conversion

The LLB has been continuously threatened by population growth, increasing and changing demands on resources, and development activities. Lakeshore has become a sanctuary of people displaced from various areas in Metro Manila and other provinces. Encroachment into the ricefields is a common scene along the lakeshore. Housing areas and even large shopping areas are being built on the ricefields.

5.5.7 Demographic Shifts vis-à-vis Food Supply and Demand

Given the current high annual growth rate of the LLB at 3.72 percent, the need for additional human settlements and other built up areas for social services like roads, schools, market places, and others are also expected to increase. The rice requirement of the region assuming the current rice consumption will also increase tremendously. Hence, the basin will continue to remain a rice-importing region to meet its expected increase in demand.

5.6 Conclusion

The LLB performs one major ecosystem function – provision of the staple food for the population, rice. Of the total land area of the region of about 3,813.2 km^2, about 380 km^2 is devoted to rice. This represents about 10 percent of the total land area of the region. The productivity of the irrigated rice is about 5 t ha^{-1} (500 t km^{-2}) per season. The total irrigated rice lands is about 233.62 km^2, the rest are classified as upland or rainfed rice. The irrigated areas alone bring about 116.82 t of palay per season or a gross return of PhP 934.48 M (farm gate price of PhP 8 per kg).

In addition to these agricultural areas devoted to irrigated and upland rice, about 57 km^2 of submerged lakebed become available for rice cultivation during the dry season. It happens when the lake level drops from 12.5 m elevation in the rainy season to 10.5 m during the dry season. This area along the 253 km strip of land is called the lakeshore lands. The productivity of lakeshore lands is low since there is only one cropping and it is beset with different pests and diseases. However, the farmers note that the input is low since they do not apply fertilizers because the lakebed is naturally fertile. It is estimated that the yield of these lands ranges from 40-75 cavans ha^{-1} (4,000-7,500 cavans km^{-2}), which can translate into about PhP 91.2 M per year revenue at the same farm gate price of PhP 8 per kilogram.

Since the lakeshore lands are within the lake’s buffer zone between 12.5 m and 10.5 m elevation, the management of these lands is a responsibility of LLDA. Several administrative orders and resolutions were passed to govern the use and management of shoreland areas of Laguna de Bay. However, to date, there was still no formal evaluation by the LLDA regarding the effectiveness of these policies as the lakeshore populations continue to use the shoreland areas for varied purposes.

This chapter highlighted the various factors influencing the ability of the LLB ecosystem to generate one of the most basic services – food for the growing population. These factors include the lake level rise and decline, the conversion of agricultural areas to other uses such as industries, human settlements, roads and bridges, and other associated activities that are expected to influence lake level. These are the basis for drawing future scenarios and how these will influence the dynamics of rice production in the region. For instance, tapping of the lake as a source of domestic water supply, industrial cooling, and power generation will certainly affect the lake level movement. This will have direct consequences on the productivity of the lakeshore lands. The uncontrolled land conversions are also seen as a major scenario that can hamper rice production. These trends are seen to be contributing factors to the decline of the capacity of this system to respond to the growing requirements for rice of the growing population in the region, if the lake resources are not managed as a whole dynamic system.

References

Espaldon, V.O., J. Floresca, M. Rodriguez, 2002: The Impact of LakeLevel Rise on Agricultural Productivity in Balian, Laguna. A paper submitted to ENS 270: Population, Resources and Environment. UPLB SESAM, 1st Semester 2002-2003.

LLDA, 1996: Laguna de Bay Master Plan.

LLDA, n.d.: Laws, Rules and Regulations Affecting the Management of Laguna de Bay and Its Basin.

LLDA, 2002: The PIDP Vision on Sustainable Development

LLDA, n.d.: Inventory of Surface Water and Water Resource Pricing Study. Text 47 pp. Appendix 155 pp.

LLDA, 2003: The Laguna Lake Development Authority website. Available at http://www.llda.gov.ph.

NCSO, 1992: Census of Fishermen and Farmers in the Laguna Lake Region.

NSO, 2000: Census 2000.

Pingali, P. and Roger, P.A. (eds.), 1995: Impact of Pesticides on Farmer Health and the Rice Environment. International Rice Research Institute, 664 pp.

Pacardo, E. P. D. Nepomuceno, F. Francisco and V.O. Espaldon, 1987: Basin Approach to Laguna Lake Water Resource Management: Problems and Issues. Project of the Institute of Environmental Science and Management, UPLB; Laguna Lake Development Authority and UN Center for Regional Development, Nagoya, Japan. 78 pp.

Rice Statistics Handbook, 1970-1992.

Rivera, M.N., H.A. Francisco, C. Taguiam, R. Pagkaliwagan, L. Pintor, M. Aparente, D. Africa, R. Payuan, L. Calderon, and A. Mora. 2001: Invertory of Users of Surface Water and Water Resource Pricing of the Laguna Lake and Its Tributaries. ERDB/LLDA.ENRAP.

6

Biodiversity

EDWINO S. FERNANDO, DANIEL A. LAGUNZAD, NEIL ALDRIN D. MALLARI,
PEDRO L. ALVIOLA III

CONTENTS

6.1 Introduction

The popularity of biodiversity over the last few decades has risen largely from the increasing public and worldwide interest and concern over environmental issues relating to our terrestrial, aquatic, and marine ecosystems. The increasing demand for precious biological resources by expanding human populations has resulted to the conversion of many natural habitats to other uses and placed hundreds of species to the brink of extinction. The issue of biodiversity conservation is now truly of global concern and has become a feature of national policy and planning for natural resources, an important component of development assistance, and the focus of many NGO-supported activities. This chapter examines the biodiversity of the LLB and current conditions and trends at ecosystems and species levels.

This assessment has limitations on the level of knowledge and confidence relating to the available published data and reports. The scope of biodiversity covered includes only vascular plants, algae, vertebrate fauna, crustaceans, and mollusks.

There are six specific areas within the lake basin that have recently been included as biodiversity conservation priority areas in the Philippines: the lake itself, the Pakil and Real area, Pasig River, Tadlak Lake, Mt. Makiling, and the Mt. Banahaw-San Cristobal complex. These ranked from very high (e.g., Pakil and Real) to extremely high critical (e.g., Mt. Makiling) in priority level (Table 6.1). Three of these (Pakil and Real area, Mt. Makiling, and Mt. Banahaw-San Cristobal complex) are also important bird areas (Mallari et al. 2001). Mt. Makiling is also one of the Philippines'18 centers of plant diversity (Cox 1988; Madulid 1993; DENR-UNEP 1997) and the country's best known biological area owing much to its long scientific history (Pancho 1983).

6.2 Ecosystem Diversity

The natural ecosystems of the lake basin include terrestrial (the mountains and hills surrounding the lake) and aquatic (the lake itself and the rivers and streams that drain into it). From the lakeshore to the summits of the mountains and ridges surrounding the lake different types of vegetation occur. These are in general similar to those on other areas in the country. The man-made agroecosystems form a large component of the lake basin.

6.2.1 Terrestrial Ecosystems

Mt. Makiling (1,090 m) and Mt. Banahaw (2,100 m) are the highest peaks within the lake basin and probably the only remaining forested areas. These two are isolated volcanic mountains and have on their summits upper montane rain forests or more commonly referred to as "mossy" forests. This type of vegetation occurs on mountains above 1,000 m elevation with the upper limits varying depending on the locality and height of the mountain. The mossy condition and dwarfed, crooked trees is characteristic of this vegetation type. The trees in the mossy forest on Mt. Banahaw tend to be taller and dominated by conifers (e.g., *Dacrycarpus imbricatus*, *Podocarpus rotundus*) (Brown 1919; de Laubenfels 1978), while those on Mt. Makiling are shorter, with species of *Cyathea* and *Astronia* as prominent taxa. Although the northern region of the basin reaches to 1,100 m in elevation, these are now deeply eroded areas. Hence, there are no mossy forest elsewhere in the lake basin except on Mt. Makiling and Mt. Banahaw on the southern margin.

Between 100 and about 750 m elevation where forests still occur especially on the southern (Mt. Makiling and Mt. Banahaw) and eastern margin (Caliraya, Pakil-Real area) of

Table 6.1. Biodiversity conservation priority areas in the Laguna Lake Basin (after DENR-PAWB et al. 2002).

Conservation Priority Area	Priority Level	Estimated Area (km^2)	Province
Pakil and Real (UP Land Grants)	Very High	226.3514	Laguna, Quezon
Pasig River	Extremely High Critical	177.3385	Manila and Rizal
Laguna de Bay	Extremely High Critical	890.2797	Laguna, Rizal, Manila
Tadlak Lake	Very High	0.2506	Laguna
Mt. Makiling Forest Reserve	Extremely High Critical	118.7190*	Laguna and Batangas
Mt. Banahaw - San Cristobal Complex	Very High	76.4159	Laguna and Quezon

* only 42.44 km^2 is actually forest reserve

the lake basin, there is usually a lowland evergreen rain forest often dominated by species of Dipterocarpaceae, and hence often called the dipterocarp and mixed-dipterocarp forests. This vegetation type is very rich in tree flora and is regarded as the typical rain forest formation in the Philippines.

At elevations above 750 m and before the mountain peak (the upper limit depending on the height of the mountain) there is a vegetation type called the lower montane rain forest**.** In this type oaks (*Lithocarpus*), oil fruits (*Elaeocarpus*), and laurels (*Litsea*) and makaasim (*Syzygium*) are common (Brown 1919; Ashton 1997). Epiphytic ferns, herbaceous shrubs of Rubiaceae (e.g., *Psychotria*) and Acanthaceae (e.g., *Strobilanthes*) are abundant in the understory. In gaps and gullies, *Saurauia* and species of Urticaceae can be common, including climbers such as *Freycinetia*.

In many areas of the lake basin, there also occur vegetation consisting of a mixture of grassland and second-growth forest more commonly called the "parang" vegetation. This usually occurs in land from which the original forest has been removed as in the northern margin of the lake basin. Two species of grass are prominent in this vegetation type, *viz*., *Imperata cylindrica* and *Saccharum spontaneum*. The tree component includes *Trema orientalis, Macaranga tanarius, Ficus hauili, Colona serratifolia, Bischofia javanica,* and many others. Often exotic but naturalized species such as *Psidium guajava* can also be common. Some tree species (e.g., *Bischofia javanica)* are common to both the parang vegetation and the dipterocarp or mixed dipterocarp forest. The *parang* vegetation is regarded as a successional stage towards the latter.

The lakeshore ecosystem of Laguna Lake is the important transition between the lake itself and the surrounding watershed. The common plants here are species of grasses (e.g., *Hymenachne amplexicaulis, Arundo donax, Phragmites vallatoria,* and *Pseudorhaphis squarrosa),* sedges (e.g., *Scirpus grossus, Cyperus spp., Fimbristylis spp.*), and legumes (*Sesbania cannabina*). Many wading birds also congregate on the lakeshore.

6.2.2 Aquatic Ecosystem

The lake vegetation generally has a low diversity of vascular plants, usually consisting of species that often have very wide distribution range. Pancho (1972) recorded 19 families and 24 genera and species of aquatic angiosperms (Table 6.2). Two dominant and economically important species here are *Eichornia crassipes* and *Pistia stratiotes*. These are characterized by generally rapid population growth and can disrupt navigation, interfere with fisheries, and affect fish and other aquatic animals by lowering oxygen and pH of the water. The latter species is native of Brazil, but is now widespread in the tropics. The lake itself is home to nearly 40 species of commercial fish, snails, and shrimps. Many of the species are exotics, and only less than half of these are indigenous to the lake.

6.2.3 Agroecosystems

As more than 50 percent of the lake basin is devoted to agricultural use, the agroecosystems component of the basin is significant (Pacardo 1993). The higher slopes are planted to coconut (*Cocos nucifera*), coffee (*Coffea arabica, C. robusta, C. liberica*), citrus (*Citrus spp.),* fruit trees (e.g., lanzones [*Lansium domesticum*], rambutan [*Nephelium lappaceum*]), and banana plantations. The lower slopes include sugar cane (*Saccharum officinalis*), cassava (*Manihot esculentum*), rice (*Oryza sativa*), corn (*Zea mays*), and a large variety of annual and perennial crops.

6.3 Species Diversity

6.3.1 Flowering Plants and Ferns

An estimated 155 families, 863 genera, and 2,313 species of vascular plants have been recorded from the LLB. About 64 percent of the species are Philippine endemics (Tables 6.3 and 6.4). The lake basin is considerably rich containing more than 31 percent of all species in the Philippines and 44 percent of the species occurring on Luzon. About 48 percent of the Philippine endemic species are found within the lake basin. There are some limitations to these tables. The data is based on Merrill's "Enumeration of Philippine Flowering Plants" (1923-26). Many hundreds of species have gone through nomenclatural changes, e.g., some names have been reduced to synonymy or transferred to other genera. Many new taxon (species, genus, or family) records or new taxa described after Merrill (1923-1926) are still not included in this database.

The floristic data in Table 6.4 were obtained from species records for the five provinces that cover the basin. Nine of the 26 Philippine endemic genera occur in the basin, with two genera (*Gongrospermum*, a tree; and *Psomiocarpa*, a fern) restricted to the provinces of Laguna and Quezon. About 159 species (or 13 percent of the total number recorded from the surrounding watershed and lake) are known only from the five provinces covering the basin. The province of Laguna has 39 endemic species; Rizal, 61; Quezon, 48; Cavite, 5; and Batangas, 6. The lake itself has 19 families and 24 genera and species of aquatic angiosperms (Pancho 1972; Table 6.2).

Four species of plants in the lake basin are regarded as rare and threatened (Table 6.5).

Table 6.2. Checklist of the aquatic angiosperms of Laguna Lake (after Pancho 1972, Aguilar et al. 1990).

Species	Family	Local Names	Distribution
Nelumbo nucifera Gaertn.	Nymphaeaceae	Baino, Sacred Lotus	Trop. continental Asia, Malesia, N Australia
Nymphaea nouchii Burm.f.	Nymphaeaceae	Labas, Lauas, Lotus lily	SE Asia to New Guinea
Polygonum tomentosum Willd.	Polygonaceae	Subsuban	Trop. Asia & Africa
Ceratophyllum demersum L.	Ceratophyllaceae	Arigman	Temp. & Tropic regions
Nasturtium indicum (L.) DC.	Brassicaceae		Trop. Asia & Malesia
Myriophyllum spicatum L.	Haloragaceae	Lomot ilog	Warm & Temp. regions
Ludwigia adcendens (L.) Hara	Onagraceae	Sigang-dagat	Pantropic
Nymphoides indica (L.) O. Kuntze	Gentianaceae		Trop. Africa & Asia, Malesia, Australia, Polynesia
Ipomoea aquatica Forssk.	Convolvulaceae	Kangkong	Trop. Africa & Asia, Malesia, Australia
Limnophila rugosa (Roth) Merr.	Scrophulariaceae	Tala, Taramhapan	India, Malesia, Polynesia
Bacopa monnieri (L.) Pennell	Scrophulariaceae	Olasimang aso	Pantropic
Potamogeton malaianus Miq.	Potamogetonaceae	Damong-kulot	India to China, Japan, Java, Sumatra, Borneo
Eichornia crassipes (Mart.) Solms	Pontederiaceae	Water hyacinth	Native of Brazil; now widespread in tropics
Scirpus grossus L.f.	Cyperaceae	Tikiu, Tikug	India, Indo-China, Malesia to Bonin Island
Panicum repens L.	Poaceae	Luya-luyahan	Trop. & Subtropics
Leersia hexandra Sw.	Poaceae	Barit	Pantropic
Lemna persilla Torrey	Lemnaceae	Liya	Pantropic
Spirodela polyrrhiza (L.) Schleid.	Lemnaceae	Liyang-laot	Pantropic
Pistia stratiotes L.	Araceae	Kiapo	Pantropic
Najas graminea Delile	Najadaceae		Africa, trop. Asia, Taiwan, Japan
Hydrilla verticillata (L.f.) Royle	Hydrocharitaceae	Lumot-lumotan	Europe, Africa, Asia, Malesia, Australia
Vallisnera natans (Lour.) Hara	Hydrocharitaceae	Sintas-sintasan	SE Asia, Malesia, Australia
Ottelia alismoides (L.) Pers.	Hydrocharitaceae	Damong ilalim	Africa, Asia, Malesia, Australia
Typha angustifolia L.	Typhaceae	Balangot	Temp. & trop. regions

6.3.2 Algae

A total of 157 species of algae have been recorded from the LLB. This includes 27 Euglenophyta, 24 Cyanophyta, 51 Chlorophyta, 3 Pyrrophyta, 51 Chrysophyta, and 1 Xanthophyta (Table 6.6).

6.3.3 Fauna – Birds

The LLB is known to hold 15 species of globally threatened birds; 21 species of birds of very restricted ranges (restricted range = breeding range of less than 50,000 km^2); and congregatory water birds representing at least 10 percent of the Asian population. This assemblage constitutes about half

Table 6.3. Number and endemism of species, genera and families reportedly distributed in the geographical units: Philippines, Luzon Island, and the Laguna Lake Basin.

	Philippines	Luzon	Laguna Lake Basin
Number/(Percentage)			
Total number of species	7,315	5,216 (71.3)	2,313 (31.6*) (44.3*)
Total number of genera	1,525	1,330 (87.2)	863 (56.6) (64.8)
Total number of families	206	193 (93.7)	155 (75.2) (80.3)
Percent Endemism			
Number of endemic species	4,716 (64.5)	3,084 (65.4)	1,481 (31.4) (47.3)
Number of endemic genera	23 (1.5)	19 (82.6)	9 (39.1) (47.3)
Number of endemic families	0 (0)	0 (0)	0 (0) (0)
Endemism within Geographical Unit (%)	64.5	59.1	64

* Percentage relative to the Philippines; ** Percentage relative to Luzon Island

Table 6.4. Genera of flowering plants (angiosperms) endemic to the Philippines and distribution in the Laguna Lake Basin.

Family	Genus	Species	Distribution
Euphorbiaceae	*Reutealis*	*Reutealis trisperma*	Laguna, Quezon, Rizal, Batangas, Cavite (also La Union, Camarines, Negros, and Davao)
Fabaceae	*Luzonia*	*Luzonia purpurea*	Quezon (also Bataan, Benguet)
Melastomataceae	*Astrocalyx*	*Astrocalyx calycina*	Laguna, Quezon (also Sorsogon, Catanduanes, and Leyte)
Rubiaceae	*Sulitia*	*Sulitia obscurinervia*	Laguna (also Sorsogon and Catanduanes)
Rubiaceae	*Villaria*	*Villaria odorata*	Laguna, Quezon (also Camarines, Albay, Sorsogon Samar, and Surigao)
Rubiaceae	*Villaria*	*Villaria philippinensis*	Quezon (also Cagayan, Camarines, Catanduanes, Leyte, Siargao, and Dinagat)
Rutaceae	*Swinglea*	*Swinglea glutinosa*	Quezon (also Isabela)
Sapindaceae	*Gloeocarpus*	*Gloeocarpus patentivalvis*	Laguna, Quezon (also Sorsogon)
Sapindaceae	*Gongrospermum*	*Gongrospermum philippinense*	Laguna
Dryopteridaceae	*Psomiocarpa*	*Psomiocarpa apiifolia*	Laguna, Quezon

Table 6.5. Annotated list of rare (R) and threatened (T) plants known from the Laguna Lake Basin.

Species	Conservation Status	Notes	Reference
Rafflesia manillana Teschem. Malaboo [Rafflesiaceae]	T	The currently active sites of *Rafflesia manillana* are on Luzon, particularly Mt. Makiling, Mt Banahaw. The species is also recorded from Mt. Isarog (also Luzon) and Samar and Leyte.	Tan et al. (1986); Meijer (1997); Barcelona & Fernando (2002); Fernando et al. (2004)
Strongylodon macrobotrys A. Gray Jade vine [Fabaceae]	T	First collected on Mt Makiling in 1854. Though widely cultivated, it is getting rare in the wild by over-collection of seeds.	Pancho (1983); Tan et al. (1986); Huang (1991); Fernando et al. (2004)
Medinilla magnifica Lindley Kapa-kapa [Melastomataceae]	T	Becoming exceedingly rare due to over-collection and forest destruction; first discovered on Mt. Makiling in 1850.	Pancho (1983); Tan et al (1986); Regalado (1995); Fernando et al. (2004)
Podocarpus rotundus de Laub. [Podocarpaceae]	R	Known in the Philippines only from the summit of Mt. Banahaw at 2,200 m (also on Mt. Beratus in Borneo).	De Laubenfels (1978, 1988)

Table 6.6. Algae in fishponds and fishpens of the Laguna Lake Basin (Martinez 1978, 1983).

Division	Number of Species
Chlorophyta	51
Chrysophyta	51
Cyanophyta	24
Euglenophyta	27
Pyrrophyta	3
Xanthophyta	1
Total Species	**157**

of all threatened species of birds and restricted range species which are known to occur in the Luzon biogeographic region (Table 6.7). The level of knowledge on birds in this region is more advanced owing to the work done at UPLB. However, there is still a need to look into other fauna which are poorly known.

6.3.4 Fauna - Mammals

Relatively the mammalian fauna of the LLB as a whole is not as impressive as that of other Southeast Asian marshlands. There are no large herbivores or carnivores that dwell on this lake basin. The largest of mammals found in the vicinity of this lake are the Philippine Deer (*Cervus marianus*) and the Philippine Warty Pig (*Sus philippensis*), which are found in Mt. Makiling and Mt. Banahaw protected areas. However, the most diverse of mammalian group are the bats and rodents. Of the total 42 species of mammals recorded in the lake basin, more than half (57 percent) are bats (24 species) and 26 percent are rodents (11 species). Bats are mostly small species, but three species are considered large fruitbats. These are: Golden Crown Giant Fruitbat (*Acerodon jubatus*), Giant Flying Fox (*Pteropus vampyrus*), and Philippine White-winged Flying Fox (*Pteropus leucopterus*). The endemic Luzon Pygmy Fruit Bat (*Otopteropus cartilagonodus*) may be present at higher elevations on Mt. Makiling. All giant fruitbats in the Philippines are threatened species. Among the rodents, the largest species are the two species of Cloud Rats, namely, Slender-tail Cloud Rat (*Phloeomys cumingi*) and the Pallid Slender-tail Cloud Rat (*Phloeomys pallidus*). These species of cat-size rodents are relatively big compared to the usual rats found in the Philippines. They are also endemic and vulnerable (Table 6.8).

A number of mammals in the vicinity of Laguna de Bay have been reported pests to agricultural crops. These include bats, rats, and civet cats. Among the rodent group, the Oriental House Rat (*Rattus tanezumi*), Polynesian Rat (*Rattus exulans*), and Malayan Ricefield Rat (*Rattus argentiventer*) are major pests to rice, coconut, corn, and pineapple. Small fruitbats, namely, Short-nose Fruitbat (*Cynopterus brachyotis*), Jagor's Fruitbat (*Ptenochirus jagori*), Common Rousette Bat (*Rousettus amplexicaudatus*), and the Long-tongued Fruitbat (*Macroglossus minimus*) are major pests to fruit crops such as Lanzones (*Lansium domesticum*), Rambutan (*Nephelium sp.*), and Star-apple (*Chrysophylum

Table 6.7. Annotated list of threatened (T) and restricted-range (R) birds recorded within the Laguna Lake Basin (after Mallari et al. 2001).

Species	Conservation Status	Notes
Gorsachius goisagi Japanese Night-heron	T	A specimen was collected at Pakil in 1971.
Egretta eulophotes Chinese Egret	T	Recorded from the International Rice Research Institute at Los Baños, on the lower slopes of Mt. Makiling.
Pithecophaga jefferyi Philippine Eagle	T	One was caught alive in 1989 at Sariaya on Mt. Banahaw.
Spizaetus philippensis Philippine Hawk-eagle	T	Seen on Mt. Makiling in the 1980s; Specimens were collected at Diman in 1969 and 1972, and at Saray in 1974, and it was seen during a survey in the UP Land Grant, Pakil in 1992.
Turnix ocellata Spotted Buttonquail	R	Seen during a survey of the UP Land Grant at Pakil in 1992.
Turnix worcesteri Worcester's Buttonquail	RT	Specimens were collected at Pangil in 1984.
Gallicolumba luzonica Luzon Bleeding-heart	R	Found to be locally common on Mt. Makiling in the 1990s; Specimens were collected at Balian in 1977, and it was seen during a survey of the UP Land Grant, Pakil in 1992.
Ptilinopus marchei Flame-breasted Fruit-dove	RT	Specimens have been collected in montane forest on Mt. Banahaw, and it was found to be uncommon and observed singly there in 1995.
Ptilinopus merrilli Cream-bellied Fruit-dove	R	Seen on Mt. Makiling in the 1980s; Specimens were collected at Balian in 1977; Specimens were collected at Lucban, near Mt. Banahaw, in the early 20th century.
Cacatua haematuropygia Philippine Cockatoo	T	Specimens were collected near Mt. Makiling at Calamba and Calauan in the 19th century, but it is almost certainly now extinct in this area; Specimens were collected at Calaguan, Dolores (presumed to be the city or adjacent area south of Laguna) and Quezon in the 19th and early 20th centuries, but it is presumably now extinct in this area.
Phaenicophaeus superciliosus Red-crested Malkoha	R	Regularly recorded on Mt. Makiling in the 1980s and 1990s; Specimens were collected at Balian in 1977, and it was seen in UP Land Grant, Pakil during a survey in 1992; Specimens were collected at Malicboy, near Mt. Banahaw, in the early 20th century.
Phaenicophaeus cumingi Scale-feathered Malkoha	R	Regularly recorded on Mt. Makiling in the 1980s and 1990s; Specimens were collected at Balian in 1977, and it was seen in UP Land Grant, Pakil during a survey in 1992; Specimens were collected at Lucban, near Mt. Banahaw, in the early 20th century.
Centropus unirufus Rufous Coucal	R	Specimens were collected at Balian in 1977, and it was seen in the UP Land Grant, Pakil during a survey in 1992.

Table 6.7. *Continued...*

Species	Conservation Status	Notes
Bubo philippensis Philippine Eagle-owl	T	Seen on Mt. Makiling in the 1980s and 1990s; A specimen was collected at Balian in 1960, it was recorded in the U.P. Land Grant, Real, in the 1980s, and it was seen at Amiakan in the U.P. Land Grant, Pakil during a survey in 1992; A specimen was collected near this IBA at Calauan in the late 19th century.
Ceyx melanurus Philippine Kingfisher	T	Recorded on Mt. Makiling in the early 20th century; Specimens were collected at Pakil and Balian in the 1960s and Diman in the 1970s, and it was recorded in the U.P. Land Grant, Real in 1990.
Penelopides manillae Luzon Hornbill	R	Recorded on Mt. Makiling in the 1990s, but local people report that their numbers have declined; Seen in UP Land Grant, Pakil during a survey in 1992.
Pitta kochi Whiskered Pitta	RT	Recorded at Balian in 1964.
Coracina coerulescens Blackish Cuckoo-shrike	R	Recorded on Mt. Makiling in the 1990s; Seen in the UP Land Grant, Pakil during a survey in 1992.
Napothera rabori Rabor's Wren-babbler	R	Specimens were collected at Saray and Balian in the 1970s, and it was observed during a survey of the U.P. Land Grant, Pakil in 1992.
Zoothera cinerea Ashy Thrush	RT	Recorded on Mt. Makiling by many observers in the 1980s and 1990s; Recorded on Mt. Banahaw in 1976.
Stachyris whiteheadi Chestnut-faced Babbler	R	Seen on Mt. Banahaw in the 1990s.
Stachyris dennistouni Golden-crowned Babbler	R	Specimens were collected on Mt. Makiling in 1915, and it was seen there in the 1980s; Specimens were collected at Balian in 1977.
Acrocephalus sorghophilus Streaked Reed-warbler	T	Specimens were collected at Pakil in 1971.
Orthotomus derbianus Grey-backed Tailorbird	R	Found to be common on Mt. Makiling in the 1980s and 1990s; Specimens were collected at Pakil in 1971, and it was seen in the U.P. Land Grant, Pakil during a survey in 1992.
Muscicapa randi Ashy-breasted Flycatcher	RT	Specimens were collected at Diman in 1970, and it was seen at Amiakan in the U.P. Land Grant, Pakil in 1992.
Hypothymis coelestis Celestial Monarch	RT	A specimen was collected at Pakil in 1983.
Cyornis herioti Blue-breasted Flycatcher	R	Seen on Mt Makiling in the 1990s.
Pachycephala albiventris Green-backed Whistler	R	Recorded on Mt Makiling; Seen on Mt. Banahaw in the 1990s.
Erythrura viridifacies Green-faced Parrotfinch	RT	Specimens were collected at Los Baños, on the lower slopes of Mt. Makiling, in 1920.

Table 6.8. Mammals of the Laguna Lake Basin.

Species	Introduced	Resident	Endemic
A. Family: Soricidae - Shrews			
Crocidura grayi			x
Suncus murinus		x	
B. Family: Pteropodidae - Fruitbats			
Acerodon jubatus			x
Cynopterus brachyotis		x	
Eonycteris robusta			x
Haplonycteris fisheri			x
Macroglossus minimus		x	
Otopteropus cartilagonodus			x
Pteropus vampyrus		x	
Pteropus leucopterus			x
Ptenochirus jagori			x
Rousettus amplexicaudatus		x	
C. Family: Emballonuridae - Sheath-tailed Bats			
Emballonura alecto		x	
Saccolaimus saccolaimus		x	
Taphozous melanopogon		x	
D. Family: Rhinolophidae- Noseleaf Bats			
Hipposideros diadema		x	
Hipposideros obscurus			x
Hipposideros pygmaeus			x
Rhinolophus arcuatus		x	
Rhinolophus rufus			x
Rhinolophus subrufus			x
E. Family: Vespertilionidae - Evening Bats			
Miniopterus schreibersi		x	
Myotis horsefieldi		x	
Scotophilus kuhlii		x	
Tylonycteris pachypus		x	
F. Family: Molossidae - Free-tailed Bats			
Chaerophon plicata		x	
G. Family: Cercopethicidae - Monkeys			
Macaca fascicularis		x	
H. Family: Muridae - Mice and Rats			
Abditomys latidens			x
Chrotomys mindorensis			x
Mus musculus	x		
Phloeomys cumingi			x
Phloeomys pallidus			x
Rattus argentiventer		x	
Rattus everetti			x

Table 6.8. *Continued...*

Species	Introduced	Resident	Endemic
Rattus exulans		x	
Rattus norvegicus	x		
Rattus tanezumi		x	
Tryphomys adustus			x
I. Family: Viverridae - Civet Cats			
Paradoxurus hermaphroditus		x	
Viverra tangalunga		x	
J. Family: Suidae - Wild Pigs			
Sus philippensis			x
K. Family: Cervidae - Deer			
Cervus marianus			x
Total = 42 Species	**2**	**21**	**19**

cainito). The Palm Civet Cat (*Paradoxurus hermaphroditus*) is an incidental pest to poultry and coffee plantation.

Two species of rodents could have been introduced with the advent of shipping. These species are the Norway Rat (*Rattus norvegicus*) and House Mouse (*Mus musculus*). Both species are associated with urban areas and human habitations. They are considered major pest to stored products and homes. There are also bats, although they do not damage crops, are considered nuisance animals in homes and public buildings. The Yellow House Bat (*Scotophilus kuhlii*) and Pouched Tomb Bat (*Saccolaimus saccolaimus*) roost in the ceilings of old buildings such as schools, churches, municipal halls, and old style houses. The bat's urine and excreta accumulated in the ceilings causes its deterioration and the foul odor emanating from the ceiling disturbs the school children, workers, parishioners, and homeowners.

The other insectivorous mammals that are beneficial to farmers include the Common House Shrew (*Suncus murinus*), and bats belonging to the various genera such as *Hipposideros, Miniopterus, Myotis, Rhinolophus*, and *Tylonycteris*. These bats feed on insects that infest crops, such as rice, corn, coconuts, and fruit trees, such as mangoes, oranges, pomelo, and others.

Threatened and poorly-known endemic threatened mammals recorded in the area include the Luzon Broad-toothed Rat (*Abditomys latidens*), Lowland Striped Shrew-rat (*Chrotomys mindorensis*), Northern Luzon Giant Cloud Rat (*Phloeomys pallidus*), and Luzon Short-nosed Rat (*Tryphomys adustus*). Large flying foxes *Pteropus* and *Acerodon spp.* have been observed flying over the forest canopy. The UP Land Grant in Pakil and Real is an important stronghold for various lowland rat species, civets, and fruitbats. It also supports heavily hunted large mammals, such as Philippine Warty Pig (*Sus philippensis*) and Long-tailed Macaque (*Macaca fascicularis*). Endemic mammals have been recorded on Mt. Banahaw-San Cristobal, including the Philippine Pygmy Fruit Bat (*Haplonycteris fischeri*), Luzon Pygmy Fruit Bat (*Otopteropus cartilagonodus*), Small Luzon Forest Mouse (*Apomys microdon*), and the Philippine Warty Pig (*Sus philippensis*).

6.3.5 Fauna – Reptiles

A total of 52 species of reptiles have been recorded in LLB. The majority of them are endemic (27 species), 23 species are residents, one introduced species, and one extirpated species (Table 6.9). The only species no longer found in Laguna de Bay but was recorded as late as 1955 (UPLB Museum of Natural History) based on juvenile specimens collected in Bay, Laguna, is the Philippine Crocodile (*Crocodylus mindorensis*). Philippine Crocodile could have been extirpated in Laguna de Bay due to over-hunting. The only introduced reptilian species is the Chinese Soft-shelled Turtle (*Pelodiscus sinensis*). This species is a current introduction brought about by pet trade during the late 1980s. Release and escapees could have been the cause of its introduction into the lake. This species has been collected in rivers and creeks in Sinoloan, Famy, and Nagcarlan towns of Laguna, as well as in Tanay, Antipolo, Morong, and Binangonan towns of Rizal.

The resident species of reptiles comprise 44 percent (23) of the total reptilian inventory records of Laguna de Bay and its watershed areas. Of this number, 1 is a turtle, Malayan Box Turtle (*Coura amboinensis*), 9 lizards, and 13 snakes. Two species are included in CITES (Convention on International

Table 6.9. Reptiles of the Laguna Lake Basin.

Species	Introduced	Extirpated	Resident	Endemic
A. Family: Trionychidae - Soft-shelled Turtles				
Pelodiscus sinensis	x			
B. Family: Crocodylidae - Crocodiles				
Crocodylus mindorensis		x		
C. Family: Emydidae - Box Turtles				
Coura amboinensis			x	
D. Family: Gekkonidae - Geckoes				
Cosymbotus platyurus			x	
Cyrtodactylus philippinicus				x
Gehyra mutilata			x	
Gekko gecko			x	
Hemidactylus frenatus			x	
Pseudogekko compressicorpus				x
E. Family: Agamidae - Angle-head Lizards				
Calotes marmoratus				x
Draco spilopterus				x
Gonycephalus semperi				x
F. Family: Scincidae - Skinks				
Brachymeles bonitae				x
Brachymeles gracilis				x
Lamprolepis smaragdina			x	
Lipinia pulchelum				x
Mabuya multicarinata			x	
Mabuya multifasciata			x	
Otosaurus cumingi				x
Sphenomorphus coxi				x
Sphenomorphus decipiens				x
Sphenomorphus jagori				x
Sphenomorphus steeri				x
Tropidophorus grayi			x	
G. Family: Varanidae - Monitor Lizards				
Varanus olivaceous grayi				x
Varanus salvator			x	
H. Family: Typhlopidae - Blind Snakes				
Rampotyphlops braminus			x	
Typhlops luzonensis				x
I. Family: Pythonidae - Python				
Python reticulatus			x	
J. Family: Acrochordidae - Elephant-trunk Snakes				
Acrochordus granulatus			x	
K. Family: Colubridae - Non-venomous Snakes				
Ahaetulla prasina			x	
Boiga dendrophila			x	

Table 6.9. *Continued...*

Species	Introduced	Extirpated	Resident	Endemic
Calamaria gervaisi				x
Cerebus rynchops				x
Chrysopelea paradisi			x	
Cyclocorus lineatus				x
Cyclocorus nuchalis				x
Dendrelaphis caudolineatus			x	
Dendrelaphis pictus			x	
Elaphe erythrura			x	
Gonyosoma oxycephala				x
Lycodon aulicus			x	
Oligodon ancorus				x
Oligodon modesdum				x
Psammodynastes pulverulentus			x	
Rhadophis chrysarga				x
Zaocys luzonensis				x
L. Family: Elapidae - Cobras and Allies				
Calliophis calligaster				x
Naja philippinensis				x
Ophiophagus Hannah			x	
M. Family: Viperidae - Vipers				
Trimeresurus flavomaculatus				x
Tropidolaemus wagleri			x	
Total = 52	**1**	**1**	**23**	**27**

Trade in Endangered Species of Wild Fauna and Flora) Appendix II on limited trade, these are: the Malayan Monitor Lizard (*Varanus salvator*) and the Reticulated Python (*Python reticulatus*). Two venomous resident species of snakes have been recorded on Mt. Makiling namely, King Cobra (*Ophiophagus hannah*) and Wagler's Pit Viper (*Tropidolaemus wagleri*). The most widespread estuarine snake in Southeast Asia, the Elephant-trunk Snake (*Acrochordus granulatus*), is found in Laguna de Bay and is considered pest to fishpen fishery inside the lake proper.

Majority of reptilian species in LLB are endemic to the Philippines, comprising 52 percent (27) of the total species. Of this number, 14 species are lizards and 13 species are snakes. One species of endemic lizard, the Gray Monitor Lizard (*Varanus olivaceus grayi*), is included in the list of endangered species of wildlife in the Philippines. The endemic list also included two venomous species of snakes, namely, the Philippine Cobra (*Naja philipinensis*) and the Philippine Pit Viper (*Trimeresurus flavomaculatus*). The Philippine Cobra, although it is included as vulnerable species, usually found in ricefield areas, is considered an incidental pest (several records of this snake entering houses) and are usually killed due to its potent venom. The Philippine Pit Viper, however, is a forest species and encounter with this snake is very rare.

Most of the reptilian fauna of the lake basin are not in anyway endangered or threatened, for as long as the forested areas of mountains that serve as the watershed of the lake remain intact. Most of the reptiles are lizards, and majority of them are insectivorous species, except the two monitor lizards, the Malayan Monitor Lizard, which is a carnivore and a scavenger, and the Gray Monitor Lizard, which is an herbivore, feeding mostly on forest fruits. The latter is the only herbivorous monitor lizard among the carnivorous family: Varanidae. This makes the Gray Monitor Lizard vulnerable to deforestation as forest fruit-bearing trees are seasonal. Deforestation by slash and burn method could wipe out the feeding trees of this endemic varanid lizard from the Philippines. Snakes are not at present threatened, but the conversion of their habitats into agricultural areas and human habitations have increased the probability of conflict.

Table 6.10. Amphibians of the Laguna Lake Basin.

Species	Introduced	Resident	Endemic
A. Family: Bufonidae - True Toads			
Bufo marinus	x		
B. Family : Ranidae - True Frogs			
Haplobatrachus rugolosus	x		
Limnonectes macrocephala			x
Occidozyga laevis		x	
Platymantis banahaw			x
Platymantis corrogatus			x
Platymantis dorsalis			x
Platymantis guentheri			x
Platymantis hazelae			x
Platymantis luzoniensis			x
Platymantis mimulus			x
Platymantis subterrestris			x
Rana cancrivora		x	
Rana catesbiana	x		
Rana erythraea		x	
Rana everetti			x
Rana limnocharis vittigera		x	
Rana signata		x	
Rana woodworthi			x
C. Family: Rhacophoridae - Tree Frogs			
Philautus surdus			x
Polypedates leucomystax		x	
Rhacophorus pardalis		x	
D. Family: Microhylidae - Narrow-mouthed Frogs			
Kaloula conjuncta			x
Kaloula picta			x
Kaloula rigida		x	
Total = 25	**3**	**8**	**14**

6.3.6 Fauna - Amphibians

A total of 25 species of Anuran Amphibians have been recorded in Laguna de Bay and the surrounding watershed areas. This consisted of three (3) species that were introduced, seven (7) species considered resident, and fifteen (15) species are endemic to the Philippines. The diversity of frogs in this particular area is very high, and it is considered a separate biodiversity area for amphibians and reptiles (Table 6.10).

The three species of introduced amphibians are the following: Marine Toad *(Bufo marinus*), American Bullfrog (*Rana catesbiana*), and Taiwanese Bullfrog (*Haplobatrachus rugolosus*). The Marine Toad was introduced as a bio-control agent against rodent pest in sugar cane fields of Canlubang, Laguna, in 1937 by the Bureau of Plant Industry of the Philippine Commonwealth government. The two other introduced species of bullfrogs were mainly for food. They were introduced in late 1970 by private individuals in Tanay, Rizal, one of the surrounding municipalities of the lake basin. The bullfrogs were raised inside enclosures, but through the years escapes were inevitable. Nonetheless, continued collection by local people of these frogs for food held the population of these introduced frogs in check. The Marine Toad, however, has spread all over Luzon and surrounding islands. It has replaced the native Philippine Ricefield Frog (*Rana limnocharis vittigera*) from most of its ricefield habitats. The Philippine Ricefield Frog is holding on in areas with permanent bodies of water such as lakes and freshwater swamps. Population of Marine Toad at present is held in-check through continuous collection as laboratory animal for dissection.

The seven resident species can be found in the LLB and also in forested areas near the lake such as Mt. Makiling and Mt. Banahaw. Of the seven, four species namely, *Rana cancrivora, Rana erythraea, Rana limnocharis,* and *Occidozyga laevis,* are found and are breeding in the lake. The three other species namely, *Rana signata*, *Polypedates leucomystax*, and *Rhacophorus pardalis* are limited to forested areas.

The mountains around the lake exhibit one of the most diverse anuran fauna of forest frogs belonging to the genus *Platymantis.* Of the 15 endemic species of frogs, more than half belong to the genus *Platymantis,* namely, *P. banahao, P. corrogatus, P. dorsalis, P. guentheri, P. hazelae, P. luzoniensis, P. mimulus,* and *P. subterrestris.* Also, Mt. Makiling, one of the mountains around Laguna de Bay, is the type locality of an endemic ranid frog, Woodworth's Frog (*Rana woodworthi*). The rest of the endemic frog species include Luzon Fanged Frog (*Limnonectes macrocephala),* Everett's Frog (*Rana everetti*), Smooth-skinned Tree Frog (*Philautus surdus*), Luzon Narrow-mouthed Frog (*Kaloula rigida*), Truncated-toed Narrow-mouthed Frog (*Kaloula conjuncta*), and Slender-toed Narrow-mouthed Frog (*Kaloula picta*).

6.3.7 Fauna – Fishes, Shrimps, and Mollusks

About 14 species of fish belonging to 12 families are indigenous to the lake; these figures include resident and migratory species (see Table 4.4). About 19 species have been introduced (exotics) into the lake either through direct stocking (e.g., species of tilapia and carps) or escapes from aquaculture (e.g., catfish, janitor fish). Many of the introduced species have already established populations in the lake.

Three species of shrimps have been recorded from the lake, viz., *Macrobrachium lanceifons*, *Caridina gracilirostris*, and *Penaeus affinis,* a salt-water migrant. The latter two species are already rare.

About 10 species of mollusks have also been recorded to occur in the lake (Table 6.11). Many of these are commercially important in duck raising, and at least two species are also harvested for human consumption, viz., Kohol *(Pila luzonica)* and Tulya (*Corbicula manillensis).*

6.4 Drivers of Change

Introduction of exotic species of fish in the lake, the destructive harvesting methods, and chemical pollution from adjacent factories, and overall industrialization are among the factors contributory to the conversion of natural habitats and the extirpation of many of the indigenous species in the lake basin. Some species have already been completely extirpated from the lake basin, e.g., the Philippine Duck (*Anas luzonica*) in the 1920s and the Philippine Crocodile (*Crocodylus mindorensis*) in the 1950s.

The introduction of Golden Snail *(Pomacea canaliculata)* into the country has become a serious environmental problem. The species is now a major pest in ricefields in the lake basin and across the whole of Luzon Island. It has now replaced *Pila conica* the dominant pilid snail in Philippine freshwaters and is seriously threatening *Pila luzonica,* previously common in the lake.

Table 5.11. Freshwater mollusks in the Laguna Lake Basin (Alonte 1930; Arriola and Villaluz 1939).

Family	Species	Common Names
Ampullariidae	*Pila luzonica*	kohol
	(=Ampularia luzonica)	
Lymnaeidae	*Amphipeplea luzonica*	
	Planorbis philippinarum	
Viviparidae	*Vivipara angularis*	Susong pangpang
Melaniidae	*Melania asperata*	Susong buele
	Melania blatta	
	Melania lateritia	Susong buele
	Melania pantherina	Susong buele
	Melania scabra	Susong buele
	Corbicula manillensis	Tulya

References

Aguilar, N.O., J.D.C. Siponco, & F.C. Pitargue, Jr., 1990: Species composition and seasonal variation in frequency, density, biomass and rate of production of some aquatic macrophytes at the southern portion of Laguna de Bay. *UP Los Baños Journal*, **1(1)**, 85-96.

Alonte, F.H., 1930: Biology of *Vivipara angularis* Muller, a common fresh-water snail in Laguna de Bay. *Philippine Agriculturist*, **19(5)**, 307-321.

Ashton, P.S., 1997: Before the memory fades: some notes on the indigenous forests of the Philippines. *Sandakania*, **9**, 1-19.

Brown, W.H., 1919: *The Vegetation of Philippine Mountains.* Bureau of Science Publication No. 13, Manila, 434 pp.

Cox, R., 1988: *The Conservation Status of Biological Resources in the Philippines*. IUCN, Gland, Switzerland.

De Laubenfels, D.J., 1978: The taxonomy of Philippine Coniferae and Taxaceae. *Kalikasan, Philippine Journal of Biology,* **7(2),** 117-152.

De Laubenfels, D.J., 1988: Coniferales. *Flora Malesiana*, **Series I**, **10**, 337-453.

Delmendo, M.N. and R.N. Bustillo, 1969: *Studies on Fish Population of Laguna de Bay.* FAO Indo-Pacific Fisheries Council Occasional Paper 69/12.

DENR-UNEP, 1997: *Philippine Biodiversity: An Assessment and Action Plan.* Department of Environment and Natural Resources and the United Nations Environment Programme. Bookmark, Inc., Makati, Philippines, 298 pp.

DENR-PAWB, CI, and UP-CIDS, 2002: *Philippine Biodiversity Conservation Priorities: A Second Iteration of the National Biodiversity Strategy and Action Plan*. Department of Environment and Natural Resources, Conservation International –Philippines, and U.P. Center for Integrated Development Studies, 113 pp.

Fernando, E.S., B.Y. Sun, M.H. Suh, H.Y. Kong, and K.S. Koh, 2004**:** *Flowering Plants and Ferns of Mt Makiling.* 368p. ASEAN-Korea Environmental Cooperation Unit, Seoul National University, Korea. ISBN 89-955147-1-X 96480.

Huang, S.H., 1991: *Strongylodon (Leguminosae-Erythrinae), A Revision of the Genus*. Wageningen Agricultural University Papers 90-8. Wageningen Agricultural University, 69 pp.

Madulid, D.A., 1993: *Field Survey of Critical Plant Sites in the Philippines.* Final Report. WWF Debt-for-Nature Swap Project No. 89.07, Philippine National Museum, Manila, Philippines.

Mallari, N.A.D., B.R. Tabaranza, Jr., and M.J. Crosby, 2001: *Key Conservation Sites in the Philippines.* Haribon Foundation and BirdLife International. Bookmark, Inc., Makati, Philippines, 485 pp.

Martinez, M.R., 1978: Taxonomy and ecology of alage in fishponds and fishpens of Laguna, de Bay, Philippines. In: *Proceedings in Life Sciences, "Microbial Ecology"*, M.W. Loutit and J.A.R. Miles (eds.). Springer-Verlag, Berlin, pp. 76-79.

Meijer, W., 1997: *Rafflesiaceae. Flora Malesiana*, **Series I, 13,** 1-42.

Mercene, E.C. and M.P. Nasino, 1991: Survey of shrimp catch distribution by fishing gear in Laguna de Bay. *Philippine Agriculturist* **74(2)**, 265-274.

Merrill, E.D. 1923-1926: *An Enumeration of Philippine Flowering Plants.* 4 vols. Bureau of Printing, Manila.

Pacardo, E.P., 1993: Agroecosystem analysis of Laguna Lake, Philippines. In: *Laguna Lake Basin, Philippines: Problems and Opportunities*, P.G. Sly (ed.). Environment and Resource Management Project, University of the Philippines – Los Baños and Dalhousie University, Halifax, pp. 212-222.

Pancho, J.V., 1972: Aquatic angiosperms of Laguna de Bay, Luzon. *Kalikasan, Philippine Journal of Biology*, **1**, 94-120.

Pancho, J.V., 1983: Vascular Flora of Mount Makiling and Vicinity (Luzon: Philippines) Part 1. *Kalikasan, The Philippine Journal of Biology*, Supplement Number 1, Kalikasan Press, 476 pp.

Regalado, J.C., 1995: Revision of Philippine *Medinilla* (Melastomataceae). *Blumea*, **40**, 113-193.

Whitford, H.N., 1911: The forests of the Philippines. *Philippine Bureau of Forestry Bulletin*, No. 10, 113 pp.

Sly, P.G., 1993: Major environmental problems in Laguna Lake, Philippines: A summary and synthesis. In: *Laguna Lake Basin, Philippines: Problems and Opportunities*, P.G. Sly (ed.). Environment and Resource Management Project, University of the Philippines – Los Baños & Dalhousie University, Halifax, pp. 304-330.

Tan, B.C., E.S. Fernando, and J.P. Rojo, 1986: An updated list of endangered Philippine plants. *Yushania (Taiwan)*, **3(2)**, 1-5. [Reprinted in *PESAM Bulletin (Philippines)*, **7(1)**, 8-9, 12 (1987)].

7

Climate Change

RODEL D. LASCO, FLORENCIA B. PULHIN, MARIBEC A. CAMPOS,
JOYCELINE A. GOCO

CONTENTS

7.1 Introduction

Climate change is one of the most alarming problems facing humanity today. As scientists and policy makers at the global arena grapple with this issue, developing countries are also sorting out the implications of climatic shifts to their people, economy, and environment.

The Earth's surface temperature this century is as warm or warmer than any century since at least 1400 AD (Nicholls et al. 1996). By the year 2100, the average surface temperature is projected to increase by 1.4-5.8ºC while sea level is expected to rise by 9-88 cm (IPCC 2001). Greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), nitrous oxides (N_2O), and chlorofluorocarbons (CFCs) absorb thermal radiation emitted by the earth's surface. If more GHGs are emitted into the atmosphere they absorb more heat, which, in turn, could lead to a change in the world's climate.

Among the GHGs, CO_2 is the most abundant and is responsible for more than half the radiative forcing associated with the greenhouse effect (Watson et al. 2000; Schimell et al. 1995). Forest ecosystems play an important role in the climate change problem because they can both be sources and sinks of atmospheric CO_2. They can be managed to assimilate CO_2 via photosynthesis, and store carbon in biomass and in soil (Watson et al. 2000; Brown 1998; Brown et. al. 1996). Thus, any change in forest land cover could either positively or negatively affect the amount of CO_2 in the atmosphere.

Similarly, the agricultural sector could also exacerbate climate change. For example, paddy fields and livestock emit methane, one of the principal GHGs. On the other hand, any change in climate including extreme weather events will have a direct bearing on the growth and yield of crops and livestock. Consequently, the food security of the country may be threatened.

In the Philippines, the study of climate change and agriculture, food security, and natural resources is relatively young. In the last five years, a number of researches have been conducted focusing on the role of Philippine forests on climate change (e.g., Lasco and Pulhin 2000; Lasco and Pulhin 2001; Lasco et al. 2002). Similarly, the impacts of climate change on water resources and agricultural resources in the Philippines have been recently investigated (Lantin 1996, etc.).

In view of the threat posed by climate change, a comprehensive assessment of the LLB should look into the contribution of the basin either to exacerbate or mitigate the rise in GHG in the atmosphere. In addition, it will provide an analysis of local problems at the global scale. Because of resource constraints, the main focus of this assessment will be on the agricultural and land use change and forestry (LUCF) sectors.

This chapter attempts to provide answers to the following questions:

- What are the impacts of current activities in agriculture and LUCF sectors on greenhouse gas emissions and removals?
- What are the key drivers leading to increase/decrease in GHG emissions and removals by sinks?
- How will climate change affect the natural resources of the LLB?
- What are the human responses to adapt to and mitigate climate change?
- What are the implications of future scenarios to climate change?

7.2 Contribution of the Agricultural and LUCF Sectors to National Emissions and Removals

7.2.1 The Agriculture Sector

The Philippines relies heavily on domestic agricultural production to support its burgeoning population. The sector accounts for 21 percent of Gross Domestic Product (GDP) and employs 46 percent of the total labor force (ADB 1998). Rice and corn are the primary staple crops. Of the total agricultural area of 129,000 km^2, 31 percent is devoted to rice while 21 percent is planted to corn.

Agriculture contributes to GHG emissions through various ways. For example, anaerobic decomposition of organic material in paddy fields and enteric fermentation of herbivores produce CH_4.

GHG emissions from the Philippine agricultural sector is significant, accounting for 33 percent of all non-LUCF emissions and second only to the energy sector. It has been estimated at 33 Mt of CO_2-equivalent was emitted in 1994 (Table 7.1). A related study based on 1990 data showed a slight lower emission levels. It will be noted that the leading cause of GHG emission is rice cultivation. This is because of irrigated rice fields which emit CH_4 at the rate of 2.3 kg ha^{-1} day^{-1} (230 kg km^{-2} day^{-1}).

7.2.2 The Land Use Change and Forestry (LUCF) Sector

When the Spanish colonizers first set foot in the Philippines in 1521, 90 percent of the country was covered with lush tropical rainforest (around 270,000 km^2 out of 300,00 km^2 total land area). By the year 1900, there were still 70 percent or 210,000 km^2 of forest cover (Garrity et al. 1993; Liu et al.

Table 7.1. GHG emissions from the Philippine agricultural sector.

Sub-Sector	CO2-equivalent Emissions (kt)	
	1994 GHG Emissions*	**1990 GHG Emissions****
Rice cultivation	13,364	11,899
Domestic livestock	10,498	8,703
Agricultural residue burning	581	422
Agricultural soils	8,680	5,676
Grassland burning	6	18
Total	**33,130**	**26,718**

*Philippines Initial National Communication 1999
**ADB 1998

1993). However, by 1996 there were only 61,000 km^2 (20 percent) of forest remaining (FMB 1997). Thus, in the last century alone, the Philippines lost 149,000 km^2 of tropical forests. The average deforestation rate from 1969 to 1973 was 1,700 km^2 per year (Forest Development Center 1987). For the past 20 years, it was about 1,900 to 2,000 km^2 per year (Revilla 1997). However, in the last few years it was estimated to be in the vicinity of 1,000 km^2 (Lasco and Pulhin 1998). The direct and indirect causes of deforestation include shifting cultivation, permanent agriculture, ranching, logging, fuel wood gathering, and charcoal making (Kummer 1990).

Forestlands are important sources of water for irrigation, hydroelectric power, industrial use, and household use. Philippine forests have extremely high floral and faunal diversity. They harbor 13,000 species of plants, which comprise 5 percent of the world's total of plant species (DENR/UNEP 1997). With continued deforestation, some species previously occurring in certain areas are now endangered or even extinct. In fact, the Philippines is one of the biodiversity "hot spots" of the world (McNeely et al. 1990).

They are also home to millions of inhabitants. There are about 20 million Filipinos living in upland watershed areas, half of whom are dependent on shifting cultivation for livelihood (Cruz and Zosa-Feranil 1987). Soil erosion and degradation are serious problems in the country where it is estimated that 83,000 km^2 out of 300,000 km^2 of land are severely eroded (EMB 1990).

Quantification of the contribution of the Philippine LUCF sector to GHG emissions and removals started as early as November 1991 (Francisco 1997). Since then, the estimates have been progressively updated in response to new methodologies as prescribed by the IPCC and the availability of new data. The most recent inventory is the 1994 inventory as contained in the 1999 Philippines' Initial National Communication.

Table 7.2 shows a comparison of the results of the 1994 inventory relative to two previous inventories using 1990 as base year. It will be noted that the LUCF sector turned from a huge net source of GHG to a slight sink in the latest inventory. Such dramatic shift in the LUCF is not unique to the Philippines. A recent analysis of the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat revealed that the LUCF estimates of Annex 1 countries have varied widely over the years (Ravindranath et al. 2000). This illustrates the importance of sources of information in the computation of the C budget of a country as part of its commitment under the UNFCCC to conduct national GHG inventory. The LUCF sector can turn from source to sink or vice-versa depending on the data used.

On the basis of the new data, GHG uptake/emissions were recalculated using the 1996 IPCC Revised Guidelines, the same method used in earlier inventories. A comparison of the results showed that the LUCF sector is a significant net sink (-107 Mt CO_2 equivalent) based on the 1997-98 land cover data. It is a much higher net sink compared to the 1994 inventory (-0.126 Mt CO_2 equivalent) (Table 7.3). The findings are also consistent with, although a little lower than, the previously performed calculation (142 Mt CO_2 equivalent).

Total LUCF sector carbon sequestration is a little higher than the total net GHG emission of the Philippines from all sources (101 Mt in 1994). This shows the importance of Philippine forests in climate change mitigation as they practically absorb all the fossil fuel emissions of the country.

Table 7.2. Total emissions from the LUCF sector of the Philippines (Gg CO_2 equivalent).

Source	1990 Inventory (1997 US Country Studies)	1990 Inventory (1998 ALGAS)	1994 Inventory (1999 Philippine Nat. Comm.)
Change in forests and biomass stocks	-48,654	2,622	-68,323
Forest and grassland conversion	120,738	80,069	68,197
Abandonment of managed lands	-1,331	-1,331	Not determined
Net emissions	70,753	81,360	-126
Total Philippine emissions	128,620	164,103	100,738
% of total Philippine emissions	55.01	49.58	-0.13

References: Francisco 1997; Murdiyarso 1996; ADB 1998; Philippines' Initial National Communication 1999.

Table 7.3. Comparison of results between the 1994, 1997-1998 inventories and this study.

Source	CO_2 Equivalent (kt)		
	1994 Inventory (Philippine Nat. Comm. 1999)	1997-98 Inventory (Lasco and Pulhin 2001)	1997-98 Inventory (this study)
Biomass growth	-111,000	-222,000	-218,000
Harvests	42,000	31,000	27,000
On site and off-site burning	36,000	23,000	43,000
Decay	33,000	23,000	40,000
Net absorption	-126	-142,000	-107,000

7.3 Overview of the IPCC GHG Inventory Methods

7.3.1 Agriculture Sector

Agricultural production activities contribute to GHG emissions. For example, rice paddy fields and animal husbandry contribute to methane concentration in the atmosphere. In the LLB, agriculture is the dominant land use accounting for 1,986.40 km^2 or more than 50 percent of the basin's total land area.

The IPCC method for the inventory of GHG emissions from agricultural activities deal with the following:

- Methane emissions from enteric fermentation and manure management systems;
- Methane emissions from rice cultivation;
- Release of non-CO_2 trace gases from savanna burning;
- Release of non-CO_2 trace gases from agricultural burning; and
- Trace gas emissions from agricultural soils.

7.3.1.1 Methane emissions from enteric fermentation and manure management systems

Methane from enteric fermentation is produced in herbivores as a by-product of the digestive process by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the blood stream. Both ruminant animals (e.g., cattle, sheep) and some non-ruminant animals (e.g., pigs, horses) produce methane, although ruminants are the largest source.

Methane from the management of animal manure occurs as the result of its decomposition under anaerobic conditions. These conditions often occur when a large number of animals are managed in a confined area (e.g., dairy farms, beef feedlots, and swine and poultry farms).

7.3.1.2 Methane emissions from rice cultivation

Anaerobic decomposition of organic material in flooded rice fields produces methane, which escapes to the atmosphere primarily by diffusive transport through the rice plants during the growing season. The parameters that affect methane emissions vary widely both spatially and temporally. At the current level of understanding, a reported range in methane emission levels for a country is more realistic than a single number.

7.3.1.3. Release of non-CO_2 trace gases from savanna burning

Savannas are tropical and subtropical formations with continuous grass coverage. The burning of savannas results in instantaneous emissions of carbon dioxide. However, because the vegetation regrows between the burning cycles, the carbon dioxide released to the atmosphere is reabsorbed during the next vegetation growth period. The burning of savannas also releases gases other than CO_2, including CH_4, carbon monoxide (CO), N_20, and oxides of nitrogen (NO_x).

7.3.1.4 Release of non-CO_2 trace gases from agricultural burning

Large quantities of agricultural residues are produced from farming systems worldwide. Burning of crop residues in the fields is a common agricultural practice in the Philippines. It has been estimated that as much as 40 percent of the residues produced in developing countries may be burned in fields. It is important to note that some crop residues are removed from the fields and burned as a source of energy.

7.3.1.5 Trace gas emissions from agricultural soils

Agricultural soils may emit or remove N_2O. It is possible to calculate N_2O emissions from agricultural systems including: 1) direct emissions of N_2O from agricultural soils (including glasshouse systems farming and excluding effects of grazing animals); 2) direct soil emissions of N_2O from animal production; and 3) indirect emissions of N_2O from nitrogen used in agriculture.

7.3.2 LUCF Sector

The role of forests and land use change in GHG emissions and removals vary depending on the situation of a specific region. To determine the contribution of LUCF, the IPCC has developed guidelines for the national inventory of GHG emitted and absorbed by forest land (Houghton et al. 1996). This is to help standardize the methods of all Parties to the UNFCCC in the conduct of their GHG inventories. The key parts of the GHG inventory for the LUCF sector are (Figure 7.1):

- Changes in forest and other woody biomass stocks
- Forests and grassland conversion
- Abandonment of managed lands

The activity data most commonly needed in all worksheets are those pertaining to area of forest/landuse, growth/ conversion rates, biomass stocks, carbon fraction/content, and harvests/extraction rates.

7.3.2.1. Changes in forest and other woody biomass stocks

Biomass is about 50 percent carbon by dry weight. The IPCC method calculates the net uptake of CO_2 by estimating the annual increment of biomass as well as harvests in natural forests and tree plantations (Houghton et al. 1997). Wood harvested for fuelwood, commercial timber, and other uses is also estimated as significant quantities may be gathered informally for traditional fuelwood consumption.

The net carbon uptake due to these sources is then calculated. If the figure is positive then this counts as a removal of CO_2, and if the figure is negative, it counts as an emission.

7.3.2.2 Forests and grassland conversion

Forest conversion to permanent agriculture or pasture is a common activity in the Philippine uplands. Tropical forest clearing is usually accomplished by cutting undergrowth and felling trees followed by burning biomass on-site or as fuelwood. By this process some of the biomass is burned while some remains on the ground where it decays slowly. Of the burned material, a small fraction (5-10 percent) is converted to charcoal which resists decay for 100 years or more, and the remainder is released instantaneously into the atmosphere as CO_2. Carbon is also lost from the soils after conversion, particularly when the land is cultivated.

7.3.2.3. Abandonment of managed lands

This sub-module deals with net-CO_2 removals in biomass accumulation resulting from the abandonment of managed lands. Carbon accumulation on abandoned lands is sensitive to the type of natural ecosystem (forest or grasslands) which is regrowing. Therefore abandoned lands regrowing should be entered by type. When managed lands are abandoned, carbon may or may not reaccumulate on the land. Abandoned areas are therefore split into those which reaccumulate carbon and those which do not regrow or which continue to degrade. Only natural lands which are regrowing towards a natural state are included.

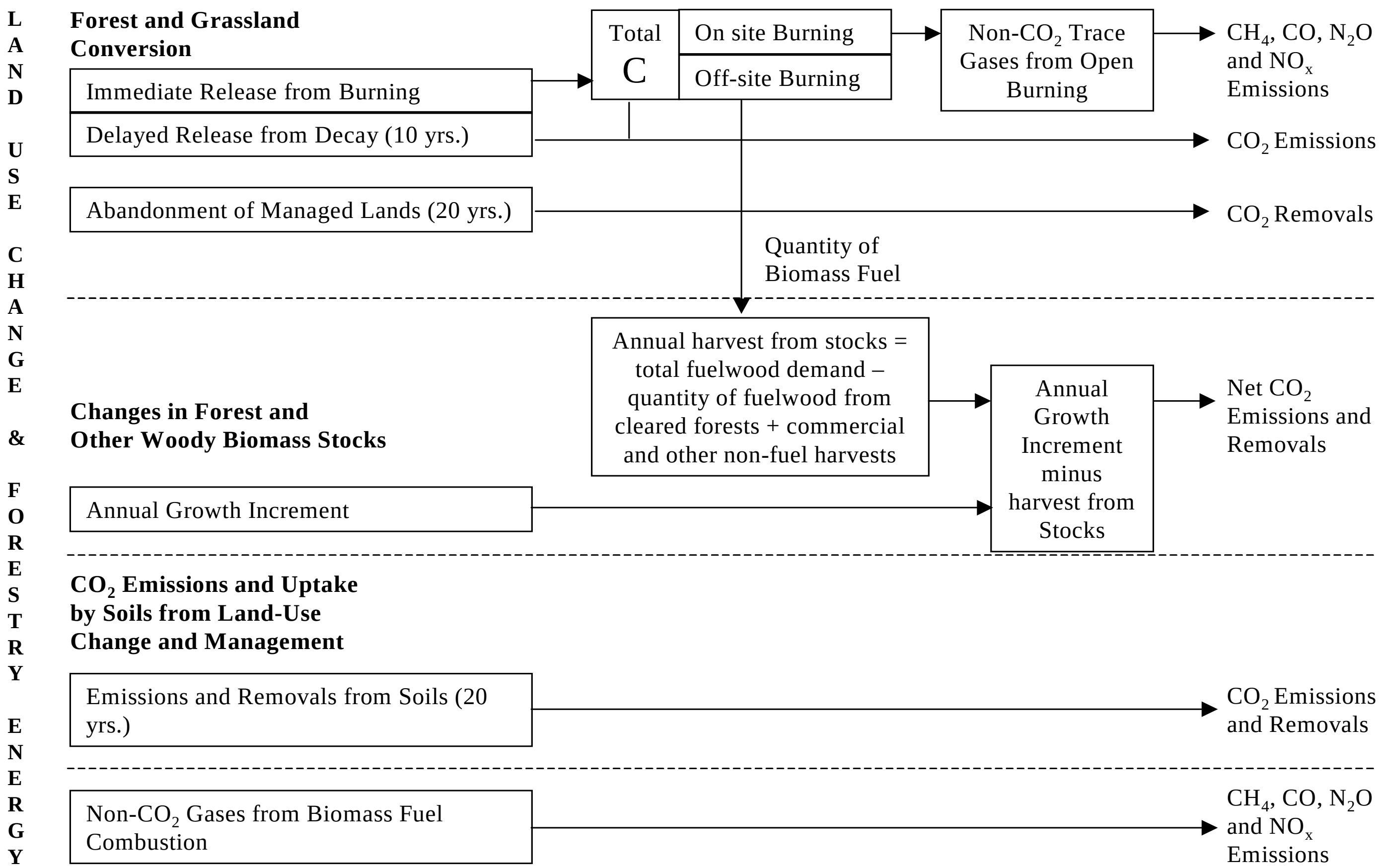

Figure 7.1. Overview of the IPCC GHG inventory method for the LUCF sector (Houghton et al. 1997).

7.4 GHG Inventory for the Base Year (2002)

7.4.1 Agriculture Sector

The LLB is basically an agricultural area. As of 2000, agricultural land utilization covers about 1,509.66 km^2 or 40 percent of the watershed's total land area of 3,813.12 km^2. The major agricultural crop grown in the area is rice. As of 1997, there are a total of 117,017 t of rice produced in the basin.

Agriculture contributes to emissions of greenhouse gases through a variety of processes. Methane is produced in herbivores as a by-product of enteric fermentation and through decomposition of manure under anaerobic conditions. Anaerobic decomposition of organic material in flooded rice fields produced methane, which escapes to the atmosphere primarily by transport through the rice plants. The burning of savannas results in emissions of CO_2 and CH_4, CO, N_2O, and NO_x. Burning of agricultural wastes in the field is a significant source of emissions of CH_4, CO, N_2O, and NO_x.

On the average, population growth rate is 2.3 percent. This means that the study area has to increase agricultural production for self-sufficiency and to meet the demand for industrialization. An increase in production, however, would lead to an increase in the emissions of GHGs.

The sources of GHGs are the following:

- Methane emissions from enteric fermentation and manure management systems;
- Methane emissions from rice cultivation;
- Release of non-CO_2 trace gases from savanna burning;
- Release of non-CO_2 trace gases from agricultural burning; and
- Trace gas emissions from agricultural soils

Emission coefficients

Default values of emissions factors for enteric fermentation and manure management were adopted from Gibbs and Johnson (1983) and Crutzen et al. (1996). In the study site, most of the animals are classified as nondairy, which are used to provide draft power and some milk. The emissions factors used in estimating CH_4 emissions are given in Table 7.4.

The emissions factors for rice under different water regimes were derived from the results of field experiments conducted by IRRI in Los Banos, Laguna and Philippine Rice Research Institute (PhilRice) in Muñoz, Nueva Ecija. Average methane emission across sites for irrigated conditions are 2.3 kg ha^{-1} day^{-1} (230 kg km^2-day^{-1}) while 0.40 kg ha-day^{-1} (40 kg km^2-day^{-1}) rainfed condition (Table 7.5).

In the case of savanna burning, factors used in the computation are based on the IPCC default value for Tropical Asia. There are about 406.45 km^2 of savanna (humid with annual rainfall >700 mm) in the study site which are burned once every three years. The emissions ratios used in calculating GHGs from savanna burning are shown in Table 7.6.

Table 7.4. Emission coefficients used to calculate methane emissions from livestock.

Animal Type	Enteric Fermentation (kg CH_4 head-day^{-1})	Manure Management (kg CH_4 head-day^{-1})
Carabao	56	3.00
Cattle	44	2.00
Hot	1	7.00
Goat	5	0.22

Table 7.5. Emissions coefficients for rice fields according to ecosystem.

Rice Ecosystem	Methane Emissions (kg CH_4 ha-day^{-1})	Data Source	Area Under Category (ha)
Irrigated	2.3	IRRI	1,961
Rainfed	0.4	IRRI	1.421

Rice and sugarcane are the two major crops grown in the study site which are subject to field burning. In computing the released gases from burning of these crops, the following IPCC default values are used:

- Fraction of biomass oxidized = 0.9 (for both crops)
- Carbon Content (fraction)
  Rice = 0.42
  Sugarcane = 0.45
- Nitrogen-Carbon Ratio
  Rice = 0.014
  Sugarcane = 0.02 (similar to maize)

The emissions of trace gases from soils are a result of microbial and chemical transformations. In estimating trace gas emissions from agricultural soils, the following sinks of N_2O are considered: mineral fertilizer application, crop residue incorporation, and the indirect emissions from atmospheric deposition of ammonia (NH_3) and other NO_x and leaching or runoff of N in soils.

It is estimated that for every kg of N applied as mineral fertilizer, 1.25 ± 1 percent is released to the atmosphere as N_2O. The amount of N excreted per head of livestock (Table 7.7) is derived from the IPCC value for Asia and the Far East (1966). For crop residues left in the field, it is assumed that the fraction of N is 0.015 kg N kg^{-1} dry biomass. An emission factor of 0.01 kg N_2O-N kg^{-1} is used to estimate the fraction of the N content of fertilizers which volatilize to the atmosphere as NH_3 and NO_x. About 30 percent of the fertilizer N in soils is lost through leaching or runoff. The amount of N_2O-N produced is estimated at 2.5 percent of the leached N.

Table 7.6. Emissions ratios for savanna burning calculations (IPCC 1995).

Compound	Emission Ratios
CH_4	10.44
CO	10.96
N_2O	11.51
NO_X	12.10

In the updated methodology, an additional source was included: N_2O emissions from animal waste management system (AWMS) (IPCC 1996). Only the number of animals are needed and the AWMS to estimate N_2O emissions. The amount of N excretion per head and per type of animal and the AWMS are in Table 7.7.

7.4.2 GHG Emissions and Removals from the LUCF Sector

Of the total basin area, forest lands occupy 730 km^2 of which only 190 km^2 are actually covered with forests. The rest (540 km^2) are mainly denuded lands with grass and annual crops.

The remaining forests are mainly secondary forests, with perhaps some remnants of the original old growth forest. They are increasingly under siege as demand for wood and other forest products soar in the heels of a rapidly rising population. Grassland areas are utilized for grazing. These places are dominated by cogon grass (*Imperata cylindrica*) whose immature shoots are good animal feeds. Some privately-owned grasslands inside alienable and disposable areas are also used for this purpose.

The LLB has the distinction of harboring the nearest intact forest reserve to Metro Manila, namely, the Makiling Forest Reserve (MFR). The reserve is a world-famous center for education and research hosting numerous national and international institutions. It also contains a rich array of plant species, comparable to old-growth forests in Southeast Asia (Luna et al. 1999).

GHG emissions from the LUCF sector due to anthropogenic activities include land use conversions and deforestation activities. These activities affect the amount of carbon in the atmosphere through biomass burning, decay, and carbon release from the soil. However, the LUCF sector becomes a sink of carbon when there is biomass growth of existing forest and non-forest stands, and biomass regrowth in abandoned lands.

7.4.2.1 Data inputs

Total carbon uptake of the LUCF sector represents the total amount of carbon absorbed by the LUCF sector due to biomass growth. The annual growth rates expressed in tons dry matter per hectare per year (t dm ha^{-1} yr^{-1}) of each land use type are derived from the values reported by Lasco et al. (1998, 1999, 2000), Kawahara (1981), and Kungu (1993). The values for fraction of carbon in the biomass are from the studies conducted by Lasco et al. (1998; 1999; 2000; 2001). The assumptions used in the GHG inventory of Laguna Lake Basin is presented in Table 6.8, and the annual growth rate and carbon content of each land use type used in this study are shown in Table 7.9.

LUCF sector emits carbon whenever biomass is removed through harvesting and land use conversion. Value for roundwood harvests is derived from the Forestry Statistics published by the DENR, while the fuelwood data is from the Food and Agriculture Organization (FAO). Since the value of the roundwood harvest is expressed as m^3, wood density is needed to convert it into biomass. Wood density value used for this study is 0.57 t dm m^{-3} because this is the recommended value for Asian broadleaf species (Brown 1997).

An expansion ratio of "3.0" is used because it is assumed that harvest production efficiency is 33 percent (Villarin et al. 1999). This means that for every ton of wood harvested, three tons of woody biomass are actually removed from the forests.

During conversion of forests to other land uses, biomass loss occurs. Volume of biomass loss depends on the initial and final use of the land. Much biomass is lost whenever a forested area is converted to grassland areas. Area converted annually is derived by examining the area for each land use for the two time periods. Biomass density values used in this

Table 7.7. Default values for N excretion and manure-N production in different AWMS.

Animal Type	N Excretion (kg N head-year^{-1})	Percent of Manure Production per AWMS		
		Liquid System	Solid Storage and Drylot	Pasture Range and Paddock
Cattle	40.0	0	83	17
Poultry	0.6	27	73	0
Goats	12.0	0	100	0
Swine	19.0	17	83	0
Carabao	40.0	0	99	1

Table 7.8. Assumptions used in GHG inventory (Lasco and Pulhin 2000).

Forest Land Use	Carbon Content of Biomass (%)	Total Above-ground Biomass (t ha^{-1})	Rate of Above-Ground Biomass Change (t ha^{-1} yr^{-1})	Sources of Data
Old-growth forest (OGF)	44.7 (Visayas)	OGF 446 in Visayas Mossy forest 272 in Luzon All others 50% of OGF	2.1 in Visayas	Lasco et al. 1999 Lasco et al. 2000; this study
Second-growth forest	43, 45 (Luzon) (Mean = 44)	279, 499 in Luzon 262 in Mindanao (Mean = 347)	7.81 in Luzon 5.2 in Mindanao (Mean = 6.5)	Lasco et al. 1999; this study Kawahara et al. 1981
Brushlands	45.3 for wood (Visayas)	65 in Visayas	9.4 in Visayas	Lasco et al. 1999
Grasslands	44.5 (Visayas)	29 in Visayas	9.4 in Visayas	Lasco et al. 1999
Agroforestry	45 *Gliricidia sepium*-based alley cropping (Luzon) 45 *Gmelina arborea* and cacao multistorey system (Luzon)	Multistorey system (Luzon): 236 Alley cropping (Luzon): 68 Fallow system (Visayas): 32 (Mean 112)	Improved fallow (Visayas): 6.0	Lasco et al. 1998a, b Kungu 1993

Table 7.9. Annual growth rate and carbon content of various land uses (Lasco and Pulhin 2000).

Land Use	Annual Growth Rate	Carbon Content
Old Growth	2.10	0.45
Residual	6.50	0.44
Upland farms	6.00	0.45
Brushland	9.40	0.45
Grassland	0.00	0.40

study are based on the results of the studies conducted by Lasco et al. (1998, 1999, 2000). Table 7.10 shows the biomass density values for each land use type.

There are three main activities in the land use conversion that release GHGs at different time scales: on-site burning (for clearing purposes), off-site burning (for domestic/ industrial fuelwood), and biomass decay. Fraction of cleared forest biomass that is burned on-site, off-site, and left to decay are shown in Table 7.11. Sources of data for fraction of forest biomass burned on-site and off-site are IPCC (1997) and United Nations Development Programme - Energy Sector Management Assistance Programme (UNDP-ESMAP) (1992), respectively. Values for fraction left to decay are based on the assumptions of Villarin (1999).

Deforestation not only causes the emission of CO_2 rather it also release other gases such as CH_4, CO, N_2O, and NO_x. While only CH_4 and N_2O are GHGs, CO and NO_x are also accounted for because they have the potential to alter the chemical balance of the atmosphere. Computation of these trace gases are gathered based on the emission ratios or the ratios of these gases to the total amount of carbon released

Table 7.10. Biomass density values for each land use type.

Land Use	Biomass Density
Old Growth	446
Residual	347
Upland farms	112
Brushland	65
Grassland	29

Table 7.11. Fraction of biomass burned on site, off-site and left to decay.

Land Use	Carbon Released				
	On site Burnng		Off-site Burning		
	Fraction of Biomass Burned on Site	Fraction of Biomass Oxidized on Site	Fraction of Biomass Burned Off-site	Fraction of Biomass Oxidized Off-site	Fraction Left to Decay
Old Growth	0.4	0.9	0.1	0.9	0.45
Residual	0.4	0.9	0.1	0.9	0.45
Upland Farms	0.4	0.9	0.1	0.9	0.45
Brushland	0.4	0.9	0.1	0.9	0.45
Grassland	0.4	0.9	0.1	0.9	0.45

Table 7.12. Emission ratios for open burning of forests.

Compound	Ratio	Range
CH_4	0.012	0.009 - 0.015
CO	0.06	0.04 - 0.08
N_2O	0.007	0.005 - 0.009
NO_X	0.121	0.094 - 0.148

in the burning process. These emission ratios are shown in Table 7.12.

7.4.2.2 GHG emissions and removals by LLB

7.4.2.2.1 Agriculture sector

In the agriculture sector of the LLB, sources of emission include: 1) domestic livestock; 2) ricefields; 3) grassland burning; 4) burning of agricultural residues; and 5) agricultural soils.

Emissions from Domestic Livestock

Among the animals present in the LLB, cattle exhibit the highest CH_4 emission from enteric fermentation followed by the carabao. The high value is not attributed to the number of cattle and carabao present in the area rather it is due to the high emission factor for enteric fermentation of these animals. Cattle and carabao have total population of 140,000 and 117,000 heads, respectively. Despite the exceedingly large number of swine in the area, the CH_4 emissions from enteric fermentation amounts only to 2,345 t yr^{-1} which is about 30-35 percent of the emissions from the cattle and carabao. Again, the reason for this is the low emission factor for enteric fermentation of the swine.

Aside from enteric fermentation, animal wastes also contribute to methane emission. Total methane emission from this source amounts to 15,895 t yr^{-1}. Around 69 percent of this emission comes from the manure of the swine while 24 percent comes from the cattle. The remaining 7 percent of the total methane emission is shared by the carabao, sheep, goats, and horses.

Animal wastes also excrete nitrogen. Total annual nitrogen excretion of animals amounts to 59,507.5 t. Almost half of this value is contributed by the swine while the smallest portion is supplied by sheep. Nitrogen emission under pasture system is 1,472.6 t yr^{-1} while under solid storage and liquid system, nitrogen emissions are 47,534 t yr^{-1} and 9,689.7 t yr^{-1}, respectively.

Methane Emissions from Rice Fields

Rice paddies in Laguna have two water management regimes: irrigated and rainfed. Irrigated farms contain the large portion of the rice paddies in the province. It constitutes about 198 km^2 or 98 percent of the total rice fields. Using emission coefficient of 2.3 kg ha^{-1} day^{-1} (230 kg km^{-2} day^{-1}), methane fluxes from this type of rice field totals to 5.2 kt yr^{-1}.

Rainfed rice fields covers an area of 4 km^2 only or 1.98 percent of the total rice paddies. In terms of its contribution to annual methane emission, it releases 0.16 t. Overall, total methane emission from rice fields is 5.2 kt yr^{-1}.

Prescribed Burning of Grassland

Burning of grassland areas results to release of trace gases such as CH_4, CO, N_2O, and NO_x. In the LLB, CO comprises the largest of the trace gases emitted due to grassland burning. Total CO emitted is 19.71 t or 95 percent of the total trace gas emission. Methane emission amounts to 0.75 t, while N_2O and NO_x emission measure around 0.01 t and 0.34 t, respectively.

Field Burning of Agricultural Residues

Most farmers in the Philippines burn agricultural residues as a site preparatory activity. However, doing such activity results to release of trace gases such as CH_4, CO, N_2O, and NO_x. Results of the GHG inventory in the LLB shows that smoldering of agricultural residues resulted to emission of 2,988.3 t of CO, 142.3 t of CH_4, 118.8 t of NO_x, and 3.3 t of N_2O.

Emission from Agricultural Soils

Sources of nitrogen emission from agricultural soils in LLB are mainly due to application of fertilizer both from synthetic source and animal wastes. Total synthetic fertilizer used in the LLB is 32.4 t N, resulting to total emission of 0.40 t N_2O-N. Emission from grazing animals amounts to 0.05 kt N_2O.

Aside from direct emission from fertilizers, nitrogen is also released indirectly through atmospheric deposition of NH_3 and NO_x. Results of GHG inventory in LLB indicate that there are 0.12 kt N_2O-N emitted resulting from atmospheric deposition.

About 30 percent of the nitrogen in the fertilizer applied in agricultural soils is also lost through leaching and run-off. Thus, there is a total of 0.4 kt N_2O-N that is leached in the agricultural soils of LLB.

In sum, agriculture sector has total CH_4 emissions of 48 kt, 0.9 kt N_2O, 0.1 kt NO_x, and 3 kt CO or 1,298.7 kt of CO_2. Among the sectors, domestic livestock accounts for the largest contributor of CO_2 emissions while the lowest is that from grassland burning (Table 7.13).

7.4.2.2.2. Land use change and forestry

Biomass growth in the LLB resulted to the sequestration of more than 2,000 kt of CO_2 from the atmosphere (Table 7.14), about 3 percent of nation's total removals by sinks based in the 1994 GHG inventory.

However, the LLB is a net source of GHG, emitting about 924 kt CO_2-equivalent in the year 2000 (Table 7.14). This can be attributed to the high fuel wood consumption by the residents of the basin (0.46 m^3) which negated the amount of carbon sequestered by the growth of trees. In addition, burning and decay contributed to GHG emission in the basin. This is primarily due to clearing of forests for agricultural purposes.

In contrast, national GHG inventories show that the country as a whole is a slight to a huge net sink of carbon (Table 7.14). This implies that something must be done in the LLB to either decrease emissions and/or enhance removals to enable to mitigate climate change.

7.5 Potential Impacts of Climate Change in the LLB

Prediction of potential climate change in the next century is still largely conjectural and varies with the simulation models used. However, scientists are agreed that the earth's climate is already changing as a result of the rise of GHG in the atmosphere.

Table 7.13. Summary of the emissions of GHG from agriculture sector (in kt).

Source	Emission Type				CO_2 Equivalent	% Share
	CH_4	N_2O	NO_X	CO		
Domestic livestock	33.1	0.0			694.2	53.5
Rice cultivation	14.8				310.4	23.9
Grassland burning	0.0	0.0	0.0	0.0	0.0	0.0
Agricultural soils		0.9			290.1	22.3
Total	**48.0**	**0.9**	**0.1**	**3.0**	**1,298.7**	**100.0**
CO_2 Equivalent	**1,007.6**	**291.1**				

Table 7.14. CO_2 equivalent emissions and uptake of the LUCF sector in the LLB for the year 2000.

Sub-sector	CO_2 Equivalent Emissions (+) and Uptake (-) (kt)
Change in Forest/Woody Biomass	800
Biomass Growth	-,2,148
Roundwood/Fuelwood Harvests	2,948
Forest/Land Use Change	124
On Site Burning	52
Off-Site Burning	12
Decay	59
Total	**924**

In the Philippines, modeling work by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) under a 2 x CO_2 (doubling of CO_2 concentration from the current 360 ppm) scenario showed that the temperature will increase by at least 2-3ºC in the Southern Tagalog region where the LLB is located (Table 7.15). Likewise, precipitation will increase by as much as double the present amount.

7.5.1 Impact on Water Resources

The availability of water is an important prerequisite to optimum agricultural production. Climate change is also predicted to affect the water resources of the country. Because of high rainfall, the country is endowed by abundant water supply. However, because of varying distribution of rainfall and degradation of watershed areas, some parts of the country experience lack of water or its opposite, flooding.

The agricultural sector is the major user of water in the country consuming 248 M m^3 equivalent to 86 percent of the country's water demand per day to irrigate about 120,000 km^2 of land. Thus, any change in water supply due to climate change will have an impact on agricultural productivity.

A preliminary study was conducted on the impacts of climate change on two watersheds (Angat and Lake Lanao) in the Philippines (Jose 1996). In Angat watershed, the effect of climate change using three global change models (GCMs) showed varying effects on surface runoff ranging from -12 percent to 32 percent. It was also shown that water runoff is more sensitive to change in precipitation than in temperature. In Lake Lanao watershed, the three GCMs predicted mostly increasing rainfall and temperature. This scenario will lead to a generally declining amount of water runoff. Similar to Angat, the amount of runoff is also more sensitive to change in precipitation rather than temperature.

The foregoing study showed how water supply is vulnerable to changes in climate, especially to the amount of precipitation. While these results are preliminary, it is clear that agricultural productivity is at risk from either a declining water supply or too much water from the watersheds which could lead to flooding.

Table 7.15. Temperature change and rainfall ratio in the Philippines based on the Canadian Climate Centre Model (CCCM) (2 x CO_2 scenario).

	Region	Temperature Change (°C)	Rainfall Ratio
1	Ilocos	<2	1.0-1.5
2	Cagayan Valley	<2	1.0-1.5
3	Central Luzon	2-3	1.0-2.0
4	Southern Tagalog	2-3	1.6-2.0
5	Bicol	2-3	1.0-1.5
6	Western Visayas	2-3	1.6-2.0
7	Central Visayas	2-3	1.6-2.0
8	Eastern Visayas	2-3	1.0-2.0
9	Western Mindanao	2-3	1.0-1.5
10	Northern Mindanao	2-3	<1.0-1.5
11	Eastern Minadanao	>-	<1.0
12	Southern Mindanao	2-3	1.0-1.5

To date, there has been no study quantifying the impacts of climate change on the water resources of the LLB. This is a knowledge gap that needs to be filled soon.

7.5.2 Impacts on Agricultural Production and Food Security

Agricultural production is highly sensitive to climate because crop growth and development are determined by rainfall pattern and temperature range among others. A few studies have been conducted in the Philippines primarily by IRRI to assess the potential impacts of climate change to rice and corn production using various GCMs.

The results of the study show that (The Philippines Initial National Communication 1999):

- Rice showed a generally slight increase in yield (e.g., 3.15 percent and 5.38 percent in the first and second crop of IR 64 using CCCM)
- Corn yields tended to decline (e.g., 12.64 percent and 7.07 percent in the first and second crop, respectively, of PS 3228 using CCCM).

These results have been attributed to the difference in physiology of these two crops. Rice is a C-3 plant which would respond to the increase in CO_2 concentration in the atmosphere. On the other hand, corn is a C-4 plant which would not respond to CO_2 concentration, but the increase in air temperature will enhance respiration and shorten maturity period.

On the national scale, various model show conflicting results ranging from 6.6 percent increase to a -14 percent decline. Scientific evidence is still rudimentary at this point. However, it is almost certain that a changing climate will affect the level of agricultural production in the country.

7.5.3 Impacts on Forest Resources

Forests are highly dependent on climate since they are limited by water availability and temperature. In fact, the survival of many species depends on temperature with a range of +12ºC to -60ºC (IPCC 2002). A sustained increase of 1ºC in mean annual temperature could cause changes in species composition. Trees are also sensitive to water availability. There are limits to which species can migrate unassisted.

Global vegetation models (BIOME, MAPSS, IMAGE) do not agree on whether tropical forests will increase or decrease (IPCC 1996, 2002). But any major shift in rainfall pattern will affect distribution of vegetation types. Under enhanced CO_2, tropical evergreen broadleaf forests could readily establish after deforestation. Decreased rainfall could accelerate loss of dry forests to savanna. Shifts in rainfall patterns could increase conversion of forests to agricultural land by increasing migration from areas affected by drought, erosion, etc. Productivity will increase or decrease depending on the amount of rainfall.

Under various GCM scenarios, tropical forest areas in the Philippines will likely expand as temperature and precipitation increase in many parts of the country. The increase in the frequency of droughts and floods due to changes in El Niño episodes will likely render many areas unfit for agricultural crop production (Cruz 1997). Together with the growth in population and the shrinkage of arable lands, the pressure to open forestlands for cultivation could heighten.

Grasslands and other areas dominated by shrub species could become more vulnerable to fire with increase in mean air temperature. This could be aggravated if these areas are subjected to prolonged dry periods which are likely under an altered El Niño pattern. Frequent fires will make these already marginal lands more difficult to rehabilitate.

Temperature change may lead to a loss of a few species of plants and animals that may significantly erode the biodiversity of these forests. The coastal areas especially mangrove forests will be at risk of being damaged by the projected increase in siltation due to the increase in soil erosion in the uplands. This is on top of the risk of being completely wiped out by sea level rise. Finally, changes in temperature and precipitation may result to the outbreak of pests and diseases.

On the specific impacts of climate change on the forest resources of LLB, no study has been conducted yet.

7.6 Responses: Policies, Programs and Activities to Enhance Adaptation to and Mitigate Climate Change

Policies and programs on climate change in the Philippines are usually confined to the National Capital Region (Metro Manila), parts of which lie in the basin. There are no policies or programs directly addressing climate change for the LLB. However, there are many policies and programs that are relevant either in enhancing adaptation to climate change or in helping mitigate climate change.

7.6.1 Agriculture

The following are policy options in order to cope with climate change.

7.6.1.1 Adaptation options

A variety of adaptation options are recommended to effectively respond to the perceived impacts of climate change. Since the climate change scenario for the year 2070 is expected to bring about changes in rainfall, temperature, CO_2 concentration, and the frequency of extreme meteorological events such as floods, droughts, and typhoons, the following response strategies for the agricultural sector are recommended:

- Development of stress-tolerant varieties through plant breeding and biotechnology;
- Development of new farm management techniques that will respond to the management of crops under stressful conditions and the management of plant pests and diseases;
- Adaptive design and development of efficient farm tools and implements; and
- Improvement of post-harvest technologies which include among others the utilization and processing of farm products, by products and agricultural wastes.

Further recommended is the design and installation of a management information system (MIS) for agriculture which would provide timely and accurate information on climate hazards and their likely impacts to agricultural activities. The proposed MIS must be able to provide the following:

- The nature of climate variability particularly rainfall;
- Effects of climate change on other physical processes, e.g., soil erosion, pests, etc.;
- Effects of crop yields from farm production, food pricing and supply, farm income; and
- Effective policy response to changes in land use, plant breeding, etc.

7.6.1.2 Mitigation options

Mitigation options that will tend to decrease net agricultural emissions are grouped into short and long-term strategies:

7.6.1.2.1 <u>Short-term strategies</u>

- Improved management of livestock wastes
- Judicious use of production and growth-enhancing agents
- Integrated pest management technologies
- Conversion of agricultural wastes into biofertilizer
- Better management of irrigation systems

7.6.1.2.2 <u>Long-term strategies</u>

- Comprehensive approach in rice cultivation (e.g., proper management of water regions, efficient use of fertilizers, improved management practices, improved cultivars, alternative crops, etc.)
- Improved livestock systems
- Use of alternative agricultural systems
- Adoption of farm technology packages which promote the use of non-conventional energy sources (e.g., solar dryers, wind driven pumps, waves and tidal wave energy, etc.)

The aforementioned will follow the strategies articulated in the Philippine strategy for sustainable development to wit:

- Integration of Environmental Considerations (including climate change) in decision-making. This means a shift from traditional single sector planning/decision-making exercises to multi-sectoral planning/decision approach (including climate change considerations). Analytical tools and methodologies that are environmentally and climatically friendly will be installed and strengthened.
- Proper pricing of natural resources based on the cost of replenishment, increasing their supply and providing appropriate substitutes in order to improve resource management.
- Property Rights Reform. The “open access” scheme has promoted exploitation. The access rights will be assigned to communities who in turn will be responsible for its protection for sustained productivity.
- Establishment of Integrated Protected Areas System for the conservation of wildlife and unique ecosystems threatened by the impact of climate change and population pressures. Protection/conservation would be for scientific, educational, cultural, and historical values.
- Rehabilitation of Degraded Ecosystem to include reforestation of denuded watersheds, mangrove re-plantation, clean-up and control of pollution, and revival of biologically dead rivers.
- Strengthening of Residuals Management in Industry (Pollution Control) by installing not only “end-of-pipe” control systems but also wastes minimization, resource recovery, recycling, and appropriate by-product design that save on materials and energy.
- Promotion of Environmental Education that will enable citizens to understand and appreciate the complex nature of the environment and the role they have to play and to develop social values that are strongly supportive of environmental protection.
- Strengthening of citizen’s participation and constituency building. Potential victims of climate change should be involved in the design process.

Setting of priorities

The priority actions that would mitigate the adverse effects of greater rainfall variability, stronger tropical storms, and surges include:

- Strengthening of disaster mitigation preparedness of the LLB from basin to village level, to minimize the adverse impacts of tropical cyclones, storm surges, floods, and droughts;
- Formulation and implementation of an LLB land use plan that will incorporate the occurrence of natural hazards resulting from climate change; and
- Building and upgrading institutional capacities to implement the various national response strategies.

The proposed set of priority actions that would contribute to global efforts to slow down or stop climate change is:

- Use of market-based instruments in promoting the development of environmentally friendly industry and energy sources.

Follow-up program of action

The follow-up program of action includes research needs and technical assistance and investment packages.

Research needs

Research needs identified is focused on the present day and projected climate change constraints in agriculture and the GHG emissions in the population centers of the LLB.

On a short-term basis these researches include:

- varietal improvement and selection of superior drought tolerant varieties, high yielding and early maturing, resistant to pests and diseases, and suitable in given farming systems and manageable under different stress conditions; and
- development of farm tools and implements that are flexible or resistant to climate changes. An example is the *tapak-tapak* or foot pump and axial flow pump used to pump out excess water from low-lying areas to areas that need irrigation water.

On a long-term basis:

- The conduct of continuing case studies of areas where climatic constraints will be a major problem in agricultural production. The use of crop-climate models and satellite technology in the determination of crop potentials, assessment of present conditions, and prediction and monitoring of crop yields in a large scale.
- Investigation of the combined impact of increase CO_2 concentration, higher temperature and rainfall in agricultural systems.
- Development of methods to assess the full socioeconomic and political implications of impacts and responses, and their interactions with the other policy issues at the LLB, and at the regional and national levels.

Technical assistance

Technical assistance needs are: 1) technology development for limiting GHG emissions; 2) policy reforms and execution; and 3) creation of public awareness.

7.6.2 Land Use Change and Forestry

7.6.2.1 Strategies to decrease GHG emissions

Key mitigation strategies that could be implemented in the LLB to decrease the GHG emissions from the LUCF sector include:

- Reduction of illegal wood harvesting and fuelwood gathering from the natural forest without a replanting program.
- Control the burning of forests through such activities as shifting cultivation.
- Conservation of carbon stocks in the remaining forest ecosystems. There are a reported 190 km^2 of forest cover left in the basin (LLDA 1995). Several studies have shown that forest ecosystems in the basin contain substantial amount of carbon (Figure 7.3). By preventing the destruction of these “carbon banks”, emission of GHG is reduced. Conservatively assuming a carbon density of 150 $t\ C\ ha^{-1}$ ($1.5\ t\ C\ km^{-2}$), the remaining forests of the basin contain 2,850 kt C (10,460 kt CO_2). This is equivalent to about 20 percent of the 1994 GHG emissions from the energy sector of the entire country.

There are existing policies and programs that contribute to the above. The DENR has banned logging in all old growth forests and protected forests in the country since 1992 (DAO 12 series of 1992; RA 7586 The National Integrated Protected Areas Systems Act). While illegal cutting of tree have been reported, no logging permit has been issued in the forest areas within the basin (based on 1997 official forestry statistics, FMB 1998) presumably because they are all part of protected forests.

One of the biggest programs launched by the government to protect existing forested areas is the Community-Based

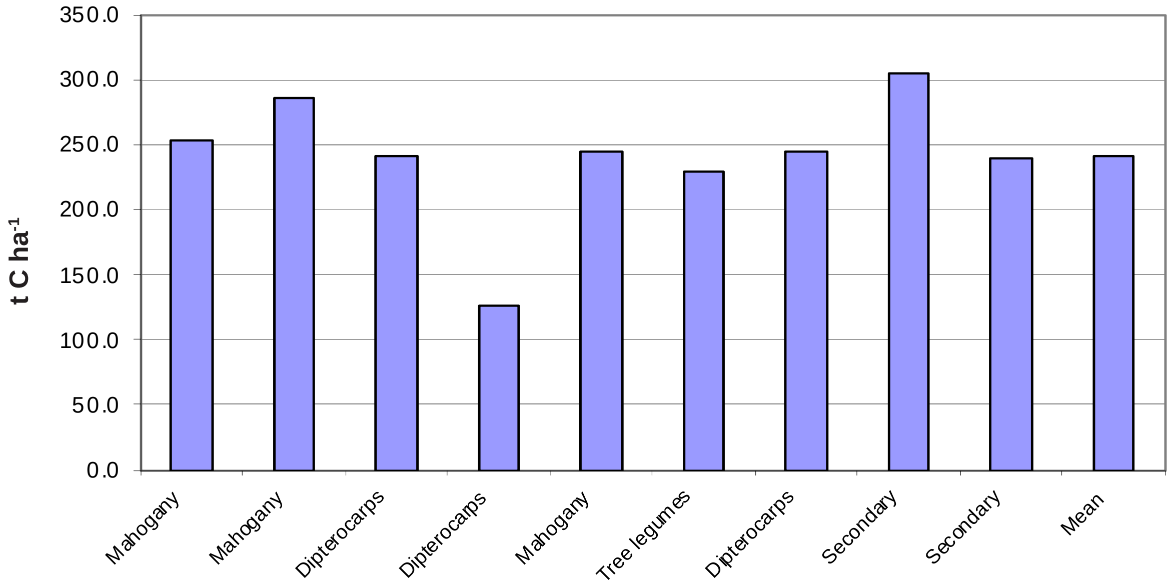

Figure 7.3. Carbon stocks of Mt. Makiling forest types.

Forest Management (CBFM). Launched on July 1995, CBFM integrated the different community forestry projects of the country through the issuance of Executive Order (EO) 263 and DAO 96-29. Objectives of the CBFM include: 1) to democratize resource access; 2) to improve socioeconomic welfare of upland communities; and 3) to promote the sustainability of the forest resources. Currently, there are a total of 4,956 CBFM sites all over the country covering an area of 57,000 km^2 (FMB 2001).

Another strategy introduced by the government to protect the country's forest resources is the establishment of the Multi-sectoral Forest Protection Committee (MFPC). The MFPC is composed of representatives from various sectors of the community such as other government agencies and institutions who come and join together to be partners in the government's forest protection efforts. Among the duties of the MFPC are to: 1) serve as a collection point for information on illegal forestry activities; 2) regularly receive and discuss reports from DENR specific to routine and special monitoring apprehension and prosecutional activities; 3) advise DENR and other relevant parties on these activities; 4) publicize the committee's discussions and findings, except where treated as confidential; 5) oversee the public awareness and other alternative livelihood progress; and 6) mobilize the members' network in support of forest protection activities.

7.6.2.2 Strategies to enhance removals by sinks

Key mitigation strategies that could be implemented in the LLB to enhance removals by sinks include:

- Reforestation and tree planting in the denuded grassland areas of the LLB. Currently, there are 540 km^2 of open lands in the basin. If planted, these lands have the potential to sequester more than 1,338 kt CO_2 yr^{-1} from the atmosphere [assuming biomass growth rate of 15 t ha^{-1} yr^{-1} (0.15 t km^{-2} ha^{-1})], more than enough to turn the basin to a net GHG sink.
- Establishment of sustainable tree farms to supply the wood and fuel wood requirements of the local communities in the basin. There is almost zero emission when the trees cut are replaced immediately. In other words, the carbon emitted by wood burning and decay is re-absorbed by the planted trees. Of course, the timing of release and absorption are different so that these are not exactly the same as far as the atmosphere is concerned.

The rate of reforestation activities for the basin is not known. However, there are indications that this is not significant. In 1997, only 6.71 km^2 have been reported in all the provinces in Region 4A (where the basin falls under), about 1 percent of total area reforested nationwide (FMB 1998). Similarly, only 4.03 km^2 of tree farms have been established in the entire region. Clearly, the potential of the basin to sequester carbon has not been fully utilized.

The Philippine government through the DENR has already embarked on a number of reforestation programs from 1910 up to the present. These programs did not only rehabilitate degraded lands but also increased the capacity of the Philippine forests to become sinks of carbon. From purely government initiated reforestation projects, the DENR involved other sectors of the society starting in 1976. Forest communities, private sectors, non-government organizations, and local government units became actively involved in forest rehabilitation activities. From 1960 up to 2002, area planted totaled to about 170,000 km^2. About 70 percent of which were planted by the government sector and the remaining 30 percent were contributed by the non-government sector (Pulhin and Peras 2002).

7.6.2.3 Research and training

The LLB is home to national and international training institutions that have conducted research and training programs in climate change. IRRI has conducted research on methane emissions from rice paddy fields, including measures to reduce emissions. UPLB is at the forefront of research efforts to quantify carbon stocks and rate of sequestration in Philippine forests. Many studies have been conducted already in the basin, specifically in the MFR (Lasco and Pulhin 2003; Lasco et al. 2001a; Lasco et al. 2001b; Juarez 2001; Racelis 2000; Zamora 1999; Lasco et al. 2000; Lasco et al. 2001; Aguiero 2002; Tamayo 2002; Lasco et al. 2003). In addition, the university has also integrated climate change issues in its instructional programs. National and international training courses have also been sponsored.

7.6.2.4 Land use planning

A key prerequisite in the rational and systematic development of the basin is a comprehensive and integrated land use plan. A master plan for the whole basin has been prepared in 1995. Among its many recommendations that will help mitigate climate change are (LLDA and UPLB 1995):

- land use planning and allocation in forest lands
- protection of remaining forests
- reforestation and agroforestry development

Additionally, master development plans have also been developed in two watersheds: the MFR (CFNR 1995) and the Caliraya-Lumot watershed (NPC 1998). Among the recommendations in these plans are protection of existing forests and rehabilitation of degraded lands through reforestation and agroforestry.

7.7 Drivers of Change: Factors Affecting the Increase/ Decrease of GHG Emissions and Removals by Sinks

7.7.1 Agriculture Sector

Rice production must increase to meet the demand of an increasing population. Lantin (2003) revealed that growing irrigated rice with less soil submergence and increased diversification in rice-based systems which includes growing in aerated soil will reduce methane emissions. However, this could lead to increased emissions of nitrous oxide – a more potent GHG. Furthermore, rice production with less soil submergence and increased rotation with upland crops can also enhance risk of nitrate contamination of groundwater and surface waters, which arises when excess use of N fertilizer leads to nitrate formation and concomitant leaching. Site-specific nutrient management (SSNM) prevents excessive rates of N fertilization and avoids risk of nitrate contamination of groundwater and surface water. SSNM involves use of crop residues and simultaneous nutrient and pest management.

Dry shallow tillage immediately after harvest of rice enables aerobic decomposition of rice residues, thereby avoiding the negative effects of residue decomposition in submerged soils on early crop growth and methane emissions (Lantin 2003).

7.7.2 LUCF Sector

Over the years, the landscape of the LLB has changed dramatically. For instance, the forest cover has shrunk to 145.16 km^2 in 2000 from about 725.80 km^2 in 1966 (LLDA 2003). These lost forested areas were most likely converted into grasslands and built-up areas. From 232.26 km^2 in 1966, grassland areas expanded to 406.45 km^2 while built-up areas that are not present in the 1966 land use data occupies in 2000 a total of 8.42 km^2.

The main driving forces that has contributed to the change in forest cover and the consequent rise in GHG emissions from LLB are (LLDA 2003):

- urbanization and industrial development
- shifting cultivation
- illegal logging
- mining and quarrying
- uncontrolled land conversion

All of the above generally contribute to the loss of forest cover and thereby increased GHG emissions.

On the other hand, there have been programs to help reverse this trend by conserving existing forest cover and even expanding forest cover. For example, the MFR is an excellent example of conservation. By working with local communities, UPLB has succeeded in preserving the carbon stocks in these forests by minimizing deforestation. In addition, the government has launched reforestation and tree planting programs in the region where LLB is located. To date, there are about 10 km^2 of reforested areas and tree farms in Region 4A (FMB 1998). However, how much of these are within the basin is not known.

The Caliraya Lumot watershed is another example of conservation. The NPC, the agency that has jurisdiction over the watershed, developed the 25-year comprehensive land use plan for Caliraya Lumot watershed. Among the components of the plan are rehabilitation and protection of the watershed. Under the rehabilitation program, cogonal/ grasslands and secondary forests with poor regeneration and regeneration potential will be revegetated with appropriate tree species in cooperation with other stakeholders, i.e., communities, resort owners. In cultivated areas, however, agroforestry farms shall be developed.

Under the forest protection program, the NPC will hire more forest guards to patrol the watershed. Adequate transportation and communication facilities shall be provided to the forest guards.

References

ADB, 1998: *Asia Least-Cost Greenhouse Gas Abatement Strategy: Philippines*. Asian Development Bank, Manila, Philippines, 228pp.

Brown, S., J. Sathaye, M. Cannel, and P. Kauppi, 1996: Management of forests for mitigation of greenhouse gas emissions, Chapter 24. In: *Climate Change 1995: Impacts, Adaptations, and Mitigation of Climate Change: Scientific-Technical Analyses*, R.T. Watson, M.C. Zinyowera, and R.H. Moss (eds.). Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge and New York, Cambridge University Press, pp. 775-797.

Brown, P., 1998: *Climate, Biodiversity and Forests: Issues and Opportunities Emerging from the Kyoto Protocol*. Washington D.C., World Resources Institute.

Cruz, M.C. and I. Zosa-Feranil, 1988: Policy implications of population pressure in the Philippines. Paper prepared for the World Bank study on Forestry, Fisheries and Agricultural Resource Management. University of the Philippines, Los Banos, Philippines.

Cruz, R.V.O., 1997: Adaptation and mitigation measures for climate change: impacts on the forestry sector. In: *Proc. Consultation Meeting for the International Conference on Tropical Forests and Climate Change*. Environmental Forestry Programme (ENFOR), CFNR, UPLB, College, Laguna, Philippines.

DENR/UNEP, 1997: *Philippine Biodiversity: An Assessment and Action Plan*. Makati City, Philippines, Bookmark Inc.

EMB, 1990: *The Philippine Environment in the Eighties*. Environmental Management Bureau. DENR. Quezon City, Philippines, 302 pp.

FMB, 1997: *Forestry Statistics* (1996). Forest Management Bureau, Quezon City, Philippines.

Forest Development Center, 1987: Towards a Successful National Reforestation Program. Policy Paper No. 24, University of the Philippines College of Forestry, Laguna, Philippines.

Francisco, R., 1997: Greenhouse Gas Sources and Sinks from Philippine Agriculture, Land Use and Forestry. Paper presented at the Synthesis Workshop on Greenhouse Gasses, Aerosols, and Land Use and Cover Change in Southeast Asia. Taipeh, Taiwan. 15-19 November 1997.

Freed and Driscol, 1997. GHG Emission Factors for Management of Selected Materials in Municipal Solid Waste.

Garrity, D.P., D.M. Kummer and E.S. Guiang, 1993: *The Upland Ecosystem in the Philippines: Alternatives for Sustainable Farming and Forestry*. National Academy Press, Washington DC.

Houghton, J.T., L.G. Meira Filho, B. Lim, K. Treanton, I. Mamaty, Y. Bonduki, D.J. Griggs and B.A. Callander (eds.), 1997: *Greenhouse Gas Inventory Workbook*. Intergovernmental Panel on Climate Change (IPCC), Organization for Economic Co-operation and Development (OECD) and the International Energy Agency (IEA), Paris, France, pp. 5.1-5.54.

IPCC, 1996: *Second Assessment Report*. IPCC, Geneva, Switzerland.

IPCC, 2002: *Third Assessment Report*. IPCC, Geneva, Switzerland.

Jose, A.M., L.M. Sosa and N.A. Cruz, 1996: Vulnerability assessment of Angat Water Reservoir to Climate Change. *Water, Air and Soil Pollution*, **92,** 191-201.

Kummer, D.M., 1990: Deforestation in the Post-war Philippines. Ph.D. dissertation, Boston, MA, Boston University.

Lantin, R.S., 2003: *Rice Production: Sustainability and Environmental Concerns*.

Lasco, R.D., J.S. Lales, M.T. Arnuevo, I.Q. Guillermo, A.C. de Jesus, R. Medrano, O.F. Bajar and C.V. Mendoza, 2002: Carbon dioxide (CO_2) storage and sequestration of land cover in the Leyte Geothermal Reservation. *Renewable Energy*, **25**, 307-315.

Lasco, R.D. and F.B. Pulhin, 2003: Philippine forest ecosystems and climate change: Carbon stocks, rate of sequestration and the Kyoto Protocol. *Annals of Tropical Research*, **25(2)**, 37-51.

Lasco, R.D. and F.B. Pulhin, 2001: Forestry mitigation options in the Philippines: application of the COMAP model. *Mitigation and Adaptation Strategies to Global Change*, **6**, 313-334.

Lasco, R.D. and F.B. Pulhin, 2000: Forest land use change in the Philippines and climate change mitigation. *Mitigation and Adaptation to Climate Change Journal,* **5**, 81-97.

McNeely, J.A., K.R. Miller, W.V. Reed, R.A. Mitternmeier, and T.B. Werner, 1990: *Conserving the World's Biological Diversity*. IUCN, Gland, Switzerland; WRI, CI, WWF-US and the World Bank, Washington DC.

Murdiyarso, D., 1996: Inventory of Asian greenhouse gas emissions and sinks in 1990. In: *Greenhouse Gas Emission Inventories*, Braatz et al. (eds.) Kluwer Academic Publishers, Dordrecht. Pp. 147-160.

Nicholls, N., G.V. Gruza, J. Jouzel, T.R. Karl, L.A. Ogallo, and D.E. Parker, 1996: Observed climatic variability and change, Chapter 3. In: *Climate Change 1995: Impacts, Adaptations, and Mitigation of Climate Change: Scientific-Technical Analyses*, J.T. Houghton, L.G. Meira Filho, B.A. Callander, N.Harris, A. Kettenberg, and K. Maskell (eds.), Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge and New York, Cambridge University Press, pp. 137-192.

Ravindranath, N. H., R. D. Lasco, and P. Sudha. 2000. Assessment of GHG Inventories from the LUCF Sector of Annex 1 Countries. *Mitigation and Adaptation Strategies to Global Change,* 00, 1-22.

Revilla, A.V., 1997: Working Paper for the Forestry Policy Agenda for the Incoming Administration. College of Forestry and Natural Resources, University of the Philippines at Los Baños, Laguna, Philippines.

Schimmel, D., I.G. Enting, M. Heimann, T.M.L. Wigley, D. Rayneud, D. Alves, and U. Seigenthler, 1995: CO_2 and the Carbon Cycle. In: *Climate Change 1994: Radiative Forcing of Climate Change and an Evaluation of the IPCC IS92 Emision Scenarios*, J.T. Houghton, L.G. Meira Filho, J. Bruce, H. Lee, B.A. Callander, E. Haites, N. Harris, and K. Maskell (eds.), Published for the IPCC, Cambridge University Press, Cambridge, pp. 35-71.

The Philippines' Initial National Communication On Climate Change, 1999: Republic of the Philippines.

Watson, R.T., I.R. Noble, B. Bolin, N.H. Ravindranath, D.J. Verado and D.J. Dokken (eds.), 2000: *Land Use, Land-use Change, and Forestry*, Published for the Intergovermental Panel for Climate Change, Cambridge University Press, Cambridge, 377pp.

8

Institutional Arrangements, Social Conflicts, and Ecosystem Trends

MA. VICTORIA O. ESPALDON, DOLORA N. NEPOMUCENO, JOSEFINA T. DIZON

CONTENTS

8.1 Institutional Arrangements

8.1.1 Laguna Lake Development Authority

Republic Act 4850 of 1966 created the Laguna Lake Development Authority (LLDA) as a government-owned corporation to carry out the development of the Laguna de Bay Region. The law gives the agency a broad mandate "…to promote and accelerate the development and balanced growth of the Laguna Lake area and the surrounding provinces, cities and towns…with due regard and adequate provisions for environmental management and control, preservation of the quality of human life and ecological systems, and the prevention of undue ecological disturbances, deterioration and pollution…" Presidential Decree (PD) 813 of 1975 further expanded LLDA's mandate to address environmental concerns and conflicts over jurisdiction and control of the lake. Executive Order (EO) 927 of 1983 further strengthened the institutional, financial, and administrative responsibilities of the agencey including its regulatory functions in industrial pollution (Figure 8.1).

The same EO granted LLDA the exclusive jurisdiction to issue permits for the use of surface water for any project or activity in or affecting the Laguna de Bay Region including construction and operation of fishpens, fish enclosures, and fish corrals. Furthermore, the same EO gave the LLDA the authority to collect fees for the use of the lake water and its tributaries for all beneficial purposes including, but not limited to, fisheries, recreation, municipal, industrial, agricultural, navigation, irrigation, and waste disposal purposes.

8.1.2 Relationship with the Department of Environment and Natural Resources

EO 149 in 1993 placed the LLDA under the administrative supervision of the DENR and made the agency a member of the defunct Presidential Task Force on Water Resources Development and Management or PTFWRDM (EO 374 of 1993 as amended by EO 409 of 1997). In 2001 through DAO 2001-29 dated Nov. 5, 2001, PTFWRDM was transformed into the Integrated Water Resources Management Division under the Office of the Secretary of the DENR.

Although LLDA is administratively attached to DENR, it maintains its separate policy-making functions through the

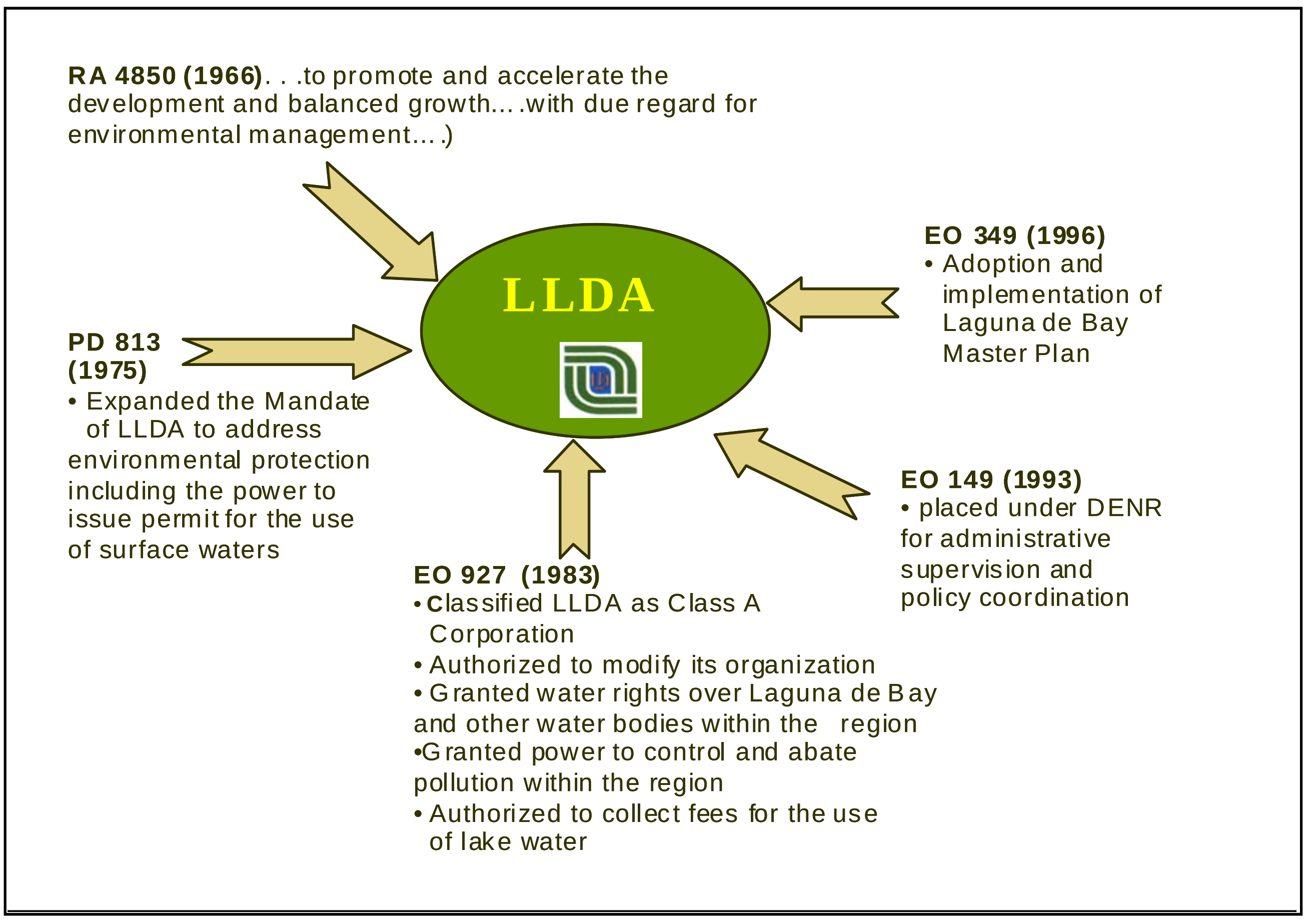

Figure 8.1. Evolution of the Laguna Lake Development Authority.

Board of Directors. The LLDA acts and decides upon policy matters; not all are necessarily elevated to the DENR Secretary for final approval. At present, the Board has ten (10) members, four of whom represent national government agencies (Office of the President, National Economic and Development Authority or NEDA, Department of Trade and Industry or DTI, and DENR). The governors of Rizal and Laguna, the Metropolitan Manila Development Authority (MMDA) Chairman, and the President of the Laguna Lake Federation of Mayors represent the LGUs. The Office of the President appoints the two other members – the General Manager of the LLDA and a representative of the private investors. Except for the latter, government representatives dominate the Board.

The LLDA Board sets the policies and directions for the operations of the agency. It has the authority to formulate, prescribe, amend, and repeal rules and regulations governing the conduct of business of the LLDA.

8.1.3 Role of the Local Government Units

Local government units enjoy a wide range of authorities and responsibilities under the 1991 Local Government Code. Certain environmental management responsibilities were devolved to LGUs, including solid waste management, noise and odor nuisance, preparation of action plans consistent with the Integrated Air Quality Improvement Framework, and other related functions. The code authorizes LGUs through the local governing councils to enact and enforce local environmental ordinances, enforce environmental laws and regulations pursuant to national policies and under the supervision, control, and review of the DENR. The code calls for the creation of the position within the LGUs of an Environment and Natural Resources Officer (ENRO) in all municipalities, cities, and provinces. In addition, the code mandates the LGUs to develop their respective land use plans through the Provincial Land Use Committees (PLUCs). The code ascertains the rights of LGUs over the resources under their jurisdiction.

The following appear to be the overlapping and in certain cases conflicting mandates and functions between LGUs and central government agencies:

- Delineation of jurisdiction over environmental compliance and enforcement;
- Clear mechanisms for land use planning at the LGU level; and
- Control of natural resources including water.

With regard to the conflicts between central government and LGUs, the regulatory and institutional issues between the LLDA and LGUs are:

- Confusion/conflicts as a result of duplication of permitting processes for business and industries;
- Lack of clear delineation of monitoring and enforcement functions; and
- Unclear responsibilities for detailed land use plan formulation and implementation.

With respect to the land use planning and enforcement issue, the LLDA is mandated by its Charter to develop regional land use plan, while LGUs are expected to enact zoning ordinances based on the regional plan. While the 1996 approved Laguna de Bay Master Plan serves as an overall development framework plan that should guide development of zoning ordinances, LGUs, independently of and without consultation with LLDA and without reference to the Master Plan, prepare their respective land use plans and zoning ordinances.

8.1.4 LLDA's Mandate and Functions

Through a series of enabling laws, LLDA's mandate has significantly expanded. It covers planning and policy making, environmental regulation, and infrastructure development (Figure 8.2).

LLDA has the power to undertake comprehensive planning for review and approve plans/programs/projects proposed by LGUs and other agencies in the region, public corporations, and private entities/enterprises; exercise exclusive jurisdiction to issue new permits for the lake water; exercise water rights over all surface water resources in the region; collect annual fees for the use of the lake water and for all beneficial uses. The fees collected are used by the LLDA for the management and development of the lake and its watershed.

While the LLDA may not have explicit jurisdiction over the river systems feeding into Laguna de Bay, it exercises regulatory and developmental powers and functions to carry out watershed protection and conservation activities. It has established a system of fees and charges to organize and finance small-scale community-based watershed management projects and activities at the LGU and/or sub-basin levels.

8.1.5 Regulatory Powers and Functions

The all-encompassing powers of LLDA are shown in its authority to pass, approve, or disapprove all plans, programs, and projects proposed by all LGUs and public and private corporations. It also has exclusive jurisdiction to issue permits for the use of the lake water including such uses as navigation, fishpen operation, fish corrals, and the like. In addition to

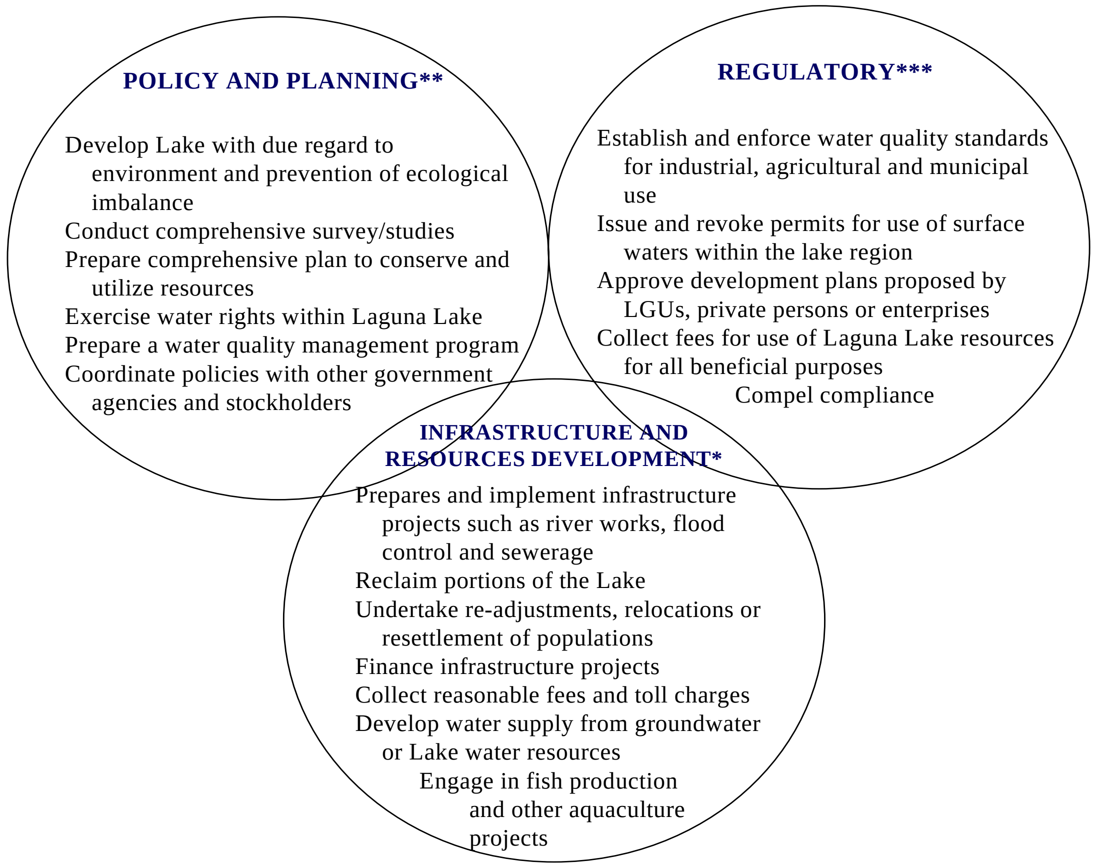

Figure 8.2. Key functions of the Laguna Lake Development Authority.

the regulatory powers of LLDA, it is also vested with the power of "eminent domain", or the power of LLDA to expropriate private property for public use and with just compensation.

LLDA is authorized to promulgate standards for waste discharges into the lake. LLDA has adopted the water classification system and standards set by DENR. However, it may promulgate more stringent standards to take into account the peculiar hydrological and hydraulic characteristics of the lake. The agency has not exercised this power to date.

LLDA is authorized to collect fees for the use of the lake, as well as to earmark revenues generated for its own activities. This power was initially applied to fishery activities (i.e., fishpen and fish cage fees). In 1997, LLDA pioneered the implementation of environmental user fee system (EUFS) as part of discharge permitting. The system is essentially a market-based instrument to induce polluters to abate wastewater discharges. EUFS has created a strong incentive for regulated firms to reduce the BOD concentration of wastewater discharged into the lake. Unfortunately, it has also created an incentive for firms to dilute their discharges. This is a potential weakness of the system, and it suggests the importance of also properly pricing input water to avoid perverse responses to EUFS. The intent of LLDA to price raw water taken from the lake is expected to correct such behavior.

LLDA's mandate allows it to introduce a wide range of innovative policies. It was the first agency in the Philippines to apply concepts of natural resource pricing in the form of fishpen fees and, more recently, the imposition of wastewater discharge fees. The experience of LLDA in resource pricing is setting the stage for a comprehensive national implementation of a similar policy by DENR. LLDA's venture into raw water pricing is set to establish another policy precedent that could have wider national application.

A case in point is the policy shift toward greater use of market-based instruments exemplified by the expanding coverage of EUFS and the proposed introduction of raw water pricing. The initiative undoubtedly has become controversial. LLDA needs to have in-house expertise to examine, debate, and advocate the policy in all possible arenas – academic, political, the media, and various public forums – fine tuning its message to suit the audience, while maintaining a strong footing on sound economic and environmental management principles. LLDA must also develop the marketing skill and sophistication to publicly argue the merits of market-oriented policy instruments. This is a task that should be assigned to a formal policy support unit within LLDA.

Coordination will be a key role for LLDA in overseeing the management of the Laguna Lake. However, coordination will remain difficult if policy making does not involve those who have a direct stake in the problems. The current composition of the LLDA policymaking board is heavily represented by the government sector (national government agencies and LGUs). Recently, the Office of the President, through EO 75, created a Board of Advisors to support the LLDA Board of Directors.

8.1.6 Management of the Laguna Lake Basin

All the problems discussed in the previous sections with regard to the physical, chemical, and biological characteristics of the Laguna Lake have been addressed by the various programs of the LLDA. The more serious and systematic approach to the integrated management of LLB was the formulation of the Laguna de Bay Master Plan in 1995. The Master Plan places heavy emphasis on the identification, formulation, and elaboration of priority programs and projects in order to attain the sustainable development of LLB. Four programs, namely, environmental management, watershed management, fisheries development, and institutional reform and development, are currently pursued.

8.1.6.1 Environmental Management Plan (EMP)

This program consists of three components, namely, water quality monitoring, EUFS, and shoreland management. Water quality monitoring which started in 1973 initially focused on lake water quality, but with the expanded mandate of LLDA it also regularly monitors industrial effluent in the lake and in the tributary rivers. The EUFS, on the other hand, primarily aims to reduce the pollution loading into the Laguna Lake by making all dischargers of liquid waste, whether industrial, residential, or commercial, pay a user fee based on the BOD content of the wastewater they discharge into the lake. With the implementation of the EUFS, there has been significant reduction in the BOD loading into the lake from 1997 figure of 5,403 t yr^{-1} to 791 t yr^{-1} in 2002 (Santos-Borja and Nepomuceno 2003).

To fully maximize the environmental benefits from the EUFS, the strategy is for LLDA to revise the existing formula for industrial EUFS by introducing other parameters aside from BOD, including the households in the EUFS, exploring opportunities for the introduction of EUFS for raw water extracted from the lake, and disclosing the program to the public.

As the primary agency mandated to promote and accelerate the development of the Laguna Lake Basin, LLDA is also in charge of the management of the lake's 140 km shoreland. Policy instruments for shoreland management are currently in place and what LLDA is doing is to look at the effectiveness of these instruments due to a number of implementation and enforcement issues. As it is now, these policies are insufficient for the shoreland restoration and environmental regulation and control (Santos-Borja and Nepomuceno 2003). This is so because LLDA's shoreland regulation is an example of a case wherein development projects have overtaken regulation and control.

8.1.6.2 Watershed Development Program (WDP)

This program has two components, reforestation and tree planting and river rehabilitation program. The first component is jointly undertaken with the LGUs and socio-

Table 8.1. Estimated BOD reduction in the lake due to EUFS implementation.

Year	Cumulative Number of Firms	BOD Loading (t yr^{-1})	BOD Loading Reduction (%)
1997	22	5,403	
1998	255	4,432	24.08
1999	429	1,790	65.80
2000	628	2,309	19.08
2001	738	1,687	40.61
2002	914	791	61.30

civic organizations and non-government organizations (NGOs) within the watershed as a response to the CLEAN and GREEN campaign of the national government.

The River Rehabilitation Program which started in 1996 covered rivers and streams flowing through the 22 sub-basins of the Laguna Lake Basin. Various stakeholders within each sub-basin were organized into River Rehabilitation and Protection Council, and these councils were federated into one umbrella organization of River Councils within the Laguna Lake Basin. Each council undertakes watershed mapping, comprehensive survey of the rivery system and its watershed, and development of a vision for a healthy river system and watershed. Based on these, the council formulates a River Rehabilitation and Protection Plan.

8.1.6.3 Fisheries Development Program (FDP)

One major use of the lake is for agriculture operation and its extensive use for this purpose became a major conflict when small fisherfolks asserted that they lost much of the traditional open lake fishing grounds (Francisco 1993). To address the issue, a Zoning and Management Plan (ZOMAP) of the lake was implemented. Fishpen belts and fishcage belts were delineated with a total area of 100 km^2 and 50 km^2, respectively. Likewise, limits were set as to the size of fish cage and fishpen that can be occupied (i.e., for fishpen, 0.05 km^2 for corporation, 0.01 km^2 for cooperative, 0.005 km^2 for individual, and for fish cage, 0.001 km^2). Fees collected from the fishpens and fish cages are shared by the LLDA and the lakeshore municipalities, with the latter using its share to finance environmental projects.

The other component of the program is the formation of Fisheries and Aquatic Resources Management Councils (FARMCs) in barangays, cities, and municipalities as provided by EO 240 issued in 1995. This is to ensure that there is active and extensive participation by those directly affected in the management and control over fisheries and aquatic resources. The FARMCs, which are composed of representatives from the Department of Agriculture (DA), LGU, NGO, and fisherfolks including women and youth, implement clean-up activities in the lake and are involved in the surveillance of illegal fishing activities. Despite these efforts, however, LLDA has been unsuccessful in the control of illegal fishing (Santos-Borja and Nepomuceno 2003).

8.1.6.4 Institutional Reform and Development Program (IRDP)

Institutional reform was basically focused at restructuring the LLDA organization and staffing, and streamlining its functions and building political and social acceptability especially among the various stakeholders of the LLB. An integrated water resources management and development institution model was recommended. The model provides the primary mandate, scope, and level of autonomy of LLDA and specifies that LLDA is the apex body in the LLB responsible for coordinating integrated watershed management and development. The LLDA Board remains as the policy-making body but will be supported by the Technical Council and the Watershed Management Council.

Capacity building is another component of the IRDP, which essentially involved the establishment of the Integrated Water Resources Management Unit within LLDA and putting up a GIS database and state-of-the-art modeling system for decision-making. The last component of the program is the forging of local and international partnerships and cooperation between LLDA and the private sector and non-government organizations. An example of this partnership is the Conservation of Laguna de Bay Environment and Resources (CLEAR), a tripartite endeavor among the LLDA, Unilever Philippines, and the Society for the Conservation of Wetlands. Other partnerships include those with the Chesapeake Bay in Eastern United States and Tha Thin River in Thailand.

8.2 The Basin of Social Conflicts

The social orientation of a natural resource like the LLB cannot be underestimated. The present environmental dilemma is much more a result of social processes than it is due to the natural process of lake decay. It is said that the fate of lakes around the world is extinction, but this can take geologic years. Human activities can accelerate the natural decay process a million times, and this is happening to the largest lake in the Philippines. Because it is located in the densest part of the country, the lake is pressured to provide various services for lake communities, huge Metro Manila, and the rest of the basin's burgeoning population: open fishing grounds (since as long as local population can remember), aquaculture (fishpen and fish cages), irrigation, transportation to island of Talim and other lakeshore municipalities and villages, recreational areas (resorts and restaurants), hydropower, and sadly a sink of wastes from various sources – industry, households, and agriculture.

Because of the multitude of resource-use and users, the occurrence of social conflicts is expected, but the magnitude of these conflicts in various time periods varied from petty to serious. Gonzales (1988) summarizes the conflicts into three levels: intrasectoral conflicts between the fishpens and the fishing villages beginning early 1970s; intersectoral conflicts between fisheries and agriculture sectors beginning early 1980s due to the expansion of agri-based infrastructure, notably irrigation system; and multisectoral conflicts emerging among the fisheries, agriculture, and human settlements (especially urban areas of Metro Manila) due to flood related infrastructures such as the MF and the NHCS. These types of conflicts exist up to the present day, although in different intensity.

8.2.1 Intrasectoral Conflicts

As the water quality of the lake began to decline since the 1960s to the early part of 1970s, the fishery production, mostly from open fishing, also declined. It was at this time when the fishpen technology provided an option for increasing the lake fishery productivity. The increase of fish production from fishpen was more than 100 percent between 1973-1976 and 1980-1983 while open fishing productivity continued its decline (Rabanal 1986). Fishpen turned out to be a very efficient aquaculture technology that attracted investors. By early 1980s, almost two third of the lake's area was covered with fishpens. At this point, fishermen organizations around the lake clashed with the fishpen operators. The conflict focused on the claim for space at the lake. Open fishermen claimed that the decline of fishery production was attributed to the dense population of fishpen, which covered much of the open fishing grounds. Navigation became a problem for them since passageways were blocked by the unorganized establishment of fishpens all over the lake. Fishermen claimed that their access to the lake water for fishing was reduced and hence their livelihood was threatened. The conflict was confounded by the overall decrease in the fishery productivity as a result of organic pollution originating from fishpen operations. Artificial feeds and fishpen materials added to the pollutants in the lake.

The crisis escalated every minute during that period. Fishpen operators hired armed guards to protect their fishpens from saboteurs. Fishermen were accused of destroying the nets of the fishpens. The tension in the lake caught the public attention. Media covered the conflicts in the lake with regularity, and public opinion came to a conclusion that fishpens must be partially or totally demolished. In the late 1980s, efforts led by the LLDA with the assistance of the military started dismantling illegal fishpens. Typhoons also assisted the process. After a series of discussions and dialogues, a ZOMAP was produced (See Figure 4.5). The ZOMAP designated areas for fishpen operation, open fishing grounds, fish sanctuary, and navigational lanes. This ZOMAP is still in operation to the present. Fish cage technology was also developed and provided the small fishermen with modest capital to engage in aquaculture. The ZOMAP and the aquaculture technology (fishpen and fish cage) allowed the conflicts within the fishery sector to subside and equitably benefit from Laguna Lake fishery resource.

8.2.2 Intersectoral Conflicts

This concerns the conflict between fisheries and agriculture. In the early 1980s, a plan to construct the NHCS was conceived. This was primarily to deter the entry of saltwater to the lake. The NHCS was also considered a multipurpose infrastructure: to control floods, to reduce saltwater intrusion into the lake from the Manila Bay backflow through the Pasig River, to reduce pollution of the lake, and to protect Metro Manila's streets from floods. This was in line with the objective of using the lake water for irrigation. The First Laguna de Bay Irrigation Project was aimed to irrigate a total of 131.6 km^2 of Cavite Friarlands and 12.8 km^2 in Laguna province. To do this, the salinity of the lake must be reduced in the summer months when backflows normally occur. The implementing agency in this regard was NIA. The Second Laguna de Bay Irrigation Project followed shortly after with the construction of a diversion dam at Pagsanjan, which rehabilitated the secondary canals (Gonzales 1988).

The center of the conflict between fisheries and agriculture is the regulation of saltwater intrusion in the lake. Saltwater backflow allows the clearing of the lakewater, as the sodium ions in saltwater has the ability to flocculate negatively charged clay colloids in suspension in the lake (Davies 1986). This means that the saltwater clears the water and reduces lake turbidity. Increased light penetration allows the growth of more phytoplanktons which provides fishes with abundant food. Fishermen organizations along with fishpen operators demanded the opening of the hydraulic control structure which is being operated by the Department of Public Works and Highways (DPWH). Whether LLDA has a significant hand in the construction or operation of these infrastructures (NHCS and MF), antagonism was mostly directed at LLDA, which they claimed was irrelevant and powerless to do anything about these issues which concerned the operation of NHCS-MF and their consequent negative impacts on the fishery sector.

Negotiation between DPWH and the fishpen and fishermen leaders occurred many times to allow the opening of the structure, especially during summertime when saltwater is most needed by fishery sector. Up to now, the operation of the NHCS from time to time has been viewed as inimical to the interest of the Laguna Lake fishery sector. To date, the plan to divert volume of water from the lake to irrigate agricultural lands of Cavite and Laguna is still waiting to be realized. From the very start, Gonzales (1988) noted that Cavite farmers were hesitant to go into the projected commercial scale vegetable farming. Hence there is no urgency to reduce salinity of lake water.

8.2.3 Multisectoral Conflicts

The multiplicity of uses of the basin gave rise to multisectoral conflicts. This is the kind of conflict among the fishery sector, agriculture, and human settlements. One apparent conflict was the use of the lake for storage of floodwaters from Marikina River during the typhoon months to prevent the flooding of Metro Manila. Mangahan Floodway is designed to divert floodwater from Marikina River to the Laguna Lake at the height of typhoons and storing the water by closing the NHCS gates. The floodwater is gradually released through the Napindan channel and the Pasig River, the only outlet of the lake to the Manila Bay. The operation of the MF in tandem with the NHCS has been blamed for the prolonged flooding of lakeshore municipalities like Napindan, Tipas, Taguig, and some parts of Pasig. This claim has logical basis, though no scientific study was conducted. The lake has 22 river tributaries and one outlet river to the Manila Bay, the Napindan River, which further north drains into Pasig River. In the early times, there was natural balance and the watershed condition was healthy. In the 1980s, the NHCS was constructed at the only outlet of the lake which regulates the water movement. With MF, the water inflow to the lake was significantly increased, hence the level of lake water during typhoons significantly increased which may have caused some lakeshore towns to submerge and for some areas to have floodwaters longer than the usual experience. The Parañaque Spillway which was supposed to allow outflow of water to the Manila Bay was permanently shelved due to budgetary constraints.

To address the intensifying floods of these lakeshore towns, the DPWH is constructing a road dike in the northern part of the lake to protect these areas. The road dike, which will serve both as a road and a dike, will soon be in operation. Whether this new infrastructure will finally address the flooding of lakeshore towns in the northern part of the LLB is subject to speculations. One reservation about this new engineering solution is the flooding of other areas around the lake that are not protected by the dike. According to the Environmental Impact Assessment and DPWH experts, this fear is unfounded; and based on existing mathematical models, the overall lake level rise is insignificant to cause intensified flooding in the lakeshore towns located in the southern part of the lake. Some sectors argue however that to rely solely on engineering solution to manage the lake system is myopic since the ability of the lake to store water depends on the overall functioning of the Laguna Lake Basin ecosystems – its watershed and rivers.

Another conflict brewing is the conflict between the local communities and the LLDA. While LLDA serves as the agency with mandate to manage the basin, its programs and policies are not always acceptable to the majority of the fisherfolks and the local community. For example, the lakeshore lands are currently being cultivated to rice, especially when the water level drops to 10.5 m elevation since as far as they can remember. This happens from January to May, when the lake water level starts to recede. The conflict emerged when the agency, as part of its master plan, commissioned NAMRIA to demarcate on the ground the 12.5 m elevation as lake buffer zone and install concrete monuments around lakeshore areas in 1997. In some municipalities, these monuments were removed by the community members who did not understand the LLDA concerns or who were opposed to the idea of regulating their normal use of the lands for livelihood.

8.3 Responses to Conflicts and Problems on the Use of the Lake Resources

Table 8.2 presents a summary of services and their related problems and issues. To summarize, institutional responses included the formation of Lake Zone Map or ZOMAP, which designated areas for fishpen operation, fish sanctuary, open fishing, and navigation. It is considered an effective institutional mechanism which addressed the conflict between the fishpen operators and the open fishermen. The development of another aquaculture technology, the fish cage, which requires modest capital and hence accessible to small fishermen allowed the distribution of benefits among the less advantaged fishery sector. In this regard, the LLDA played a major role in diffusing an explosive conflict between what was perceived to be the powerful fishpen operators and the powerless majority of fisherfolks who demanded their moral right to the Laguna Lake for being the traditional user of the resource.

Other responses to the conflicts created by government-conceived development projects (particularly by DPWH and NIA) included dialogues and informal negotiations such as in the operation of NHCS. In other cases, the flooding of lakeshore towns which was attributed to the operation of NHCS and MF is resolved by another huge infrastructure – the road dike. Despite its professed intention, the local communities around the lake expressed their reservations that the new structure may just transport the problem of localized flooding to other lakeshore areas.

The degradation of the Laguna Lake water quality however underlies many of its problems. During the administration of LLDA General Manager Carlos Tamboc, a comprehensive program to rehabilitate the 22 river systems flowing into Laguna Lake was launched. This is anchored on the fact that these river systems are directly contributing pollution load into the lake. The rehabilitation program covered a comprehensive survey of the river systems to build a strong baseline information, education, and motivation campaigns; creation of the environmental army (called *Hukbong*

Table 8.2. A summary of the responses to various issues or problems on the use of Laguna Lake Basin resources.

Ecosystem Services	Problems	Responses	Assessment
Water quality	Deteriorating water quality	Formation of multisectoral river rehabilitation councils	Fairly addressing water quality problems in some areas
		Laguna Lake Master Plan	
Fish	Declining open fish catch	Development of ZOMAP	Regulated the use of surface lake water for open fishing, navigation, fish sanctuary, and fishpen structures
		Introduction of aquaculture	Improved total fish production but contributed to pollution loading and dominance of exotic species in the lake; Decreased catch from open water
Rice	Decreasing areas for rice growing along the lake	No response	
Biodiversity	Lake: Decline in fish diversity and dominance of exotic aquaculture species	Delineation of fish sanctuary (in the ZOMAP)	Not effective
	Forest: Extirpation and decline of some naturally growing species; Continuing threats to the indigenous biodiversity of the lake	Inclusion of some areas in the biodiversity conservation areas (e.g., Mt. Makiling and Mt. Banahaw - San Cristobal complex)	Regulated harvesting of forest resources in some areas
Carbon Storage and climate change mitigation	Declining capacity to store carbon due to deforestation	Carbon sequestration projects to be implemented	Climate mitigation projects underway through the LLDA
		Methane reduction project in solid waste	

Pangkapaligiran); organization of river rehabilitation councils and foundations to ensure multisectoral partnerships and stakeholder involvement; and sustainability of the rehabilitation efforts.

One major strategy to address the degradation of water quality is the formation of river rehabilitation councils. The formation of river councils was motivated by a shared concern among different stakeholders (community members, local government officials, non-government organizations, and civic organizations) to reduce the pollution of the lake and its 22 major sub-basins. LLDA facilitated the process. At present, there are 16 river councils or foundations covering several river basins in the Laguna Lake region (LLDA 2000). These councils or foundations are seen to be effective mechanisms for ensuring multisectoral partnerships and stakeholders' involvement in as well as the sustainability of the rehabilitation efforts. The Board of Directors issued a resolution institutionalizing such councils and extending to these organizations official recognition and support (LLDA 2000).

So far, the experiences of river councils vary, but there are some limited successes in some rivers. For example, BISIG-CATA (Biñan, Silang, General Mariano Alvarez, Carmona, and Tagaytay City) River Rehabilitation and Protection Foundation, Inc. has already registered accomplishment. The key players in the action viewed this experience as a process that galvanized their community into taking one definite action: to arrest the decay of the Biñan River. By setting an example, they feel more confident to share with other communities the process and the difficulties they have gone through, and the fruits of their labor.

At a broader scale, the initiative has assisted other groups in their organizing work in other areas within the Laguna Lake Basin. BISIG-CATA has set up the Biñan River Rehabilitation Project and became a functional example of multisectoral partnerships to address urban environmental problem and potential conflicts arising from the different uses of environmental resources. Members of the foundation served as resource persons in various occasions during organizational seminars being conducted by other councils.

Being more informed and fresh from the Biñan River cleaning up activities, the group shared its experience with their colleagues upstream of Biñan River – the Save Sta. Rosa-Silang River Rehabilitation (S^3R^2). This is a multisectoral river council organized by the LLDA to address industrial as well as domestic pollution of the river that the municipalities of Sta. Rosa and Silang shared. Sta. Rosa and Silang municipalities are dominated by industrial parks, commercial establishments, and residential housing. Silang however remains to be predominantly an agricultural area, with its share of agro-industrial and industrial establishments.

8.4 Ecosystem Trends

The SGA for the Philippines which focused on the LLB indicated the general trends across the globe. For Laguna Lake Basin, five ecosystem services were considered: water quality, fish production, rice production, biodiversity, and carbon storage, including a brief mention on cultural services. A summary of the conditions and trends of these ecosystem services is presented in Figure 8.3.

For water quality, the general conditions of the rivers and the lake itself were poor and deteriorating. Based on DO and BOD levels, most of these rivers are virtually dead such as San Pedro, Tunasan, San Cristobal, and San Juan rivers with DO and BOD levels below Class C standards. Tanay River is deteriorating as indicated by increasing turbidity, BOD, COD, conductivity, chloride, total phosphorous, and ammonia-nitrogen loads (Figure 8.4). The problem concerning BOD is most pronounced in rivers.

Water quality assessment of lake waters also revealed that many parameters have exceeded the prescribed criteria for Class C waters while others have fallen to levels indicative of the stressed state of the resource. The LLDA data showed that the decline however has been noticeably gradual in the last decade, and indicated some successes in the water pollution abatement programs. It was this initial success that landed the lake in the list of the World's Living Lakes.

Lake waters are also found to be contaminated with toxic and hazardous substances (e.g., heavy metals and persistent organic pollutants including pesticides) coming from the industrial and agricultural sectors. The heavy metals Pb, Cr, Cd, Cu, As, and Hg, at one time or another, have been found in concentrations exceeding the prescribed safe levels for Class C waters. Results of the measurements by various workers differ, underscoring the importance of considering

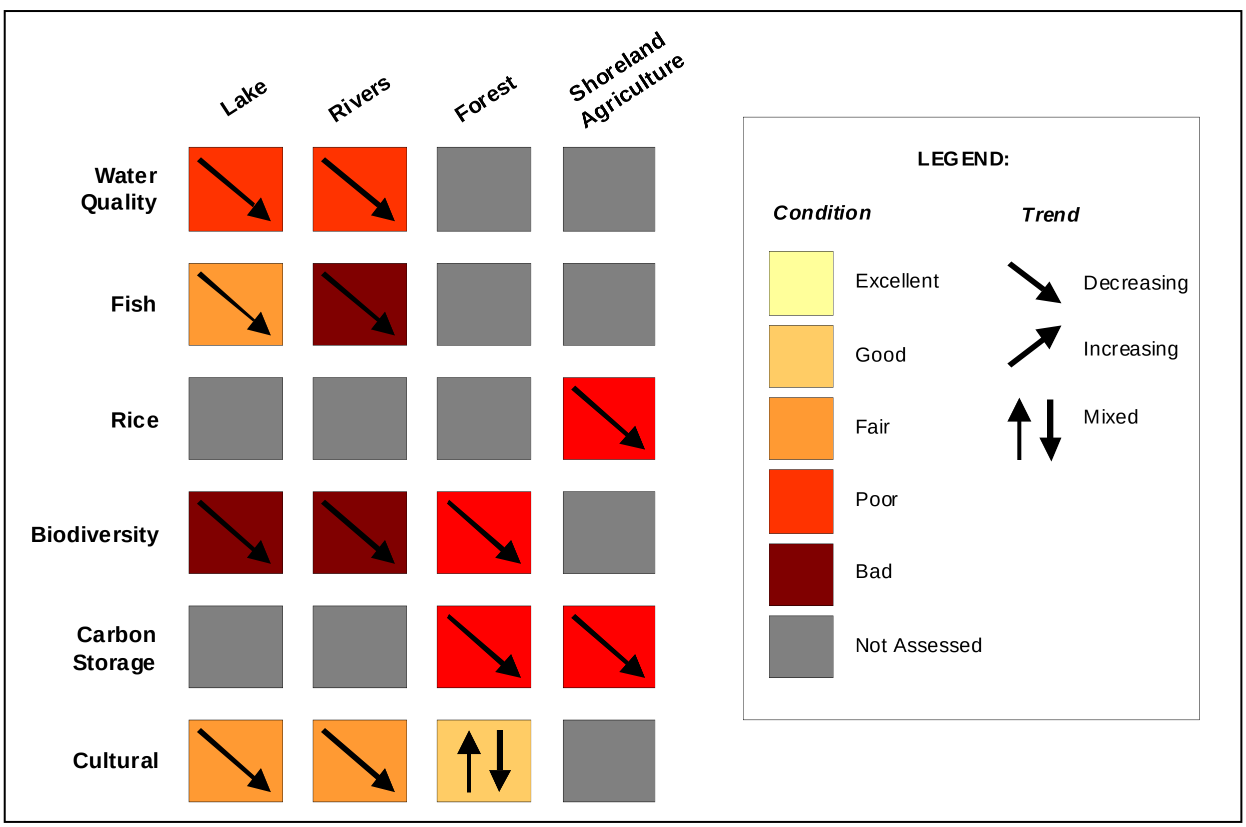

Figure 8.3. Assessment of the conditions and trends of Laguna Lake Basin ecosystems and the services that they provide.

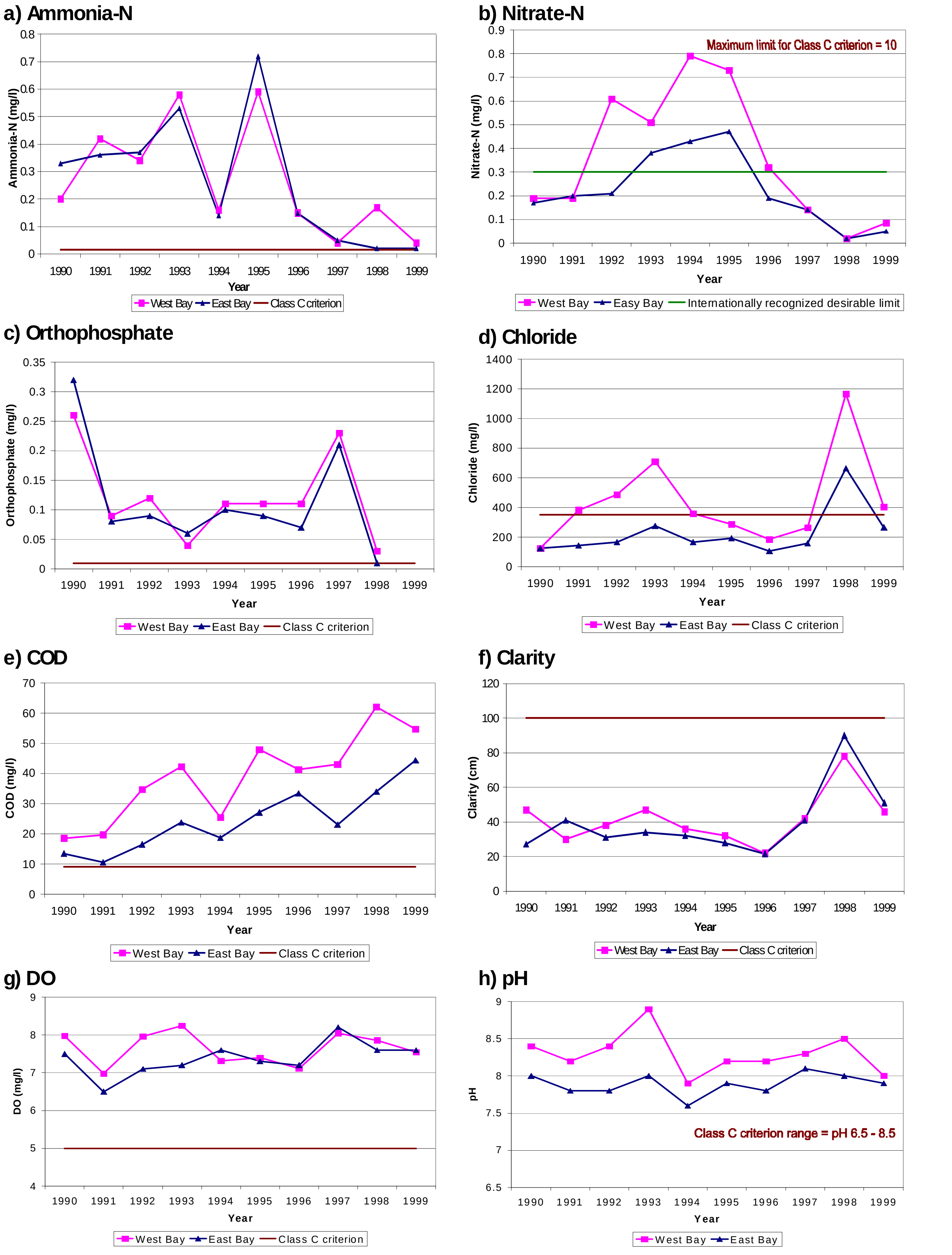

Figure 8.4. Concentrations of selected water quality parameters in the Laguna Lake, 1990-1999. These parameters have either exceeded or fallen below the criteria for Class C waters (Note: Barril's data = 1990-1996; LLDA data = 1997-1999).

in the interpretation of data, the place, and time of sampling, not to mention the operation of the method used in sample preparation. Some of the toxic and hazardous chemicals have found their way in the biota.

Lake sediments are likewise contaminated with heavy metals. Some parts of the lake have low levels while other parts have high. Nevertheless, the reported concentrations of heavy metals in the sediments are rated very low. The results of analysis for heavy metals and organic chemicals such as pesticides and other industry-derived, persistent organic chemicals in fish and other biota are inconclusive and need further verification and assessment.

Fish production is still in good condition, which can be attributed to successes in the aquaculture technology. Much of the fishery production is generated by fishpen and fish cage operation. The trend, however, is still declining (See Figures 4.6 and 4.8). Between 1980 to 1996, a 64 percent decline in fish production levels was observed due to effects of human, industrial, and environmental factors. Hence, the capacity of the lake to supply almost 70 percent of the total freshwater fish requirement of Metro Manila and adjoining provinces before was reduced to only 18 percent at present. On the other hand, fishery production of the rivers in the basin is in bad state and continues to decline.

Rice production of the shoreland is in good state, although not as productive as its lowland irrigated counterpart. Around 570 km^2 of the shoreland is planted to rice. At an average yield of 4.1 t ha^{-1} (410 t km^{-2}), the area can supply 22,800 t of palay or almost 9,000 t of milled rice, or 14 percent of total rice requirement in the Laguna de Bay Region. Meanwhile, with improvement in rice cultivation such as use of better rice varieties and better fertilizer management, it can readily supply 20 percent of the rice requirement in the basin. Rice production in the basin however is declining, mainly due to the reduction of the area cultivated for rice and the aggressive implementation of RA 4850. The act stipulates that the shoreland within the 12.5 m elevation is within the jurisdiction of LLDA. This policy has generated negative reactions from rice farmers who have been cultivating the shorelands with rice for several generations and have in fact evolved a system of informal ownership arrangement within the lakeside communities.

Biodiversity of the forest ecosystems within the basin is still in good conditions, but is also declining as results of agricultural encroachment, development projects, and continued harvesting of timber from its watershed. Consequently, its carbon storage function is also declining. Mt. Makiling, Mt. Banahaw, and parts of the Sierra Madre Mountain Range are depository of diverse flora and fauna that represent distinct biogeographical zones. Mt. Banahaw, a declared national park under the NIPAS, remains a home to various religious communities who regard it as a sacred mountain. It is also a destination for the curious, for mountain hikers, and recreationists who enjoy the cool waters of Sta. Lucia Falls and River especially during the height of summer. Mt. Makiling, a UPLB forest reserve, serves as an educational destination to students of forestry, ecology, geography and related sciences, both from primary to graduate school. It is also identified as one of the 32 ecotourism sites in the country. Biodiversity of the lake and the river, however, is in dismal state. Because of the focus on aquaculture, fish population has been dominated by commercial fishes like tilapia and milkfish. The loss of indigenous fish species in the lake has been attributed to the introduction of exotic species like the Janitor fish, tilapia, and milkfish, both intentional and accidental.

References

Davies, J., 1986: The problems affecting the small fishermen in Laguna de Bay. Service Bureau for Small Fishermen. Sta. Ana, Metro Manila. 22 pp. Reprint.

Escobin, A., 2001: *Institutional Arrangement in the Rehabilitation of Biñan River, Laguna, Philippines*. MS Thesis (Environmental Science). UPLB.

Espaldon, M.V.O., 2000: Community Participation in Metropolitan Environmental Improvement Program: Stories in the Philippines. A Report to the World Bank, Washington, USA.

Gonzales, E.R., 1988: Policy Issues in Philippine Fishery Resource Based Development. Philippine Institute for Development Studies (PIDS) and University of Sto Tomas Graduate School, Philippines.

LLDA, 1995: The Laguna De Bay Master Plan, Final Report.

LLDA, 2003: The Laguna Lake Development Authority website. Available at http://www.llda.gov.ph.

Santos-Borja, A. and D. Nepomuceno, 2003: Experience and Lessons Learned Brief for Laguna de Bay. Laguna Lake Development Authority, Pasig City, Philippines.

9

Conclusions

RODEL D. LASCO, MA. VICTORIA O. ESPALDON

The Laguna Lake Basin is a classic model of a multiple resource with multiple users. Its capacity to provide various ecosystem services to various users is continuously being challenged mainly by anthropogenic factors. Deforestation of its watersheds in favor of other uses such as agriculture, industry, and human settlements is expected to cause imbalance in the lake hydraulic processes. Prolonged flooding and gradual shallowing of lakebed due to sedimentation and siltation are detrimental to the welfare of communities living along the lakeshore, including cities and towns. Lakewater quality has deteriorated through the years due to various point sources of pollution: industry, agriculture, and households. Some physico-chemical parameters like nitrate, phosphate, DO, and BOD met the standards of Class C waters, according to LLDA. However, the detection of traces of heavy metals like Cu, Cd, Cr, and Pb, and other PAHs in the water and sediment is a grave concern for human health. Traces of heavy metals are also found in fishes although higher concentrations are found in the inedible part of the fish. The concept of biomagnification, however, does not ensure safety from these threats. These studies are only sparse and limited, and no conclusive findings can be established yet.

Fish production is still viable which can be attributed to successes in aquaculture technology. Much of the fishery production is generated by fishpen and fish cage operation. The trend, however, is still declining. On the other hand, fishing in the rivers in the basin is in bad state and continues to decline. This is mainly due to the pollution of major river systems in the basin.

Rice farming in the shorelands is still being practiced the way it was before. The decline in the production, however, is mainly due to the reduction of the area for rice. Many factors contribute to this: land conversion to non-agriculture uses like housing, prolonged flooding in some areas, and implementation of RA 4850 which stipulates that the shoreland within the 12.5 m elevation is within the jurisdiction of LLDA. This is already a brewing conflict between the rice farmers particularly in Laguna. These are the farmers who have been traditionally cultivating the shorelands with rice with an evolved system of informal ownership arrangement or social contracts among themselves.

Biodiversity of the forest ecosystems within the basin is still in good condition. However, it is also declining as results of agricultural encroachment, development projects, and continued harvesting of timber from its watershed. Mt. Makiling, Mt. Banahaw, and parts of the Sierra Madre Mountain Range are depository of diverse flora and fauna that represent distinct biogeographical zones. Consequently, its carbon storage function is also declining.

The multiple resource-multiple users nature of the basin has resulted to various types of social conflicts: intrasectoral, intersectoral, and multisectoral. Within the fishery sector, fishermen and fishpen operators conflicts at one time in the history of the lake had turned violent. The government through the LLDA with the assistance of the military (and nature – typhoons) had to mediate to settle the conflict. Between the fishery and agricultural sectors was the conflict over the use of irrigation water and open fishing and aquaculture. Fishery sector argued that the control of saline water inflows through the Pasig River, its only outlet to Manila Bay, is detrimental to fishery productivity. The saline water causes the flocculation to occur and results to greater transparency of the lake water, a condition that is conducive to fish growth. Multisectoral conflicts are conflicts occurring between fishery, agriculture, human settlements, and cities and towns due to various development projects like flood control, road dikes, water supply, among others.

An array of institutional and policy responses were designed to address various types of conflicts. A landmark response was the creation of the ZOMAP which became the guidelines for the use of the lake surface water. It designated areas for fishpens, fish cages, open fishing, fish sanctuary, and navigational lanes. This prevented the further deterioration of the peace and order problem in the lake basin. The ZOMAP emanated from the LLDA, the main agency tasked to manage the lake basin. Another equally significant stride in the effort to control lake pollution was the involvement of local communities in the control and prevention of pollution of the 22 river systems. The efforts started in 1997 when environmental armies were organized to assist in the clean up of the lake. This was the precursor for the formation of multisectoral river rehabilitation councils, which now have taken an identity of its own. They now operate as independent entity from LLDA or from local government. Other responses are mainly legal instruments that LLDA passed like the Laguna Lake Development Master Plan.

In general, the SGA-Laguna Lake Basin focused on the assessment of the conditions of the lake biophysical environment and its relationship with human well-being as measured in terms of its ability to provide ecosystem services such as water, food such as fish and rice, biodiversity, and climate regulation through a study of LLB as a potential carbon storage. The study attempted to highlight the interaction between human well-being and the conditions of the biophysical environment. It also presented accounts of the social dynamics intricately related to the multidimensional nature of the lake basin as a resource and an array of institutional and policy responses. However, several gaps in the science about the lake and lake dynamics still remain:

- What is the extent of pollution with heavy metals and other toxic substances like PAHs in the lake? What are its impacts on human health? What are its impacts to the fishery sector? To other uses like domestic water supply? What is the geography of heavy metal pollution (e.g., sources, concentration, and distribution)?

- What are the significant strides in the activities and proceedings of river rehabilitation councils? What are the areas that need improvement? How do river councils tap community resources and social capital, and even indigenous knowledge?
- How do we encourage communities in the remaining intact watersheds to protect these and reduce lake siltation? What potential mechanisms can be applied? How do we involve local and traditional institutions in the lake basin management?
- How do we regulate land conversions within the basin? How do we synchronize the municipalities comprehensive land use plans/development plans and the Laguna Lake Master Plan?
- How will the construction of more recent development infrastructures, like polder projects, road dikes, and dams, influence the ecological and socio-economic dynamics in the lake basin?

These may not be an exhaustive list. However, addressing these gaps in the knowledge may contribute to the sustainable management of the Laguna Lake Basin. Sustainable management regime is one that is decentralized, and involves multistakeholders' interests yet can provide a holistic and coordinated framework that ensures the continuous provision of ecosystem services to the basin's population.

Appendix A

ADDITIONAL DATA AND INFORMATION ON LAGUNA LAKE BASIN

Appendix A1. Physico-chemical properties of water from Pagsanjan River (wet season).

Parameter	I	II	III	IV	V	VI
pH, units	6.9	7.7	8.1	7.8	8.1	6.9
TSS, mg l^{-1}	5	2	<2	57	26	3
TDS, mg l^{-1}	215	133	170	189	351	198
COD, mg l^{-1}	88	56	8	16	84	12
BOD, mg l^{-1}	33	5	1	1	0.7	2
DO, mg l^{-1}	0.6	8.4	8.4	7.5	6.8	6.5
Oil/Grease, mg l^{-1}	nd	3	3	<2	<2	<2
Ammonia, mg l^{-1}	3.8400	0.0600	0.0696	0.0528	0.0960	0.0960
Nitrate, mg l^{-1}	0.0495	0.0110	0.2310	0.0170	0.0248	0.0248
Inorganic phosphate, mg l^{-1}	0.8960	0.0840	0.448	0.3640	0.007	0.0070
Chloride, mg l^{-1}	22.32	14.88	11.16	22.32	14.88	14.88
Alkalinity, mg l^{-1} $CaCO_3$	46	20	28	40	12	40
Hardness, mg l^{-1} $CaCO_3$	36	16	28	36	12	40
Total hardness, mg l^{-1} $CaCO_3$	328	296	308	332	288	361
Turbidity, mg l^{-1} SiO_2	3	3	3	3	5	7

	VII	VIII	IX	X	XI	Water Quality Criteria Class C Waters
pH, units	8.4	7.5	7.4	7.4	8.2	3.5-8.5
TSS, mg l^{-1}	3	10	2	7	<2	
TDS, mg l^{-1}	207	215	157	401	147	1,000
COD, mg l^{-1}	8	4	8	20	28	
BOD, mg l^{-1}	1	2	1	1	0.8	7 (10)
DO, mg l^{-1}	8	4.6	6.4	4.6	7.9	(minimum)
Oil/Grease, mg l^{-1}	2	<2	<2	2	3	2
Ammonia, mg l^{-1}	0.0864	0.0920	0.0460	0.0640	0.0320	
Nitrate, mg l^{-1}	0.1788	0.0960	0.0400	0.0480	0.0430	10.0000
Inorganic phosphate, mg l^{-1}	0.3920	0.3820	0.1029	0.1470	0.0660	
Chloride, mg l^{-1}	14.88	22.32	26.04	163.68	22.32	350
Alkalinity, mg l^{-1} $CaCO_3$	40	48	32	34	28	
Hardness, mg l^{-1} $CaCO_3$	40	40	40	32	36	
Total hardness, mg l^{-1} $CaCO_3$	332	328	328	372	356	
Turbidity, mg l^{-1} SiO_2	7	7	7	5	3	

Legend:

I Brgy. Camatian
II Brgy. Pagsipi
III Brgy. Tiklingan
IV Brgy. Balanac
V Caliraya Spillway
VI Lumut Spillway
VII San Isidro Majayjay
VIII Brgy. Dos Balanac
IX Brgy. Magdapyo
X Mouth
XI Rapida

Appendix A2. Physico-chemical properties of water from Pagsanjan River (dry season).

Parameter	I	II	III	IV	V	VI
pH, units	6.7	7.3	7.4	7.8	7.5	6.9
TSS, mg l^{-1}	11	<2	5	7	3	2
TDS, mg l^{-1}	212	140	101	139	297	71
COD, mg l^{-1}	48	<4	16	8	16	8
BOD, mg l^{-1}	19	0.5	1	0.9	1	1.3
DO, mg l^{-1}	1.5	7.8	7.3	7.7	7.5	7.4
Oil/Grease, mg l^{-1}	2	2	2	2	<2	<2
Ammonia, mg l^{-1}	0.9700	<0.002	<0.002	<0.002	<0.002	0.0130
Nitrate, mg l^{-1}	<0.005	0.0260	0.1380	0.1200	0.0100	0.0050
Inorganic phosphate, mg l^{-1}	0.5200	0.0800	0.06	0.1670	0.0200	0.0100
Chloride, mg l^{-1}	22.3	11.2	11.2	14.9	123	11
Alkalinity, mg l^{-1} $CaCO_3$	42	20	18	18	12	10
Hardness, mg l^{-1} $CaCO_3$	36	8	12	16	12	8
Total hardness, mg l^{-1} $CaCO_3$	68	32	32	60	80	40
Turbidity, mg l^{-1} SiO_2	9	<1	12	8	2	7

Parameter	VII	VIII	IX	X	XI	Water Quality Criteria Class C Waters
pH, units	7.6	7.1	7.1	7	7.6	3.5-8.5
TSS, mg l^{-1}	11	11	32	4	<2	
TDS, mg l^{-1}	126	127	84	135	62	1,000
COD, mg l^{-1}	8	8	8	4	4	
BOD, mg l^{-1}	1	3	0.7	8	0.6	7 (10)
DO, mg l^{-1}	8.2	6.2	7.1	53	7.9	(minimum)
Oil/Grease, mg l^{-1}	2	2	2	2	<2	2
Ammonia, mg l^{-1}	<0.002	<0.002	<0.002	<0.002	<0.002	
Nitrate, mg l^{-1}	0.110	0.0700	0.0040	0.0140	0.0090	10.0000
Inorganic phosphate, mg l^{-1}	0.1500	0.1370	0.0200	0.0980	0.0200	
Chloride, mg l^{-1}	11.2	18.6	22.3	37.2	18.6	350
Alkalinity, mg l^{-1} $CaCO_3$	22	36	16	18	20	
Hardness, mg l^{-1} $CaCO_3$	16	12	12	12	12	
Total hardness, mg l^{-1} $CaCO_3$	44	56	44	48	44	
Turbidity, mg l^{-1} SiO_2	18	18	28	12	3	

Legend:

I Brgy. Camatian
II Brgy. Pagsipi
III Brgy. Tiklingan
IV Brgy. Balanac
V Caliraya Spillway
VI Lumut Spillway
VII San Isidro Majayjay
VIII Brgy. Dos Balanac
IX Brgy. Magdapyo
X Mouth
XI Rapida

Appendix A3. Physico-chemical properties of water in San Cristobal River gathered on April 1996.

Parameter	Station 1	Station 2	Station 3	Station 4	Station 5
Air Temperature (°C)	27.5	28.5	35.5	35.5	32.5
Temperature (°C)	26.4	27.1	35.7	34.7	31.6
pH	7.8	7.92	7.39	7.24	7.14
DO, mg l^{-1}	7.09	6.96	2.95	0.08	0.41
Conductivity, mS cm^{-1}	0.26	0.293	0.592	0.561	0.533
Turbidity (NTU)	7.00	5.00	109.00	60.00	19.00
BOD, mg l^{-1}	0.5 ± 0.1	1.34 ± 0.15	13.5 ± 0.15	21.35 ± 0.35	17.25 ± 0.25
COD, mg l^{-1}	14.3 ± 1.3	17.5 ± 0.5	18.0 ± 1.0	33.5 ± 0.5	21.0 ± 1.0
TOC, ppm	5.32 ± 0.08	5.64 ± 0.06	10.79 ± 0.07	15.88 ± 0.06	13.70 ± 1.14
Alkalinity, mg l^{-1} $CaCO_3$	84.4 ± 0.6	85.0 ± 1.2	137.5 ± 1.3	158.8 ± 2.5	153.1 ± 0.6
Chloride, mg l^{-1}	5.0 ± 0.0	6.25 ± 0.0	41.49 ± 1.5	23.74 ± 1.25	23.74 ± 1.25
Hardness, mg l^{-1}	21.46 ± 1.26	26.51 ± 1.26	31.56 ± 1.26	45.45 ± 2.52	39.14 ± 1.26
TSS, mg l^{-1}	2.8 ± 0.8	11.6 ± 2.0	76.2 ± 16.6	37.4 ± 4.2	12.2 ± 0.6
TDS, mg l^{-1}	211.0 ± 13.0	295.0 ± 9.0	363.0 ± 7.0	417.0 ± 5.0	364.0 ± 4.0
Orthophosphate, mg l^{-1} P	0.22 ± 0.02	0.30 ± 0.005	0.42 ± 0.005	0.49 ± 0.01	0.44 ± 0.02
Total Phosphate, mg l^{-1} P	0.22 ± 0.10	0.32 ± 0.005	0.46 ± 0.005	0.56 ± 0.02	0.50 ± 0.01
Ammonia-N, mg l^{-1}	0.42 ± 0.01	0.46 ± 0.01	0.40 ± 0.06	0.72 ± 0.06	1.42 ± 0.04
Nitrate-N, mg l^{-1}	0.41 ± 0.01	1.20 ± 0.01	0.44 ± 0.01	1.17 ± 0.04	0.43 ± 0.01

Appendix A4. Physico-chemical properties of water in San Cristobal River gathered on July 1996.

Parameter	Station 1	Station 2	Station 3	Station 4	Station 5
Temperature (°C)	---	26.8	31.9	30.2	29.4
pH	---	7.81	7.42	7.29	7.56
DO, mg l^{-1}	---	5.3	5.14	0.64	1.71
Conductivity, mS cm^{-1}	---	0.293	0.613	0.651	0.562
Turbidity (NTU)	---	11.00	63.00	60.00	44.00
BOD, mg l^{-1}	---	2.27 ± 0.02	6.08 ± 0.31	10.52 ± 0.08	7.87 ± 0.23
COD, mg l^{-1}	---	6.8 ± 0.5	22.4 ± 1.6	36.9 ± 0.5	26.0 ± 3.1
TOC, ppm	---	5.03 ± 0.09	9.72 ± 0.11	13.85 ± 0.16	10.13 ± 0.18
Alkalinity, mg l^{-1} $CaCO_3$	---	135.0 ± 0.0	195.5 ± 13.5	234.5 ± 0.5	222 ± 1.0
Chloride, mg l^{-1}	---	21.94 ± 0.2	38.57 ± 1.0	43.87 ± 0.5	32.78 ± 0.0
Hardness, mg l^{-1}	---	67.5 ± 7.5	103.5 ± 5.5	110.5 ± 7.5	138.0 ± 12.0
TSS, mg l^{-1}	---	12.6 ± 1.4	34.4 ± 4.8	30.6 ± 1.0	26.0 ± 2.8
TDS, mg l^{-1}	---	307.5 ± 2.5	322.5 ± 12.5	412.0 ± 7.5	360.0 ± 15.0
Orthophosphate, mg l^{-1} P	---	0.25 ± 0.01	1.32 ± 0.03	0.63 ± 0.00	0.75 ± 0.02
Total Phosphate, mg l^{-1} P	---	0.42 ± 0.00	1.36 ± 0.01	0.75 ± 0.01	0.91 ± 0.00
Ammonia-N, mg l^{-1}	---	0.31 ± 0.10	1.63 ± 0.06	0.80 ± 0.09	1.84 ± 0.01
Nitrate-N, mg l^{-1}	---	2.68 ± 0.07	0.15 ± 0.03	0.42 ± 0.05	0.10 ± 0.01

Legend:

Station 1 Matangtubig
Station 2 Mangumit
Station 3 San Isidro
Station 4 Paciano
Station 5 Looc
--- Data not available due to instrument malfunction

Appendix A5. Physico-chemical properties of water in Tanay River gathered on February 1998.

Parameter	Station 1	Station 2	Station 3	Station 4	Station 5
Temperature (^oC)	24.7	---	26.6	28.6	28.3
pH	7.68	---	9.09	7.97	7.64
DO, mg l^{-1}	6.55	---	7.87	7.36	3.885
Conductivity, mS cm^{-1}	0.17	---	0.36	0.37	0.71
Turbidity (NTU)	2	---	2	1	8
TSS, mg l^{-1}	14.00 ± 0.00	---	24.00 ± 1.00	2.50 ± 0.50	6.00 ± 1.00
TDS, mg l^{-1}	87 ± 9	---	133 ± 1	138 ± 2	243 ± 7
BOD, mg l^{-1}	1.74 ± 0.72	---	5.05 ± 1.33	3.16 ± 0.06	5.51 ± 0.87
COD, mg l^{-1}	4.50 ± 1.50	---	9.00 ± 3.00	4.50 ± 1.50	16.00 ± 2.00
Alkalinity, mg l^{-1} $CaCO_3$	71 ± 1	---	120 ± 5	145 ± 9	268 ± 11
Hardness, mg l^{-1}	41.65 ± 3.57	---	111 ± 1	131 ± 7	186 ± 14
Chlorides, mg l^{-1}	7.06 ± 0	---	7.06 ± 0	7.77 ± 0	62.17 ± 0
Orthophosphate, mg l^{-1} P	0.03 ± 0.00	---	0.23 ± 0.01	0.11 ± 0.00	0.16 ± 0.00
Total Phosphorus, mg l^{-1} P	0.10 ± 0.00	---	0.74 ± 0.01	0.14 ± 0.01	0.30 ± 0.01
Ammonia-N, mg l^{-1}	0.59 ± 0.08	---	0.61 ± 0.10	0.24 ± 0.08	1.61 ± 0.08
TKN, mg l^{-1}	1.12 ± 0.18	---	1.45 ± 0.00	2.43 ± 0.04	3.51 ± 0.10
Nitrite-N, mg l^{-1}	nd	---	0.01 ± 0.00	nd	0.07 ± 0.00
Nitrate-N, mg l^{-1}	0.12 ± 0.02	---	0.89 ± 0.02	0.14 ± 0.04	0.28 ± 0.05
Chlorophyll a, mg m^{-3}	2.49 ± 0.16	---	4.00 ± 0.30	2.89 ± 0.18	24.04 ± 8.33

Appendix A6. Physico-chemical properties of water in Tanay River gathered on March 1998.

Parameter	Station 1	Station 2	Station 3	Station 4	Station 5
Temperature (^oC)	24.8	29.5	28.7	29.2	29.8
pH	7.12	8.57	8.51	7.1	7.27
DO, mg l^{-1}	---	---	---	---	---
Conductivity, mS cm^{-1}	0.71	0.4	0.36	0.38	0.65
Turbidity (NTU)	1.60	6.00	3.00	1.00	14.00
TSS, mg l^{-1}	6.00 ± 1.00	10.50 ± 0.50	5.50 ± 1.50	6.00 ± 1.00	12.50 ± 1.50
TDS, mg l^{-1}	24 ± 8	144 ± 24	120 ± 0	146 ± 2	196 ± 12
BOD, mg l^{-1}	0.31 ± 0.11	2.78 ± 0.16	2.50 ± 1.50	0.20 ± 0.10	9.22 ± 0.79
COD, mg l^{-1}	1.59 ± 0.53	5.30 ± 1.06	3.18 ± 0.00	1.06 ± 0.00	20.67 ± 1.59
Alkalinity, mg l^{-1} $CaCO_3$	47.00 ± 5.64	159 ± 4	135 ± 2	155 ± 5	180 ± 3
Hardness, mg l^{-1}	8.33 ± 1.19	162 ± 5	100 ± 9	145 ± 7	105 ± 9
Chlorides, mg l^{-1}	2.79 ± 0.12	6.32 ± 0.48	6.31 ± 0.00	5.10 ± 0.24	34.97 ± 0.97
Orthophosphate, mg l^{-1} P	0.18 ± 0.00	0.24 ± 0.00	0.12 ± 0.00	0.11 ± 0.00	0.12 ± 0.00
Total Phosphorus, mg l^{-1} P	0.27 ± 0.00	0.36 ± 0.02	0.17 ± 0.00	0.16 ± 0.00	0.34 ± 0.00
Ammonia-N, mg l^{-1}	nd	nd	nd	nd	1.72 ± 0.02
TKN, mg l^{-1}	0.28	0.60 ± 0.09	0.64 ± 0.14	0.45 ± 0.00	3.61 ± 0.19
Nitrite-N, mg l^{-1}	nd	0.02 ± 0.01	0.02 ± 0.00	nd	0.11 ± 0.00
Nitrate-N, mg l^{-1}	2.18 ± 0.00	1.89 ± 0.31	0.47 ± 0.50	0.72 ± 0.00	0.77 ± 0.50
Chlorophyll a, mg m^{-3}	2.19 ± 1.28	2.64 ± 0.23	4.97 ± 2.00	2.54 ± 0.64	31.74 ± 0.97

Legend:

Station 1 Cuyambay
Station 2 Daranak
Station 3 Upper Tandang Kutyo
Station 4 Lower Tandang Kutyo
Station 5 Wawa (River mouth)
nd not detected
--- Data not available due to instrument malfunction

Appendix A7. Physico-chemical properties of water in Tanay River gathered on April 1998.

Parameter	Station 1	Station 2	Station 3	Station 4	Station 5
Temperature (°C)	26.4	29.5	28.9	29.2	28.4
pH	7.15	8.58	8.39	7.42	7.84
DO, mg l^{-1}	7.96	8.68	9.95	3.26	5.7
Conductivity, mS cm^{-1}	0.22	0.42	0.4	0.38	1.16
Turbidity (NTU)	2.00	4.00	1.00	0.00	45.00
TSS, mg l^{-1}	8.00 ± 0.00	4.50 ± 1.50	8.00 ± 0.00	2.50 ± 0.50	36.50 ± 1.50
TDS, mg l^{-1}	169 ± 9	350 ± 2	343 ± 5	333 ± 5	691 ± 7
BOD, mg l^{-1}	1.52 ± 0.16	1.57 ± 0.19	1.16 ± 0.00	4.72 ± 0.30	6.87 ± 0.18
COD, mg l^{-1}	5.00 ± 0.00	5.00 ± 0.00	5.00 ± 0.00	7.00 ± 0.00	47.50 ± 2.50
Alkalinity, mg l^{-1} $CaCO_3$	23.36 ± 1.60	74.88 ± 1.28	73.12 ± 2.08	66.72 ± 0.48	71.84 ± 0.16
Hardness, mg l^{-1}	46.25 ± 3.75	255 ± 3	239 ± 1	208 ± 0	230 ± 10
Chlorides, mg l^{-1}	2.96 ± 0.00	4.43 ± 0.00	4.93 ± 0.00	4.92 ± 0.98	181 ± 1
Orthophosphate, mg l^{-1} P	nd	0.63 ± 0.01	0.43 ± 0.00	0.08 ± 0.00	0.28 ± 0.00
Total Phosphorus, mg l^{-1} P	0.05 ± 0.00	0.71 ± 0.03	0.51 ± 0.02	0.26 ± 0.05	1.21 ± 0.09
Ammonia-N, mg l^{-1}	0.08 ± 0.02	0.34 ± 0.08	0.22 ± 0.04	0.14 ± 0.04	1.61 ± 0.02
TKN, mg l^{-1}	0.34 ± 0.08	0.50 ± 0.08	0.43 ± 0.14	0.24 ± 0.01	5.23 ± 0.06
Nitrite-N, mg l^{-1}	nd	0.03 ± 0.00	0.02 ± 0.00	0.01 ± 0.00	0.08 ± 0.00
Nitrate-N, mg l^{-1}	0.28 ± 0.01	1.64 ± 0.14	0.30 ± 0.08	1.20 ± 0.02	0.66 ± 0.08
Chlorophyll a, mg m^{-3}	6.18 ± 0.98	3.48 ± 0.88	5.47 ± 1.38	3.30 ± 0.07	61.78 ± 4.98

Appendix A8. Physico-chemical properties of water in Tanay River gathered on May 1998.

Parameter	Station 1	Station 2	Station 3	Station 4	Station 5
Temperature (°C)	---	27	27.6	28.5	28.2
pH	---	8.13	7.92	7.4	7.66
DO, mg l^{-1}	---	11.66	8.46	5.32	5.25
Conductivity, mS cm^{-1}	---	0.38	0.42	0.39	0.94
Turbidity (NTU)	---	66.00	5.00	0.00	40.00
TSS, mg l^{-1}	---	39.5 ± 0.50	8.00 ± 2.00	25.50 ± 2.50	3.50 ± 0.50
TDS, mg l^{-1}	---	302 ± 2	333 ± 1	287 ± 9	534 ± 2
BOD, mg l^{-1}	---	1.60 ± 0.50	1.52 ± 0.00	3.19 ± 0.05	11.55 ± 0.05
COD, mg l^{-1}	---	7.02 ± 0.47	8.89 ± 0.47	3.74 ± 0.00	25.74 ± 3.28
Alkalinity, mg l^{-1} $CaCO_3$	---	143 ± 3	142 ± 3	150 ± 1	211 ± 0
Hardness, mg l^{-1}	---	196 ± 22	181 ± 2	171 ± 6	246 ± 3
Chlorides, mg l^{-1}	---	5.38 ± 0.98	6.36 ± 0.00	6.36 ± 0.00	103 ± 0.5
Orthophosphate, mg l^{-1} P	---	0.52 ± 0.01	1.36 ± 0.01	0.21 ± 0.01	0.67 ± 0.00
Total Phosphorus, mg l^{-1} P	---	0.75 ± 0.09	1.59 ± 0.19	0.24 ± 0.01	0.96 ± 0.00
Ammonia-N, mg l^{-1}	---	1.38 ± 0.46	1.55 ± 0.01	0.32 ± 0.08	5.97 ± 0.05
TKN, mg l^{-1}	---	1.54 ± 0.15	2.33 ± 0.03	0.80 ± 0.01	9.39 ± 0.80
Nitrite-N, mg l^{-1}	---	0.08 ± 0.00	0.20 ± 0.00	0.02 ± 0.00	0.03 ± 0.00
Nitrate-N, mg l^{-1}	---	3.55 ± 0.78	5.29 ± 0.50	0.73 ± 0.03	0.21 ± 0.00
Chlorophyll a, mg m^{-3}	---	1.67 ± 0.25	2.91 ± 0.09	2.00 ± 0.71	30.33 ± 2.58

Legend:

Station 1 Cuyambay
Station 2 Daranak
Station 3 Upper Tandang Kutyo
Station 4 Lower Tandang Kutyo
Station 5 Wawa (River mouth)
nd not detected
--- Data not available due to instrument malfunction

Appendix A9. Physico-chemical properties of water in Tanay River gathered on June 1998.

Parameter	Station 1	Station 2	Station 3	Station 4	Station 5
Temperature (°C)	25.8	27.7	28.4	28.9	30.3
pH	6.79	8.03	7.74	7.17	7.32
DO, mg l^{-1}	7.57	8.9	7.56	7.18	3.3
Conductivity, mS cm^{-1}	0.16	0.42	0.4	0.4	1.94
Turbidity (NTU)	7.00	25.00	7.00	3.00	52.00
TSS, mg l^{-1}	15.00 ± 3.00	19.00 ± 5.00	19.00 ± 2.00	1.50 ± 0.50	65.50 ± 13.50
TDS, mg l^{-1}	79.5 ± 2.5	174 ± 2	157 ± 2	159 ± 1	280 ± 8
BOD, mg l^{-1}	1.55 ± 0.07	1.70 ± 0.33	1.16 ± 0.10	1.72 ± 0.03	8.96 ± 0.00
COD, mg l^{-1}	2.34 ± 0.00	5.14 ± 0.93	2.81 ± 1.41	2.34 ± 0.94	43.06 ± 0.47
Alkalinity, mg l^{-1} $CaCO_3$	57.72 ± 0.31	136 ± 1	154 ± 0	151 ± 4	167 ± 4
Hardness, mg l^{-1}	56.70 ± 1.00	195 ± 4	177 ± 6	167 ± 0	291 ± 4
Chlorides, mg l^{-1}	4.03 ± 0.00	8.05 ± 0.00	5.54 ± 1.51	8.30 ± 0.25	415 ± 13
Orthophosphate, mg l^{-1} P	0.05 ± 0.00	0.83 ± 0.04	0.13 ± 0.00	0.14 ± 0.00	0.31 ± 0.02
Total Phosphorus, mg l^{-1} P	0.07 ± 0.00	1.11 ± 0.01	0.60 ± 0.09	0.19 ± 0.01	5.11 ± 0.12
Ammonia-N, mg l^{-1}	0.51 ± 0.14	0.49 ± 0.04	0.51 ± 0.06	nd	4.94 ± 0.014
TKN, mg l^{-1}	0.68 ± 0.21	0.53 ± 0.00	0.94 ± 0.07	0.47 ± 0.15	5.80 ± 1.38
Nitrite-N, mg l^{-1}	nd	0.22 ± 0.00	0.03 ± 0.00	0.02 ± 0.00	0.03 ± 0.00
Nitrate-N, mg l^{-1}	0.24 ± 0.00	3.38 ± 0.29	3.20 ± 0.16	1.72 ± 0.04	0.25 ± 0.01
Chlorophyll a, mg m^{-3}	3.50 ± 0.01	2.49 ± 0.90	1.78 ± 0.37	1.46 ± 0.42	26.98 ± 3.94

Appendix A10. Physico-chemical properties of water in Tanay River gathered on July 1998.

Parameter	Station 1	Station 2	Station 3	Station 4	Station 5
Temperature (°C)	26.9	28.8	30.7	29.4	31.6
pH	7.8	8.88	8.53	7.7	7.74
DO, mg l^{-1}	6.79	7.92	7.18	5.72	4.29
Conductivity, mS cm^{-1}	0.12	0.42	0.4	0.4	2.1
Turbidity (NTU)	13.00	4.00	30.00	2.00	9.00
TSS, mg l^{-1}	7.00 ± 1.00	1.00 ± 0.00	5.00 ± 1.00	6.00 ± 1.00	12.50 ± 2.50
TDS, mg l^{-1}	210 ± 30	428 ± 3	373 ± 28	385 ± 0	1,460 ± 30
BOD, mg l^{-1}	1.11 ± 0.24	0.40 ± 0.00	0.40 ± 0.10	3.77 ± 0.17	6.07 ± 0.5
COD, mg l^{-1}	10.50 ± 1.50	11.00 ± 2.00	8.50 ± 1.50	5.50 ± 0.50	52.50 ± 4.50
Alkalinity, mg l^{-1} $CaCO_3$	59.68 ± 1.55	224 ± 2	203 ± 3	202 ± 4	240 ± 0
Hardness, mg l^{-1}	35.65 ± 1.15	221 ± 0	223 ± 25	196 ± 7	357 ± 21
Chlorides, mg l^{-1}	1.21 ± 0.25	2.65 ± 0.24	1.93 ± 0.00	3.86 ± 0.00	435 ± 5
Orthophosphate, mg l^{-1} P	0.06 ± 0.01	0.11 ± 0.00	0.65 ± 0.02	0.12 ± 0.01	1.09 ± 0.13
Total Phosphorus, mg l^{-1} P	0.11 ± 0.01	0.64 ± 0.14	0.67 ± 0.00	0.21 ± 0.00	1.43 ± 0.16
Ammonia-N, mg l^{-1}	0.27 ± 0.00	0.16 ± 0.00	0.30 ± 0.02	0.22 ± 0.00	5.60 ± 0.60
TKN, mg l^{-1}	0.64 ± 0.16	0.43 ± 0.17	0.80 ± 0.19	0.38 ± 0.11	7.23 ± 0.98
Nitrite-N, mg l^{-1}	0.01 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.01 ± 0.00	0.07 ± 0.00
Nitrate-N, mg l^{-1}	0.15 ± 0.00	2.00 ± 0.03	1.50 ± 0.12	0.85 ± 0.01	0.14 ± 0.02
Chlorophyll a, mg m^{-3}	4.33 ± 1.07	7.22 ± 1.12	7.43 ± 1.10	4.34 ± 0.38	84.83 ± 4.12

Legend:

Station 1 Cuyambay
Station 2 Daranak
Station 3 Upper Tandang Kutyo
Station 4 Lower Tandang Kutyo
Station 5 Wawa (River mouth)
nd not detected
--- Data not available due to instrument malfunction

Appendix A11. Physico-chemical properties of water in Tanay River gathered on August 1998.

Parameter	Station 1	Station 2	Station 3	Station 4	Station 5
Temperature (°C)	25.8	27.8	27.7	29.4	31.3
pH	7.66	8.39	8.15	7.55	7.09
DO, mg l^{-1}	6.6	6.75	6.3	5.73	2.26
Conductivity, mS cm^{-1}	0.22	0.37	0.34	0.38	1.46
Turbidity (NTU)	6.00	10.00	10.00	3.00	7.00
TSS, mg l^{-1}	5.00 ± 0.00	15.00 ± 0.00	12.00 ± 0.00	9.5 ± 0.50	9.00 ± 0.00
TDS, mg l^{-1}	212 ± 24	288 ± 0	270 ± 18	286 ± 14	850 ± 14
BOD, mg l^{-1}	0.20 ± 0.00	3.50 ± 0.15	1.73 ± 0.05	1.68 ± 0.10	4.28 ± 0.00
COD, mg l^{-1}	2.97 ± 0.99	9.90 ± 0.00	7.42 ± 0.49	5.94 ± 0.99	21.29 ± 2.48
Alkalinity, mg l^{-1} $CaCO_3$	66.69 ± 1.95	113 ± 0.9	117 ± 15	141 ± 15	183 ± 4
Hardness, mg l^{-1}	84.60 ± 1.80	133 ± 4	122 ± 0	133 ± 4	207 ± 9
Chlorides, mg l^{-1}	1.58 ± 0.52	3.68 ± 0.52	3.15 ± 0.00	4.20 ± 0.00	310 ± 3
Orthophosphate, mg l^{-1} P	nd	0.59 ± 0.02	0.10 ± 0.00	0.20 ± 0.02	0.06 ± 0.00
Total Phosphorus, mg l^{-1} P	0.06 ± 0.00	0.67 ± 0.01	0.11 ± 0.00	0.30 ± 0.04	0.30 ± 0.05
Ammonia-N, mg l^{-1}	0.34 ± 0.00	0.73 ± 0.12	0.28 ± 0.04	0.19 ± 0.04	1.37 ± 0.01
TKN, mg l^{-1}	0.68 ± 0.10	1.37 ± 0.06	1.01 ± 0.01	0.77 ± 0.04	1.84 ± 0.20
Nitrite-N, mg l^{-1}	nd	0.17 ± 0.00	0.04 ± 0.00	0.02 ± 0.00	0.11 ± 0.00
Nitrate-N, mg l^{-1}	0.27 ± 0.00	0.18 ± 0.01	0.21 ± 0.00	0.15 ± 0.01	0.39 ± 0.00
Chlorophyll a, mg m^{-3}	2.21 ± 0.92	2.60 ± 0.61	2.72 ± 0.34	1.54 ± 0.07	19.56 ± 2.16

Appendix A12. Physico-chemical properties of water in Tanay River gathered on September 1998.

Parameter	Station 1	Station 2	Station 3	Station 4	Station 5
Temperature (°C)	25.7	27.2	26.5	27	26.6
pH	7.53	8.01	7.88	7.69	7.09
DO, mg l^{-1}	8.03	7.95	8.82	8.02	6.51
Conductivity, mS cm^{-1}	0.23	0.28	0.29	0.3	0.33
Turbidity (NTU)	11.00	14.00	9.00	8.00	10.00
TSS, mg l^{-1}	8.50 ± 1.50	23.50 ± 4.50	14.50 ± 4.50	24.00 ± 4.00	14.00 ± 1.00
TDS, mg l^{-1}	188 ± 3	253 ± 13	238 ± 8	240 ± 0	278 ± 13
BOD, mg l^{-1}	0.55 ± 0.00	0.30 ± 0.14	0.39 ± 0.00	0.08 ± 0.02	1.24 ± 0.50
COD, mg l^{-1}	3.96 ± 0.44	7.48 ± 1.32	6.16 ± 0.00	6.60 ± 0.44	8.80 ± 0.88
Alkalinity, mg l^{-1} $CaCO_3$	152 ± 2	184 ± 3	196 ± 0	197 ± 1	211 ± 1
Hardness, mg l^{-1}	114 ± 1	113 ± 4	127 ± 0	120 ± 3	132 ± 9
Chlorides, mg l^{-1}	3.35 ± 0.48	3.59 ± 0.24	3.11 ± 0.24	4.31 ± 0.48	3.35 ± 0.48
Orthophosphate, mg l^{-1} P	nd	0.26 ± 0.00	0.13 ± 0.03	0.12 ± 0.03	0.32 ± 0.03
Total Phosphorus, mg l^{-1} P	nd	0.37 ± 0.02	0.17 ± 0.00	0.18 ± 0.03	0.44 ± 0.06
Ammonia-N, mg l^{-1}	nd	nd	nd	nd	0.11 ± 0.00
TKN, mg l^{-1}	nd	0.24 ± 0.06	nd	nd	0.86 ± 0.01
Nitrite-N, mg l^{-1}	nd	0.10 ± 0.00	0.06 ± 0.00	0.05 ± 0.00	0.17 ± 0.00
Nitrate-N, mg l^{-1}	0.55 ± 0.00	0.51 ± 0.00	0.52 ± 0.02	0.56 ± 0.05	0.65 ± 0.04
Chlorophyll a, mg m^{-3}	1.32 ± 0.01	1.29 ± 0.02	4.44 ± 0.36	2.28 ± 0.19	1.34 ± 0.18

Legend:

Station 1 Cuyambay
Station 2 Daranak
Station 3 Upper Tandang Kutyo
Station 4 Lower Tandang Kutyo
Station 5 Wawa (River mouth)
nd not detected
--- Data not available due to instrument malfunction

Appendix A13. Physico-chemical properties of water in Tanay River gathered on October 1998.

Parameter	Station 1	Station 2	Station 3	Station 4	Station 5
Temperature (°C)	---	26	26.8	25.9	25.7
pH	---	7.74	7.87	7.83	7.44
DO, mg l^{-1}	---	8.22	7.72	8.15	8
Conductivity, mS cm^{-1}	---	0.26	0.2	0.27	0.28
Turbidity (NTU)	---	45.00	28.00	59.00	63.00
TSS, mg l^{-1}	---	102 ± 3	70.00 ± 4.00	136 ± 12	140 ± 0
TDS, mg l^{-1}	---	195 ± 15	175 ± 15	178 ± 3	210 ± 0
BOD, mg l^{-1}	---	1.80 ± 0.10	0.60 ± 0.00	0.44 ± 0.05	1.47 ± 0.05
COD, mg l^{-1}	---	6.03 ± 0.47	4.64 ± 0.93	4.41 ± 1.16	5.80 ± 1.16
Alkalinity, mg l^{-1} $CaCO_3$	---	183 ± 1	109 ± 18	192 ± 0.5	175 ± 19
Hardness, mg l^{-1}	---	136 ± 12	80 ± 9	142 ± 0	153 ± 0
Chlorides, mg l^{-1}	---	7.12 ± 1.19	17.22 ± 1.78	6.53 ± 0.59	8.90 ± 0.60
Orthophosphate, mg l^{-1} P	---	0.37 ± 0.05	0.20 ± 0.02	0.26 ± 0.03	0.26 ± 0.02
Total Phosphorus, mg l^{-1} P	---	0.38 ± 0.02	0.26 ± 0.02	0.29 ± 0.08	0.35 ± 0.04
Ammonia-N, mg l^{-1}	---	0.31 ± 0.07	0.20 ± 0.02	0.40 ± 0.20	0.62 ± 0.20
TKN, mg l^{-1}	---	0.92 ± 0.01	0.24 ± 0.07	0.70 ± 0.20	0.96 ± 0.00
Nitrite-N, mg l^{-1}	---	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.30 ± 0.03
Nitrate-N, mg l^{-1}	--	1.53 ± 0.36	3.04 ± 0.18	2.42 ± 0.01	3.22 ± 0.50
Chlorophyll a, mg m^{-3}	---	2.47 ± 0.29	2.74 ± 0.07	2.11 ± 0.25	1.40 ± 0.25

Legend: same as Appendices A5-A12.

Appendix A14. Physico-chemical properties of water in Molawin River gathered on May 1996.

Parameter	Station 1	Station 2	Station 3	Station 4	Station 5
Air Temperature (°C)	29.1	28.2	29	30.5	31.1
Temperature (°C)	27.4	26.5	27.1	29.3	30.1
pH	7.4	8.2	8.2	8.1	7.5
DO, mg l^{-1}	4.3	5.6	5.1	3.8	1.2
Conductivity, mS cm^{-1}	0.23	0.136	0.189	0.368	0.674
Turbidity (NTU)	23	6	18	14	12
BOD, mg l^{-1}	5.43 ± 0.09	6.23 ± 0.14	5.61 ± 0.55	13.16 ± 0.04	12.55 ± 0.65
COD, mg l^{-1}	33.04 ± 3.92	22.96 ± 0.56	29.12 ± 7.84	18.48 ± 0.56	26.32 ± 0.56
TOC, ppm	7.94 ± 0.21	8.97 ± 0.24	11.68 ± 0.43	14.05 ± 0.1	16.98 ± 0.17
Alkalinity, mg l^{-1}	47.2 ± 1.2	47.25 ± 0.8	66.0 ± 1.5	212.5 ± 0.6	285.0 ± 17.5
Chloride, mg l^{-1}	34.5 ± 1.7	32.8 ± 2.4	22.7 ± 2.4	29.16 ± 0.24	67.5 ± 0.0
Hardness, mg l^{-1}	73.5 ± 0.5	35.0 ± 4.0	54.0 ± 2.0	149.5 ± 42.5	196.5 ± 1.5
TSS, mg l^{-1}	16.4 ± 0.4	1.4 ± 0.2	2.6 ± 1.0	3.0 ± 1.04	5.0 ± 0.2
TDS, mg l^{-1}	210.0 ± 10.0	192.5 ± 2.5	247.5 ± 2.5	312.5 ± 7.5	335.0 ± 5.0
Orthophosphate, mg l^{-1}	0.070 ± 0.004	0.19 ± 0.03	0.19 ± 0.07	0.30 ± 0.02	0.39 ± 0.02
Total Phosphate, mg l^{-1}	0.093 ± 0.002	0.15 ± 0.00	0.39 ± 0.03	0.34 ± 0.07	0.54 ± 0.01
Ammonia-N, mg l^{-1}	0.73 ± 0.11	1.26 ± 0.11	1.05 ± 0.03	1.10 ± 0.00	0.53 ± 0.03
Nitrate-N, mg l^{-1}	0.084 ± 0.010	0.53 ± 0.00	1.30 ± 0.09	1.56 ± 0.04	1.34 ± 0.18
Sulfate, mg l^{-1}	195.0 ± 3.0	15.0 ± 0.4	19.1 ± 0.3	15.1 ± 0.3	17.8 ± 0.4

Legend:

Station 1 Mudspring
Station 2 Botanical Garden
Station 3 Hortorium
Station 4 Amtec
Station 5 Kabaritan

Appendix A15. Physico-chemical properties of water in Molawin River gathered on August 1996.

Parameter	Station 1	Station 2	Station 3	Station 4	Station 5
Temperature (°C)	25	25	26.2	28.1	30
pH	7.4	7.9	7.7	7.5	7.5
DO, mg l^{-1}	5.3	5.8	6.7	2.4	4
Conductivity, mS cm^{-1}	0.137	0.111	0.149	0.31	0.517
Turbidity (NTU)	12	11	12	22	14
BOD, mg l^{-1}	3.30 ± 0.32	1.34 ± 0.08	0.47 ± 0.16	5.58 ± 0.24	2.83 ± 0.63
COD, mg l^{-1}	13.00 ± 1.00	12.50 ± 0.50	11.50 ± 0.50	16.50 ± 1.50	20.00 ± 3.00
TOC, ppm	6.75 ± 0.18	5.03 ± 0.10	3.11 ± 0.19	8.95 ± 0.21	5.83 ± 0.15
Alkalinity, mg l^{-1}	51.0 ± 1.8	39.6 ± 0.9	54.6 ± 1.8	120.6 ± 2.6	183.0 ± 0
Chloride, mg l^{-1}	9.36 ± 0.00	9.36 ± 0.00	9.36 ± 0.00	13.10 ± 2.34	23.87 ± 3.75
Hardness, mg l^{-1}	176.28 ± 2.26	167.24 ± 4.52	201.14 ± 6.78	311.88 ± 0.00	311.88 ± 0.00
TSS, mg l^{-1}	9.0 ± 1.0	15.2 ± 0.8	7.2 ± 0.4	7.6 ± 0.8	10.2 ± 1.0
TDS, mg l^{-1}	181.0 ± 17.0	169.0 ± 15.0	194.0 ± 2.0	288.0 ± 20.0	404.0 ± 4.0
Orthophosphate, mg l^{-1}	0.05 ± 0.00	0.09 ± 0.00	0.15 ± 0.00	0.44 ± 0.06	0.26 ± 0.09
Total Phosphate, mg l^{-1}	0.11 ± 0.01	0.28 ± 0.13	0.25 ± 0.08	0.64 ± 0.03	0.48 ± 0.03
Ammonia-N, mg l^{-1}	1.17 ± 0.03	0.15 ± 0.01	0.30 ± 0.01	3.62 ± 0.54	0.27 ± 0.00
Nitrate-N, mg l^{-1}	0.05 ± 0.00	0.12 ± 0.00	0.15 ± 0.02	0.26 ± 0.01	0.52 ± 0.04

Legend:

Station 1 Mudspring
Station 2 Botanical Garden
Station 3 Hortorium
Station 4 Amtec
Station 5 Kabaritan

*Source of Appendices A1-A15: Lake Management Division, LLDA

Appendix A16. Irrigators' Associations in the Laguna Lake Basin.

MUNICIPALITY	BARANGAY	IRRIGATORS' ASSOCIATION
Biñan	Pasong Kabayo	Nagdadamayang Buklod ng Magsasaka ng Biñan
	San Vicente	
Carmona	No data	Maduya
	No data	Lantic I
	No data	Lantic II
	Maduya	P. Laurito
	Maduya	A. Sarroso
	No data	Dynavision
	Maduya	C. Casal
	No data	Dynavision
Los Baños	Bayog	Bayog Communal Irrigation System
Bay	Dila	Dila Irrigators Association CIS
		Doña Ma. Pelaez Irrigators Association (Ma. Pelaez CIS)
Bay	Puypuy	Puypuy (CIS)
Victoria	Banca banca	Banca banca Multi-purpose Cooperative
Victoria		San Benito CIS
		San Roque CIS
		Pook CIS
		San Roque PCIS
		Fernandez-Cayco CIS
		Sta. Cruz-Mabacan Irrigation System
Calauan	Bangyas	Bangyas CIS
	Masiit	Masiit CIS
	Mabacan	Mabacan Samahan ng Magpapatubig Inc. Mabacan RIS
Caluan		SCRIS
		Balumbong (San Crispin CIS)
		Canlubang CIS
		Prinza CIS
Pila		Sta. Cruz-Mabacan RIS
		Tubuan CIS
Pila	Sta. Clara Norte	Ibaba Samahang Magsasaka
Sta. Rosa	Macabling	Macablling RIS
Sta. Rosa		Diezmo RIS
Cabuyao		Cabuyao East PIS
Calamba		San Cristobal RIS
		San Juan RIS
Lucban	Ayuti	Ayuti IA
	Samil	Samil IA
	Igang	Igang IA
	Kulapi	Kulapi IA
	Tinamnan	Tinamnan IA
	Kakawit	Kakawit IA
	Abang	Abang IA
	Palola	Palola IA
	Malupak	Malupak IA
	Manasa	Manasa IA
	Tiawe	Tiawe IA
	May-it	May-it IA
	Nagsimano	Nagsimano IA
	Atulinao	Atulinao IA

MUNICIPALITY	BARANGAY	IRRIGATORS' ASSOCIATION
	Pilis	Pilis IA
	Aliliw	Aliliw IA
	Kilib	Kilib IA
	Kalyaat	Kalyaat IA
	M. Parang	M. Parang
	Kalangay	Kalangay
Cavinti	Sumucab	Sumucab-Beunavista IA
	Layug	Caaavinti Farmers IA Inc.
	Udea	Udea IA
	Layug	Layug IA
	Bombongan	Bombongan IA
Famy	Bulihan	Lilian Famy IA
Famy		MIFFI
		Mayputat IA
Famy	Cortadilla	Cortadilla Irrigators Association
Paete	Ilaya del Norte	Paete Farmers Association
Pakil	Burgos	Samahang Magbubukid
Pangil	Bambang Hari	Bambang Hari Irrigators Associaation
	San Jose	Pangil Irrigators Asssociation
	Natividad	Balian Pangil Irrigators Association Inc.
	Dambo	Dambo Farmers Cooperative
	Lakian	Lakian Irrigators Association
Kalayaan		Kalayaan Irrigators Association
		Lunao/Kalayaan
	Longos	Longos Irrigators Association
	San Juan	Irrigators Service Association
Mabitac		MIFFI
		STAMASI
	Matalatala	Matalala Farmers Association
Sta. Maria		STAMASI
Pagsanjan		BRISIA
Lumban		BRISIA
		LUCIA
	Concepcion	Pinagbuklod na Magsasaka ng Concepcion, Inc.
	Binambang	Binambang Irrigators Association
	Wawa-Ibayo	Wawa-Ibayo Irrigators Association
	Wawa	Wawa-Kawayan Irrigators Association
	Lewin	Lewin Irrigators Association
Sta. Cruz	Gatid	SCRICIA
Sta. Cruz		Buklod-Bukid ng Bagumbayan, Inc.
Sta. Cruz		BRISIA
Siniloan		MIFFI
	Mabini St.	Romelo-Pinsit Irrigators Association
	Wawa	Siniloan-Wawa Farmers Association
	Mapagong	Siniloan Upland Farmers Cooperative
Siniloan		BPAC
Liliw	Calumpang	Camlumapang Irrigators Association
Liliw		Arjona Irrigators Association
Liliw	Bungkol	Bungkol Irrigators Association, Inc.
	Tuy-Baanan	Baanan Irrigators Association, Inc.
	Silangan Bukal	Mamalin Irrigators Association
Nagcarlan	Sitio Biga	Sitio Biga Irrigators Association, Inc.

MUNICIPALITY	BARANGAY	IRRIGATORS' ASSOCIATION
	Manao	WATISA
	Palayan	Palayan Irrigators Association
	Taytay	Taytay Irrigators Association
	S. Napapatid	S. Napapatid Irrigators Association
	Buboy	Buboy Irrigators Association
Rizal		Mayton Irrigators Association, Inc.
	Tala	Tala Irrigators Association, Inc.
	Talaga	Talaga Irrigators Association
	Laguna	Laguna Irrigators Association
	San Miguel	San Miguel Irrigators Association
Taytay	San Juan and Sta. Ana	Tabing Ilog Farmers Association
	Muzon	Muzon Farmers Association
	Bangiad	Bangiad Farmers Association
	San Juan	Panghulo Farmers Association
Angono	San Roque	Pioneer Farmers Association
	Mahabang Parang	Kasamahang Magsasaka ng Kalayaan (KAMAKA)
	Poblacion Ibaba	Angono Farmers Irrigators Association
	CARDONA	Cardona Irrigator's Multi-purpose Cooperative
	Balso-Catahan, Cardona	Members Uugong-NIA FA
	Balibago, Cardona	Balibago Farmers Association
	Looc, Cardona	Looc Farmers Association
Morong	Caniogan	Samahang Maggugulay sa Caniogan
	Wawa, San Juan	Farrows Farmers Association
	Kanang	Calero Lanang Farmers Association
	San Juan	San Juan Farmers Association
	Wawa, San Pedro	Runggot Farmers Association
	Wawa, San Pedro	Bigay Hilig Farmers Association
	Wawa, San Pedro	Upper Hibihan Farmers Association
	Wawa, San Pedro	Matinik Farmers Association
	San Guillermo	Kay-atay Farmers Association
	Maybancal	Maybancal Farmers Association
	San Guillermo	Kay Mapate Farmers Association
	Lagundi	Manggugulay ng Pil-kum
	San Pedro	U-ugong Farmers Association
	San Guillermo	Kay-Amper Farmers Association
	San Guillermo	Magtutumana sa Ilog
	San Pedro	Wawa-San Pedro Farmers Association
	San Guillermo	Agas-as Farmers Association
	Lanang	Kay-Pinkok Farmers
	Lagundi	Labangan Farmers Association
	Caniogan	Caniogan Farmers Association
	Wawa, San Juan	Masikap Farmers Association
	Maybancal	Samahang Manggugulay ng Maybakal
	San Pedro	Pulo Farmers Association
	Calero	Calero Farmers Association
	San Pedro	Lower Hibaan
	Wawa, San Juan	Valentin Arabit
Pillilia	Hulo	Hulo Farmers Association
	Wawa	Wawa Farmers Association
	Halayhayin	Halayhayin Farmers Association
	Quisao	Lamuan Farmers Association
	Niogan	Niogan Farmers Association

MUNICIPALITY	BARANGAY	IRRIGATORS' ASSOCIATION
	Malaya	Malaya Farmers Association
	Quisao	Balo-balo Yakat Farmers Association
Jala-jala	Bagumbong	Lumang Nayon Farmers Association
	Lobo	Lobo Farmers Irrigation Association
	Poblacion	Upper and Lower Mapakla Farmers Association
	Palaypalay	Palaypalay Farmerrrs Association
	Bagumbong	Sambungan Farmers Association
	Sipsipin	Sipsipin Farmers and Irrigators Association
	Bayugo	Leano Farmers Association
	Bagumbong	Ilog Munti Farmers Association
	Pagkalinawan	Pagkalinawan Farmers Association
San Mateo	Maly	Maly Farmers Association
	Guinayang	Ginayang Farmers Association
	Malanday	Malanday Farmers Association
	Daloy Bayas	Daloy Bayas Farmers Association
	Sta. Ana	Sta. Ana Farmers Vegetables Association
	Banaba	Banaba Farmers Assoication
Rodriguez	San Isidro	Magalipit Farmers Associatiion
		Magasuksok Farmers Association
		Pakiing Farmers Association
	Burgos	Burgos-Maly Farmers Association
Antipolo	Tina Pantay	Tina Pantay Farmers Irrigators Association
	Boso-boso	Boso-boso Farmers Irrigators Association
	Kaysiput	Kaysiput Farmers Association
Teresa	Dalig, Pantay	Pantay Farmers Irrigators Service Association
	Dalig	Sta. Rosa Farmers Association
	Prinza	Prinza Farmers Association
	Dalig, Buhangin	Buhangin Farmers Association
	Dalig	Anak Pawis ng Sta. Rosa Farmers Association
	San Roque	Putakti Farmers Association
	Dalumbayan (Sitio Pamanaan)	Kalubkob Farmers Association

Appendix A17. Administrative Orders and Resolutions to Govern the Management and Development of Shoreland Areas of Laguna de Bay.

Resolution No. 10, Series of 1995 "Asserting LLDA's Authority and Exclusive jurisdiction in Laguna De Bay Concerning Issuance of Permits for Reclamation Projects and Disallowing Any Non-environmentally Feasible Activities in the Lake" that will contribute to the pollution of the lake, bring about ecological imbalance of the region or diminish the total surface area of the lake.

Invoking its exclusive jurisdiction to issue new permits for the use of the lake waters for any projects or activities in or affecting the Laguna de Bay as well as its power to reclaim or cause to reclaim portions of the lake, the LLDA through its Board issued the above-mentioned resolution on 29 June, 1995. Accordingly, the Authority bans reclamation or any project or activity in the lake that will contribute to lake pollution, bring about ecological imbalance or diminish the total surface area or water volume of the lake and thus also reduce its water holding capacity which would result in the diversion of flood waters to other low-lying areas.

DENR Administrative Order No. 27-95 issuing "Moratorium on the Acceptance and Processing of All Public Land Applications Covering Areas Immediately Adjacent to the Laguna de Bay Basin" pending the delineation and marking on the ground areas within the 12.50 MLLW along the shoreline surrounding the Laguna de Bay basin by Regional Executive Director of DENR Region IV-A in coordination with the LLDA.

Resolution No. 23, Series of 1996 "Approving the Rules and Regulations Implementing Section 41(11) of RA 4850, As Amended, Defining and Regulating the Use/Occupancy of Laguna de Bay Shoreland Areas"

This Board Resolution established the framework for the development and management of the lake's shoreland areas. It embodies the policies and regulations on the use/occupancy of shoreland areas of Laguna de Bay shoreland which includes the lease of untitled areas. Furthermore, a Lakeshore Management and Development Plan shall be formulated to carry out the declared policy to include among others, environmental, management, legal and administrative systems, and the necessary fiscal measures.

Under these rules, it is the declared policy of the LLDA, pursuant to RA 4850 as amended to: (i) properly manage and control the use and/or occupancy of the shoreland areas of Laguna de Bay, within the context of national socio-economic development plans and policies and environmental concerns; (ii) maintain all shoreland areas lying below elevation 12.50 meters as buffer zones in consonance with the Authority's policies, plans and programs for the management of the water quality and protection and conservation of the water resources of Laguna de Bay; (iii) exercise administrative and regulatory control on the land use and/or occupancy of the shoreland areas within the context of the plans and programs of the LLDA, and to manage such uses and occupancy along desirable environmental considerations; and (iv) provide an administrative system whereby the rights of legitimate titleholders shall be respected.

Thus, Resolution No. 23 prescribes uses/activities that may be allowed in all lands located at and below elevation 12.50 meters including agricultural uses, provided that:

- The use of fertilizers shall be regulated based on DA/FPA standards;
- Use of less persistent pesticides shall be required (Category IV or FPA Standards);
- Integrated Pest Management is practiced;
- Such use does not result in land reclamation or backfilling.

Other allowable uses include tree farming/planting, recreational use provided no permanent structures shall be constructed, fishponds provided that exotic species shall not be allowed, poultry provided that only backyard scale shall be allowed, and support facilities such as dockyard/board shed, research facilities and fishport.

On the other hand, piggery farms regardless of number of heads, dumpsites, housing projects and subdivisions, factories, quarrying and all other activities that will pose pollution and cause ecological disturbance to the lake are strictly prohibited.

The enforcement of these implementing rules and regulations is monitored by the LLDA through the Special Concerns Division in coordination with the LGUs concerned.

Resolution No. 39, Series of 1997 "Approving the Increase of Rates for the Survey of Shorelands Within the Laguna de Bay Region and Areas for Aquaculture Operation".

Resolution No. 110, Series of 1999 "Amending the Administrative Fine for Violation of LLDA Rules on Reclamation/Landfilling of Any Portion of the Laguna de Bay and Its Shoreland"

Board Resolution No. 42, Series of 1997 provides that an administrative fine of P5,000.00 per hectare or less per year shall be imposed for violation of policy on reclamation or landfilling any portion of the Laguna de Bay and its shoreland. To further discourage further illegal reclamation and to effectively implement LLDA's rules and regulations on the use/occupancy of shoreland areas (Resolution No. 23, Series of 1996), Resolution No. 110, Series of 1999 amended Board Resolution No. 42, specifically "An administrative of P5,000.00 plus 10 percent of the zonal value per square meter of the land shall be imposed for violation of policy on reclamation or landfilling of any portion of the Laguna de Bay and its shoreland. Notwithstanding the penalty as imposed by the administrative fine, the use of such reclaimed area shall be subject to LLDA Clearance. his resolution also emphasizes that any reclaimed area in the Laguna de Bay and its shoreland, whether done with LLDA Clearance or not, shall remain the property of the national government through the Authority."

Resolution No.113, Series of 1999 "Amending Board Resolution No. 23, Series of 1996, by Adding the Implementing Guidelines Governing the Lease of the Laguna de Bay Shoreland Areas".

Article 8 of Board Resolution No. 23, Series of 1996 states that shorelands not otherwise covered by legitimate titles or by any government development plans, programs and projects may be leased to *bonafide* residents or duly organized people's organizations, associations or cooperatives in accordance with the terms and conditions and subject to approval of the LLDA. For this purpose, the LLDA commissioned the National Mapping and Resource Information Authority (NAMRIA) to delineate and demarcate on the ground the reglementary elevation 12.50 meters around Laguna de Bay. Hence, Resolution No. 113 prescribes the guidelines on the lease of untitled shoreland areas and the corresponding lease rates for pertinent areas within the shoreland municipalities as part of the regulation of the use/ occupancy of these areas. In addition, the aforementioned resolution set in place the systems and procedures in leasing the untitled shoreland areas and identified the responsibilities of agencies and LLDA units concerned in the operationalization of the systems and procedures. Therefore, the following, among others, are covered in the resolution:

- Lease regulations governing untitled shoreland areas including prioritization by cluster of user groups;
- Terms and conditions of the lease
- Lease rates
- Lease procedures

Appendix B

ACRONYMS

AD	*Anno Domini*
ADB	Asian Development Bank
AGR	Annual Growth Rate
APHA	American Public Health Association
AWMS	Animal Waste Management System
AWWA	American Waterworks Association
BAS	Bureau of Agricultural Statistics
BCEOM	Bureau Central D'Etudes Pour Les Equipments D'Outre-Mer
BFAR	Bureau of Fisheries and Aquatic Resources
BGA	Blue-Green Algae
BISIG-CATA	Biñan, Silang, General Mariano Alvarez, Carmona, and Tagaytay City
BOD	Biochemical Oxygen Demand
BR	Board Resolution
BSP	Boy Scouts of the Philippines
CALABARZON	Cavite, Laguna, Batangas, Rizal and Quezon
CB	Central Bay
CBFM	Community-Based Forest Management
CBK	Caliraya-Botocan-Kalayaan
CCCM	Canadian Climate Centre Model
chl a	Chlorophyll a
CIS	Communal Irrigation System
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CLA	Coordinating Lead Author
CLEAR	Conservation of Laguna de Bay Environment and Resources
COD	Chemical Oxygen Demand
CTP	Central Treatment Plant
DA	Department of Agriculture
DAO	DENR Administrative Order
DDE	Dichlorodiphenyl Ethene
DENR	Department of Environment and Natural Resources
DO	Dissolved Oxygen
DPWH	Department of Public Works and Highway
DTI	Department of Trade and Industry
EB	East Bay
EC	Electrical Conductivity
EMB	Environmental Management Bureau
EMB	Environmental Management Bureau
EMP	Environmental Management Plan
ENRO	Environment and Natural Resources Officer
EO	Executive Order
ERDB	Ecosystems Research and Development Bureau
ESMAP	Energy Sector Management Assistance Programme
EUFS	Environmental User Fee System
FAO	Food and Agriculture Organization
FARMC	Fisheries and Aquatic Resources Management Council
FDP	Fisheries Development Program
FMB	Forest Management Bureau
GCM	Global Change Model
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
GRDP	Gross Regional Domestic Product
IC	Institute of Chemistry
ICLARM	International Center for Living Aquatic Resources Management
IMAGE	Integrated Model to Assess the Greenhouse Effect
IPCC	Intergovernmental Panel on Climate Change
IRDP	Institutional Reform and Development Program
IRRI	International Rice Research Institute
ISO	Irrigation System Office
IWRMD	Integrated Water Resource Management Division
KEPHILCO	KEPCO Philippine Corp.
KPSPP	Kalayaan Pumped Storage Power Plant
LA	Lead Author
LBFDP	Laguna Bay Fishpen Development Program
LFLIS	Laguna Friar Lands Irrigation System
LGU	Local Government Unit
LISO	Laguna Irrigation System Office
LLB	Laguna Lake Basin
LLDA	Laguna Lake Development Authority
LUCF	Land Use Change and Forestry

MA	Millennium Ecosystem Assessment
MAPSS	Mapped Atmosphere-Plant-Soil System
masl	meter(s) above sea level
MF	Mangahan Floodway
MFB	Methyl Formyl Benzoate
MFPC	Multi-sectoral Forest Protection Committee
MFR	Makiling Forest Reserve
MIS	Management Information System
MLLW	Mean Lower Low Water
MMDA	Metropolitan Manila Development Authority
msl	minimum sea level
MWSS	Metropolitan Waterworks and Sewerage System
NAC	National Art Center
NAMRIA	National Mapping and Resource Information Authority
NCIP	National Commission on Indigenous People
NCR	National Capital Region
NEDA	National Economic and Development Authority
NGO	Non-government Organizations
NHCS	Napindan Hydraulic Control Structure
NHRC	National Hydraulic Research Center
NIA	National Irrigation Administration
NIPAS	National Integrated Protected Areas System
NIS	National Irrigation System
NPC	National Power Corporation
NSCB	National Statistical Coordination Board
NSO	National Statistics Office
OPEC	Organization of Petroleum Exporting Countries
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PAH	Polyaromatic Hydrocarbon
PAWB	Protected Areas and Wildlife Bureau
PCAMRD	Philippine Council for Aquatic and Marine Research and Development
PCARRD	Philippine Council for Agriculture, Forestry and Natural Resources Research and Development
PCB	Polychlorinated Biphenyls
PD	Presidential Decree
PEA	Public Estates Authority
PhilRice	Philippine Rice Research Institute
PhP	Pesos
PIDP	Polder Island Development Plan
PLUC	Provincial Land Use Committee
PNOC	Philippine National Oil Company
POP	Persistent Organic Pollutant
PPDO	Provincial Planning Development Office
PTFWRDM	Presidential Task Force on Water Resources Development and Management
RA	Republic Act
RUEP	Rehabilitation, Upgrading and Expansion Project
SAEP	State Administration of Environmental Protection
SB	South Bay
SD	Secchi Depth
SDLBE	Sustainable Development of Laguna de Bay Environment
SEAFDEC	Southeast Asian Fisheries Development Center
SGA	Sub-Global Assessment
SMMRIS	Sta. Maria-Mayor River Irrigation System
SOGREAH	Societe Grenebloise D’Etudes et D’Applications Hydrauliques
SSNM	Site-Specific Nutrient Management
TDS	Total Dissolved Solid
THS	Toxic and Hazardous Substance
TOC	Total Organic Carbon
TRS	Turbidity Silicate Dioxide
TSS	Total Suspended Solid
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UPLB	University of the Philippines Los Baños
URSI	URS International, Inc.
USEPA	United States Environmental Protection Agency
WB	West Bay
WDP	Watershed Development Program
WHO	World Health Organization
WPCF	Water Pollution Control Facility
WTF	Water Treatment Facilities
ZOMAP	Zoning Management Plan

CHEMICAL SYMBOLS

As	Arsenic	N_2O	Nitrous Oxide
C	Carbon	NH_3	Ammonia
$CaCO_3$	Calcium Carbonate	NH_4	Ammonium
Cd	Cadmium	Ni	Nickel
CFC	Chlorofluorocarbon	NO_2	Nitrite
CH_4	Methane	NO_3	Nitrate
Cl^-	Chloride	NO_x	Oxides of Nitrogen
CO	Carbon Monoxide	P	Phosphorus
CO_2	Carbon Dioxide	Pb	Lead
Cr	Chromium	PO_4	Phosphates
Cu	Copper	SiO_2	Silicon Dioxide
Fe	Iron	TKN	Total Kjeldahl Nitrogen
H_2S	Hydrogen Sulfide	TN	Total Nitrogen
Hg	Mercury	TP	Total Phosphorus
N	Nitrogen	Zn	Zinc

Appendix C

UNITS OF MEASUREMENT

SI (Systéme International) and SI-derived Units

Physical Quantity	Name of Unit	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
conductivity	siemens	S
power	watt	W
area	hectare	ha
weight	ton	t

Fraction	Prefix	Symbol	Multiple	Prefix	Symbol
10^{-1}	deci	d	10	deca	da
10^{-2}	centi	c	10^{2}	hecto	h
10^{-3}	milli	m	10^{3}	kilo	k
10^{-6}	micro	µ	10^{6}	mega	M
10^{-9}	nano	n	10^{9}	giga	G
10^{-12}	pico	p	10^{12}	tera	T
10^{-15}	femto	f	10^{15}	peta	P
10^{-18}	atto	a	10^{18}	exa	E

Other Units of Measurement Used

ºC	degrees Celsius (0ºC = ~273 K)
cavan	cavan (1 cavan = 50 kg)
day	day
ipl	individuals per liter
MLD	million liters per day
MPN	most probable number
NTU	nephelometric turbidity unit
ppm	parts per million (10^{6})
ppt	parts per thousand (10^{3})
yr	year

Appendix D

THE PHILIPPINE SUB-GLOBAL ASSESSMENT TEAM

Technical Working Group

Rodel Lasco (Chair)	University of the Philippines Los Baños/World Agroforestry Centre (ICRAF-Philippines)
Ma. Victoria Espaldon (Co-Chair)	University of the Philippines Diliman
Macrina Zafaralla	University of the Philippines Los Baños
Josefina Dizon	University of the Philippines Los Baños
Willie Abasolo	University of the Philippines Los Baños
Adelina Santos-Borja	Laguna Lake Development Authority
Eduardo Manalili	Philippine Council for Aquatic and Marine Research and Development

Coordinating Lead Authors

Ma. Victoria Espaldon	University of the Philippines Diliman
Edwino Fernando	University of the Philippines Los Baños
Rodel Lasco	University of the Philippines Los Baños/World Agroforestry Centre (ICRAF-Philippines)
Leonardo Liongson	University of the Philippines Diliman
Adelaida Palma	Department of Agriculture – Bureau of Fisheries and Aquatic Resources
Adelina Santos-Borja	Laguna Lake Development Authority
Benito Vergara	National Academy of Science and Technology
Macrina Zafaralla	University of the Philippines Los Baños

Lead Authors

Willie Abasolo	University of the Philippines Los Baños
Norma Aguilar[†]	University of the Philippines Los Baños
Pedro Alviola III	University of the Philippines Los Baños
Carlito Barril	MADECOR Environmental Management System, Inc.
Maribec Campos	Southeast Asia Ministers of Education Organization - Regional Centre for Graduate Study in Agriculture
Antonio Daño	Ecosystems Research and Development Bureau, DENR
Josefina Dizon	University of the Philippines Los Baños
Joyceline Goco	Department of Environment and Natural Resources
Milagrosa Goss	University of the Philippines Los Baños
Daniel Lagunzad	University of the Philippines Diliman
Neil Aldrin Mallari	Haribon Foundation
Eduardo Manalili	Philippine Council for Aquatic and Marine Research and Development
Eliadora Mercene	Department of Agriculture – Bureau of Fisheries and Aquatic Resources
Dolora Nepomuceno	Laguna Lake Development Authority
Florencia Pulhin	University of the Philippines Los Baños
Merlyn Carmelita Rivera	Ecosystems Research and Development Bureau, DENR
Jocelyn Sta. Ana	Laguna Lake Development Authority
Guillermo Tabios III	University of the Philippines Diliman

Contributing Authors

Alice Bongco	Laguna Lake Development Authority
Grace Chua	Laguna Lake Development Authority
Oliver Barbosa	Laguna Lake Development Authority

Advisory Board

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Former Gen. Mngr. Calixto Cataquiz	
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Gov. Rebecca Ynares	Rizal province
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Ramos Razal	University of the Philippines Los Baños
Enrique Pacardo	University of the Philippines Los Baños
Patricio Faylon	Philippine Council for Agriculture, Forestry and Natural Resources Research and Development
Rafael Guerrero	Philippine Council for Aquatic and Marine Research and Development
Emerson Jacinto	Appropriate Technology Center for Rural Development

Review Panel

Zubaida Basiao	Southeast Asian Fisheries Development Center
Mario delos Reyes	University of the Philippines Diliman
Marian delos Angeles	World Agroforestry Centre (now with the World Bank)
Danielito Franco	University of the Philippines Los Baños
Rhoda Lantin	Asia Rice Foundation
Cipriano Lopez	Fisheries and Aquatic Resources Management Council
Ben Malayang	Philippine Sustainable Development Network/University of the Philippines Los Baños
Cesar Mamaril	Philippine Rice Research Institute
Masatoshi Matsumura	University of Tsukuba
Perry Ong	University of the Philippines Diliman

Sub-global Reviewers

Zainal Arifin	Indonesian Institute of Sciences, Indonesia
Carlo Custodio	Department of Environment and Natural Resources, Philippines
Marcus Lee	Millennium Ecosystem Assessment Secretariat, Malaysia
Tolentino Moya	University of the Philippines Los Baños, Philippines

Technical Support Unit

Richievel Arche	University of the Philippines Los Baños
Enrico Laluan	University of the Philippines Los Baños
Maricel Tapia	University of the Philippines Los Baños

Peer Reviewers

Romulo Aggangan	Philippine Council for Agriculture, Forestry and Natural Resources Research and Development
Porfirio Aliño	University of the Philippines Diliman
Julian Amador	Department of Environment and Natural Resources
Wilfredo America	Forest Products Research and Development Institute
Jonas Bautista	Philippine National Oil Company
Renato Broqueza	Office of the Governor, Rizal
Lourdes Castillo	University of the Philippines Los Baños
Manuel Castillo	University of the Philippines Los Baños
Zenaida Catalan	University of the Philippines Los Baños
Rex Victor Cruz	University of the Philippines Los Baños
Norberto Decena	Office of the Provincial Agriculturist, Rizal
Lucenda delas Alas	Provincial Planning and Development Office, Cavite
Agnes de Jesus	Philippine National Oil Company
Usec. Renato de Rueda	Department of Environment and Natural Resources
Rolando Edra	Philippine Council for Aquatic and Marine Research and Development
Daniel Gonzaga	Office of the Governor, Rizal
William Gruezo	University of the Philippines Los Baños
Edmund Guillen	Office of the Governor, Laguna
Emil Javier	Institute of Plant Breeding, University of the Philippines Los Baños
Theresa Mundita Lim	Department of Environment and Natural Resources
Alexander Madrigal	Department of Science and Technology
Vergel Medina	Philippine National Oil Company
Wilfrido Pollisco	Department of Environment and Natural Resources
Juan Pulhin	University of the Philippines Los Baños
Blesshe Querijero	Philippine Council for Aquatic and Marine Research and Development
Romeo Rillon	National Irrigation Administration
Rogelio Soriano	Coastal Management Center
Noel Sabino	University of the Philippines Los Baños
Gertie Sison	Provincial Planning and Development Office, Rizal
Guillermo Trinidad	Provincial Government – Environment and Natural Resources Office, Laguna
Nilda Ubaldo	University of the Philippines Los Baños
Emmanuel Umali	National Power Corporation
Vivian Valdez	Philippine Council for Agriculture, Forestry and Natural Resources Research and Development
Ruben Villareal	Southeast Asia Ministers of Education Organization - Regional Centre for Graduate Study in Agriculture
Jose Villarin	Manila Observatory
Lope Villenas	National Water Resources Development Board

Appendix E

ABOUT THE AUTHORS*

The Coordinating Lead Authors

Ma. Victoria O. Espaldon is Associate Professor in UP Diliman where she teaches geography. She is a consultant of Southeast Asia Ministers of Education Organization – Regional Center for Graduate Study and Research in Agriculture (SEAMEO-SEARCA). She holds a PhD degree in Geography from University of Guelph, Canada, and MSc in Forestry and BSc Biology from UPLB. Dr. Espaldon's teaching areas are in geography, resource conservation management, geography of Southeast Asia, population geography, and cultural geography.

Edwino S. Fernando is Professor at the Department of Forest Biological Sciences, College of Forestry and Natural Resources (CFNR), UPLB. He teaches undergraduate and graduate courses in forest botany, forest biodiversity, dendrology, plant taxonomy, plant genetic resources, and tree architecture. He is also the director of the Makiling Center for Mountain Ecosystems, CFNR, UPLB. Dr. Fernando has a PhD degree in Botany (molecular phylogenetics) from the University of New Wales, Australia; MSc in Plant Taxonomy from the University of Reading, England; and BSc in Forestry major in Forest Biological Sciences from UPLB.

Rodel D. Lasco is Professor at Institute of Renewable Natural Resources, CFNR, UPLB and the Programme Coordinator of the World Agrofrestry Centre (ICRAF-Philippines). He teaches and conducts research on environmental assessment, tropical forests and climate change, agroforestry, and silviculture. He was a visiting scientist at Center for International Forestry Research (CIFOR), Bogor, Indonesia in October to November 1999. Dr. Lasco is also a lead author of the Intergovernmental Panel for Climate Change (IPCC) on land use change and forestry. He earned his post-doctorate degree in the University of Guelph, Canada and his PhD, MSc, and BSc degrees from UPLB.

Leonardo Q. Liongson is currently the director of the National Hydraulic Center in UP Diliman where he is also Professor at the Department of Civil Engineering. Dr. Liongson is alumnus of University of Arizona where he took his PhD degree in Water Resources Administration/Hydrology. He earned his MSc degree in Engineering Sciences/Hydraulics and BSc degree in Chemical Engineering from UP Diliman. He is an expert in the fields of hydrology and water resources.

Adelaida L. Palma is currently the Agricultural Center Chief IV of the National Inland and Fisheries Technology, Bureau of Fisheries and Aquatic Resources of the Department of Agriculture (NIFT-BFAR-DA). She has a PhD degree in Fisheries Technology from UP Diliman, MSc degree in Aquaculture from UP Visayas, and BSc degree in Biological Science from the University of the East, Philippines. She is an expert in the fields of fish breeding and culture inland resource management.

Adelina Santos-Borja is currently the chief of the Research and Development Division of the LLDA. She earned her MSc and BSc in Biology from UPLB, and currently a PhD candidate in Environmental Science in UP Diliman. She has attended numerous national and international conferences on lake management. Santos-Borja is an expert in the field of limnology, lake basin management, and environmental impact assessment.

Benito S. Vergara is National Scientist in National Academy of Science and Technology. He is a retired consultant and currently an affiliate faculty member of the International Rice Research Institute. Dr. Vergara is the project leader of the Philippine Science Heritage Center, Department of Science and Technology. He is an authority in the field of rice physiology and ornamental plants.

Macrina T. Zafaralla is Professor at the Institute of Biological Sciences, College of Arts and Sciences (IBS-CAS), UPLB. Dr. Zafaralla finished her PhD degree in Environmental Science from UP Diliman, MSc degree in Botany from UPLB, and BSc degree in Botany from UP Diliman. Phycology and environmental science are among her fields of expertise.

*Affiliation and description of the authors at the time of writing of the assessment report.

The Lead Authors

Willie P. Abasolo is Assistant Professor at the Department of Forest Products and Paper Science, CFNR, UPLB. Dr. Abasolo earned his PhD and MSc degrees in Forest Products from Nagoya University, Japan and his BSc in Forest Product Engineering from UPLB. He is an expert in the field of forest products utilization, wood anatomy, and wood physics.

Norma O. Aguilar[†] is Professor at IBS-CAS, UPLB. Dr. Aguilar is an alumna of the University of Tokyo with a PhD degree in Systematic. She earned her MSc and BSc degrees in Botany from UPLB. She is an expert in the fields of systematic, legumes, and angiosperms.

Pedro L. Alviola III is Professor at IBS-CAS, UPLB. He holds an MSc degree in Zoology from UPLB and BSc degree in Biology from Silliman University. His expertise includes vertebrate zoology, wildlife biology, ecology and management, and environmental impact assessment (EIA).

Carlito R. Barril is President of the MADECOR Environmental Management Systems, Inc., Los Baños, Laguna. He is Team Leader of the DENR Accredited Environmental Impact Assessment (EIA). He is an alumnus of the Cornell University, Ithaca, New York where he took his MSc in Analytical Chemistry. Dr. Barril earned his PhD degree in Agriculture Chemistry/ Food Science from UPLB. He also holds postdoctoral degrees in Biotechnology, Electrochemistry, and Environmental Toxicology from University of New Wales, Australia, LaTrobe University, Australia, and Dalhousie University, Canada, respectively. His areas of specialization include analytical and environmental chemistry, toxicology, water quality and pollution assessment and management, EIA and environmental risk assessment, and environmental biotechnology (bioconversion and biomethanation).

Maribec A. Campos is currently consultant of the Asian Development Bank (ADB), SEAMEO-SEARCA, United Nations Development Programme (UNDP), World Bank, Geosphere Technologies, Inc., and Lichel Technologies, Inc. She also is a part time faculty member of the Graduate School of Business; and Graduate School of Education, Arts and Sciences of the De La Salle University-Dasmariñas. Dr. Campos earned her PhD, MSc, and BSc degrees in Agricultural Economics from UPLB. She is an expert in the disciplines of environmental and resource economics, and greenhouse gas valuation.

Antonio M. Daño is Senior Science Research Specialist in the Coastal Zone and Fresh Water Ecosystems Division of the Ecosystems Research and Development Bureau, DENR. Dr. Daño holds a PhD degree in Land and Water Resources and MSc degree in Watershed Management from UPLB. He earned his BSc degree in Agricultural Engineering from the Central Mindanao University, Philippines. Dr. Daño is a specialist in watershed and hydrology.

Josefina T. Dizon is Assistant Professor at Institute of Community Education, College of Public Affairs, UPLB. She obtained her PhD degree in Community Development, MSc degree in Social Forestry, and BSc degree in Agriculture from UPLB. Dr. Dizon is a specialist in community development, social forestry, and environmental studies

Joyceline A. Goco is Supervising Environmental Management Specialist at the Environmental Management Bureau, DENR and heads the Inter-Agency Committee on Climate Change Secretariat. Goco is an alumna of the University of Santo Tomas with an MSc degree in Biological Science. She also earned her BSc degree in Biological Science from University of the East. Climate change, environmental planning, and environmental education are among her specializations.

Milagrosa R. Goss is Professor at the IBS-CAS, UPLB where she teaches Botany, Biology, Natural Science, and Science, Technology and Society. Dr. Goss finished her PhD degree in Botany from UPLB, MSc in Botany from University of Maryland, USA, and BSc in Botany from UP Diliman. She specializes in Phycology.

Daniel A. Lagunzad teaches at the Institute of Biology Herbarium, College of Science, UP Diliman. He earned his PhD and MSc degrees in Botany, and BSc degree in Biology from UP Diliman. He is an expert in the field of plant ecology.

Neil Aldrin D. Mallari is the Director of the Institutional Partnership Development of the Haribon Foundation for the Conservation of Natural Resources, Philippines. He earned his BSc degree in Biology from UPLB.

Eduardo V. Manalili is Senior Science Research Specialist at the PCAMRD-DOST. He finished his MSc degree in Agricultural Engineering major in Land and Water Resources Management from UPLB and a PhD candidate in Environmental

Science in the same university. Engr. Manalili's fields of expertise are water resources management and inland water quality and pollution.

Eliadora C. Mercene is Agricultural Center Chief II at the NIFT-BFAR-DA. Mercene is Affiliate Professor in UPLB Aquatic Invertebrate Zoology Laboratory. She is a member of PCARRD's Inland Fisheries Commodity Team where she reviews and evaluates fisheries project proposals and technical reports. She holds an MSc degree in Biological Science from University of Sto. Tomas and BSc degree in Zoology from UP Diliman.

Dolora N. Nepomuceno is the Assistant General Manager of the LLDA. She earned her MSc degree in Public Management from Development Academy of the Philippines, received a Diploma in Development Economics from UP School of Economics, and obtained her BSc degree from UP College of Administration. Among her areas of competence are regional and urban planning, corporate planning, environmental planning and management, environmental impact assessment study, land use planning, development management, organization development, institutional development and network or consensus building, project feasibility study, project monitoring and evaluation, financial and economic analysis, and water resources and lake and river basin planning and management.

Florencia B. Pulhin is University Researcher II at the Forestry Development Center, CFNR, UPLB and the Office Manager of the Environmental Forestry Programme, CFNR. Dr. Pulhin earned her PhD degree in Forestry major in Silviculture and Forest Influences, MSc degree in Forestry, and BSc degree in Forest Product Engineering from UPLB. She is a specialist in the disciplines of climate change, silviculture, forest utilization, and industrial management.

Merlyn Carmelita N. Rivera is Chief of the Hydrology Section at the Forest Ecosystem Research Division and Supervising Science Research Specialist at ERDB, DENR. Dr. Rivera earned her PhD degree in Forestry major in Forest Resource Management, MSc degree in Forestry, and BSc degree in Agriculture from UPLB. Among her expertise are marketing, resource economics, community forestry, climate change, carbon sequestration, introduction of livelihood projects, and policy analysis.

Jocelyn G. Sta. Ana is Officer-in-Charge at the Environmental Quality Management Division-LLDA. She took her MSc degree in Environmental Engineering and BSc degree in Chemical Engineering from UP Diliman. She is an expert in environmental management.

Guillermo Q. Tabios III is Associate Professor at the Department of Civil Engineering, UP Diliman. He is Research Fellow of the National Hydraulic Research Center, UP Diliman. Dr. Tabios is an alumnus of the Colorado State University where he finished his PhD degree in Civil Engineering. He took his MSc degree in Land and Water Resources and his BSc degree in Agricultural Engineering from UPLB. Hydrology and water resources are among Dr. Tabios' expertise.

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