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COST-EFFECTIVENESS OF NUTRIENT POLLUTION
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ARVIN BUENO VISTA

has been accepted towards fulfillment
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M.S. degree in Agricultural Economics

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# COST-EFFECTIVENESS OF NUTRIENT POLLUTION REDUCTION IN TAAL LAKE, PHILIPPINES

By

Arvin Bueno Vista

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
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ABSTRACT

COST-EFFECTIVENESS OF NUTRIENT POLLUTION REDUCTION IN TAAL LAKE, PHILIPPINES

By

Arvin Bueno Vista

Stakeholders of the Taal Lake fish cage industry face the challenge of producing fish in a situation of frequent fish kill occurrences, which have been attributed to the deteriorating water quality due to nutrient pollution from fish cages. This study estimates the cost-effectiveness of nutrient pollution reduction options. Fifty operators were surveyed and the production data elicited were used in the estimation of a Cobb-Douglas production function. Results show that the types of ownership arrangements and institutional set-up in the municipalities of Agoncillo, Laurel, San Nicholas, and Talisay affect the production efficiency and nutrient loadings in the four cage locations. Marginal analysis reveals that operators are over-utilizing stocking density relative to feeding ration. At different percentage reductions in nutrient loadings, the cost-effectiveness of nutrient pollution reduction options differs among municipalities. With the current fish production technology and institutional set-up, nutrient pollution and decreasing biodiversity are inevitable. Developments in the institutional structures may lead to future technological changes in the fish production system and improvement of water quality in cage areas.

To a dear friend and sister in Christ.

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## KEY TO ABBREVIATIONS

BFAR – Bureau of Fisheries and Aquatic Resources

CAC – command-and-control

CD – Cobb-Douglas

CEA – cost-effectiveness analysis

DA – Department of Agriculture

DENR – Department of Environment and Natural Resources

DO – dissolved oxygen

EGP – Economically growth point

EMB – Environmental Management Bureau

EO – Executive Order

FARMCs – Fisheries and Aquatic Resource Management Councils

FCR – feed conversion ratio

GIFT – genetically improved farmed tilapia

GMT – genetically male tilapia

IFRS – Inland Fisheries and Research Station

LGUs – Local Government Units

MAC – marginal abatement cost

MAO – Municipal Agricultural Office

MBI – market based instruments

MC – marginal cost

MGP – maximum growth point

MPDO – Municipal Planning and Development Office

MR – marginal revenue

N – nitrogen

NFBC – National Fisheries Biological Center

NPV – net present value

NSC – Natural Science

NSO – National Statistics Office

OLS – ordinary least square

P – phosphorus

PAWB – Protected Areas and Wildlife Bureau

PCARRD – Philippine Council for Agriculture, Forestry, and Natural Resources Research and Development

PCMARD – Philippine Council for Aquatic and Marine Research and Development

PCTT – Presidential Commission on Tagaytay-Taal

PD – Presidential Decree

PhP – Philippine Peso

SR – sex reverse

TC – total cost

TLDA – Taal Lake Development Authority

TR – total revenue

UPLBFI – University of the Philippines Los Banos Foundation, Inc.

US EPA- United States Environmental Protection Agency

# CHAPTER 1

# INTRODUCTION

Philippine lakes are threatened with various stressors, such as watershed deterioration, domestic and agricultural pollution, unregulated open water fishing, and lately, fish cage sprawl (Zafaralla, 1999). Recent fish kill occurrences in Taal Lake in the province of Batangas suggest a deteriorating water quality in cage areas (UPLBFI, 1995). An excessive amount of nutrients accumulating from the cages led to nutrient enrichment, endangering the industry itself and the general lake ecosystem. The high nutrient loadings in Taal Lake are due to the excessive amounts of nitrogen (N) and phosphorus (P). The expected causes of high nutrient loading are the fish cage activities, and non-point sources such as watershed/agricultural run-off and household wastewater discharges (Hilario *et al.*, 2000).

Research results show that local government implementation of the open-access policy in Taal Lake tends to have negative effects on the lake's fisheries (Mutia and Magistrado, 1999). Rosana and Salisi (2001) reported that the pollution due to wastes coming from tilapia[1] cages in certain areas of Taal Lake has caused massive fish kills from 1999 to 2001. Other studies conducted indicate that the practice of aquaculture technology in many areas is on a destructive path that poses a threat not only to endemic fish populations but also to the industry's own long-term potential (Naylor *et al.*, 2003). Many other areas in the Philippines are facing the same problem due to nutrient pollution (Dela Rosa, 1992; Sumalde *et al.*, 2002). Marte *et al.* (1999) pointed out that the more

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[1] *Oreochromis nilotica*, a mouth-brooder perch-likes ray-finned fishes, which originated from Africa but has been introduced in many countries around the world (Pullin, and Lowe-McConnell, 1980).

informed local government authorities chose to adopt measures that limit further expansion of cage and pen culture activities beyond the carrying capacity of the freshwater bodies because of the periodic occurrences of massive fish kills. The problem of periodic fish kills was due to the deteriorated water quality brought about by unregulated expansion of cages and pens, high stocking densities used, and excessive feeding.

Examining the past and present status of the lake is imperative for finding a sustainable solution to the problem. Many scientific studies have been conducted to describe the limnological, ecological, and biophysical characteristics of the lake and its watershed, and the socio-economic and legal considerations of cage culture (Herre, 1927; Castillo and Gonzales, 1976; Hargrove, 1991; Acedera, 1993; UPLBFI, 1995; Tan, Baskinas, and Garcia, 1995; PCTT, 1997; Noche, 1998; Bartolome, 1999; Malayang, 1999; Mutia and Magistrado, 1999; Zafaralla, 1999; Mercene-Mutia, 2001; Rosana and Salisi, 2001; Guerrero III, 2002). Various researchers have suggested different management techniques (Coche, 1980; Dela Vega, 2001), yet the majority of the fish cage operators are not very receptive to changing their current practices. The bottom line question: what is the least-cost nutrient pollution reduction option(s) for the fish cage production in Taal Lake?

## Problem Statement

The choice of nutrient pollution reduction strategy is a difficult task. Unless we know the sources of interdependencies between cage production inputs, outputs and the nutrient enrichment in cage areas, we cannot decide what policy alternatives would be possible. Looking into the policy history of the Philippines, "command-and-control" instruments have not been successful enough to counteract existing problems on natural resources. Market forces therefore need to be considered in the search for the most cost-effective options. The design of the policy should be as inexpensive as possible. Regulations that impose very high costs are more likely to be disobeyed by the operators themselves (Tietenberg, 2000; Meister, 2002). According to Weersink (1998), "the appropriate environmental policy is one that minimizes the environmental costs of the residuals, the abatement costs to producers in reducing those levels, and the administrative costs to the regulator of monitoring and enforcing compliance."

Naylor *et al.* (2003) explained that the current management options for reducing the loss of nutrients into the surface water are largely limited to controlling the intensity of fish cage production. Along this line, Yambot (1999) suggested the following strategies: (a) reduction in the total number of cages, (b) reduction in feeding ration, (c) reduction in stocking density; (d) single-line positioning of cages, and (e) the use of an aerator during problem situations. Overall, decreasing the input rates of $N$ and $P$ from cages can minimize the nutrient loading (Carpenter *et al.*, 1998). Tan, Baskinas, and Garcia (1995) raised the issue of exploring the kinds of economic arrangements between caretakers and owner in minimizing inefficiencies and other wastages, which are usually accounted for by the absence of the owner. These recommendations warrant further study and evaluation. More information is needed so that policy- makers will be better guided and make more informed decisions about the relative worth of these strategies. For this reason, finding the lowest-cost means of accomplishing the objective seems promising and practical.

## Research Questions

This study focuses on three main research questions. The first question is: what is the nature of the fish cage production technology in Taal Lake and the interdependencies of cage production inputs and output with nutrient enrichment in cage areas? Knowing these dynamics could facilitate understanding the nutrient pollution brought about by the cage production activities. The second question: how is efficiency related to the different municipal regulations and ownership arrangements in the lake? This question will investigate if there are differences in efficiency, and ultimately in income, of using the technology given different municipal regulations and labor hours employed. The third question is: what are possible pollution reduction options and from these options, the most cost-effective one? This question will evaluate the least-cost option based on the cost-effectiveness of nutrient loading reduction.

## Research Objectives

In view of the above questions, the main objective of the research is to look for the cost-effectiveness of nutrient pollution reductions in Taal Lake. The specific objectives are:

1) To describe the nutrient pollution dynamics in the lake and the impacts on the fish cage production and operators;
2) To evaluate and estimate physical efficiency according to municipal jurisdictions and ownership arrangements.
3) To estimate the costs of reducing the nutrient loadings from the fish cage production by reducing the total number of fish cages, reducing the feeding

ration, reducing the stocking density, and reducing the water quality impacts of nutrient loadings by the introduction of single-line positioning of cages and the use of aerator.

The achievement of these objectives will provide information on the impacts of implementing nutrient pollution reduction strategies on individual fish cage operators. The results of the study will also help public policy decision-makers enhance existing institutions or create alternative structure(s) geared toward addressing the problem.

## Organization of the Thesis

This research study is composed of seven chapters. Chapter 1 identifies the research issues related to the nutrient pollution reduction in Taal Lake and presents the research questions and objectives that are addressed in this study. Chapter 2 describes the totality of the Taal Lake's environment, with emphasis on water quality parameters, history of the fish cage industry, and development, and fishery management, regulation and legislation. Chapter 3 reviews the conceptual framework for the efficient allocation of inputs to produce the output, linking technical efficiency with the externalities and the pursuit of cost-effectiveness of pollution reduction options. Chapter 4 discusses the fish cage operator survey employed, the stochastic frontier production estimation following the log-linear Cobb-Douglas form, and the method for estimating the cost-effectiveness of pollution reduction options. Chapter 5 presents the result of the fish cage operator survey, detailed income analysis, and the optimum input-output analysis on the fish cage production. Chapter 6 presents the evaluation results of the pollution reduction options iden

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identified; discusses the waste reduction or minimization and waste management options; and presents the cost-effectiveness assessment. Finally, Chapter 7 summarizes the findings of the study and draws policy implications from it.

# CHAPTER 2

# TAAL LAKE AND ITS ENVIRONMENT

This chapter presents the historical and current situation of Taal Lake and its environment. The first section describes the salient features of the Taal Lake ecosystem. The next section describes the historical background of the Batangas Province, where the study area is located. It highlights the distinguishing features of the province and Taal Lake. The third section presents the biological, physical, and chemical characteristics of the Taal Lake watershed. It describes the relationships among the different components of the watershed significant to the analysis of the nutrient pollution problem. The discussion focuses on the dynamics of water quality and nutrient enrichment. The last two sections present the history and development of fish caging, and the overall fishery management, regulations and legislations in the watershed. Indeed, the ownership arrangement and fishery regulations among the four municipalities influence the dynamics of nutrient pollution in Taal Lake.

## A Glimpse of Taal Lake and the Fish Cage Industry

Taal Lake is located in the province of Batangas, which lies approximately 60 km south of Manila (Figure 1). Formerly known as Bombon Lake, it is the deepest and the third largest lake in the country. Taal Lake is a major tourist attraction and best viewed from the Tagaytay Ridge, which lies to its North. It is one of the 10 priority freshwater wetlands in the Philippines, as declared by the Protected Areas and Wildlife Bureau (PAWB), an agency under the Department of Environment and Natural Resources (DENR). Its watershed has 38 tributary rivers draining into the lake. The only outlet, to

Balayan Bay, is the Pansipit River, which has an outflow of 15 $m^3/s$. Of the 37 inflow rivers, only two perennial rivers exist, one in Agoncillo and one in Balete (Folledo and Cruz, 1999).

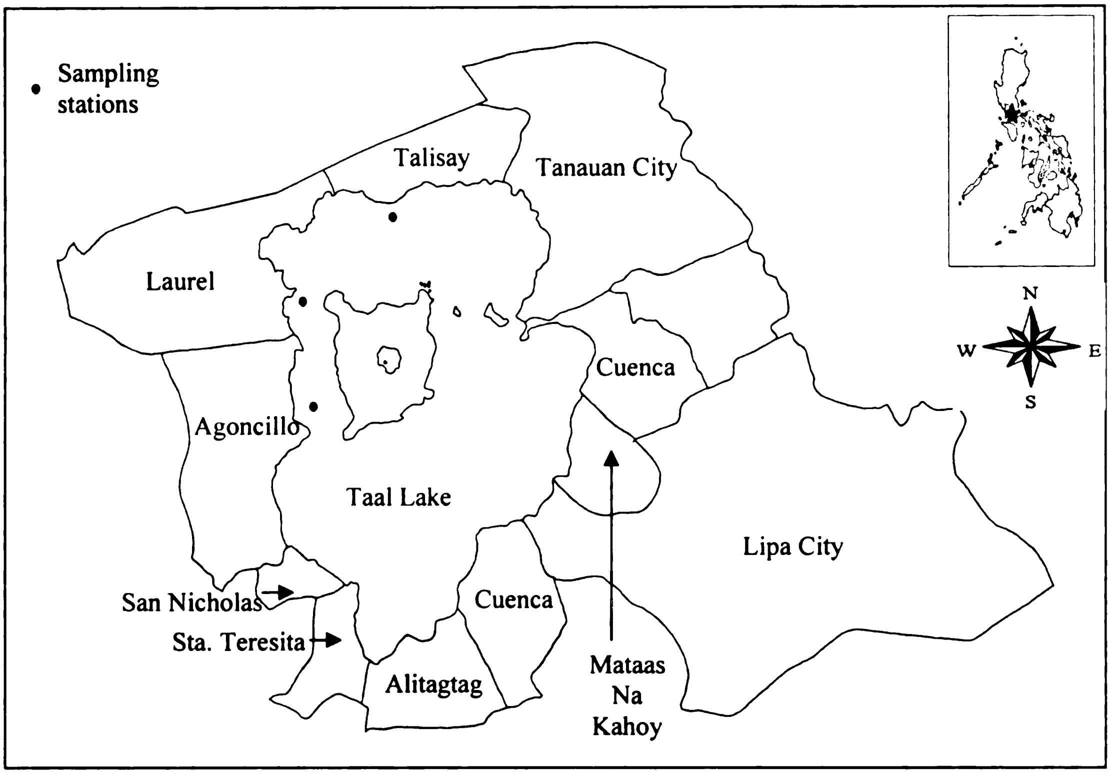


Figure 1. Map of Taal Lake, located in the province of Batangas, Philippines.

The lake covers an aggregate area of 24,236 ha, excluding the islands, and has an average depth of 60 m (Folledo and Cruz, 1999). It has a circumference of 120 km and is bounded by nine municipalities and two cities. Namely: Agoncillo, San Nicolas, Sta. Teresita, Alitagtag, Cuenca, Mataas na Kahoy, Lipa City, Balete, Tanauan City, Talisay, and Laurel. The fish cages are limited to the barangays of four municipalities: Laurel, Agoncillo, Talisay, and San Nicholas (Figure 2). Cages are mostly concentrated in the fish sanctuary area between Barangay Manalao, Agoncillo and Barangay Gulod, Laurel, although regulation restricts construction of cages in this area. Cages located in these areas are protected from the destructive effect of strong winds. The Tagaytay ridge acts as buffer decreasing the wind velocity as it approaches the cage areas. Other cages were located on the west side of the volcano island and a few cages are located near the smaller islands. Cages are absent in the northeast and southwest portions of the lake because of their susceptibility to strong winds and waves during the southwest monsoon season (Herre, 1927). Three types of cages exist in Taal Lake: floating, fixed, and submerged (Figure 3).

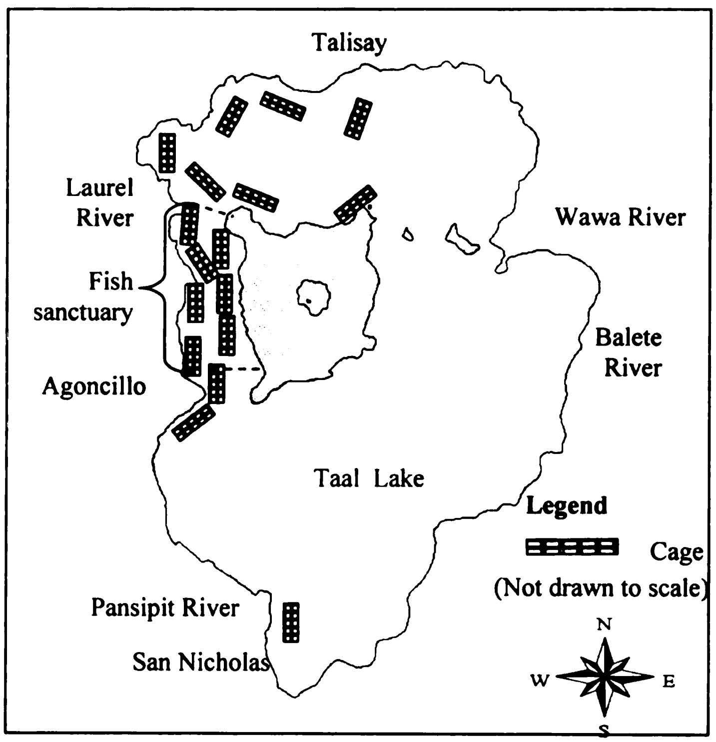


Figure 2. The location of cages in the four municipalities of Taal Lake, Philippines, 2002.

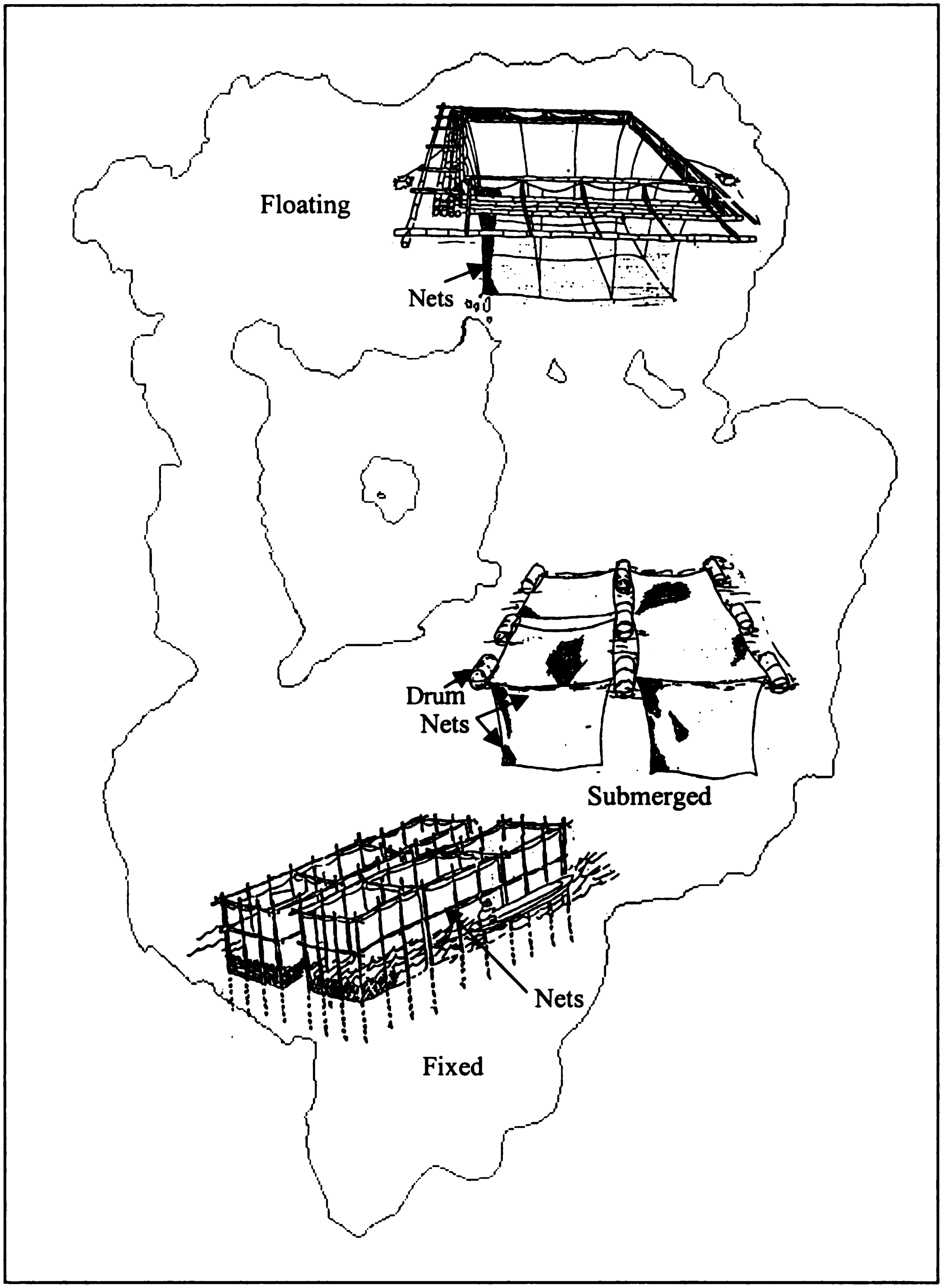


Figure 3. Cage types in Taal Lake, Philippines (Courtesy of PCTT, 1997).

The lake provides multiple and often conflicting services to various users. Current uses of the lake include: (1) open water fishing; (2) fish cage culture; (3) navigation routes; (4) recreation / tourism; (5) water source for the City of Tagaytay; and (6) source of food for waterfowl. Agriculture is the main use of the watershed while tourism predominates on the Volcano Island and Tagaytay Ridge. The catchment area is largely deforested and used for agriculture. Coconut cultivation is important, with additional crops such as coffee, cocoa, and cassava grown under the coconut trees. Other areas are dominated by grassland (*Imperata cylindrica*) and there is some small and large-scale livestock raising within the watershed. There is very little industry in the catchment area at present. Major threats to the lake include over-exploitation of fishery resources, inappropriate development for tourism, and plans to use the lake water for irrigation and domestic water supply (Acedera, 1993; ILEC, 2002).

Fish cage culture has been practiced for the past two decades, and the present trend is towards increased stocking density and intensive feeding. At present, the species cultured in cages are tilapia (*Oreochromis niloticus*), bangus (*Chanos chanos*), and maliputo (*Caranx ignobilis*). Among the three species, tilapia is the most commonly cultured. The culture period spans from 4-7 months, depending on the intensity of feeding and the quality of fingerlings. The fish are heavily fed with different types of commercial feeds. In 2001, fish cages in the lake numbered 7,433 (Table 1). Each fish cage measures an average of 10 x 10 x 6 m with a stocking of 65 -100 tilapia fingerlings/$m^3$. This cage structure is relatively sturdier than larger cages (Tan, Baskinas, and Garcia, 1995), hence most preferred by the operators.

Table 1. Number of fish cages and operators in Taal Lake, Philippines, 2001.

| Municipality | Number of cages | Number of operators |
|---|---|---|
| Agoncillo | 2362 | 682 |
| Laurel | 2729 | 590 |
| San Nicholas | 481 | 210 |
| Talisay | 1861 | 260 |
| Total | 7433 | 1742 |

(Source: MAO of the four municipalities)

The deepest cages result in the best growth of tilapia and the highest fry production (Coche, 1980). Table 2 shows the known nutrition requirements of *O. nilotica.*

Table 2. Summary of known nutrient requirements of tilapia (O. *nilotica*).

| Nutrient | Requirement |
|---|---|
| Protein [a] | 35 % for fry, 25-30 % for fingerlings |
| Essential amino acids [b] | |
| Arginine | 4.2 % |
| Histidine | 1.7 |
| Isoleucine | 3.1 |
| Leucine | 3.4 |
| Lysine | 5.1 |
| Methione + Cysteine | 3.2 (Cysteine, 0.5) |
| Phenylalanine + Tyrosine | 5.5 (Tyrosine, 1.8) |
| Threonine | 3.8 |
| Tryptophan | 1.0 |
| Valine | 2.8 |
| Lipid [a] | 6–10 % |
| Essential fatty acids [a] | 0.5 %, 18:2 n-6 |
| Phosphorus [a] | < 0.9 % |
| Carbohydrates [a] | 25 % |
| Digestible energy | 2500 – 4300 Kcal/kg |

[a] Requirement as percent of dry diet

[b] Requirement as percent of protein

(Source: SEAFDEC/AQD, 1994)

Taal Lake is oligotrophic (Guerrero III, 2002); some areas were already eutrophic in the mid-1970's (Zafaralla, 1999). The surface water is moderately hard, relatively high in chloride and phosphorus but low in nitrogen, with an annual mean pH of 8. Electrical conductivity is in the range of 105-236 m. Table 3 presents the significant features of Taal Lake and its watershed.

Table 3. Significant features of Taal Lake and its watershed.

| **Features** | **Brief Description** |
|---|---|
| *Biophysical characteristics* | |
| Location | $120^0$56'50" to $121^0$10'0" longitude and $13^0$51'54" to $14^0$8'41" latitude |
| Surface Area (ha) | 24,236 |
| Altitude (m) | 2.5 (wet season); 1.5 (dry season) |
| Depth (m) | 60 (average)<br>198 (deepest portion) |
| Drainage | 38 inlets (2 perennial); 1 outlet (Pansipit River) |
| Watershed Area (ha) | 66,342 |
| Shoreline length (km) | 82.5 |
| Biodiversity | 238+ species |
| Water classification, 2001 | Class C |
| *Physico-chemical characteristics in cage areas (2001)* | |
| Surface Temperature, ($^0$C) | 25.5 - 32.2 |
| Dissolved Oxygen (mg/L) | 3.4 - 15.6; low at surface water and increasing at depth greater than 10 m |
| pH Values | 8 - 9.5 |
| Transparency (m) | 1.2- 4.1 |
| *Cage area coverage* (ha) | 74.33 (0.31 % of lake water) |
| *Land Tenure* | Taal Lake and Volcano Island are government owned |
| *Coastal communities* | 9 municipalities, 2 cities |
| *Watershed population* (2001) | ≥ 535,323 |

(Source: UPLBFI, 1995; Zafaralla, 1999; NSO, 2000; BFAR-IFRS, 2002)

The relevant stakeholders in the cage industry are the fish cage operators[2] (classified either as financiers/owner or caretakers), open water fishermen[3], middlemen[3], feed producers/suppliers/retailers, research institutions, local government units (LGUs), cooperatives, and the general household consumers.

There is little variation in the practices of fish cage culture in Taal Lake. This situation is common because many individuals own cages in several different municipalities. By law, the right to own at most five cages is vested to the local residents. However, due to the lack of financial capital, local residents end up as caretakers for an absentee owner. Financial capital is the limiting input to most of the local residents, who do not have access to or preference for accessing credit facilities. They are also not receptive to applying for and securing credit from formal financing institutions but instead utilize individual lenders with high interest rates (UPLBFI, 1995). Small-scale operators are reluctant to acquire a loan from the bank, which requires collateral before a person can borrow money. Avoiding this process, these operators prefer to borrow money from close relatives and/or eagerly look for financiers. Hence, without the financiers, the majority of the caretakers cannot enter the cage business. The financiers generally own the fish cage units and provide all the production inputs. They also influence most of the decisions about cage culture, specifically those related to financial matters. Caretakers provide the labor input in the production process. Overall, fish cage management is laborious. From cage construction, stocking, feeding, until harvesting, caretakers are expected to inspect their cages every day.

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[2] Generally known as fisherfolks, people directly or personally and physically engaged in culture and processing fishery and/or aquatic resources.

Aragon *et al.* (2001) reported a disturbing attitude of operators towards adoption of new aquaculture techniques. Their study showed that operators did not fully adopt all the recommended practices in tilapia culture because they lacked the needed amount of capital, limited awareness of the recommended practices, and personal preferences for following prior experiences in the area.

The estimated total fish production in Taal Lake in selected years between 1993 and 2002 is shown in Table 4. Production from the open water fisheries dwindled after fish cage culture flourished in the lake. The promising results of cage culture adoption led to a shift in the use of technology and resulted in increased fish cage production but decreased fish catch in the open water. The lower productivity of native fish may also be attributed to the disturbance and displacement of fish spawning ground brought about by tilapia dominance, fish fecal materials and wasted feed. Tilapia is an exotic and a prolific breeder, and hence, a competitor of native fish species. Financially, the net real income per grow-out cage per culture cycle per square meter increased from PhP 40 in 1986 to PhP 63 in 1990 (Noche, 1998). The 2001 estimate of net real income of the same unit amounts to PhP 160.

In 2000, Batangas Province was the top freshwater fish cage producer. It contributed a total of 15,268 *mt* of fish equivalent to 52 % of the total freshwater fish cage production in the Philippines (BAS, 2001). Apacionado Jr. (2001) reported that in the Southern Tagalog region, about 40 % of the tilapia demand was supplied by the booming business of aquaculture in the lake.

Table 4. Estimated total fish production (metric tons) of Taal Lake, Philippines, 1993-2002.

| Year | Open water fish catch (*mt*) | Fish cage production (*mt*) | Total Production (*mt*) |
|---|---|---|---|
| 1993 [a] | 8,792 | 4,984 | 13,776 |
| 1994 [a] | 2,446 | 12,097 | 14,543 |
| 1995 [a] | 2,767 | 26,376 | 29,143 |
| 1998 [a] | 1,681 | 38,572 | 40,253 |
| 1999 [b] | 1,015 | 22,235 | 23,250 |
| 2000 [b] | 883 | 21,309 | 22,192 |
| 2001 [b] | 1,008 | 23,772 | 24,780 |
| 2002 [b] | 925 | 23,080 | 24,005 |

[a]Mutia, 1999.

[b]BAS, 2003.

Table 5 presents the number of fish cages in the lake in selected years between 1993 and 2001. The total number of cages increased over time as more gains were realized. Although the data in Table 5 show an increasing trend in the total number of fish cages, the trend was not consistent for the municipalities of Agoncillo and Laurel. The impacts of nutrient enrichment were so great that, beginning in 1999, massive fish kills occurred in most cage areas. Fish kills in Taal Lake typically happen in the months of May and June, except in the municipality of Laurel, where most occur in August. Many fish cage operators exited the market because of the longer cropping cycle and poor investment recovery and the risk-averse behavior of the financiers. In Agoncillo alone, fish cage operators reported that many financiers abandoned their cages because they had lost millions of pesos. This situation was inevitable, given increased costs of fish production, reduced profit, and/or loss of capital investments.

Table 5. Number of fish cages in Taal Lake, Philippines, 1993-2001.

| Municipality | 1993 | 1995 | 1998 | 2000 | 2001 |
|---|---|---|---|---|---|
| Agoncillo | 469 | 304 | 2,467 | 3,436 | 2,362 |
| Laurel | 548 | 148 | 1,785 | 2,817 | 2,729 |
| San Nicholas | 159 | 312 | 433 | 221 | 481 |
| Talisay | 95 | 87 | 409 | 649 | 1,861 |
| Other Municipalities | 330 | 760 | 49 | 0 | 0 |
| Total | 1,601 | 1,611 | 5,143 | 7,123 | 7,433 |

(Source: MAO of the four municipalities)

Permits to operate fish cages at the Taal Lake fish cage zone are obtained from the respective municipal offices. Upon presentation of the supporting documents (location map, barangay clearance, pervious permit, ID picture) and payment of fees, operators are legally allowed to start the business or renew previous production activities. In the 2001 data for Talisay, only 362 cages of the 1861 reported were with permit, 1421 cages did not have a permit, while the remaining 78 cages were abandoned/empty. Non-payment of permit and other fees was also prevalent in the other municipalities.

## Batangas Province and Taal Lake: Historical Background

The establishment of the Province of Batangas dates back to 1581. It was originally called Balayan, with the municipality of Balayan as the capital. In 1732, the municipality of Taal became the province's capital. Finally, in 1754, the municipality of Batangas became the capital, which is the name of the province to this day. The beautiful Taal Lake lies at the very heart of Batangas and within its center lies the world's smallest and restless Taal Volcano (Hargrove, 1991; Guerrero III, 2002). Hargrove (1991) describes the mystery of Taal Lake and its volcano, and how the several municipalities of Batangas evolved through time since 1521, when the Spanish came to the Philippines.

Batangas is bounded in the east by the provinces of Laguna and Quezon, in the west by the South China Sea, in the north by the province of Cavite, and in the south by the Verde Island Passage. It has a land area of 316,581 ha and is subdivided into 31 municipalities and three cities (Batangas City, Lipa City, and City of Tanuan) with 1,078 barangays (NSCB, 2002). The terrain is generally rolling, and 50 % of the total land area has a grade of less than 15 degrees. The remainder is mountainous and hilly. Agriculture is the main economic activity in the province. The major crops, in terms of area planted, are rice, sugarcane, coconut, and coffee or cacao. The province is also a major supplier of cattle to Metro Manila, which is the national capital of the Philippines.

The people of Batangas, often called Batangueños, are renowned for being industrious traders. The province has a total population of 1,905,348, a population density of 602 persons per $km^2$ in 2000, and an annual population growth rate of 2.58 % during 1990-2000. Out of this total population, there are at least 535,323 people comprising the 374,767 households in the nine municipalities and two cities surrounding Taal Lake. The average household size is five persons per family. National Statistics Office (NSO) expects that the population will double in the next 23 years. The 1999 census reveals that the province ranks 57 out of 77 Philippine provinces in terms of selected poverty indicators. The average per capita income in Batangas in 2000 was PhP 32,055 while average per capita expenditure was PhP 27,209 (NSO, 2002).

Many scientists, researchers, nature enthusiasts, and tourists are fascinated with the beauty and splendor of Taal Volcano and Taal Lake. Volcanologists consider Taal Volcano one of the world's 10 deadliest volcanoes. It has erupted at least 42 times between 1572 and 1977 (Hargrove, 1991), four of which were considered major eruptions (PHIVOLCS, 1993). Herre (1927) characterized the lake as "a sheet of very beautiful, clear water, of moderately irregular outline…." Likewise, the lake ecosystem is an assemblage of rich biological treasures, which are believed to have originated from the sea. The lake's water was salty before 1754, but is now classified fresh (Hargrove, 1991; Zafaralla, 1999). Tan, Baskinas, and Garcia (1995) highlight and emphasize prominent features of Taal Lake. It has a "crater" lake within itself, i.e. the crater lake is the mouth of an active volcano. The entire Taal Lake is a crater of a great volcano, a caldera with the surrounding mountains as its walls that are 150-304 m high (Figure 4). It is the habitat of the only freshwater sardines in the Philippines, called tawilis, freshwater snakes (*Hydrophis semperi*); and other endemic fauna and flora. Compared with other lake ecosystems, it is rich in phosphorous, which is often a limiting factor to the growth of fishes. Surprisingly, there is a warming of water in Taal Lake during the rainy season, instead of cooling (Acedera, 1993; Zafaralla, 1999).

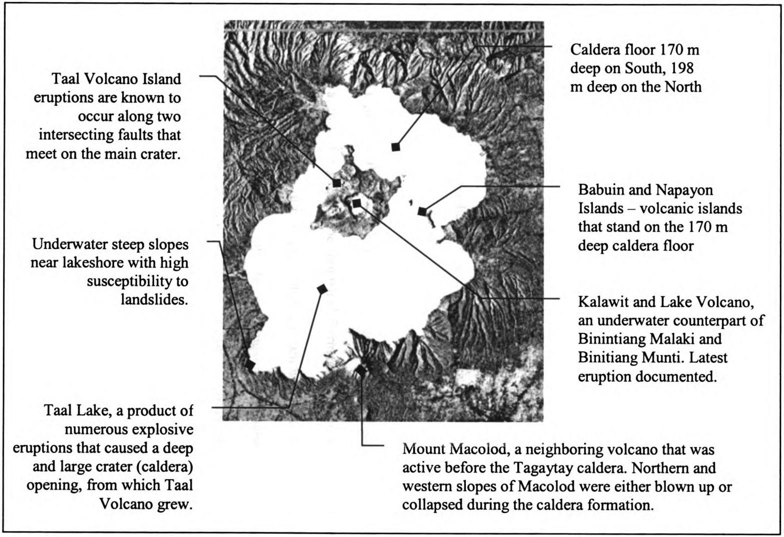


Figure 4. Prominent topographic features of Taal Lake and Volcano Island, Philippines (Source: JPL- CIT, 1994; PCTT, 1994).

## The Taal Lake Watershed

### Bio-Physical Characteristics

Taal Lake watershed lies at $120^0$ 56' 50" to $121^0$ 10' 0" longitude and $13^0$ 51' 54" to $14^0$ 8'41" latitude. The watershed has a total area of about 66,342 ha, which is composed of the surrounding land (39,264 ha), the lake (24,236 ha), the volcano island (2,767 ha), and several small islands (75 ha) (Folledo and Cruz, 1999). The lake has an average elevation of 2.5 m above sea level in wet and 1.5 m in dry seasons (Herre, 1927) and fluctuates by about 0.75 m. It has a shoreline of 82.5 km and is relatively deep, having an average depth of 60 m and maximum depth of 198 m (Figure 5). The northeast and southeast portions of the lake have generally steeper lake bottom slopes near the shorelines.

Table 6 presents the land uses in the Taal Lake watershed in 1999. Areas planted with coconut account for 31 % of the watershed. Farmers intercrop their coconut with coffee, mango, or other agricultural trees. Other agricultural lands comprise only 7.36 % of the total watershed area and are cultivated with sugarcane, banana, upland and lowland rice, corn, vegetables, and other cash crops. Forest areas comprise about 1.34 % of the land area, while built-up areas cover 1.66 %. There is no commercial forest. Lake water covers 36.53 % of the watershed. Volcano Island is mainly grassland with patches of brush land and some exposed volcanic sand. In the southwest portion of the Volcano Island next to the Binintiang Maliit crater lies a 57 ha deposit of volcanic rocks (UPLBFI, 1995; Zafaralla *et al.*, 1999).

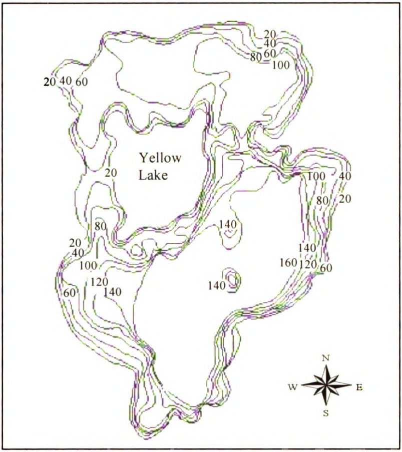


Figure 5. Bathymetric map of Taal Lake, Philippines (Source: ILEC, 2002).

Table 6. Land uses in the Taal Lake watershed, Philippines, 1999.

| Land use type | Area (ha) | Percent |
|---|---|---|
| Built-up areas | 1,100 | 1.66 |
| Agricultural lands | 4,884 | 7.36 |
| Forests | 886 | 1.34 |
| Coconut | 20,660 | 31.14 |
| Volcano Island | 2,767 | 4.17 |
| Small islands | 75 | 0.11 |
| Lake water | 24,236 | 36.53 |
| Unclassified lands | 11,734 | 17.69 |
| Total | 66,342 | 100.00 |

(Source: Zafaralla, *et al*., 1999)

Fifty percent of the watershed's total area has slopes greater than 18 % (steep to very steep categories). This condition is sensitive to land-use disturbance (Folledo and Cruz, 1999). Soil erosion rate in the Taal Lake watershed amounts to 83.28 *mt*/ha, which is about 761,780 $m^3$/year (UPLBFI, 1995).

Volcanic materials dominate the soil in the watershed area (UPLBFI, 1995). Landscape fragmentations are common in the higher elevation of the watershed due to conversion of primary lands for tourism development, urbanization, improvement of the road network, and industrialization in the CALABARZON[3]. Residential subdivisions have sprouted up in the upper slopes of Talisay and Laurel. The anthropogenic disturbances further threaten the environmentally sensitive landscape of the watershed and the water quality of Taal Lake (Alcantara, 1999).

The lake is rich in endemic species, such as the tawilis, the migratory yellow fin jack, locally called maliputo, and the sea snake. However, these migratory species are fast disappearing due to limitations of their migration from the sea to the lake (UPLBFI, 1995; Magistrado and Mercene, 2000). Other less prevalent fish species include the red snapper, mullets, silversides, anchovies, gobies, and the Pacific freshwater eel. Crustaceans and mollusks also abound in the lake. The lake and its streams are also rich in varied bottom organisms, which include various kinds of annelids, aquatic insect larvae like the midgets, and various types of mollusks, snails, clams, etc. The watershed harbors at least 415 species of plants belonging to 90 families and 300 species of animals in 73 families. A total of 126 phytoplanktons (algae), 13 zooplanktons, 5 species of

[3]CALABARZON is the an acronym for the provinces of **CA**vite, **LA**guna, **BA**tangas, **R**izal, and Que**ZON**, which are the growth areas of the Southern Tagalog Region in terms of industrial resources, socio-economic importance and tourism potential.

macrophytes, and 28 fish species, 7 of which were introduced, inhabit Taal Lake (UPLBFI, 1995; Zafaralla, 1999; Guerrero III, 2002). The watershed serves as habitat for 184 species of birds and 31 species of wild animals (bats, rodents, monkeys, reptiles, etc.). Herre (1927) cited that the fish fauna in the lake are marine in origin. Tilapia, an introduced species, now dominates its waters (UPLBFI, 1995; Mutia and Magistrado, 1999).

Taal Lake watershed has a Type I climate, characterized by two pronounced seasons: dry from November to April and wet during the rest of the year. This climate is favorable to agriculture and industries. Table 7 presents the summary of selected climatic parameters for the Taal Lake watershed. Typhoons occasionally visit during the rainy months (May to November), while March is the driest month. The increased rainfall in May and June brings warming of the water temperature (Zafaralla *et al.*, 1990; Acedera, 1993). The mean annual rainfall from 1961 to 1997 is estimated to average 1,883 mm. The months of June to October receive the highest rainfall amount while January to April are the months with lowest rainfall. The cold months span from November to February while the warm months occur March to May.

Table 7. Selected average monthly climatological data for Taal Lake watershed, Philippines, from 1961-1997.

| Month | Rainfall (mm) [a] | Prevailing wind direction [a] | Wind speed (mps) [b] | Relative Humidity (%) [b] | Air Temperature ($^{0}C$) [b] | Evaporation (mm) [c] |
|---|---|---|---|---|---|---|
| January | 17.5 | NE | 2 | 76 | 21.5-30.5 | 106 |
| February | 8.2 | NE | 1 | 72 | 21.5-31.8 | 113 |
| March | 17.7 | NE | 1 | 70 | 22.2-33.6 | 137 |
| April | 32.6 | NE | 1 | 69 | 23.4-34.9 | 153 |
| May | 125.1 | SW | 1 | 74 | 24.1-34.3 | 145 |
| June | 249.1 | SW | 1 | 80 | 24.1-32.5 | 119 |
| July | 342.0 | SW | 1 | 83 | 23.7-31.4 | 110 |
| August | 323.9 | SW | 1 | 84 | 23.8-30.9 | 109 |
| September | 279.2 | SW | 1 | 84 | 23.5-31.5 | 105 |
| October | 221.1 | NE | 1 | 82 | 23.1-31.7 | 106 |
| November | 173.4 | NE | 1 | 81 | 22.9-31.3 | 101 |
| December | 93.1 | NE | 2 | 79 | 22.2-30.3 | 97 |
| Annual | 1,882.9 | | | 78 | | |

[a]1961-1997

[b]1961-1990

[c]1959-1974

NE – northeast

SW-southwest

(Source: UPLBFI, 1995; Zafaralla, 1999)

The prevailing wind direction is northeasterly, southwesterly, and southeasterly. The northeasterly wind (amihan) starts weak in October, attains a maximum in January, weakens in March and disappears in April. An extended visit of the northeasterly winds may limit the growth of natural food for fish. Southwesterly winds (habagat) appear in May, attains maximum in August, and gradually disappear in October. The transition period between the southwest and northeast monsoon occurs in May and October, and brings an increase in rainfall in the North. Southeasterly winds (salatan) occur during the transition period and result in a sudden variability of weather conditions in the watershed.

They also influences the de-stratification of lake water layers, in which the bottom sediments and decomposing organic matters rise up causing turbidity and oxygen depletion at the surface water (Rosana and Salisi, 2001). Wind speed has an average of 2 mps from December to January and 1 mps during the rest of the year. These wind patterns greatly influence the physico-chemical characteristics of the lake (Rosana and Salisi, 2001). Monthly air temperature fluctuates between 22 $^0$C and 35 $^0$C, while the monthly relative humidity ranges from 69 to 84 % with an annual mean of 78 %. Evaporation rates are high from March to May but low from July to February (PCTT, 1993; UPLBFI, 1995).

Water transparency normally ranges from 4 to 6 m. It decreases to 1.1 to 2.8 m during the overturn process, caused by the high amount of suspended solids that results in high water turbidity. Water mixing affects the water quality and the lake's ability to support fish. Water temperature ranges from 25 $^0$C to 35.5 $^0$C and decreases by 0.5 to 2 $^0$C per 10 m intervals as the lake approaches the bottom (Rosana and Salisi, 2001). It is the temperature that has a direct influence on morbidity (Zafaralla, 1999). The rapid rise of temperature during the rainy and summer months results in a decreasing level of dissolved oxygen, which is detrimental to fish survival.

**Water Quality and Chemical Characteristics**

Nutrient loading in the lake is high, which may suggest a deteriorating water quality in cage areas (UPLBFI, 1995). When the nutrient [mainly *N* and *P*] loading and concentration increases beyond the natural endowment and assimilative capacity of the lake, water quality deteriorates to a level toxic to fish (Naylor *et al.*, 2003) and results in water quality impairment, fish kill incidences, and financial losses. Figure 6 shows a schematic diagram of nutrient enrichment, which is mainly contributed by the fish cages, watershed/agricultural run-off, and household sewages. The concentration of nutrients is affected by the physico-chemical, socio-economic, and institutional environment.

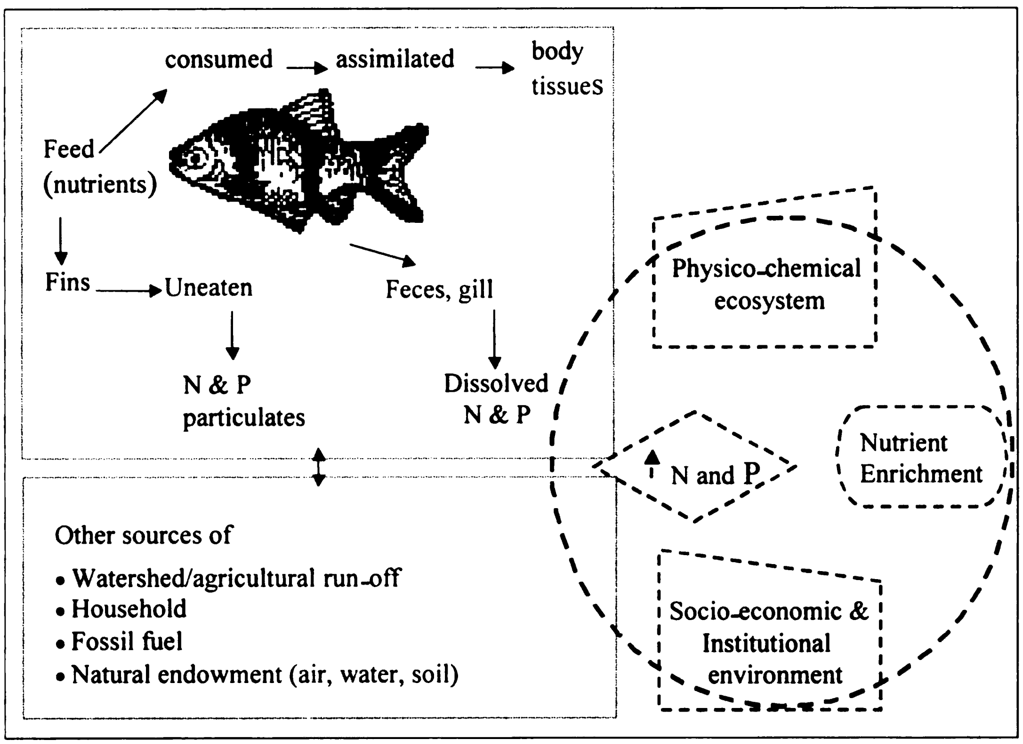


Figure 6. Schematic diagram of nutrient flows and enrichment in Taal Lake, Philippines.

The standard water quality parameters relevant in studying freshwater ecosystems include dissolved oxygen (DO), carbon dioxide ($CO_2$), temperature, pH, ammonia ($NH_3$), nitrite ($NO_2$), nitrate ($NO_3$), hydrogen sulfide ($H_2S$), and total phosphorus (P) (DENR, 1990; EPA, 1999). These parameters are closely correlated with stress and incidence of diseases in farmed fish (Naylor *et al.*, 2003). DO is negatively correlated with the main nutrients causing pollution and a good indicator of the nutrient concentrations in the lake.

Following the DENR Administrative Order No. 34, Taal Lake has Class C surface water, i.e. fishery water used for the propagation and growth of fish and other aquatic resources. Table 8 presents the selected water quality parameters in comparison with the DENR water quality criteria. While the DO level fluctuates monthly and yearly, its level became critical in the past three years, particularly in the congested cage areas. Rosana and Salisi (2001) recorded at least 38 fish kill incidences in various cage areas from May 1999 to June 2001. The fish kills were attributed to oxygen depletion during overturn and toxic poisoning from the suspected pollutants ($NH_3$, $NO_2$ and $H_2S$). The concentration of ammonia in 1995 and 2000 exceeded the acceptable level of 0.02 mg/L. Rosana and Salisi (2001) reported high levels of ammonia (0.15 – 0.30 mg/L) and pH (8.5 to 9.0) indicating heavy feed load and fecal matters accumulated at the bottom of the lake. Nitrate is within the acceptable level of below 10 mg/L. Nitrite reached a toxic level in 2000, when massive fish kills occurred in Taal Lake. Orthophosphate was in abundance in 1973 but has decreased in concentration since the 1977 eruption of Taal Volcano.

Volcanic lakes are known to have a high amount of phosphorus (Zafaralla, 1999). Elemental phosphorus is a toxin subject to bioaccumulation. The key nutrient stimulating excessive plant growth for both weeds and algae in lakes is phosphate phosphorus. Phosphates, which occur in low concentrations in most natural waters, are increased by domestic use, principally by synthetic detergents, and often become long-term constituents of the lake's bottom sediments. Cultural eutrophication is the accelerated fertilization of surface waters arising from phosphate pollution associated with discharge of wastewaters and agricultural drainage (Viessman and Hammer, 1985).

Table 8. Comparison of selected water quality parameters of Taal Lake, Philippines with the DENR water quality criteria for fresh waters.

| **Parameters (mg/L)** | **Acceptable Level** | **Year** | | | | |
|---|---|---|---|---|---|---|
| | | **1973** [a] | **1990** [b] | **1995** [c] | **1999** [d] | **2000** [d] |
| DO | > 5.0 | 3.14 | 4.4-11.6 | 6.5-9.1 | 3.4-11 | 0.3-10.5 |
| $NH_3$ | < 0.02 | 0.11 | 0.02-0.9 | 0.44-0.71 | nd | 0.15 |
| $NO_3$ | <10.0[e] | 0.29 | 0.37 | 0.14-0.53 | 0.146 | 0.016 |
| $NO_2$ | < 0.1 | 0.003 | nd | 0.006 | nd | 0.25-0.35 |
| P | < 0.4 | 67 [f] | 0.01-0.23 [f] | 0.04-0.27 [f] | 0.054 [g] | .083 [g] |

[a] after SOGREAH, 1973

[b] after Zafaralla, 1991

[c] after UPLBFI, 1995, June-July measurement

[d] after Hilario, 2000; and Rosana and Salisi, 2001

[e] applicable only to lakes or reservoir, and similarly impounded water

[f] orthophosphate

[g] total phosphorus

nd – no data

After DO, ammonia is considered the second limiting factor that inhibits fish production. When ammonia is dissolved in water, a portion reacts with the water to form ammonium ions ($NH_4^+$) with the balance remaining as un-ionized ammonia. Un-ionized ammonia increases with increasing pH, increases with increasing temperature, and decreases with decreasing ionic strength. It is toxic to fish and other aquatic animals. The common sources of ammonia in water are fertilizers, fish excreta, and microbial decay of nitrogenous compounds.

Nitrate is the common form of inorganic N found in water solution. The standard of 10 mg/L is the maximum contaminant level for water with no adverse health effects. The first group of bacteria to develop in the lakes converts ammonia into nitrite. Once absorbed by fish, nitrite combines with the hemoglobin in blood, eliminating its ability to carry oxygen. The fish can thereby suffocate even though there may be plenty of oxygen in the surrounding water. Nitrite is probably second in importance in lake water chemistry only to ammonia.

***Dissolved Oxygen as Water Quality Indicator***

Dissolved oxygen is necessary for the propagation of fish and other aquatic life, enhances recreation and reduces the odors resulting from decomposition of organic matter, and maintains a suitable quality for water treatment (Viessman and Hammer, 1985). A high DO concentration can significantly increase fish yield and size (Teichert-Coddington *et al.*, 1991). In Taal Lake, DO level is negatively correlated with increasing water temperature but positively correlated with increasing lake depth (Castillo and Gonzales, 1976; Rosana and Salisi, 2001). Colder temperatures in the lake's bottom hold higher DO while warmer temperatures in the surface hold less. However, during the months of May and June, the levels of DO at a 10 m depth are observed to be lower than the surface DO. This observation supports the finding of Zafaralla (1990) that the lake tends to be warmer (2.5–4.5 $^0$C) at the onset of the rainy season. Critical levels of DO occur during the months of June and July. This situation is caused by high nutrient loading, basically nitrogen from $NO_2$ and $NH_3$.

Figure 7 presents the DO trend in Leviste, Laurel measured near the surface of the water from July 1999 to July 2002. Surface water measurement was used because fish in cages usually congregate within the upper 2-m where DO produced through photosynthesis by algae is highest (Guerrero III, 1982). DO concentrations reached a critical level (< 5.0 mg/L) in the months of May to early August, and reports of fish kills occurred during those months. On the other hand, DO concentrations above the critical level were observed from September to October and from December to May.

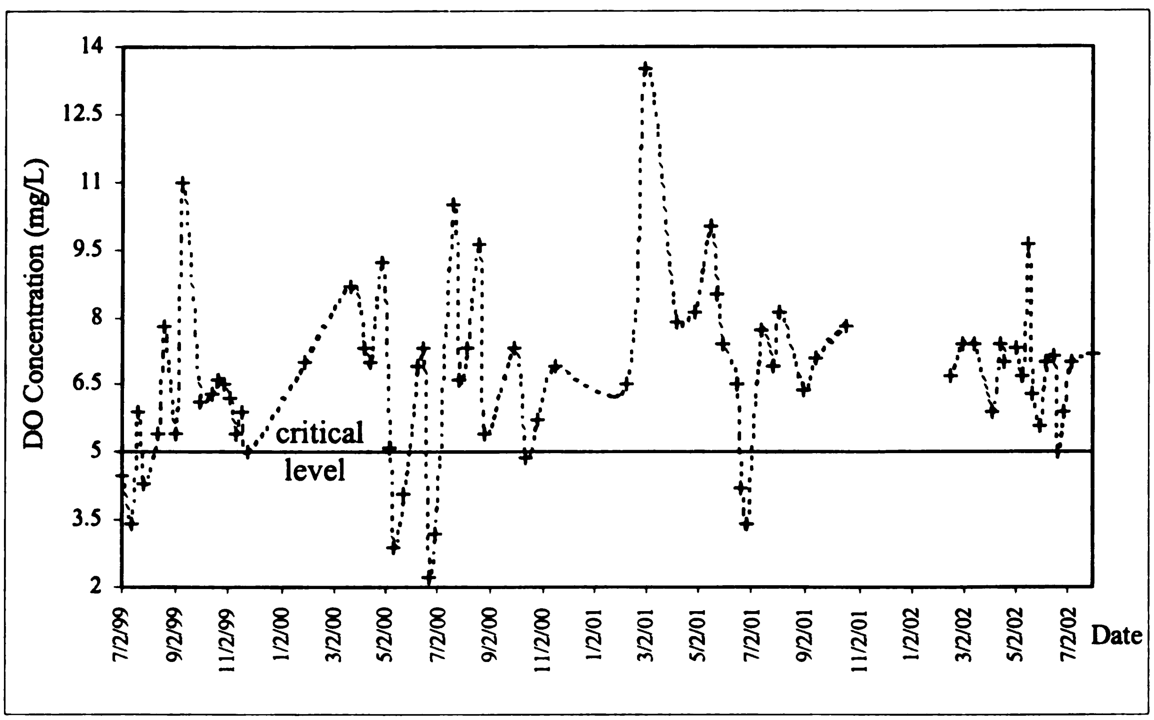


Figure 7. Trend of dissolved oxygen above and below the critical of 5 mg/L in Leviste, Laurel, Philippines from July 1999-July 2002 (Source: BFAR-IFRS, 2002).

Rosana and Salisi (2001) suggest the parasitic timud (*Alytropus typus*)[4] infestations of tilapia cages in the months of February and March as one of the possible reasons for fish kills. Although earlier records show infestation of timud, its effects were largely observed in the last five years. Researchers from the Bureau of Fisheries and Aquatic Resources (BFAR) are studying the causal factors that lead to the infestations. It may be possible that timud has a direct link with the increasing amount of nutrients in Taal Lake since it thrives in water with high organic loading and in areas with high stocking density and abundant aquatic grasses (Del Mundo, Albeladejo, and Vera, 1996).

***Relevant Nutrients and Their Sources***

Nutrients occur naturally in water, soil, and air (Martin and Hine, 2000). Among the different nutrients, *N* and *P* are principally associated with over-enrichment (Howarth, 2003). Nitrogen contributed by cage culture brings about higher amounts of ammonia-N and nitrate-N, which limit primary production. Phosphorus is a key nutrient stimulating excessive plant growth, including weeds and algae, in lakes. In Taal Lake, *N,* more so than *P,* seems to limit primary production in the lake (Zafaralla, 1999). This observation contradicts the phenomenon where P seems to be limiting in freshwater lakes (Zafaralla, 1999; Howarth, 2000).

In the Taal Lake watershed, excess nutrients are supplied to the system through point and non-point sources. Non-point sources include household sewage and watershed/agricultural run-off. The greatest source of nutrients to surface water with fish cage production is fish feed (Alvarado, n.d.). The main source of N in feed is proteins (Pillay, 1990). Loadings of N and P come from uneaten feed, feces, and excretion via the

[4] A macroscopic isopod under the Family Aegidae.

gills and urine, mainly in the form of ammonia ($NH_3$) and urea ($CH_4N_2O$) (Chervinski, 1982; Beveridge, 1993; Kibria *et al.*, 1996; 1998). About 23 % of nitrogen and 15 % of phosphorus in feed are retained on the tilapia body tissues and the rest is loss into the surrounding environment (Table 9).

Table 9. Nutrient retention and losses from tilapia cages fed with commercial feed.

| Nutrient load (kg/mt feed) | Retention (%) | Nutrient losses (dissolved, feces, and uneaten) % | Reference |
|---|---|---|---|
| Nitrogen | 23.44 | 76.56 | Beveridge, 1993 |
| Phosphorus | 15.00 | 85.00 | Phillips, 1994 |

While it is important to address the contribution of non-point source pollution, this study focused only on a point source, fish cages, since in the highly eutrophic areas of the lake the fish cage operators are mostly affected by the nutrient loading. The transport of nutrients from the non-point sources in the East portion of the lake are assumed to have the least effect to the cage culture industry, since they are diluted by the lake's great depth (Figure 5). The disorderly arrangement of existing (and many abandoned/empty cages) exacerbates the poor water circulation and low productivity (Tan, 1993). The slow water circulation in cage areas significantly influences the concentration of nutrients. When water circulation is limited, the concentration of nutrients inside cages and in nearby areas tends to increase. This condition results in a depletion of DO.

## Fish Cage History and Development in Taal Lake

Aquaculture is a thriving business in Taal Lake. In the 1970s, tilapia cage culture was introduced in the lake to increase fish production, raise the income of local fishermen, and as an alternative source of livelihood (Guerrero III, 2002). At that time, a private foundation trained a group of fishermen in the techniques of culture operation, and the knowledge they gained was passed from one fish farmer to another (Acedera, 1993). In 1986, a downtrend in cage numbers occurred in Laurel due to typhoon Sisang, which destroyed many of the cages. That event paved the way for the acquisition of abandoned cages by investors from Manila (Tan, Baskinas, and Garcia, 1995), who now comprise some of the absentee owners in the area. In 1988, Mr. Chi Pong was the first to apply the fish cage technology utilizing fish feed formulation in the Pansipit River (Cabrera, 2002, pers. com.). In that same year, commercial feeds were introduced in Laurel (Tan, Baskinas, and Garcia, 1995) and marked the start of intensive feeding practices in Taal Lake.

In 1995, typhoon Rosing hit Taal Lake hard and washed out hundreds of fish cages. A year later, the industry recovered and the genetically improved farmed tilapia variety (GIFT) became popular (Mutia and Magistrado, 1999). In 1997, an over-supply of feed in Agoncillo reduced feed costs, encouraging other fish farmers to initiate fish cage production in their area (De Villa, 2002, pers. com.). Although fish cage culture has been practiced for the past two decades, rapid expansion of the number of cages occurred from the early 1990s to the present.

The anticipated economic potential of the cage culture explains, in part, the currently booming fish industry in Taal Lake. However, current operating practices result in aquaculture wastes and other residuals, which can be a precursor to fish diseases (Gupta, 1998). Tan, Baskinas, and Garcia (1995) characterized the lake-based cage culture industry as undergoing a vicious cycle. The present trend of increased stocking density and intensive feeding (UPLBFI, 1995) results in seasonal fish kill occurrences due to depletion of DO near the surface water. Consequently, the use of this technology has benefited various stakeholders, but has also resulted in social and environmental costs.

## Fishery Management, Regulation, and Legislation

Fish cage operators, open water fishermen, middlemen, and different feed producers/suppliers/retailers are the key actors in the industry. The authorities responsible for the management of Taal Lake and its resources are the National Water Resources Board (NWRB), the Environmental Management Bureau (EMB), and the Taal Lake Development Authority (TLDA). NWRB is the government agency coordinating all water resource development activities, while the EMB is an agency under the Department of Environment and Natural Resources. The TLDA is the provincial authority that oversees the natural resource conservation in Taal Lake and its socio-economic development. The main tools of control include: the regulation of water use, abatement of water pollution, and development of the lake basin, in general. In addition, the BFAR, Region IV, is in-charge of other institutional measures.

The BFAR-Inland Fisheries and Research Station (IFRS) in Ambulong, Tanuan City, Batangas, and the National Fisheries Biological Center (NFBC) in Butong, Taal, Batangas, provide technical assistance and various support services; they conduct water-quality monitoring and surveillance, research, and development. Other key research institutions are the University of the Philippines in Los Banos and Diliman, Central Luzon State University, Laguna Lake Development Authority (LLDA), and the Philippine Council for Aquatic and Marine Research and Development (PCAMRD).

Table 10 summarizes the important legal and administrative decisions that have affected the management and utilization of Taal Lake, its watershed, and the Taal Volcano Island. In 1967, the Taal Volcano Island became a National Park through Proclamation No. 235. The Fisheries Code of 1975 promulgated through Presidential Decree (PD) 704 was the first law addressing the management of fishery resources, until it was updated to the current Philippine Fisheries Code of 1998 or known as Republic Act (RA) 8550. PD 704 established the open access policy that allowed unlimited numbers and types of fishing gears to be used in municipal waters, including lakes (Mercene-Mutia, 2001). In the same year, a fish sanctuary covering an area of about 1,289 ha was declared under Fisheries Administrative Order 118, which covers the waters between the western side of the Volcano Island and the eastern shores of Barangay Bugain, Laurel down to Barangay Manalaw, Agoncillo. In 2002, the fish sanctuary is full of cages despite of this regulation.

Table 10. Milestones of legal and administrative decisions affecting Taal Lake and its watershed, and the Volcano Island, Philippines.

| Year | Policy | Description |
|---|---|---|
| 1967 | Proclamation 235 | Declaring the Taal Volcano Island National Park. |
| 1975 | Presidential Decree 704 | The Philippine Fisheries Code of 1975. Revising and consolidating all laws and decrees affecting fishing and fisheries. The fisheries operate in an open access policy of the government. |
| | Fisheries Administrative Order 118 | Establishing a fish sanctuary in Taal Lake to be known as the Taal Lake Fish Sanctuary, with an area of 1,289 ha. |
| 1991 | Republic Act 7160 | Local Government Code of the Philippines. It gives full authority to municipal and city governments to formulate and enforce all fishery rules and regulations concerning municipal waters. |
| 1993 | Executive Order 84 | Creating a presidential commission on Tagaytay-Taal to formulate short and long-term plans for the development of Tagaytay City and its adjacent municipalities, and the Taal Volcano Island and its surrounding coastal municipalities. |
| | Executive Order 144 | Amending Executive Order 84, dated April 1993. |
| | Republic Act 7623 | Declaring the Taal Volcano and its surrounding coastal municipalities as tourism zone areas. |
| 1995 | Executive Order 240 | Creating Fisheries and Aquatic Resource Management Councils in Barangays, Cities, and Municipalities, their composition and functions. |
| | Executive Order 323 | Adopting the Tagaytay-Taal Integrated Master Plan and for other purposes. |
| 1996 | Proclamation 906 | Amending Proclamation 235, declaring the Volcano Island, Taal Lake, and the watershed areas as a protected landscape. |
| | Executive Order 296 | Ordering the dismantling of fish cages, fish pens, fish trays, and other aquaculture structures in Taal Lake and the Pansipit River. |
| 1997 | Executive Order 3 | Creating the Taal Lake Development Authority. |
| 1998 | Republic Act 8550 | An act providing for the development, management, and conservation of the fisheries and aquatic resources-known as The Philippine Fisheries Code of 1998. |
| 2000 | Fishery Administrative Order 196 | Guidelines on the Creation and Implementation of FARMC to institutionalize the major role of the fisherfolk and other resource users in the planning and formulation of policies and programs for the management, conservation, protection, and sustainable development of fisheries and aquatic resources (Sec. 3). |

The practice of cage culture began with a few fisherfolk beginning in the mid-1970s. With the increasing demands for various lake uses and institutional arrangements, RA 8550 gave more power to fisherfolk through the formation of Fisheries and Aquatic Resources Management Councils (FARMCs). FARMCs assist in the preparation and implementation of municipal fisheries development plans; assist in the enforcement of fishery laws, rules and regulations in municipal waters; and advise the municipal body on fishery matters through its Committee on Fisheries (DA, 2000).

Significant developments in fishery policy occurred during the 1990s. By virtue of RA 7160, known as the Local Government Code of 1991, the management of all municipal waters was placed under the authority of municipal and city governments. The devolution of power gave LGUs direct control over the management of the lake through their issuance of fishery ordinances and other regulatory measures and the power to enforce such regulations. The LGUs, through the Municipal Agricultural Office (MAO), in partnership with FARMCs and cooperatives in Taal Lake, regulate the fish cage industry. A total of 24 cooperatives exist in the four municipalities. The LGUs issue permits to any interested operators, subject to space availability and after the payment of corresponding fees (Table 11). The permit shall be for a one-year period starting January and renewable annually. No information exists about the total allowable number of cages per municipality, so primarily it is market forces that govern entry and exit of operators into the cage business. Non-compliance with the rules and regulations regarding the cage operations are subject to a fine of not less than PhP 20,000, dismantling of fish cages or by imprisonment of not more than 5 days, or both at the discretion of the court.

Table 11. Salient features of the fishery ordinances of Agoncillo, Laurel, San Nicholas and Talisay, Philippines.

| Selected Sections | Agoncillo[a] | Laurel[a] | San Nicholas[b] | Talisay[c] |
|---|---|---|---|---|
| Fee per cage | | | | |
| Municipal/Barangay license | 50 | 60 | - | 330 |
| Application fee | - | - | 20 | 10 |
| Mayor's permit per cage | 200 | 250 | 500 | 350 |
| Fishery rental/lake use per cage | 100 | 100 | - | 200 |
| Plate fee per cage | - | - | - | 60 |
| Total (PhP) | 350 | 410 | 520 | 950 |
| Max stocking density (pieces) | 20,000 | 20,000 | 20,000 | 15,000 |
| Nearest distance of cage from the shoreline (m) | 75 | 50 | 75 | 50 |
| Navigation lanes (m) | 30 | 30 | 10 | 30 |
| Number of cages per module or cluster | 10 | 10 | 4 | 10 |
| Distance between module (m) | 3 | 3 | 10 | 3 |

[a] Municipal Ordinance 06-96

[b] Municipal Ordinance 07-97

[c] Municipal Ordinance 01-96

A highlight in the history of Taal Lake management was the formulation of 10-year and 20-year Integrated Tourism Master Plans for Tagaytay-Taal established through Executive Order (EO) 84, series of 1993. Executive Order 84 created the Presidential Commission on Tagaytay-Taal (PCTT), an advisory commission to the President of the Philippines, which monitors and implements the Master Plan by conducting the technical review for private and government projects in Tagaytay City and its adjacent municipalities, the Taal Volcano Island, and its surrounding coastal municipalities. The Master Plan includes a zoning and management plan, which outlines the recommended locations of fish cage belts, and other lake uses. During that year, RA 7623 declared Taal Volcano and the surrounding coastal municipalities as tourism zone areas. Strict implementation of RA 7623 mandates the absence of any fish cage structures along the coastal barangays. This declaration posed a legal threat to the growing number of fisherfolk engaged in cage culture business.

In 1995, former President Fidel V. Ramos signed EO 323. It approved the Integrated Management Plan for Tagaytay-Taal, assigning the PCTT the lead role in the implementation. In the same year, EO 240 paved the way for the creation of the FARMCs in barangays, cities, and municipalities. FARMCs were created to institutionalize the major role of the fisherfolk and other lake users so that they could participate in the planning and formulation of policies and programs for the management, conservation, protection, and sustainable development of fisheries and aquatic resources (DA, 2000). FARMC members became pioneer advocates of cooperatives in their own barangays.

In line with the National Integrated Protected Area System (RA 7586), Proclamation 906 amended Proclamation No. 235, declaring the Volcano Island, Taal Lake, and its watershed areas as a protected landscape [International Union for Conservation of Nature and Natural Resources (IUCN) Category V]. The fears of fisherfolks engaged in aquaculture were realized in 1996, when former President Ramos signed the immediate implementation of EO 296, ordering the dismantling of fish cages, fish pens, fish traps, and other aquaculture structures in Taal Lake and the Pansipit River. It took 2 years to dismantle all the cages in Pansipit River. After another year, operators returned and re-established their cages along the river. Many operators transferred to other areas in the lake where regulation is not strictly enforced. Another task force was created to dismantle the cages in the river but the cages along the lakeshore in the four municipalities were allowed to operate. The use and operation of jet skis and similar watercrafts were also prohibited within the lake, as well as the use and construction of fish corals and pens. The following year, provincial government spearheaded the institutionalization of the Taal Lake Development Authority. Three years later, the PCTT ceased to operate due to budgetary constraints (Guerrero III, 2002).

The legal and institutionalized support systems have not been effective for various reasons. National and local legislation passed to manage the lake is not strictly enforced. Non-compliance with the fishery regulations, such as failure by the fish cage operators to secure permits from the municipal office, is prevalent. In Agoncillo, a detailed survey of the actual number of fish cages in their area of jurisdiction was done only after the fish kill occurrence in 1999. At the same time, the four municipalities had different rates of fees when securing an operator's permit (Table 11). The lower fee in Agoncillo and Laurel was an obvious incentive for more operators to locate in these areas.

# CHAPTER 3

# CONCEPTUAL FRAMEWORK

This chapter presents a theoretical discussion of the biological and economic approach to the efficient allocation of fishery resources. It discusses the relationship between different inputs and output defining efficiency in the Taal Lake resource utilization and the link to externalities. Sections on the institutional perspectives and the pollution reduction options drawn from the literature discuss the basic concepts of the nutrient pollution dynamics in Taal Lake. While institutional pollution reduction options are necessary in the evaluation of cost-effectiveness, the thesis focuses in greater detail changes in production practices for addressing the problem. The last sections present the cost-effectiveness criteria as a decision-making tool in choosing the most feasible pollution reduction option(s) and the methods for evaluating them.

## The Bio-Economic Approach to Efficient Allocation of Fishery Resources

According to Lapido (1973), the main problem in the fishery sector is the allocation of scarce resources in an environment of complex interactions, among physical, social, economic, and political components, involving multiple and often conflicting values. By adopting the economic efficiency criterion, inefficient allocation of inputs can be eliminated (Gittinger, 1982). The economically efficient allocation of a resource in partial equilibrium terms maximizes the net benefits to the society. In theory, efficiency can be achieved when the marginal benefit of the last unit of input used is equal to the marginal cost of its provision (Tietenberg, 2000).

Establishing the link between the different inputs and output is important in understanding the biological and economic relationship in the fish cage production process. The nature of fish cage culture discussed here follows the intensive production system, which relies heavily upon the commercially formulated diets rather than the naturally occurring food in the lake. Output from fish production is a function of inputs used. The quantity of fish produced (kg) depends on stocking density (number of fingerlings per cage per cropping cycle); the feeding ration (kg per cage per cropping cycle); the quantity of capital inputs (e.g. cage, raft, aerator); quantity of labor (man-hours); environmental factors (dissolved oxygen, pH, water salinity, assimilative and carrying capacity of the cage or habitat, nutrient loading, etc.); and the underlying technology used. Mathematically, the relationship can be express as:

$$Y = f(X_1, X_2, X_3, ... X_n)$$

where $Y$ = output and $X_1, X_2, X_3, ... X_n$ are variable inputs.

The output in fish cage production is the total product (*TP*). The average product (*AP*) and marginal product (*MP*) curves can be derived from the production function to determine the rational range of input use and production of the cage operators. *AP* refers to the quantity of total output produced per unit of a variable input, holding all other inputs fixed. *MP* refers to the additional output that can be produced by one more unit of a particular input, holding other inputs fixed. Figure 8 shows the relationship among the three curves. *MP* is at its maximum at point *A*, the point at which diminishing marginal returns begin. *AP* is still increasing at this point and the producer can still increase the use of variable inputs until point *B*, where *AP* is at its maximum. The area between point *B* and *C*, i.e. the second stage of production, defines the rational economic production. Point *C* is reached with further use of the variable inputs, where *MP* reaches zero and *TP* begins to decline. Beyond this point is stage three of production, an irrational area of production because the same level of output can be produced at lower levels of input use and cost.

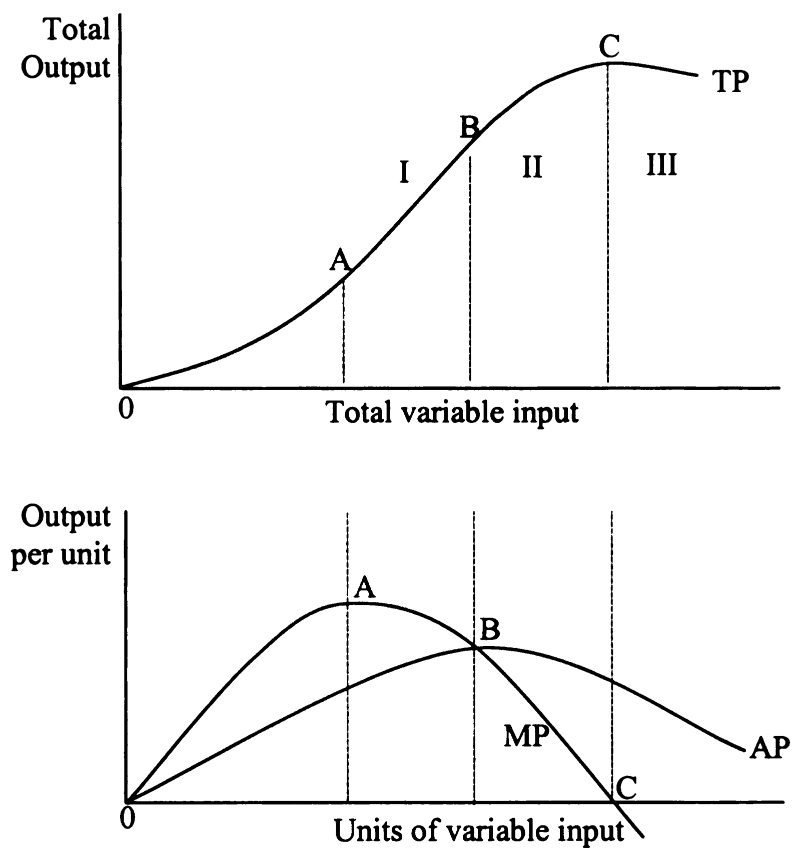


Figure 8. The production function, where TP = total product, AP = average product, and MP = marginal product (Snodgrass and Wallace, 1970).

When inputs employed exceed the assimilative capacity of the cage and its surrounding environment, externalities occur. Assimilative capacity refers to the ability of the natural system to accept certain pollutants and render them benign or inoffensive. Externality is defined as "...a by-product of some production process..." (e.g. water pollution) or "...the lost opportunity occasioned by the incompatible use of a good...." (Schmid, 2002). In the fish cage industry, each individual production function depends on the total nutrient loading.

Combining input cost and output price with the production function, Figure 10 shows the hypothetical total revenue (*TR*) and cost curves. It is assumed that the output price ($P_y$) does not change in response to changes in output. An operator would try to maximize profits from the fish production by finding the optimal amount of inputs. Profits are maximized in Figure 9.1, when the difference between *TR* and total costs (*TC*) is at its maximum. In Figure 9.2, this is achieved when the value of the marginal product (*VMP*) is equal to the input price ($P_x$), or the cost of the added input. Further use of inputs beyond the point where $VMP = P_x$ is economically inefficient, since the additional cost exceeds the value of fish obtained.

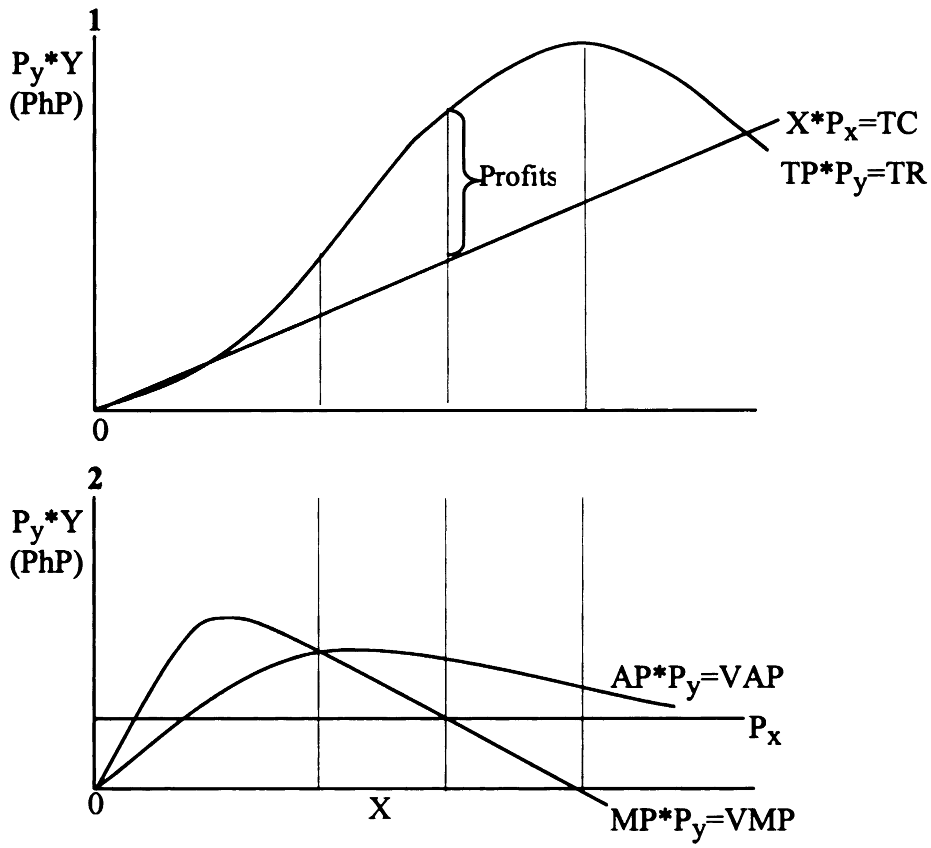


Figure 9. Hypothetical total revenue and cost curves, where *TP* = total product, *AP* = average product, *MP* = marginal product, *TR* = total revenue, *TC* = total costs, *VAP* = value of the average product, and *VMP* = value of the marginal product.

## Institutional Perspectives for Understanding the Nutrient Pollution Dynamics in Taal Lake

Matter and energy on Earth are being transformed by human activities in an economic setting from relatively ordered and useful resource inputs into useful products and into less well-ordered or less useful by-products, which, if not fully recycled, re-enter the environment as waste flows. Nutrient pollution due to intensive fish cage production, then, is the result of nutrient flow rate in excess of the assimilative capacity of the receiving environment.

The cage and its surrounding environment support two incompatible uses. Fish cage operators rely on water both as an input into the production and as a place to put waste. Using the water excessively for the latter decreases the productivity of the former. Since no one claims the responsibility of cleaning the waste storage (*i.e.* the lake itself), nutrient pollution is not fully addressed. This situation arises for two reasons.

The first reason is that the inherent characteristics of the lake make it difficult to assign property rights, to implement laws, and to monitor compliance with regulations. The high transaction costs of allocating and managing the lake ecosystem have interdependence with its inherent characteristics. Similarly, there is interdependence among economic incentives perceived by the people, the current utilization of Taal Lake's resources, and the resulting performances of operators' activities. In a situation where property rights are not fully defined and specified, externalities are common. This situation is prevalent in the Philippines where the lake is implicitly allocated based on an open-access policy. In theory, open-access policy has this problem of "free ridership, " where every individual has an unrestricted access to space and, as a result, the right to extract resource rents. The reasoning of rational stakeholders is to take advantage of the resources before other users extract them. There is high opportunism in this situation since a dominant strategy of non-cooperation is to maximize one's own pay-off. Research results show that the local government implementation of the open-access policy in Taal Lake tends to have negative effects on the lake's fisheries (Mutia and Magistrado, 1999). The open-access policy implicitly contributes to nutrient pollution in the lake.

The lake's resource uses and water quality are high exclusion cost (HEC) goods; hence, excluding other people from using the same good without paying (i.e. they can be free riders) is difficult. A HEC good is "one where if the good exists for one user, it is costly to exclude others, i.e. the exclusion cost is greater than net revenue" (Schmid, 2002). No one operator wants to invest in cleaning the water if everybody else will benefit from it. Incentives to contribute to lake quality are low. Even if one could exclude other operators from benefiting, it would be inefficient to do so. The marginal cost of another beneficiary of clean water is zero. The character of interdependence created by a HEC good depends on whether one party is made aware of the effect of their action on the supply of the goods. When interests diverge in a situation of HEC, the decision-maker, i.e. the LGUs, may have to choose sides on the basis of fairness or overall performance of the policy structure chosen. Whose preferences count and who are the losers? An operator may not be willing to pay for a conservation program in the Taal Lake watershed when incentives to contribute are limited. In the same way, the lake quality characterizes a congestible good. Once the good becomes congested, each additional user imposes external costs on all the other users. Since each additional user does not pay the full marginal cost of their activities, the resource becomes overused. Thus, a market situation will fail to produce an efficient quantity of the good.

The second reason that the nutrient pollution problem arises is that the input-specificity associated with an intensive production system, such as the fish cage culture, is in itself a polluting technology. Many experts are skeptical of the sustainability of intensive fish farming using fish oil and high protein fish feed because of its detrimental impacts on the environment (Kibria *et al.*, 1998; Pantastico *et al.*, 1986). This production technology results in a larger volume of wastes generated, which leads to nutrient enrichment (Handy and Poxton, 1993) and greater possibilities for the spread of disease (Naylor *et al.*, 2003). Previous studies reported that the increase in nutrient loading might be attributed to the intensive feeding practices in cage areas (Tan, Baskinas, and Garcia, 1995; UPLBFI, 1995; Aypa and Villanueva, 2001; Dela Vega, 2001; Rosana and Salisi, 2001). Nutrient pollution disrupts the balance of plant and animal life (Howarth *et al.*, 2000) resulting in a reduction of the species diversity (e.g. tawilis) and a dominance of the surviving organisms (e.g. tilapia) in Taal Lake (Magistrado and Mercene, 2000). This situation poses constraints and threats on the fish cage industry itself and the lake ecosystem. Indeed, operators face a dilemma of addressing the two issues together. It is apparent that the issue of water quality deterioration is directly related to the current fish production technology, the structure of resource allocation, and of owner rights and inputs.

Looking into the policy history of the Philippines, command-and-control (CAC) instruments have not been successful enough to counteract existing problems for natural resource utilization. An example of the CAC approach is the direct regulation method, which can control the discharge of a target pollutant within a relatively short period, but cannot provide the industry an incentive to make greater efforts for pollution control beyond the minimum safety level of standard required by law. Market-based instruments (MBIs), as opposed to the CAC, work through market forces to combine economic and environmental decision-making. They use market signals, like prices, to influence the behavior of players to coincide with environmental goals set by society. An environmental tax is one example of MBIs. It is based on the "polluter-pays-principle" which puts into effect an environmental tax imposed on the actual pollution loading taking into account the volume of pollutants discharged and the concentration of pollutants in such effluents. Imposing an environmental tax will force polluters to account for the damages in their production and consumption decisions. As a result, appropriate levels of pollution will be achieved, if externalities are internalized. However, this type of approach reduces profits, so it does not appeal to the operators. A third approach is the use of permits to allow cages. It addresses the problem on common property resource by rationing access to the resource and privatizing the resulting rights (Tietenberg, 2000).

Self-enforcing regulations are likely to be desirable to the operators, once they see incentives to participate in the implementation of a resource conservation measure. The design of the policy should be as inexpensive as possible. The imposition of added cost in terms of fees, in reality, would be very difficult to implement and enforce in a common pool resource, such as Taal Lake. Other policy options for inducing operators to adopt particular management practices, include mandating the use of particular practices or a combination of the institutional measures stated above and the options discussed in the next section. Operators are looking for policy options that they do like. While most operators will not like any change, it does not mean that public policy is not necessary from the public welfare perspective.

### Nutrient Pollution Reduction Options in the Taal Lake Fish Cage Industry

The challenge of nutrient pollution is both internal and external to fish cage culture management. Pollution reduction can be done through waste reduction and waste management to reduce its quantity, harmfulness, or to prevent damage from its release into the environment. US EPA (1999) recommends waste minimization and reduction as the most desirable among the management options available for point source and non-point source pollutants. Naylor *et al.* (2003) explained that current management options for reducing the loss of nutrient from fish cages into the surface water are largely limited to controlling the intensity of fish cage production, e.g. reducing stocking and feeding rations, rather than treating the wastes.

Figure 10 shows a flow chart of the proposed pollution reduction options, which were suggested by Yambot (1999). Waste reduction/minimization options include: (1) reduction in the total number of cages, (2) reduction in feeding ration, and (3) reduction in stocking density; while waste management includes: (1) single-line positioning of cages, and (2) use of an aerator during problem situations. Waste reduction in the fish production system is dependent upon the total number of cages being managed. Reducing the total allowed number of cages also translates into a lesser amount of wastes generated. Limiting the total number of cages changes the open-access policy in Taal

Lake. Nutrient pollution is also related to the feed quality and feeding techniques (Jensen, 1991; Kibria, *et al.*, 1998). Controlling the feeding regimes can minimize nutrient loading. It is imperative to attain efficiency in feeding ration since an intensive fish production system contributes greatly to nutrient pollution of nearby waters (Kibria *et al.*, 1998). Tan (1993) found that stocking density and rearing period affect inefficiency.

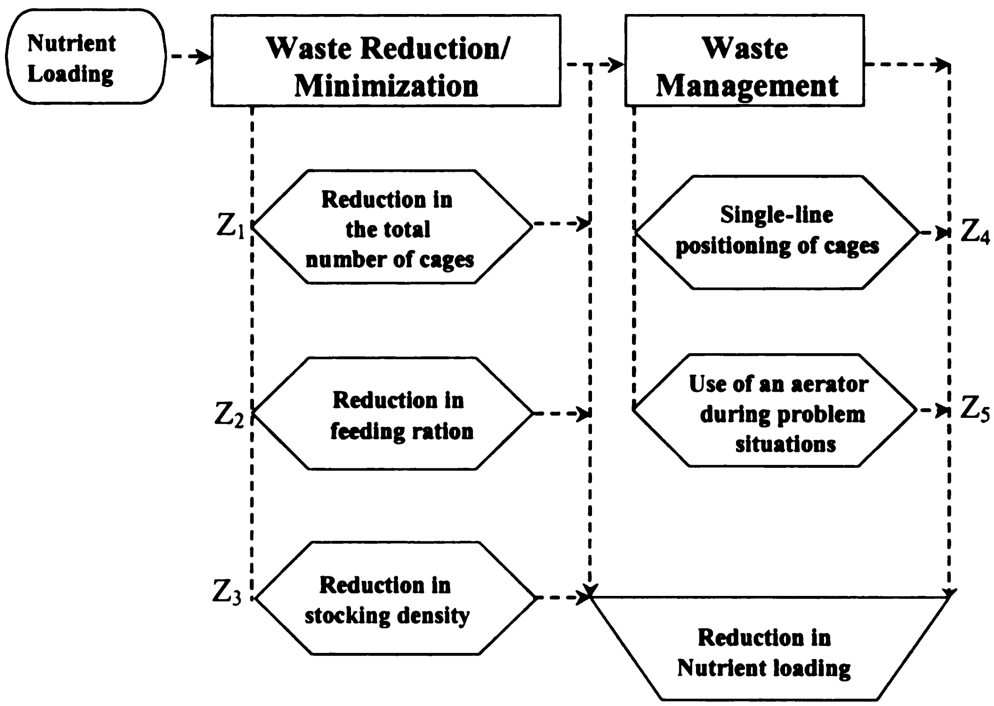


Figure 10. Pollution reduction options for the fish cage industry in Taal Lake.

Proper waste management transforms the concentration of waste into a less harmful state. Waste management through single-line positioning of cages and the use of an aerator impacts dissolved oxygen concentration level in the water for fish survival and growth. According to Coche (1982), the maximum carrying capacity of a cage depends on the dissolved oxygen in the cage, which varies with cage size. There is an inverse relationship between cage size and carrying capacity of the cage. The smaller the cage, the greater is the lateral surface area to volume ratio. In this regard, single-line positioning of cages and the use of an aerator may be necessary since they encourage water flow and dilution of concentrated nutrients from feed waste.

## Why Cost-Effectiveness Analysis?

Cost effectiveness analysis (CEA) frequently involves an optimization procedure, which is a systematic method for finding the lowest-cost means of accomplishing an objective (Tietenberg, 2000). However, Tietenberg noted that this procedure does not, in general, result in an efficient allocation because the predetermined objective may not be sufficient.

There are two reasons why CEA was chosen as the framework of analysis for this research. The first reason is that CEA offers a practical and promising approach in finding the least-cost means of accomplishing the objective. Minimizing the costs of improving the water quality, which thereby increases fish productivity, seems a straightforward approach for decision-making. A second reason is that regulations and strategies that impose very high costs are more likely to be disobeyed by the operators themselves (Tietenberg, 2000). To cut costs and help the environment simultaneously, Reinhardt (1999) suggested focusing on internal cost reductions, increasing pressure to reduce pollution, and increasing investment in improving the environment. According to Hoag and Hughes (1997), applying the theory requires a compromise between the desire to promote cost-effectiveness and to have an administratively simple and politically acceptable program.

Annett (1985) emphasized that cost-effective management in a fish production process requires the following information: a) the environmental requirements of the organism, b) dietary requirements of the organism, and c) identification of the ability of the organism to harvest, digest, and assimilate the form of feed. She reported the need to find the economically optimal feeding ration by balancing the market price of the organism against the feeding cost at different efficiencies. This trade-off is made since the profit margin is a function of sale price and the cost of production, with feed being the major production expense. Likewise, the stocking density, along with the amount of feed added, determines the percent body weight of feed available to the fish. The calculation of the time to reach marketable feeding levels and different efficiencies, along with considerations of feed cost and market value would permit the determination of cost-effective feeding levels.

## Evaluating the Pollution Reduction Options

Evaluating the cost-effective pollution reduction option starts with the measurement of baseline waste generation (Figure 11). Survey data serve as input into the estimation of a Cobb-Douglas production function and the optimal values of inputs and output. Identifying the pollution reduction options follows, as does measuring the associated costs and benefits of each option. Then, costs of each option are compared with the baseline data. Finally, conduct of sensitivity analyses follows, which indicate how measures of each option's worth might change under different assumptions about values, input-output relationships, and other changes.

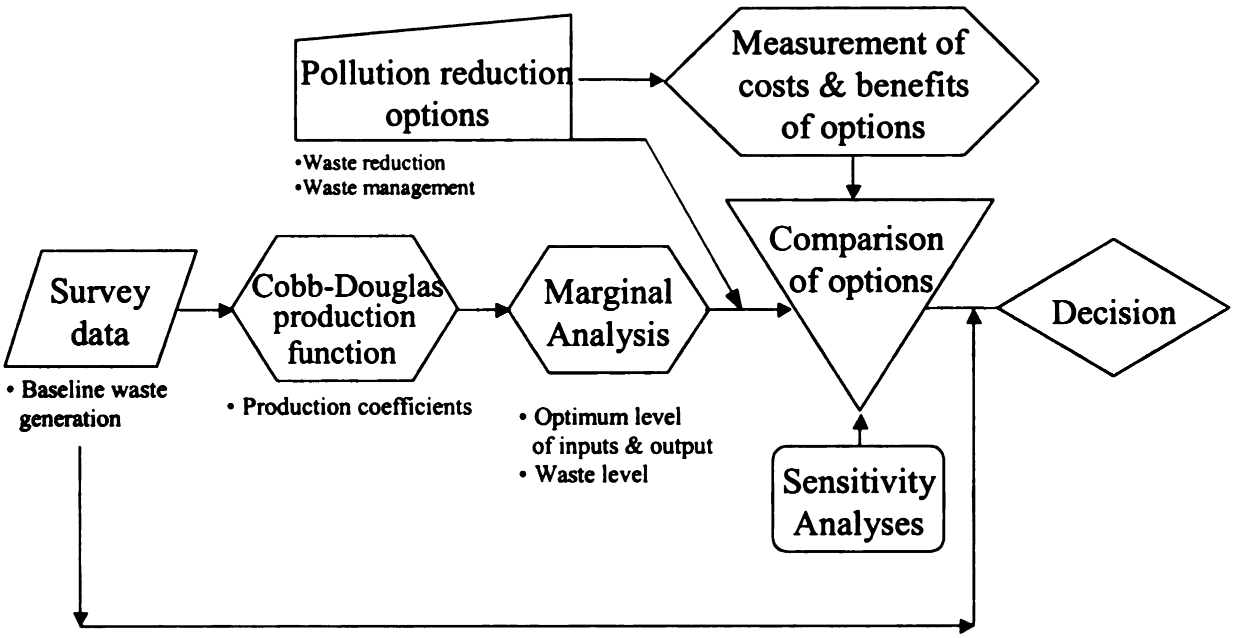


Figure 11. Flow chart of evaluating the pollution reduction options.

A cost-effective solution to nutrient enrichment in Taal Lake is based on the comparison of the baseline cost with pollution reduction costs associated with the option (s) selected. The decision variables include *N* and *P* level or loading, and the rule is to choose the option with the lowest cost of attaining the objective.

# CHAPTER 4

# RESEARCH METHODS

The previous chapter laid out the conceptual framework of the research, including the theoretical basis for the estimation and interpretation of the fish cage production function. The link between input, output, and waste was also discussed, emphasizing the cost-effectiveness criterion as the tool chosen for selecting the necessary pollution reduction option. This chapter presents the implementation model of the Cobb-Douglas (*C-D*) production function, and based on this model, the cost-effective nutrient reduction solution was derived. The last section describes the fish cage operator survey process, survey questionnaire, sample size, and the secondary sources of information.

## Implementation Model

In fish cage production, output is related to the following variables: a) feed, b) stocking density, c) labor, and d) differences in location and ownership arrangements. The production function is defined as:

$$Y = f(X_{SD}, X_F, X_L, X_D) \qquad \text{(Equation 4.1)}$$

where

$Y$ = yield, kg per cage per cropping cycle;

$X_{SD}$ = stocking density, number of fingerlings per cage per cropping cycle;

$X_F$ = total feeding ration, kg per cage per cropping cycle;

$X_L$ = total labor in tending the cages, man-hours per cage per cropping cycle; and

$X_D$ = dummy variables.

Since ownership arrangement and location are also important in determining yield, dummy variables ($D_1$, $D_2$, $D_3$, $D_4$) were also included, such that:

$D_1$ = 1 if owner is the operator

= 0 if owner hire a caretaker(s)

$D_2$ = 1 if cage is located in Talisay

= 0 otherwise

$D_3$ = 1 if cage is located in Agoncillo

= 0 otherwise; and

$D_4$ = 1 if cage is located in Laurel

= 0 otherwise.

In the specification of the appropriate functional form for finding the physical relationship between output and inputs in the fish cage production, the following forms of the production function were tested and evaluated: a) linear; b) full quadratic; c) log-linear (*C-D*); and d) translog form of the quadratic function. Scatter plots of output against feeding ration, stocking density, and labor were made to aid in the choice of the production function models. An F test[5] was used in the comparison of the different production function forms, except for log linear vs. linear. The estimation results show that the full quadratic and the translog form of the quadratic function models have largely insignificant coefficients of the explanatory variables and they do not conform to the expected signs. Hence, these models were rejected. The two remaining models have better fit[6] than the full quadratic and translog models.

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[5] Ho: Choose the response function with the least model residual.
[6] In *Stata* software, the command 'DFFITS' was used to evaluate the effect of the specific observation on the fit.

A Cobb-Douglas[7] model was used rather than the linear model because of the following advantages. First, the elasticities of production are identical to the production coefficients. Second, the sum of the production coefficients $\left(\sum \beta_i\right)$ can be interpreted as a measure of economies of scale, i.e. assuming that the $\left(\sum \beta_i\right)$ is not constrained to unity as in the original *C-D* case where $Y = \beta_0 X_1^{\beta_1} X_2^{\beta_2}$. Third, input and output data can be used readily without aggregation to estimate the parameters of the model. Finally, a *C-D* function uses only one degree of freedom per explanatory variable (Smith, 1981). The *C-D* log linear model[8] is written as:

$$Y = AX_1^{\beta_1} X_2^{\beta_2} \dots X_n^{\beta_n}$$

or

$$\log Y = \log A + \beta_1 \log X_1 + \beta_2 \log X_2 \dots + \beta_n \log X_n \qquad \text{(Equation 4.2)}$$

Data were transformed into their logarithmic value. The production function was estimated employing the ordinary least square (*OLS*) method and using *Stata* version 8 software. Smith (1981) pointed that the estimated production function derived by *OLS* is an industry 'average' function because it is derived by *OLS* methods that account all observed input-output combinations. To test whether multicollinearity presented problems, simple correlation among the independent variables was examined. To test homoskedascity, a plot of the residuals (the difference between the observed *Y* and the estimated *Y*) against the independent variables was also made to look for systematic

[7] One limitation of the *C-D* is that it does not have stage III of the production function.
[8] *Y*=output; $X_i$=inputs; $\beta i$= factor productivities; *A* = constant. Error terms are omitted.

distribution of the deviations around the regression line. The results show no evidence of multicollinearity and homoskedasticity.

To determine the maximum productive capacity of fish production per cage per cropping cycle, a stochastic frontier estimation of the *C-D* production function [$f(X_i;\beta)$] was also evaluated using *Stata* and *LIMDEP* softwares. However, the results were not acceptable. The correct convergence was not attained given the data available.

Variable inputs include feeding ration, stocking density, labor, transportation, and cage structure, while capital fixed costs includes the license fees, aerator, boat, etc. Both variable and fixed costs were expressed on a per cage (100 $m^2$) per cropping cycle basis. In the short-run period, individual operators are likely to respond to certain changes by changing their variable inputs. Operators will seek to maximize profit ($\pi$) above the cost of production per cage per cropping cycle (Equation 4.4).

$$\text{Max } \pi = \sum_{i=1}^{N} \left[ YP_Y - \left( C_F + C_G + C_L + C_A + C_T + C_O \right) \right] \qquad \text{(Equation 4.4)}$$

where

$Y$ = quantity of fish sold + home consumption, kg per cage per cropping cycle

$P_Y$ = price of fish, PhP per kg

$C_F$ = cost of feed, PhP per kg

$C_G$ = cost of fingerlings, PhP per cage per cropping cycle

$C_L$ = cost of labor[9], PhP per cropping cycle

$C_A$ = cost of aeration, PhP per cage per cropping cycle

[9] Include net cleaning and harvesting only.

$C_T$ = cost of transportation, PhP per cropping cycle

$C_O$ = other costs, PhP per cage per cropping cycle

Other input costs include fees, depreciation costs of cage and raft, medicine, etc. The fish production cost is defined by:

$$C_F = P_F * F * RD \quad \text{(Equation 4.5)}$$

$$C_G = P_G * SD \quad \text{(Equation 4.6)}$$

$$C_L = W_L * D \quad \text{(Equation 4.7)}$$

$$C_A = P_A * A \quad \text{(Equation 4.8)}$$

$$C_T = P_T * FL \quad \text{(Equation 4.9)}$$

$$C_O = P_O * V \quad \text{(Equation 4.10)}$$

where $P_F$ is the price of feeds (PhP per kg), $F$ is the feeding ration[10] (kg per day per cage), $RD$ is the total rearing days equivalent to the cropping cycle, $P_G$ is the price of fingerling (PhP per fingerling), $SD$ is the stocking density (number of fingerlings per cage per cropping cycle), $W_L$ is the wage rate (PhP per day), $D$ is the number of days of work per cropping cycle, $P_A$ is price of electric power (PhP per kW hour), $A_t$ is energy used for aeration (kW), $P_T$ is the price of gasoline (or fare) (PhP per liter), $FL$ is the amount of fuel used (Liter), $P_O$ is price of other input(s), and $V$ is the quantity of other inputs (fees, depreciation cost of cage and raft, medicine, etc.).

[10] Changes depending on the size of fish and the type of feed used. See Chapter 5 for details.

To determine profit maximizing level of production, the marginal product of $X_i$ $\left[MP_{X_i} = \frac{\partial Y}{\partial X_i} = \frac{\beta_i}{X_i}(Y)\right]$ was calculated. The optimum value of $X_i$ was derived by equating $MP_{Xi}$ to the $X_i$ input and output price ratio. The optimal yield was derived from the optimal input levels obtained. Numerical solutions were derived through optimization of the variables *F* and *SD* using Microsoft Excel Solver.

The price of fingerlings ($P_{Ga}$) used in the estimation of the optimal stocking density was adjusted since the variable *SD* used in the estimation of the production function coefficients was the net stocking density (*SDa*), i.e. actual stocking density (*SD*) less fingerlings mortality (*SDm*). The variable *SDa* was assumed to account for the effects of water quality and/or the impacts of increasing the density per unit of space in the cage during the stocking period. The relationship between *SDm* (dependent variable) and *SD* (independent variable) was estimated using *Stata*.

## Cost-Effectiveness of Nutrient Pollution Reduction

The objective of the research is to find the cheapest option feasible for reducing nutrient loadings from cage production. Nutrient loadings depend on the amounts of N and P included in food and the amount of N and P removed when fish are harvested. The total nutrient consumption (*Q*) from the fish cage production is defined as:

$$Q = R_{kg}(N, P) + L_{kg}(N, P) \quad \text{(Equation 4.11)}$$

where

$R_{kg}$ = nutrient retention, kg per cage per cropping cycle

$L_{kg}$ = nutrient loss, kg per cage per cropping cycle

$N$ = nitrogen, and

$P$ = phosphorus.

The nutrient loss is defined as:

$$L_{kg} = \frac{[F_{kg}\,(0.76^{11}) \times (47.36 \text{ g N per 1 kg feed}^{12})] + [F_{kg} \times (0.85^{13}) \times (9 \text{ g P per 1 kg feed}^{14})]}{1000 \text{ g}},$$

where $F_{kg}$ = the total amount of feed put into use in kg per cage per cropping cycle.

The different nutrient pollution reduction options are: reduction in the number of cages (Option $Z_1$), reduction in the total feeding ration (Option $Z_2$), and reduction in stocking density (Option $Z_3$). The options for reducing the impacts of nutrient loading are single-line positioning of fish cages (Option $Z_4$) and the introduction of an aerator during a situation problem (Option $Z_5$). In the comparison of pollution reduction options, the cost directly associated with reducing the amount of nutrient loading, i.e. Options $Z_{1\text{-}3}$, was determined and compared at different percentages of nutrient reduction. The costs for Options$_{4\text{-}5}$ were also determined. The cost-effectiveness of each option was compared with the baseline level. The impacts of the pollution reduction options for individual operators may be (a) decrease in the variable costs of production, (b) increase in fixed costs of production, (c) combination of a and b, and/or (d) a reduction in *Y*. Sensitivity

[11] Percentage nitrogen loss from the total nutrient used as estimated by Beveridge (1993).
[12] Computed as: crude protein in feed/6.25
[13] Percentage phosphorus loss from the total nutrient used as estimated by Phillips (1994).
[14] Based from feed labels.

analyses were done to measure the change in the economic rents from fish production given different magnitudes of nutrient reduction.

## Fish Cage Operator Survey

A fish cage operator survey was conducted in four municipalities surrounding Taal Lake. The four municipalities are: Agoncillo, Laurel, San Nicholas, and Talisay. The information gathered through the survey served as input into the analysis of fish production in the lake.

### The Survey Process

The survey process involved two stages. The first stage, community familiarization and field reconnaissance, acquainted the researcher with the current practices of fish farming in the area. It involved simple and informal consultations and interactions with community residents and barangay officials. Field reconnaissance included the researcher's participation in one of the FARMC meetings in Agoncillo. The researcher also participated in one of the monthly water quality monitoring events by the BFAR-IFRS Fish Health Team. Sampling stations were selected in high-risk areas for fish kills.

The second stage, the fish cage operator survey, involved interviews of 50 randomly selected fish cage operators (classified as owners or caretakers) from the four municipalities. Consent from the fish cage operators was obtained before the actual administration of the survey questions. The consent and interview questions were administered in the local language, Tagalog. The overall process focused on generating detailed information on fish cage operations and costs, community feedback, and perceptions of pollution problems. The following considerations were applied to the survey process.

- The survey utilized the network of people in the local area established by the BFAR and Philippine Council for Aquatic and Marine Research and Development.
- Permission and cooperation of officials of the four municipalities and barangays were obtained before the interviews proceeded.
- Written consent was not obtained because it is culturally inappropriate. People in rural areas of the Philippines are hesitant to sign their name because this is associated with legal actions.
- The interview was only conducted if the fish cage operators agreed orally to participate, after they had finished feeding their fishes, and were free to accommodate the interviewers.

**The Survey Questionnaire**

The survey questionnaire consisted of eight sections: background information, fish cage operation, fish cage structures, fingerlings, feed and feeding management, fish farming practices and management, other production inputs and expenses, and pollution problems associated with fish production. A number of steps were undertaken to develop the survey questionnaire.

- The thesis guidance committee at MSU was consulted, with regard to the content, form, and usefulness of the questions.

- The questionnaire was discussed with the researchers in UPLB and BFAR-IFRS, who had previous experience with questionnaire-based surveys in the Taal Lake area.
- The questionnaire was pre-tested in Talisay, Batangas to check its design and the average time required to conduct the interview, to identify problems and solutions imbedded while conducting the interview, and to check the validity and reliability of the questions in relation to the attainment of research objectives.
- The questionnaire was revised and finalized, incorporating the suggestions from the staff of BFAR-IFRS, and the lessons from the pre-testing.

The questionnaire used short questions with pre-coded answers. Instructions, reminders, and definitions were built in to aid in the survey process. A copy of the questionnaire (in English version) is given in Appendix A. The actual questionnaire in the local language (Tagalog) consisted of 81 short questions, a total of 14 pages, and averaged 45 to 90 minutes of interview time.

Sections 1 and 2 of the questionnaire obtained basic socio-economic background of the fish cage operators, e.g. ownership of their cage business, other sources of livelihood, and their involvement with organizations in their municipality. The current situations and existing institutional structures that cage operators deal with, directly and indirectly determine the cage culture performance. Sections 3 and 4 elicited detailed information on fish cage structures, material inputs and costs, fingerlings, and labor costs associated with the construction of the cages. Section 5 obtained detailed information on the type of feed used, the feeding ration and methods employed, and other feeding management practices. This section was critical for estimating wasted feed, which is assumed to be the major source of pollutants in the lake. Section 6 asked about the current cultural practices of fish cage operators. The questions were patterned after the recommended cultural practices for cage culture in the lake (SEAFDEC/AQD, 1998). Section 7 obtained information on other production input costs and modes of income sharing. Finally, Section 8 elicited information on the pollution problem, the cage operators' perceptions of it, and policy issues. In summary, the questionnaire targeted relevant information on the costs of fish cage culture, the current status of cage operators and their management practices, and existing institutional structures that determine the performance of the industry.

**The Survey Sample Size**

A list of fish cage operators was obtained from the MAO of the four municipalities. This list became the basis for selecting candidate respondents to the survey interview, who initially were selected at random. The MAO personnel and other BFAR staff assisted in the final selection of respondents because some of the fish cage operators did not welcome interviews about their fish cage business. From the list generated, 50 respondents were interviewed, representing varying numbers of fish cages and types of ownership arrangements. Table 12 shows the number of respondents per municipality. A total of 316 cages comprised the survey. The expected number of fish cage structures and operators in the lake for 2002 was assumed to be more or less equal to 2001. The 2002 municipal data that pertain to all fish cage operators were not yet available during the data collection.

Table 12. Number of respondents from Agoncillo, Laurel, San Nicholas and Talisay, Philippines, 2002.

| Municipality | No. of Respondents | | | Percentage |
|---|---|---|---|---|
| | Owner | Caretaker | Total | |
| Agoncillo | 3 | 6 | 9 | 18 |
| Laurel | 3[a] | 11 | 14 | 28 |
| San Nicholas | 2 | 12 | 14 | 28 |
| Talisay | 6 | 7 | 13 | 26 |
| Total | 14 | 36 | 50 | 100 |

[a] One respondent was considered an owner-operator as well as caretaker at the same time. He was considered as caretaker in the comparison of net revenue under the two ownership arrangements since most of his time is devoted to tending other operators' cages. (Source: Fish Cage Operator Survey 2002).

**Secondary Sources of Information**

Aside from the data gathered through the survey questionnaire, auxiliary information was obtained from various sources. Research results from studies conducted by the BFAR-IFRS, in Ambulong, Tanauan City, Batangas, provided estimates of feed wasted from cages, the monthly physico-chemical data collected from three of the nine sampling stations in Taal Lake from July 1999 to July 2002, and the estimated economic impacts of fish kill incidences between 1999-2001. The three sampling stations are located in the municipal waters of Leviste, Laurel; Aya, Talisay; and Banaga, Agoncillo (Figure 1 of Chapter 2). The NFBC in Butong, Taal, Batangas, provided complete fish cage production data for 2001. The MAO and the Municipal Planning and Development Office (MPDO) of four municipalities supplied the fishery profile. They provided research collaboration and constant assistance during the survey process. Various institutions involved in the research and management of the lake were also contacted for data validation. The Statistical Package for the Social Sciences (SPSS) software was used in the analysis of the data gathered. Finally, cost analysis was done at Michigan State University.

# CHAPTER 5

# RESULTS OF SURVEY OF THE TAAL LAKE FISH CAGE OPERATORS

This chapter presents the detailed information gathered through the fish cage operator survey. The first two sections presents the survey results, emphasizing the socio-economic characteristics of the fish cage operators, the production process, and cage management from cage construction to harvesting or marketing. The third section presents, in addition to nutrient pollution problems, other pressing problems operators face in their respective locations. The fourth section discusses how the average income per cage per cropping cycle differs among the four municipalities and between ownership arrangements. The estimation results of the production function and the optimum input-output of the sample data for the fish cage production are presented next.

## Socio-Economic Characteristics of the Fish Cage Operators

Fifty fish cage operators comprised the survey. More than half of the respondents were below 40 years of age. Hired caretakers fall in the range of 21-30 years of age, while most of the financiers fall into the range of 41 years of age and above. The majority of the respondents were male (98 %) (Table 13). While men are actually involved in the cage culture operations, women also contribute to the daily activities by overseeing the expense record-keeping, net weaving, cleaning, etc. Thirty-seven of the respondents were married while the rest were single, with most of the single respondents in the role of a caretaker. Thirteen respondents had college educations, 24 had secondary educations, 8 had elementary educations, and 1 had a vocational degree.

Table 13. Socio-economic characteristics of 50 cage operators in Taal Lake, Philippines, 2002.

| Characteristics | No. of reporting | % |
|---|---|---|
| Age in years | | |
| 21-30 | 17 | 34 |
| 31-40 | 12 | 24 |
| 41-50 | 12 | 24 |
| 51 and above | 9 | 18 |
| Civil Status | | |
| Single | 13 | 26 |
| Married | 37 | 74 |
| Sex | | |
| Female | 1 | 2 |
| Male | 49 | 98 |
| Educational Attainment | | |
| Elementary | 8 | 16 |
| Secondary | 24 | 48 |
| Vocational | 4 | 8 |
| Tertiary | 13 | 26 |
| Post graduate | 1 | 2 |
| Nature of involvement | | |
| Owner-operator | 13 | 26 |
| Caretaker | 36 | 72 |
| Owner-operator/caretaker [a] | 1 | 2 |
| Membership in organization | 24 | 48 |
| Years operating in Taal Lake | | |
| ≤ 5 Years | 26 | 52 |
| ≥ 6 years | 24 | 48 |
| Dependency of family income on cage culture | 8 | 16 |

[a] Considered as an owner-operator in the income analysis of the fish cage operators.

(Source: Fish Cage Operator Survey 2002)

Thirty-six of the respondents were caretakers, 13 were owner-operator or financiers, and one was an owner-operator/caretaker. An owner-operator/caretaker is a person who operates their own cages while at the same time serves as caretaker to absentee-owners. Most of the owner-operators have more than six years of cage culture experience in Taal Lake and no previous experience in other areas. Only five respondents have prior fish cage experience in areas other than Taal Lake. Almost half of the respondents were members of the fishery organization, 40 % of which said they were benefiting from their membership. Active participation of most members in the fishery cooperative was uncertain because some of them are not performing well. Assuming a 90 % confidence interval with a 7 % margin of error, the majority of the entire fisherfolk populations based on the results are married male cage operators and taking the role of a caretaker.

The majority of the family income of most caretakers comes from cage culture while supplementary income comes from farming, open water fishing, retail stores, fish marketing, carpentry, and small-scale businesses. Eight respondents were solely dependent on cage culture as the source of family income. As expected, caretakers were more financially vulnerable to income fluctuations.

### Fish Cage Production and Management

The results of the survey of 50 respondents done in 2002 showed that the majority of the operators (96 %) were engaged in the grow-out cage business, i.e. culturing fish for sale in the market. Thirty-six respondents gained knowledge of cage culture practices through personal experience, 9 respondents acquired it from co-operators, and 5 respondents learned through attendance in training, seminars, and advice of fishery technicians. Twenty-eight respondents expressed the need to attend a training or seminar about fish disease and control, feed and feeding management, recent developments in the fish cage technology, or bangus culture. The remaining 22 respondents (16 were caretakers) expressed their reliance on personal knowledge and experience, and disregarded the need for attending any training or seminar. It was apparent in the interview that owners and caretakers did not share common views and perceptions about each other's roles and performance.

In the 2002 survey, it was evident that the national and local legislation passed to manage the lake were not uniformly enforced. While municipal ordinances and regulations limit the ownership to five cages per person, 11 respondents had more than five. Of these 11 respondents, six were financiers. The name of the caretakers was listed in the application for a cage culture mayor's permit.

**Fish Cage Construction**

Prior to fish cage construction, owners have to acquire permits and pay corresponding fees to the MAO. Table 11 of Chapter 2 outlines the schedule of fees and the applicable regulations, which include a maximum stocking density of 15,000-20,000 fingerlings per cage, a 50-75 m nearest distance of cage from the shoreline, a width of 10-30 m navigational lanes, 10 cages per module or 4 cages per cluster (San Nicholas), and a 3 m distance between modules or 10 m between clusters (San Nicholas). The average distance between cages within a module is 0.5 m. The majority of the cages (90 %) in Taal Lake are of the floating type, which is the most costly among the three types of cages. Likewise, the majority of the respondents' cages (88 %) were used for at least two cropping cycles and the bamboo-made framework can still be used for at least two cropping cycles. Cages have a uniform size of 10 x 10 m (100 $m^2$), which is prescribed in the municipal ordinances. The majority of respondents (92 %) have their cages at least 50 m distances from the nearest shoreline. However, the 30 m width of navigational lanes is not followed in most cage areas. The fixed cage is used mainly in shallow areas (i.e. less than 50 m from the nearest shoreline) and less popular with most operators. The submerged cage is used in deeper parts of the lake and is 1 m underwater, with a 3-6 m net depth. Based on the survey sample, net depth ranges from 3–12 m, with an average of 6.90 m.

Cage type dictates the kind and amount of materials needed to construct one fish cage (100 $m^2$). Table 14 shows the capital investment for a 100 $m^2$ floating type cage and the different materials needed for its construction. The frames of the cages are made with bamboo, which also serves as the floaters. Very few frames are made with steel and polyvinyl chloride pipes, since they entail higher cost. Some operators used drums (plastic or steel-made) as floats, specifically in the submerged cage. These materials last 3-5 years (based on normal wear and tear) but are more expensive and less suited to changing water currents. Bamboo is the preferred material because it is readily available in the province and best suited to floating. The fixed cages require a lesser quantity of bamboo, while the submerged cages do not need bamboo at all.

On average, it takes 1-2 days to construct a cage (bamboo frame and net structure) and costs about PhP 650. Construction of a cage starts with framing the bamboo, weaving the nets, and preparing the anchors offshore. Since the majority of the cages are intended for grow-out, the net most commonly used was size No. 14 (94 %). Net weaving would cost the owner PhP 925 per unit (72 %). After the cage is put in the lake, the net is attached to the main frame of the cage. Positioning the cage in the lake costs PhP 990. The suspended bamboo poles used as floating frame are anchored to the bottom by means of concrete weights (anchors) tied to nylon ropes. One cage requires 2-4 anchors, which are made of one-part cement, two parts gravel, and three parts sand and weigh between 50-100 kg. In total, a 100 $m^2$ floating cage costs about PhP 13,640 (Table 15). The submerged cage is the cheapest of among the three.

Table 14. Capital investment for a 100 $m^2$ floating cage structure in Taal Lake, Philippines, 2002.

| **Item** | **Specification** | **Quantity** | **Price/unit (PhP)** | **Cost (PhP)** | **Life expectancy** |
|---|---|---|---|---|---|
| Bamboo | 10-11 m | 25 | 90 | 2,250 | 2 years |
| Net | No. 14 knotless polyethylene | 1 roll | 7,500 | 7,500 | 7 years |
| Ropes | No. 26-30 | 160 m | 3 | 480 | |
| Sinkers (Lead) | 12 /kg | 5 kg | 15 | 65 | |
| Anchors | 100-120 kg/each | 4 | 100 | 400 | |
| Nylon cords | No. 1 | 3 rolls | 40 | 120 | |
| | No. 7 | 1 roll | 60 | 60 | |
| | No. 8 | 1 roll | 80 | 80 | |
| | No. 12 | 1 roll | 120 | 120 | |
| Labor Cost | | | | | |
| Net Mending | | | | 925 | |
| Cage frame construction | | | | 650 | |
| Positioning of a cage in lake | | | | 990 | |
| Total | | | | 13,640 | |

(Source: Fish Cage Operator Survey 2002)

Table 15. Investment comparisons for the three types of cage and area coverage in 2001, all municipalities in Taal Lake, Philippines combined.

| Cage Type | Total Investment per Cage Structure (PhP) | Average cost/m$^2$ (PhP) | No. of cages in 2001[a] | Area covered (ha) |
|---|---|---|---|---|
| Floating | 13,640 | 136 | 6,766 | 67.66 |
| Submerged | 11,690 | 117 | 260 | 2.60 |
| Fixed | 12,310 | 123 | 407 | 4.07 |
| Total | | | 7,433 | 74.33 |

[a]Author's best estimate based on the list generated from the MAO.

(Source: Fish Cage Operator Survey 2002)

Many factors were considered in the selection of cage location. Operators often selected a location with water depth of at least 6 m (38 %) and a wide surrounding space for relatively unrestricted water flow (26 %). New operators who do not have much choice end up establishing cages in front of their land property or other available space adjacent to existing cages. Returning operators use the same location they have used during the previous production cycle.

**Fingerlings and Stocking**

After the cages have been established, they are stocked with fingerlings. The mesh size of the net has to be smaller than the size of fingerlings. Net size no. 14 will contain size 12 fingerlings. The higher the fingerling size number, the smaller its length (Table 16). Purchased fingerlings that are smaller than the grow-out cage's net mesh size are being reared in a separate cage with smaller mesh size until they are big enough to be stocked in the grow-out cage. The tilapia fingerling sizes most commonly stocked in cages include no. 12, 14, 17, and 20. The majority of the operators interviewed (42 respondents) culture tilapia while very few culture bangus and maliputo. Previous research has reported the same observation for Taal Lake (Acedera, 1993; UPLBFI, 1995; Bartolome, 1999; Mutia and Magistrdo, 1999; Zafaralla, 1999; Aypa and Villanueva, 2001; Rosana and Salisi, 2001; Dela Vega, 2001; Guerrero III, 2002). For this reason, the remainder of discussion focuses on tilapia culture. Twenty-three respondents stocked their cages with the "genetically improved modified tilapia" (GIFT) while a few operators stock native tilapia (*O. mossambicus)*, sometimes mixed with other tilapia variety. Six operators stocked the genetically male tilapia (GMT)/sex reversed (SR) tilapia and the BFAR strain 2000. Thirteen respondents do not know the variety of their fingerlings. Fingerling variety dictates its cost in the market. Native tilapia is cheaper than the other tilapia varieties and was observed to have lower mortality rates, but requires 5-7 months to grow before attaining marketable size (usually 3-5 fish per kg). The hybrid tilapias (GIFT, GMT/sex-reversed, and the BFAR strain 2000) grow faster but cost twice as much as the native tilapia species and may have high mortality if not properly acclimated before and during stocking.

Table 16. Size and cost of tilapia fingerling in Taal Lake, Philippines, 2002.

| Size | Body weight (g) | Length (cm) | Age after hatching (wk) | Fish/kg | Average Cost/pc (PhP) | | Recommended Feed type |
|---|---|---|---|---|---|---|---|
| | | | | | Native | GIFT, GMT/ SR, BFAR | |
| 22 | 0.325 | 2.50 | 3 | 3,077 | 0.20 | 0.50 | Fry mash |
| 20 | 0.475 | 3.06 | 4 | 2,105 | 0.20 | 0.60 | Starter crumble |
| 17 | 0.785 | 3.81 | 5 | 1,274 | 0.30 | 0.65 | Crumble |
| 14 | 1.895 | 4.85 | 6 | 528 | 0.35 | 0.70 | Starter pellet |
| 12 | 3.190 | 6.10 | 7 | 313 | 0.40 | 0.80 | Starter pellet |

(Courtesy of Tateh Aqua Feeds through the College of Fisheries, Central Luzon State University)

The municipal ordinances limit the stocking density to 15,000-20,000 fingerlings per cage (Table 11 of Chapter 2). Dela Vega (2001) suggested that a stocking density between 10,000-30,000 fingerlings per cage provides better harvests. Increased stocking density decreases the survival of tilapia in cages (Yi, *et al.*, 1996). However, forty-six respondents prefer to double or triple the stocking density, believing that more than half of them will die during the first 2-3 weeks of stocking. Some operators are not following the recommended stocking density because the fingerling mortality in certain locations is high; hence, to guarantee harvesting the desired production, operators stocked more fingerlings. In the 2002 survey, stocking density varied from 3,000 to 150,000 fingerlings per cage and with an average of 46,856 fingerlings (Table 17). At present, no institution regulates the quality of fingerlings available for distribution to fish cage operators. The average mortality rate of fingerlings in 2002 is comparable with the findings reported by Tan (1995) (15 % +/-4% vs. 12 %). Usually, mortality is higher during the cold months of November to February than the hot months of March to early May. Fingerling mortality varied among the different barangays of the four municipalities. Appendix B presents the stocking density, fingerling mortality during stocking, and the actual number of fingerlings that were harvested of the 50 respondents interviewed.

Table 17. The stocking density, fingerling mortality, feeding ration, fish production per cage per cropping cycle, feed conversion ratio, total rearing days, and cropping per year in Taal Lake, Philippines, 2002.

| **Municipality** (n=50) | **Stocking Density** | **Fingerling mortality[a] (%)** | **Feeding ration (kg)** | **Production (kg)** | **FCR[b]** | **Rearing days** | **Cropping/ yr** |
|---|---|---|---|---|---|---|---|
| Agoncillo | 66,222 (20,074) | 19 (15) | 8,336 (2,516) | 3,588 (733) | 2.32 (0.54) | 156 (13) | 2.00 |
| Laurel | 40,714 (4,927) | 7 (2) | 5,081 (1,255) | 2,058 (189) | 2.55 (0.59) | 121 (10) | 2.71 |
| San Nicholas | 37,500 (3,518) | 14 (8) | 9,745 (1,220) | 3,277 (543) | 3.37 (0.59) | 129 (10) | 2.00 |
| Talisay | 50,140 (14,988) | 23 (7) | 5,460 (989) | 2,575 (459) | 2.69 (0.93) | 152 (13) | 2.00 |
| Average | 46,856 (5,886) | 15 (4) | 7,171 (836) | 2,809 (164) | 2.78 (0.34) | 137 (6) | |

Notes: Number in parenthesis is the margin of error at 90% confidence interval, defined as: standard error of the mean x 1.64.

[a] Respondents best guess.

[b] Feed conversion ratio, calculated as mass of feed given (dry) divided by the increase in mass of fish produced. (Source: Fish Cage Operator Survey 2002)

Tilapia fingerlings were mostly purchased from Laurel, Batangas; Hagonoy, Bulacan; and Calauan, Laguna. Other sources of fingerlings were Bay, Los Banos, Mabitac in Laguna; Jala-jala, Rizal; Pampanga; and Nueva Ecija. Fingerlings are usually placed in a plastic bag with oxygen, and acclimation takes about 1-2 weeks. The suppliers of fingerlings assume all the delivery costs.

**Feed and Feeding Management**

Feed types include fry mash, starter crumble, starter pellet, grower, and finisher. One sack of feed weighs 25 kg, except for Tateh and Limcoma fry mash, which weighs 10 kg per sack and Tateh starter crumble and pellet, which weighs 20 kg per sack. Only one operator out of the 50 respondents used pelleted floating feed[15], which is relatively stable and less polluting (Lorque, n.d.). The average feed conversion ratio was 2.78 +/- 0.34 and ranges from 2.32–3.37 (Table 17). Dela Vega (2001) reported an FCR range of 2.0 to 2.7. An FCR of 2.78 suggests a requirement of 2.78 kg of feed to produce a gain of 1 kg fish weight.

Fish are fed to satiation 2-3 times daily, usually 7-8 am, 10-12 pm, and 3-4 pm. Each feeding takes 30 minutes to two hours. Feeding three times daily was the common practice (68 %). As the fish approach marketable size, feeding time takes more than an hour (at most three hours). Even distribution of the feed in the standing position while feeding the fish was observed to prevent stampede, thereby reducing fish stress and body lesions. Of the 50 operators interviewed, 43 (33 were caretakers) believe that increasing the feeding ration results in greater harvest. However, this perception of some operators reaped little marginal increase in terms of productivity (i.e. high feed conversion ratio), thereby entailing higher marginal costs (Figure 12).

[15] More expensive than the regular feed type.

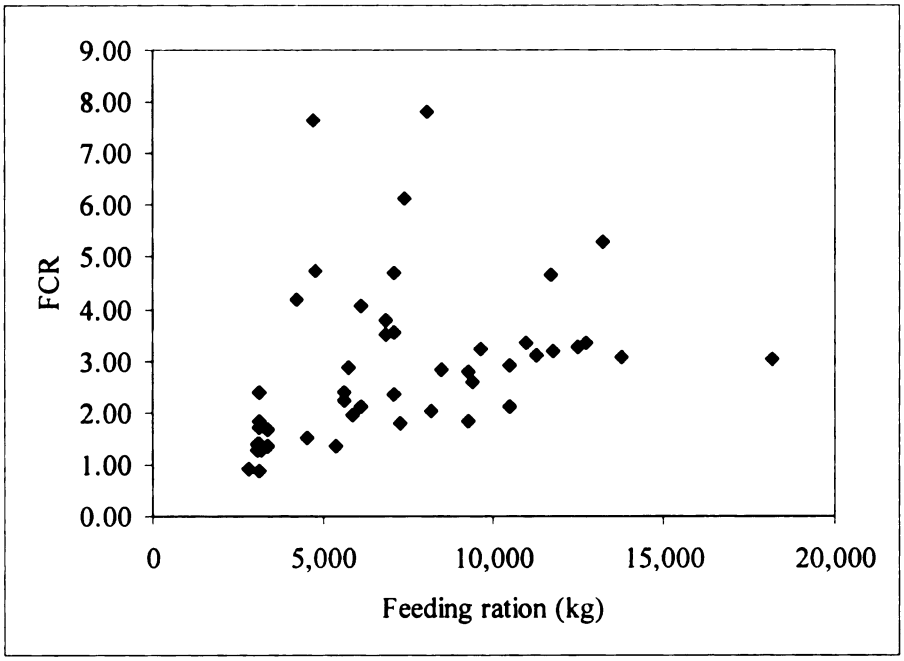


Figure 12. Scatter plot of feeding ration against feed conversion ratio of the 50 sampled operators in Taal Lake, Philippines (Source: Fish Cage Operator Survey, 2002).

In the 2002 survey, operators used 17 commercial brands and types of feed. The popular feed brands were B-Meg, Ace Feed, Atlantica, Tower, Tateh, and Robina. Brand preferences differ by municipalities. B-Meg feed was popular and patronized by Talisay operators, Ace feed by San Nicholas operators, and Atlantica by Laurel operators. The operator's preference, access to credit, and feed price influenced the choice of feed. Feeding is done mostly (98 %) by hand or broadcasting using an improvised small pail made from a plastic beverage bottle. While hand feeding allows uniform feeding and observation of appetite and feed response, it is labor intensive, therefore costly. Of the 50 respondents, only one respondent used feed trays. Field observation revealed that very few operators used improvised demand feeders, which are both cost and labor efficient, reflect fish condition and appetite, and are best suited for grow-out cages, except for fish smaller than 20 g (FAO, 2001).

The amount and type of feed given to fish varies among the four locations (Figure 13). Of the total feed given, fry mash feed comprised less than 4 % while starter crumble and pellet feed comprised between 10-19 % and 15-25%. Grower feed comprised 29-53 % of the total feed given, followed by finisher feed at 11-42 %. Some operators believed that it is necessary to add more feed when fish are nearing marketable size. The operators from Agoncillo and San Nicholas provided more feed (specifically grower type) to fish per cage per cropping than operators in Talisay and Laurel. But providing more feed to fish beyond the requirement of fish results in a higher FCR.

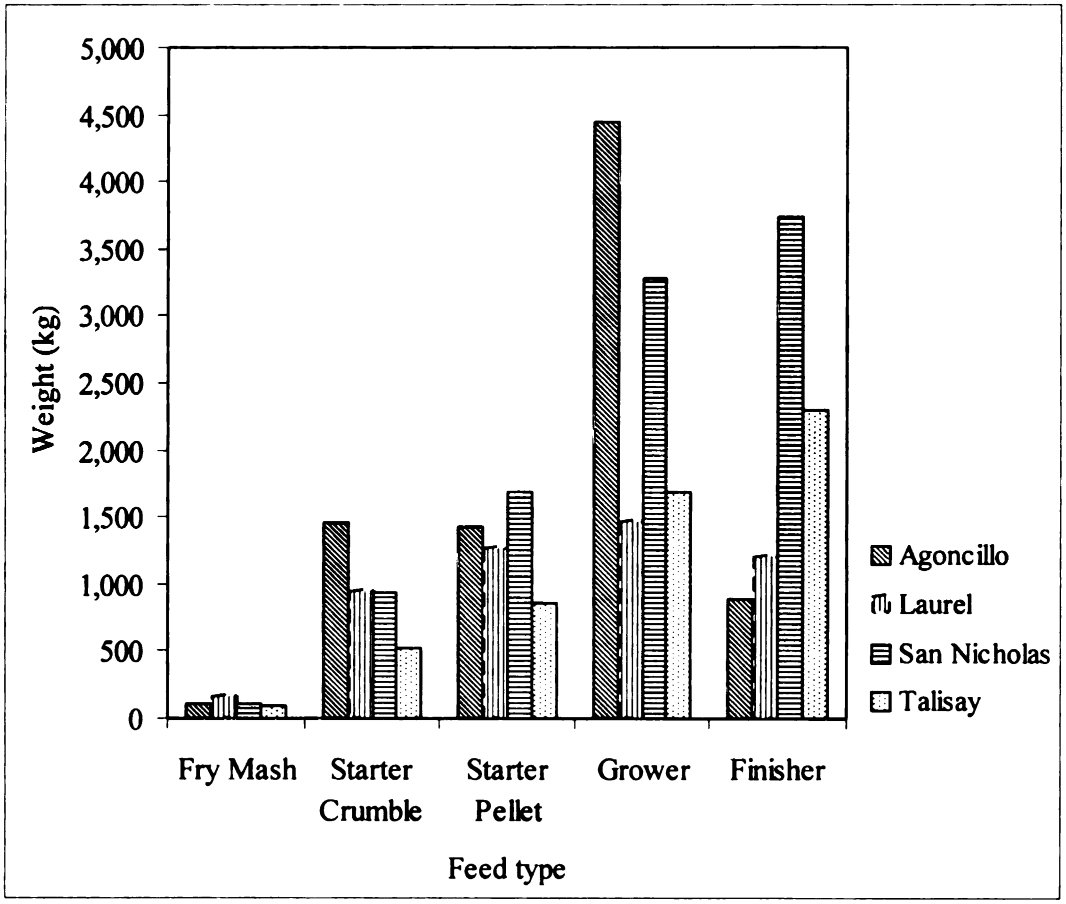


Figure 13. Feed usage per cage per cropping cycle in Agoncillo, Laurel, San Nicholas, and Talisay, Philippines, 2002.

Feed expenses account for 71 % of the total production costs in cage culture. Average cost of feed per cage per cropping cycle was PhP 115,267, which is equivalent to an average of 7,171 +/- 836 kg of feed given (Table 17). Table 18 presents the average total cost of feed per cage per cropping of Talisay operators in 2002.

Operators adjust feeding practice through inspection of fish growth and appetite (60%), which is done by visual observation of fish feeding habits, size, and weight. They rely on fish behavior, e.g. satiated fish will leave the group, produce feces, and stay below the surface area. Other operators (40%) relied on personal knowledge and common practice. Forty-three respondents (86 %) believed that increasing the amount of feed would result in increased harvest.

Table 18. Cost of feed per cage per cropping cycle of the 13 sampled Talisay operators, Philippines, 2002.

| **Feed Type** | **Amount used** | | **Price/kg** | **Cost** | **No. of** |
|---|---|---|---|---|---|
| | **Wt.** | **%** | **(PhP)** | **(PhP)** | **days fed** |
| Fry Mash | 93 | 2 | 20 | 1,860 | 20 |
| Starter Crumble | 518 | 9 | 17 | 8,879 | 32 |
| Starter Pellet | 852 | 16 | 17 | 14,236 | 26 |
| Grower | 1,692 | 31 | 16 | 27,630 | 34 |
| Finisher | 2,304 | 42 | 16 | 36,657 | 26 |
| Total | 5,459 | | | 89,261 | 138 |

(Source: Fish Cage Operator Survey 2002)

Feed in a sack is either brought directly by the financier to the house of the caretaker or is bought from a local feed depot. From the house to the cage location, feed is transported using a bamboo raft or motorized boat. This activity is labor intensive and is part of the duty of caretakers. Average transport cost was PhP 5/bag.

Considering a retention rate of 23 % N and 15 % P on the tilapia body tissues (Table 9 of Chapter 2) and given an average feeding ration per cage per cropping cycle per municipality (Table 19), the estimated N and P lost into the surface water in Taal Lake in 2001 amounted to 3,758 and 816 mt, respectively (Table 20). The data on Table 20 suggest that for every 1000 kg tilapia harvested in 2002, 83 kg N and 18 kg P were lost, assuming that the total number of cages in 2002 was equal to the 2001.

Table 19. Estimated feed and nutrient used and loss into the municipalities of Agoncillo, Laurel, San Nicholas, and Talisay, Philippines, per cage per cropping cycle, 2002.

| **Municipality** (n=50) | **Feed Consumption (kg)** | **Amount of nutrient used (kg)** | | **Amount of nutrient loss (kg)** | |
|---|---|---|---|---|---|
| | | **N** | **P** | **N** | **P** |
| Agoncillo | 8,336<br>(2,516) | 395<br>(120) | 75<br>(23) | 302<br>(92) | 64<br>(20) |
| Laurel | 5,081<br>(1,255) | 241<br>(59) | 46<br>(11) | 184<br>(46) | 39<br>(10) |
| San Nicholas | 9,745<br>(1,220) | 462<br>(57) | 88<br>(11) | 353<br>(44) | 75<br>(10) |
| Talisay | 5,460<br>(989) | 259<br>(48) | 49<br>(8) | 198<br>(36) | 42<br>(8) |

Notes: Number in parenthesis is the margin of error at 90% confidence interval, defined as: standard error of the mean x 1.64. (Source: Fish Cage Operator Survey 2002)

Table 20. Estimated amount of N and P lost into Taal Lake, Philippines, 2002.

| **Municipality** | **Fish cage production (mt/year)** | **Feed consumption (mt/year)** | **Total N loss (mt)** | **Total P loss (mt)** |
|---|---|---|---|---|
| Agoncillo | 16,952 | 39,380 | 1,399 | 301 |
| Laurel | 15,224 | 37,576 | 1,328 | 287 |
| San Nicholas | 3,153 | 9,374 | 326 | 72 |
| Talisay | 9,584 | 20,317 | 705 | 155 |
| Total | 44,912 | 106,647 | 3,758 | 816 |

(Source: Fish Cage Operator Survey 2002)

### Rearing and Production

The rearing period depends on the nature of production system, the size of fingerlings at stocking, and the fish genetic variety. On average, an intensive culture cycle takes about 137 +/- 6 days (Table 17). This duration is likely for size 12 fingerlings that are subsequently reared for 3-4 months. Laurel operators have fewer days of rearing than the other three municipalities, and they have a 2.7 cropping periods per year. However, some operators observed extended periods of intensive tilapia culture from 4-7 months. Half of the respondents claimed longer rearing periods compared to the last 5-10 years of operation. Reasons provided were fish kill occurrences (38%), too much wasted feed (28%), polluted water (16 %), and other factors (18%), such as low quality of fingerlings, poor water circulation, and bad weather.

Stocking density, feeding rate, and survival rate at harvest time influence fish production. Figure 14 presents the trend of total fish produced by the 50 sampled operators and nutrient losses plotted against the stocking density. As the stocking density increases beyond the recommended 10,000-30,000 fingerlings, the total product per cage per cropping cycle slightly increased, except for one operator from Agoncillo with a stocking density of 90,000 fingerlings. The nutrient losses are more or less proportional to the amount of fish produced. The estimated fish cage production in 2002 was 2,809 +/- 164 kg per cage per cropping. During the months of November to February, when northeast monsoons (amihan) sweep the area, the rearing period extends by another month or two because water becomes clearer compared to the rest of the year. Sometimes, harvesting twice per year is difficult. Better harvest can be achieved during the months of June to October because of the increased productivity of the algal population, a natural food source, under the turbid water, which is influenced by the southwest monsoon (habagat). However, operators observe that during the transition of monsoon winds from northeast to southwest (May and October), which bring about the easterly wind, temperature is higher than normal range and fish kill is most likely to occur. Hence, a cropping cycle between September and April maybe the best period to culture fish in Taal Lake.

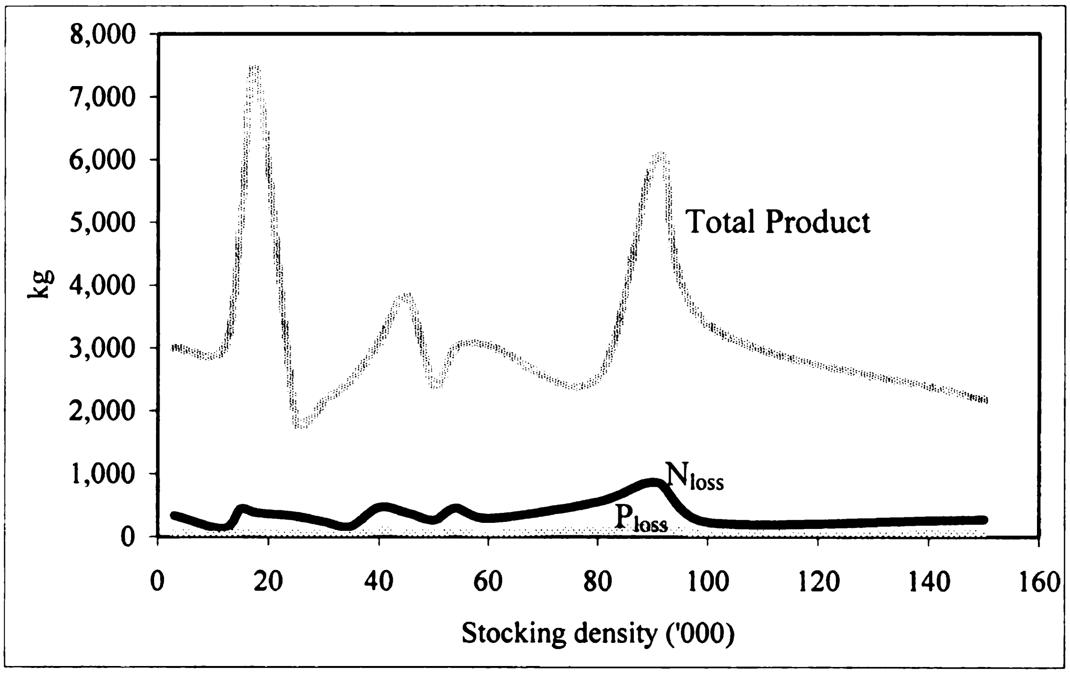


Figure 14. Plot of total fish product and nutrient loss (*N* & *P*) against stocking density, of the 50 sampled operators in Taal Lake, Philippines (Source: Fish Cage Operator Survey, 2002)

When the DO concentration decreases to critical levels (< 5 mg/l), aeration is encouraged through the use of motorized boats running around the cages. Only six of the 50 respondents employed such a measure. However, the high cost of an aerator prevents the operators from buying this equipment. Others believed that it is not practical to have an aerator since it is only applicable to ponds and not in deep lakes, such as Taal. In critical situations, discontinuing the provision of feed became a common practice and in the worst-case scenario, the immediate harvesting of fish.

Cleaning nets is important to increase the exchange of water inside and outside the cages. Cleaning and changing the net, included in the tasks of the caretaker, require at least 8 hours and is done once per cropping cycle. Nets are dried first, then soak in the water and then washed. Some operators just leave the nets drying in the raft. The cost of net cleaning and changing in 2002 was PhP 600. Thirty-nine respondents claimed that wastes from cage activities are disposed and burned on the lakeshore, while the rest are being thrown into the water.

Thirteen respondents from Laurel and three from Agoncillo used fish medicine or anti-stress medication and vitamins while respondents from Talisay and San Nicholas did not use any. Products used were Sunjin, Tower, B-meg antibacterial powder/solution, and salt (Table 21). When signs of fish disease due to bacteria and other stressors are observed, these products are given with the feed. The need for these products may also suggest decreasing water quality. Aggressive marketing of these products was observed and their use is expected to increase as more fish kills occur. However, fish aquaculture experts have not yet fully studied and or endorsed these products.

Table 21. Cost of fish medicines used in Laurel and Agoncillo, Philippines, 2002.

| Medication Brand | Fingerling size | Frequency of application | Amount used | Total Cost/ cycle (PhP) | Remarks |
|---|---|---|---|---|---|
| B-meg | 14 | 2x/day | 3 tbsp | 300 | Used as needed |
| Sunjin | 14, 17 | 2x/ week am | 3.5 tbsp | 880 | Used as needed |
| Tower | 14 | 2x/day | 2 tbsp | 530 | Used as needed |
| Salt | 14 | 2x /day | 1 kilo[a] | 30 | Used when fish have scars |

[a] Mixed with half bag of feed

(Source: Fish Cage Operator Survey 2002)

**Harvesting and Marketing**

Harvesting was either total or partial/selective, using a seine or gill net. A seine is used for total harvest while the gill net is used in selective/partial harvest. Partial harvest uses nets with mesh size of five, which leaves the smaller fishes in the cage. The remaining fish are allowed to grow until they reach a marketable size. Half of the respondents harvested partially and half totally. When fish are ready to be harvested in the submerged cage type, they are placed into the floating cage for a week to darken their body appearance. The three factors which influence the frequency of harvesting are: (1) the prevailing price of fish in the market; (2) the need for money in the family; and (3) the size of fish being cultured in the cage.

Operators sell their fish to a direct buyer (middlemen), who handles the harvesting and marketing. Most middlemen are direct buyers and sellers of fish, shifting the costs of harvesting and marketing (ice, salt, labor, transportation, etc.) away from the operators. Ice blocks are available in most municipalities and nearby towns. Arrangements are either cash (37 respondents) or credit (13 respondents). The average farm-gate price of tilapia received by the operators ranges from PhP 55-57, while the estimated revenue ranges from PhP 114,864 to 202,324 in 2002 (Table 22). Laurel operators harvested the least amount of fish in 2002 and earned the least revenue compared to other municipal operators.

Table 22. Estimated revenue for a 100 $m^2$ grow-out cage per cropping cycle in Agoncillo, Laurel, San Nicholas, and Talisay, Philippines, 2002.

| **Municipality (n=50)** | **Production [a] (kg)** | **Farm Gate Price (PhP)** | **Revenue (PhP)** |
|---|---|---|---|
| Agoncillo | 3,588 | 55.65 | 202,324 |
| | (447) | (1.80) | (28,548) |
| Laurel | 2,058 | 55.40 | 114,864 |
| | (115) | (1.29) | (7,897) |
| San Nicholas | 3,277 | 56.35 | 179,998 |
| | (331) | (1.65) | (17,784) |
| Talisay | 2,574 | 57.20 | 148,103 |
| | (280) | (1.73) | (17,487) |

Notes: Number in parenthesis is the margin of error at 90% confidence interval, defined as: standard error of the mean x 1.64.

[a] Exclude fish mortality during harvest.

(Source: Fish Cage Operator Survey 2002)

In the past 10 years, there has been an increasing market demand for tilapia. Fish harvested from the 324 cages included in the survey were distributed in the different cities of Metro Manila, mostly in Malabon, Novaliches, Cubao, and Alabang. Other markets were also available in Binan, Sta. Rosa, Calamba City, and San Pablo City in Laguna; Indang and Tagaytay City in Cavite; Lucena City, Quezon; and nearby municipalities in Batangas, such as Lipa City, Tanuan City, and Bauan. Fish condition when sold to the middlemen was mostly live (72%). Fish marketed in more remote places (28%) were packed in containers with ice and salt.

## Nutrient Pollution and Other Problems

The operators are confronted with different problems with regard to their cage production. Of primary concern are bad weather, such as typhoons with strong winds (27) and the high mortality of fingerlings (19). Secondary challenges that operators face are mortality of fish of marketable sizes (11), pollution (11), and fluctuating and/or low price of fish in the market (9). Other problems are fish diseases and parasitic infestations (6); damaged nets (4); theft (3); slack caretakers and low concentration of dissolved oxygen (2); and turbid water, congestion in cage area, low quality of fingerlings, delay in the delivery of feed, and problems with financiers (1).

Thirty-seven respondents observed changes in the water quality compared to the previous 10 years of cage operation. Of the 13 respondents who believed that the water quality remains the same, 12 were caretakers, who have less than 10 years of cage operation in Taal Lake. The deteriorating water quality, according to the respondents, is attributed to too many cages releasing excessive feed wastes, coupled with some slack caretakers who do not properly dispose of waste materials and leave dead fishes floating in the water. Forty respondents experienced massive fish kills, mostly between 1999-2002. The causes of fish kill were by and large attributed to the low DO concentration (88 % of reporting) during overturn and toxic poisoning of pollutants, while other causes were typhoon (7 %) and parasitic infestation (5 %). Dead fish ranges from fingerlings to grow-out sizes, and operators reported an approximate weight of 8-30,000 kg per fish kill occurrence. Based on the surveyed sample, many fish cage operators pulled out their investment after they had experienced massive losses due to recent fish kill occurrences in 1999 to 2001.

As the number of cages increased and the use of the land in the upper watershed has changed over the past five years, the amounts of nutrients entering the lake may have increased tremendously after 2001. Data show that the feeding and metabolic activities of fish in cages contributed as much as 75 % N and 82 % P while the household sewage inputs amounted to 20 % N and 14% P of the total nutrient loading (Table 23). Agricultural and watershed run-off contributed only 5% N and 4% P. These include siltation, leachates from solid waste, effluent from poultry farms and piggeries, and fertilizers (PCTT, 1997). Appendix C presents the detailed computation of the estimated nutrient loading rates from the various sources. It is assumed that the nutrient inputs from the household sewage may be of little concern considering the slight increase in population in the nine municipalities and two cities surrounding the lake, i.e. from 406,639 in 1990 (UPLBFI, 1995; Folledo and Cruz, 1999) to 535,323 in 2000 (NSO, 2000). However, the projected increase in population in the next 20 years could further increase the nutrient loading from the household sector in the future. Assuming that the estimated nutrient loading is more or less correct, then the 2002 situation empirically implies that future policy regulation should prioritize regulating the nutrient input loading from the fish cage industry.

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Table 23. Estimated nutrient input loading rates from various sources in Taal Lake, Philippines, 2002.

| Source of Nutrients | Total N (t) | Total N % | Total P (t) | Total P % |
|---|---|---|---|---|
| Fish Cages | 3,758 | 75 | 816 | 82 |
| Household sewage [a] | 969 | 20 | 146 | 14 |
| Agriculture/watershed [b] | 239 | 5 | 35 | 4 |
| Total | 4,965 | | 997 | |

[a] Adopted from Jacinto *et al.* (1998), assuming a 1.96 kg N per person per yr and 0.29 kg P per person per yr loss.

[b] Adopted from Clemente and Wilson (2000), assuming a 6.48 kg N per ha per yr and 0.96 kg P per ha per yr loss and a 10% filtration of nutrients by the watershed vegetations.

Operators employ different techniques to minimize or prevent fish kill. As mentioned in the previous sections, caretakers provide medicine and vitamins mixed into the feed (16 operators) and the use of motorized boats running around the cages (6 operators) to encourage aeration. Discontinuing feeding (11 respondents) and early harvesting are also done (5 respondents). Other measures suggested to solve the problem are reducing the number of cages (4 respondents), decreasing the feeding ration (2 respondents), and the removal of abandoned cages (1 respondent). Twenty-one operators believed that the researchers from BFAR should act to solve the problem in Taal Lake, e.g. provision of seminars, while 13 operators identified themselves as persons who need self-discipline in properly managing cage production activities. Eight operators thought that the concerned incumbent officials of the local government units should help in the facilitation of credit provision and other institutional support measures. Seven operators consider the need for cooperation and unity among the stakeholders as part of the solution. One respondent from Talisay claimed the importance of and the need for strict implementation of municipal fishery ordinances. Two operators mentioned the increased involvement of private companies and financiers.

## Income Analysis of the Fish Cage Production

The previous sections presented the fish cage production activities. This section expands on the comparison of income among the four municipalities and between the two ownership arrangements, namely 'owner as operator' and 'owner hires a caretaker.' The first comparison highlights specifically the change in net income as feed usage increases while the second investigates the differences in net income when additional labor input is added in the production.

Table 24 shows the comparative income estimates for a 100 $m^2$ grow-out cage per cropping cycle in the four municipalities in 2002 based on the 50 sampled operators. Notable among the four municipalities was the high cost of feed, specifically for San Nicholas, and the low fish productivity in Laurel. Indeed, net income is very sensitive to the amount and cost of feed and the productivity in the cage areas. Some respondents believed that, for 2002, many operators are still recovering financial losses from the effects of massive fish kill occurrences attributed to nutrient pollution and other causes. It is also possible that some respondents understated yield and overstated costs.

Table 24. Estimated average net revenue for a 100 m$^2$ grow-out cage per cropping cycle in the four municipalities of Taal Lake, Philippines, 2002.

| **Item** | **Agoncillo** (n=9) | **Laurel** (n=14) | **San Nicholas** (n=14) | **Talisay** (n=13) | **Total Average** |
|---|---|---|---|---|---|
| Revenue [a] | 202,323 | 114,864 | 179,998 | 148,103 | 157,486 |
| | (28,547) | (7,897) | (17,784) | (17,168) | |
| Operating costs | | | | | |
| Fees [b] | 350 | 410 | 520 | 950 | 558 |
| Fingerlings [c] | 43,044 | 26,464 | 24,375 | 32,591 | 30,456 |
| | (7,956) | 1,952) | (1,394) | (5,940) | |
| Feed [d] | 133,777 | 85,734 | 154,225 | 92,302 | 115,267 |
| | (25,743) | (12,440) | (11,423) | 10,714) | |
| Labor [e] | 744 | 1,766 | 1,378 | 1,422 | 1,384 |
| Transportation [f] | 1,058 | 2,219 | 1,357 | 3,382 | 2,071 |
| Depreciation [g] | 5,394 | 4,176 | 4,447 | 5,233 | 4,813 |
| Misc. expenses (medicine, etc.) | 520 | 535 | 250 | 250 | 389 |
| Total | 184,888 | 121306 | 186,553 | 136,131 | 154,938 |
| Net revenue (PhP) | 17,435 | -6,441 | -6,555 | 11,971 | 2,611 |
| | (38,868) | (24,333) | (19,724) | (33,705) | |

(Source: Fish Cage Operator Survey 2002)

Notes: Number in parenthesis is the margin of error at 90% confidence interval, defined as: standard error of the mean x 1.64.

[a] Total harvest x farm gate price.

[b] Based on Municipal Ordinances, as shown in Table 11 of Chapter 2.

[c] Stocking density x price of fingerlings.

[d] Feeding ration (kg) x $\text{Price}_{\text{feed type}}$ (PhP/kg).

[e] Include only net cleaning and harvesting & excluding the feeding labor cost.

[f] Include feed delivery cost and other transportation expenses.

[g] PhP 4,815 (capital investment for a 100 m$^2$ cage frame) divided by 730 days (estimated useful life of cage bamboo frame) x rearing days (e.g. Agoncillo 156 days) + PhP 8,825 (net and other materials, with estimated useful life of seven years) divided by 2,555 days x 156 days + 1,713 (capital investment for bamboo raft divided by 365 days (useful life) x 156.22 = PhP 5,394.

The 'owner hires a caretaker' employed more feed than the 'owner as operator' arrangement (Table 25). The cost of hiring a caretaker for an owner is equal to 50 % of the net income from the cage production. The additional labor hours provided by the caretakers in the 'owner hires a caretaker' arrangement reflect an increased production. Feed wastage is minimized when operators devote longer time in feeding, which is mostly done manually. These results are contingent upon the proper cultural management practices, good interpersonal skills, and paternalistic management style of owner and caretakers.

Table 25. Comparative estimated net revenue of 50 cage operators in Taal Lake, Philippines, in 2002, given a 100 m$^2$ grow-out cage per cropping cycle under two ownership arrangements.

| **Item** | **Owner as operator** (n=13) | **Owner hires a caretaker** (n=37) |
|---|---|---|
| Revenue [a] | 133,056<br>(32,821) | 166,070<br>(17,541) |
| Operating costs | | |
| Fees | 662 | 538 |
| Fingerlings [b] | 37,250<br>(5,952) | 28,070<br>(2,292) |
| Feed [c] | 84,369<br>(11,410) | 126,123<br>(16,609) |
| Labor [d] | 1,384 | 1,384 |
| Transportation [e] | 2,312 | 1,987 |
| Depreciation [f] | 4,986 | 4,661 |
| Misc. (medicine, etc.) | 356 | 386 |
| Total | 131,320 | 163,150 |
| Net revenue | 1,735<br>(33,497) | 2,919[i]<br>(15,250) |

(Source: Fish Cage Operator Survey 2002)

Notes: Number in parenthesis is the margin of error at 90% confidence interval, defined as: standard error of the mean x 1.64.

[a] Total harvest x farm gate price.

[b] Stocking density x price of fingerlings.

[c] Feeding ration (kg) x $\text{Price}_{\text{feed type}}$ (PhP/kg).

[d] Include only net cleaning and harvesting. In the case of 'owner hires a caretaker,' most labor inputs are included in the overall tasks of the caretakers.

[e] Include feed delivery cost and other transportation expenses.

[f] Average among the respondents, see Table 24.

[i] Fifty % to owner, 50 % to caretaker.

**Optimum Input-Output Analysis of the Fish Cage Production**

This section presents the estimation results of the *C-D* production function. The results serve as the basis of the estimation of the efficient allocation of inputs, the most profitable production level, and a guide for comparing the cost-effectiveness of pollution reduction options. The important variables that operators look for are the optimal levels of feeding ration, stocking density, and yield. Figures 15, 16, 17 present the scatter plot of yield against feeding ration, stocking density, and labor in tending cages of the 50 sampled operators in Taal Lake, Philippines in 2002.

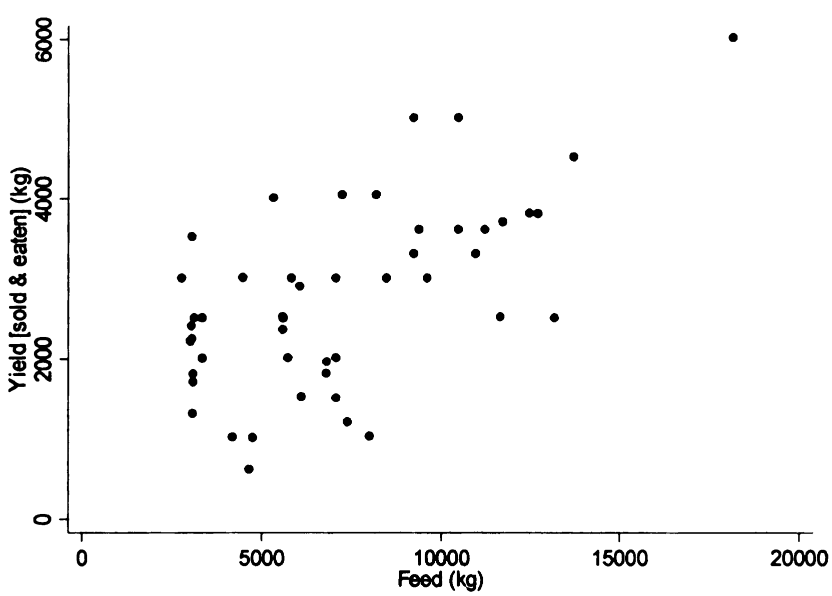


Figure 15. Scatter plot of yield against total feeding ration of the 50 sampled operators in Taal, Lake, Philippines, 2002.

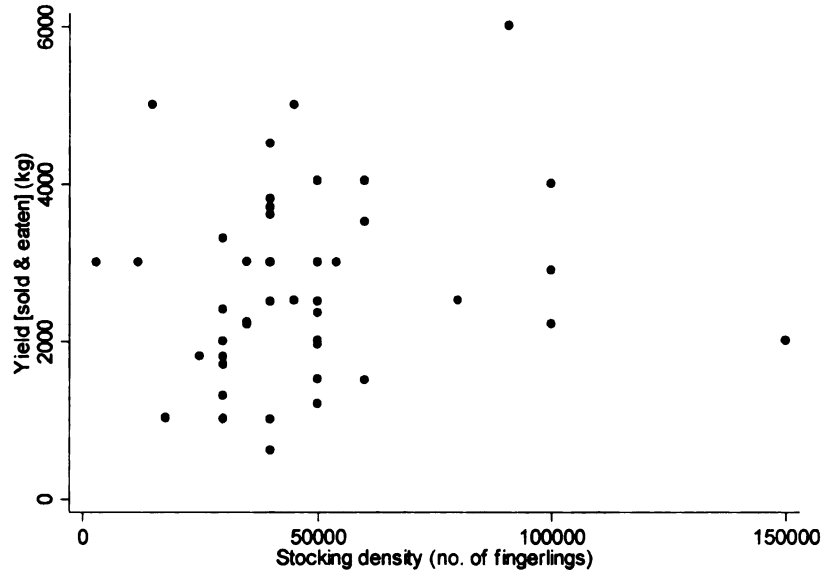


Figure 16. Scatter plot of yield against stocking density of the 50 sampled operators in Taal, Lake, Philippines, 2002.

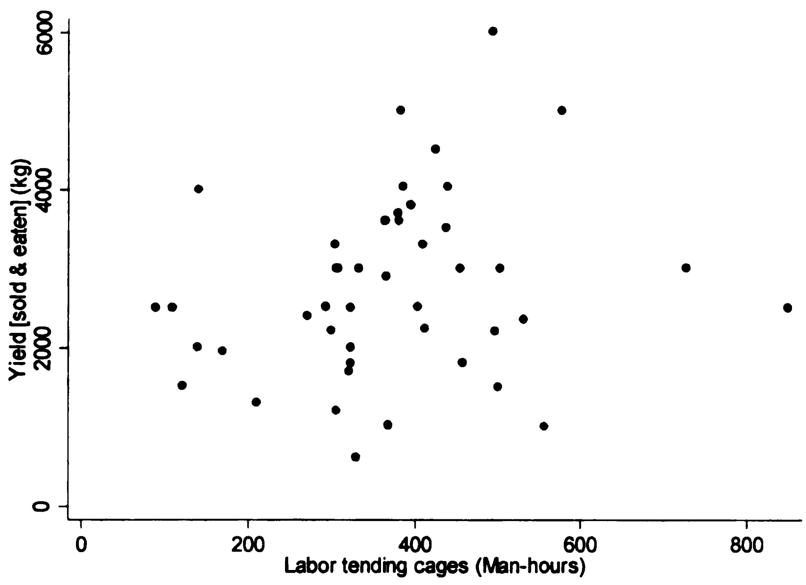


Figure 17. Scatter plot of yield against labor of the 50 sampled operators in Taal, Lake, Philippines, 2002.

An *OLS* regression was employed using the cage production technology inputs and output data from the 50 respondents, regressing yield $(Y)$ on feeding ration $(X_F)$, stocking density $(X_{SD})$, labor in tending cages $(X_L)$, and dummy variables $(X_{D_{1-4}})$ representing ownership arrangements and locations. Based on the initial *OLS* regression, the variables $X_{SD}$, $X_L$, $X_{D_2}$, and $X_{D_3}$ were found to be not statistically significant at 10 % level of significance. However, the variable $X_{SD}$ is a required input in the production function based on *a priori* knowledge. Adjusting the data for the two over-stocked operators in the sample did not affect the significance of $X_{SD}$. Dropping them and/or trimming the two extreme *SD*, the highest and lowest, had no effect either. As discussed in the previous section, there is an uncertainty with the stocking density and risk of getting zero output because of the decreasing water quality in cage areas and for other reasons not known yet. In certain cage areas, operators are encouraged to increase the stocking density to ensure the attainment of the desired harvests. On the other hand, this practice entails additional cost to the operator. Given this situation, the net stocking density (*SDa*)[16] was used instead of the actual stocking density (*SD*) (Appendix B) in the estimation of the *C-D* production function coefficients. Table 26 presents estimation results of the C-D production function model regressing $Y$ on $X_F, X_{SD_a}$, $X_{D_1}$, and $X_{D_4}$. The model could be written as:

$$\log \hat{Y} = \log \hat{B}_0 + \hat{\beta}_1 \log X_F + \hat{\beta}_2 \log X_{SD_a} + \log \hat{\beta}_3 X_{D1} + \log \hat{\beta}_4 X_{D4} \qquad \text{(Equation 5.1)}$$

$$= \log 3.99 + 0.20 \log X_F + 0.22 \log X_{SDa} - \log 0.33 X_{DI} - \log 0.29 X_{D4}$$

[16] Defined as stocking density at stocking (*SD*) less fingerling mortality at stocking ($SD_m$).

Table 26. Estimated C-D production function coefficients and related statistics for a sample of 50 operators in Taal Lake, Philippines, 2002.

Dependent variable: Log Y [Yield (kg) per cage per cropping]

| Variables (Log) | Parameter | Coefficient | Standard Error (se) | P value |
|---|---|---|---|---|
| Intercept | $\beta_0$ | 3.99 | 1.33 | 0.00[a] |
| Total feeding ration $(X_F)$ | $\beta_1$ | 0.20 | 0.12 | 0.12[b] |
| Net stocking density $(X_{SDa})$ | $\beta_2$ | 0.22 | 0.09 | 0.03[a] |
| Ownership arrangement $(X_{D_1})$ | $\beta_3$ | -0.33 | 0.13 | 0.01[a] |
| Location, i.e. Laurel $(X_{D4})$ | $\beta_4$ | -0.29 | 0.13 | 0.04[a] |

Observations: 50
$R^2$: 0.37
F statistics: 6.6

[a] Significant at 5 % level. $H_o$: $B_i = 0$.

[b] Significant at 13 % level.

(Source: Fish Cage Operator Survey 2002)

The net stocking density, ownership arrangement, and location (Laurel) were found to be statistically significant at 5 % level of significance. The production coefficients for feeding ration $(\beta_1)$ and stocking density $(\beta_2)$ have the expected positive sign while the ownership arrangement $(\beta_3)$ and location $(\beta_4)$ are negative. All the coefficients of the explanatory variables $X_{SD_a}$, $X_{D1}$, and $X_{D4}$ are significantly different from zero at 10 % level according to the t-test[17]. The explanatory variable $(X_F)$ is only significantly different from zero at 12 % level. With regard to the overall regression, the computed $F$ value (6.60) is greater than the critical value (2.09) at 10 % level of significance. It can be said that the overall regression is statistically significant. The

[17] $H_0 : \beta_i = 0$. T-statistics is computed as $\frac{\beta_i}{se}$.

coefficient of determination ($R^2$=0.37) represent the variation in the log of yield as explained by the following log of the variables: $X_F, X_{SD_a}$, $X_{D_1}$, and $X_{D_4}$. The value 0.37 means that the logged value of four explanatory variables ($X_F, X_{SD_a}$, $X_{D_1}$, and $X_{D_4}$) explain 37 % of the variation in the log of yield in the sample. The production elasticities are 0.20, 0.22, -0.33 and –0.29, respectively. A 10 % increase in feeding ration will produce a 0.20 % increase in yield (not significant) while a 10 % increase in the net stocking density will produce a 0.22 % increase in yield. Since the sum of the production coefficients is < 1, a decreasing return to scale exists; a doubling of $X_F$ and $X_{SD}$ inputs will less than double yield.

Testing for efficiency, the marginal rate of technical substitution and the input price ratio are estimated and compared to find out the optimal level of use of inputs. The optimal condition is written as:

$$\hat{\psi} = \hat{\beta}_1\left(\frac{X_{SD_a}}{X_F}\right) - \hat{\beta}_2\left(\frac{P_{SD_a}}{P_F}\right) = 0, \qquad \text{(Equation 5.2)}$$

where $X_{SD_a}$ and $X_F$ values are the geometric mean, $P_{SD_a}$ is the price of fingerlings for net stocking density and $P_F$ is the price of feed. The price used for the net stocking density was the adjusted price, which is estimated as:

$$P_{SD_a} = \frac{P_G}{\left(1 - \hat{\gamma}_1\right)}. \qquad \text{(Equation 5.3)}$$

The coefficient $\hat{\gamma}_1$ is derived from the relationship between fingerlings mortality (*SDm*) and stocking density (*SD*)[18], which is defined as:

$$SD_m = \hat{\gamma}_o + \hat{\gamma}_1 SD. \qquad \text{(Equation 5.4)}$$

Table 27 shows the estimated stocking density coefficients as linked with fingerling mortality, based from the 50 sampled operators in Taal Lake, Philippines, 2002. Both the parameter estimates are statistically significant at 5 % level. The overall regression is also statistically significant.

Table 27. Estimated stocking density coefficient and related statistics for a sample of 50 operators in Taal Lake, Philippines, 2002.

Dependent variable: Fingerling mortality ($SD_m$)

| **Variables** | **Parameter** | **Coefficient** | **Standard Error (se)** | **P value** |
|---|---|---|---|---|
| Intercept | $\hat{\gamma}_0$ | -20,337.41 | 4,009.37 | 0.00[a] |
| Stocking density (*SD*) | $\hat{\gamma}_1$ | 0.64 | 0.07 | 0.00[a] |
| Observations: 50 | | | | |
| $R^2$: 0.60 | | | | |
| F statistics: 72.71 | | | | |

[a] Significant at 5 % level. $H_O$: $B_i = 0$.

(Source: Fish Cage Operator Survey 2002)

[18] Net stocking density (*SDa*) = actual stocking density (*SD*) – fingerling mortality (*SDm*)

Fingerling mortality is a function of stocking density and the interviews with operators suggest that they know that the actual yield would depend on the net stocking density. The relative price of net stocking density is derived by getting the first order condition of equation 5.5 with respect to stocking density (*SD*):

$$Pf\left(F, SD - \hat{\gamma}_1 SD\right) - P_G SD - P_F F = 0 \qquad \text{(Equation 5.5)}$$

The first order condition with respect to SD is written as:

$$f'\left(1-\hat{\gamma}_1\right) - P_G = 0 \quad \rightarrow \quad f'\left(1-\hat{\gamma}_1\right) = P_G \quad \rightarrow \quad f' = \frac{P_G}{\left(1-\hat{\gamma}_1\right)}.$$

The resulting value $\left(\hat{\psi} = 1.45\right)$ is > 0, which suggests that the fish cage operators in Taal Lake appear to be over utilizing stocking density relative to the feeding ration. This implies that the marginal productivity of feeding ration over the marginal productivity of net stocking density is greater than the price ratio of feeding ration over net stocking density.

Increasing physical efficiency and the optimal use of inputs will maximizes profits. In this regard, the marginal product (*MP*) of each of the variable inputs was calculated and compared with the input-output price ratio. The *MP* of feeding ration and stocking density were less than the price ratios (0.08 < 0.30; 0.01 < 0.13); hence, increasing these inputs are discouraged. This can also be concluded from the fact that the value of the *MP* of feed ($VMP_F = MP_F{*}P_Y$ = PhP 4.54) is less than the marginal cost

($MC$) of feed ($P_F$ = PhP 17.23). Similarly, the value of the $MP$ of net stocking density ($VMP_G = MP_{SDa} * P_Y$ = PhP 0.92) is less than the MC of net stocking density (PhP 7.84).

The optimal input and yield levels, which were obtained using marginal analysis, are shown on Table 28. The optimal feeding ration was found to be 2,606 kg per cage per cropping cycle. Given the current cage production technology, it may be beneficial to reduce feeding ration, which would ultimately decrease feed cost. Operators can also substantially reduce costs by decreasing the amount of stocking density. The optimal net stocking density (i.e. actual stocking density less fingerling mortality) was found to be 5,362 fingerlings plus or minus 10% fingerling mortality per cage per cycle. The optimal yield was derived using the optimal values of net stocking density and total feeding ration. The estimated optimal yield was 1,689 kg per cage per cropping. Given the optimal values of stocking density, feeding ration, and yield, and using the average cost data for other inputs, the estimated net revenue increased seven fold times the baseline average net revenue (Table 29). It should be noted that these results rely on use of the estimated coefficient for $X_F$, which was only significant at the 12 % level.

Table 28. Baseline levels, prices, price ratio, and optimal levels of feeding ration $(X_F)$, net stocking density $(X_{SD_a})$, yield $(Y)$ and nutrient loss per cage per cropping cycle of the 50 sampled operators in Taal Lake, Philippines, 2002.

| **Variables** | **Baseline levels** | | | **Prices per kg (PhP)** | **$P_X/P_Y$** | **Optimal levels** [b] | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | **Yield** | **Nutrient Loss (kg)** | |
| | **Mean** [a] | **Low** | **High** | | | | N | P |
| Feeding ration (kg) | 6,188 | 2,800 | 18,200 | 17.23 | 0.31 | 2,606 | 94 | 20 |
| Net stocking density (No.) | 33,126 | 2,900 | 81,000 | 7.84 [c] | 0.14 | 5,495 | | |
| Yield (kg) | 2,495 | 612 | 6,002 | 56.19 | | 1,689 [d] | | |

[a] Geometric mean: $g(X_i) = e^{\left[\left(\frac{1}{n}\right) * \sum \ln X_i\right]}$. The baseline geometric N loss is estimated at 224 kg per cage per cropping cycle while P loss is estimated at 47 kg per cage per cropping cycle.

[b] Derived by equating the $MP_{X_i}$ to the $X_i$ input and output price ratio.

[c] Based on the average of 4 pieces per kg of market size tilapia at PhP 1.96 per fingerling (adjusted price from the net *SD*)

[d] The optimal yield was obtained using the optimal feeding ration (2,606) and net stocking density (5,495).

Table 29. Comparative estimates of net revenue based on average and optimal levels of inputs and yield in Taal Lake, Philippines, 2002.

| **Item** | **Average (PhP)** | **Optimum (PhP)** |
|---|---|---|
| Revenue | 161,322 | 94,943 |
| Operating costs | | |
| Fees | 558 | 558 |
| Fingerlings | 31,619 | 11,851[a] |
| Feed | 116,510 | 44,896 |
| Labor (cleaning, harvesting) | 1,328 | 1,328 |
| Transportation | 2,004 | 2,004 |
| Depreciation (cage + raft) | 4,813 | 4,813 |
| Misc. (medicine, etc.) | 389 | 389 |
| Total | 157,219 | 65,838 |
| Net Revenue | 4,104 | 29,105 |

[a] Cost includes the fingerlings mortality, based on survey average.

(Source: Fish Cage Operator Survey 2002)

# CHAPTER 6

# ESTIMATES OF THE COST-EFFECTIVENESS OF NUTRIENT POLLUTION REDUCTION OPTIONS

This chapter presents the estimates of the cost-effectiveness of nutrient pollution reduction options for the Taal Lake fish cage industry. The waste reduction or minimization and waste management strategies address the problems brought about by feed wastes from fish cages. The first section presents the options for waste reduction or minimization, comparing the net revenue per cage per year, costs per year, and incentives per year among the four municipalities. The second section presents the options for waste management, which reduces the impacts of nutrient loadings to the fish productivity in the lake. The success of implementing these options requires strong 'political will' of the LGUs and active participation of all stakeholders in the industry.

## Waste Reduction or Minimization in the Fish Cage Industry

Waste reduction or minimization reduces the release of nutrients into the surface water. The three options are: (1) Option $Z_1$ - reduction in the total number of cages; (2) Option $Z_2$ – reduction in feeding ration; and (3) Option $Z_3$ – reduction in stocking density. Costs of 5 %, 10 %, and 15 % reductions in nutrient loadings were estimated for the four municipalities in Taal Lake. The general assumption is that the ownership arrangement follows that of 'an owner hires a caretaker.' The estimation of total revenue used the average price of PhP 56 per kg fish.

Based on expert recommendations and the survey interview of operators in Taal Lake, one of the strategies that LGUs could employ to address the nutrient pollution problem is to reduce the total number of cages. The objective of *Option* $Z_1$ (fewer cages) is to rejuvenate the lake ecosystem to its normal ecological functioning. Reducing the total number of cages, which reduces the total fish production per municipality, may be a short-term solution; hence, this option may not be fully supported by the operators in the long run. Many local residents are dependent upon the cage culture business as their primary source of family income. This strategy has more appeal with the more informed local government officials rather than the operators.

Option $Z_2$ (reduction in feeding ration) is directly related to nutrient pollution reduction. Reducing the amount of feed employed results in less nutrient loss, better water quality, and a possible increase in output. In the projection of feeding ration, the average stocking density was used among the four municipalities. Option $Z_3$ (reduction in stocking density) also assumes a proportional reduction in the feeding ration employed. This strategy may result in decreased nutrient loss or better water quality, which in turn may lead to an improvement in fish productivity. Based on the results of Chapter 5, Options $Z_2$ and $Z_3$ are cost saving strategies that operators' could employ to augment their net revenue. These two pollution control strategies are assumed to improve yield.

The data from the 2002 fish cage operator survey served as the baseline level. The net revenue per cage per year was calculated per municipality. The number of cages in 2002 was assumed to be equal to the 2001 data.

Tables 30, 31, and 32 show the comparisons of net revenue of fish production per cage per year and cost or incentive per year of implementing Options $Z_1$, $Z_2$ and $Z_3$ for reducing the nutrient pollution at 5 %, 10 %, and 15 % in the four municipalities. Option $Z_1$ incurs costs to operators in all the municipalities. Option $Z_2$ and $Z_3$ are cost-saving strategies. At 5 % and 10 % reduction in nutrient loading, operators in Agoncillo are losing less money than the baseline when the three options are implemented and start to save input costs when Option $Z_2$ and $Z_3$ are employed to achieve the 15 % reduction in nutrient loading.

Based on net revenue per cage per year, reduction in feeding ration (Option $Z_2$) is suggested for the municipalities of Laurel, San Nicholas, and Talisay (except at 15 % reduction in nutrient loading) (Table 33). For the municipality of Agoncillo, reduction in stocking density (i.e. with proportional reduction in feeding ration, Option $Z_3$) is recommended. Option $Z_2$ is advised for Talisay at 5 % and 10 % reduction in nutrient loading and Option $Z_3$ at 15 % reduction in nutrient loading. Based on cost or incentive per year, Option $Z_2$ is recommended in all municipalities, expect for Agoncillo at 5 % reduction in nutrient loading and for Talisay at 15 % reduction in nutrient loading (Table 34). It should be noted that these results based on Chapter 5 model implies inefficiency, so caution is warranted for Option $Z_2$ and $Z_3$.

Table 30. Comparisons of the baseline level with Options $Z_1$, $Z_2$ and $Z_3$ at 5 % reduction in nutrient loadings in Agoncillo, Laurel, San Nicholas, and Talisay, Philippines.

| | | Municipality | | | |
|---|---|---|---|---|---|
| | | **Agoncillo** | **Laurel** | **San Nicholas** | **Talisay** |
| **Baseline**[a] | Net revenue/cage/yr [e] (PhP) | 34,873 | -17,455 | -13,108 | 23,946 |
| | No. of cages | 2,362 | 2,729 | 481 | 1,861 |
| **Option $Z_1$**[b] | Net revenue/cage/yr (PhP) | 4,093 | 26,451 | 7,565 | 82,039 |
| | Fewer cages | 235 | 368 | 48 | 185 |
| | Cost/yr [f] (PhP) | -960,513 | -9,721,811 | -361,556 | -15,153,688 |
| **Option $Z_2$**[c] | Net revenue/cage/yr (PhP) | 4,093 | 31,347 | 29,622 | 85,545 |
| | Less feed (*mt*)/yr [g] | 1,969 | 1,879 | 469 | 1,016 |
| | Cost or incentive/yr [h] (PhP) | -26,159,164 | 55,193,193 | 10,300,177 | 114,635,480 |
| **Option $Z_3$**[d] | Net revenue/cage/yr (PhP) | 24,232 | 10,665 | -9,770 | 81,616 |
| | Less SD/yr [i] | 10,956,609 | 17,152,962 | 2,231,215 | 8,632,621 |
| | Cost or incentive/yr [j] (PhP) | -25,133,635 | 29,105,180 | 1,605,752 | 107,324,747 |

[a] Source: Fish Cage Operator Survey 2002

[b] Reduction in the number of cages

[c] Reduction in feeding ration

[d] Reduction in stocking density

[e] Net revenue per cage x no. of cropping cycle per year

[f] Net revenue x total reduction in the no. of cages

[g] Reduction in feeding ration per cage x cropping cycle per year x total no. of cages

[h] Change in net revenue x cropping cycle per year x total no. of cages

[i] Reduction in stocking density (SD defined as net stocking density + mortality based on survey average) x cropping cycle per year x total no. of cages

[j] Change in net revenue x cropping cycle per year x total no. of cages

Note: negative sign denotes cost.

Table 31. Comparisons of the baseline level with Options $Z_1$, $Z_2$ and $Z_3$ at 10 % reduction in nutrient loadings in Agoncillo, Laurel, San Nicholas, and Talisay, Philippines.

| | | Municipality | | | |
|---|---|---|---|---|---|
| | | **Agoncillo** | **Laurel** | **San Nicholas** | **Talisay** |
| **Baseline**[a] | Net revenue/cage/yr [e] (PhP) | 34,873 | -17,455 | -13,108 | 23,946 |
| | No. of cages | 2,362 | 2,729 | 481 | 1,861 |
| **Option $Z_1$**[b] | Net revenue/cage/yr (PhP) | 14,378 | 34,568 | 20,148 | 87,699 |
| | Fewer cages | 469 | 735 | 96 | 369 |
| | Cost/yr [f] (PhP) | -6,747,914 | -25,410,271 | -1,925,884 | -32,398,354 |
| **Option $Z_2$**[c] | Net revenue/cage/yr (PhP) | 14,378 | 39,214 | 41,053 | 91,028 |
| | Less feed (*mt*)/yr [g] | 3,938 | 3,758 | 937 | 2,032 |
| | Cost or incentive/yr [h] (PhP) | -1,867,289 | 76,662,921 | 15,798,297 | 124,839,957 |
| **Option $Z_3$**[d] | Net revenue/cage/yr (PhP) | 33,423 | 23,224 | 6,107 | 90,565 |
| | Less SD/yr [i] | 21,913,219 | 34,305,923 | 4,462,429 | 17,265,241 |
| | Cost or incentive/yr [j] (PhP) | -3,423,543 | 63,378,517 | 2,937,470 | 123,979,196 |

[a] Source: Fish Cage Operator Survey 2002

[b] Reduction in the number of cages

[c] Reduction in feeding ration

[d] Reduction in stocking density

[e] Net revenue per cage x no. of cropping cycle per year

[f] Net revenue x total reduction in the no. of cages

[g] Reduction in feeding ration per cage x cropping cycle per year x total no. of cages

[h] Change in net revenue x cropping cycle per year x total no. of cages

[i] Reduction in stocking density (SD defined as net stocking density + mortality based on survey average) x cropping cycle per year x total no. of cages

[j] Change in net revenue x cropping cycle per year x total no. of cages

Note: negative sign denotes cost.

Table 32. Comparisons of the baseline level with Options $Z_1$, $Z_2$ and $Z_3$ at 15 % reduction in nutrient loadings in Agoncillo, Laurel, San Nicholas, and Talisay, Philippines.

| | | Municipality | | | |
|---|---|---|---|---|---|
| | | Agoncillo | Laurel | San Nicholas | Talisay |
| **Baseline**[a] | Net revenue/cage/yr [e] (PhP) | 34,873 | -17,455 | -13,108 | 23,946 |
| | No. of cages | 2,362 | 2,729 | 481 | 1,861 |
| **Option $Z_1$**[b] | Net revenue/cage/yr (PhP) | 24,476 | 42,515 | 32,539 | 93,188 |
| | Fewer cages | 704 | 1,103 | 143 | 554 |
| | Cost/yr [f] (PhP) | -17,231,613 | -46,877,564 | -4,665,544 | -51,639,551 |
| **Option $Z_2$**[c] | Net revenue/cage/yr (PhP) | 24,476 | 46,911 | 52,292 | 96,341 |
| | Less feed (*mt*)/yr [g] | 5,907 | 5,637 | 1,406 | 3,048 |
| | Cost or incentive/yr [h] (PhP) | 21,986,458 | 97,667,544 | 21,204,316 | 134,727,077 |
| **Option $Z_3$**[d] | Net revenue/cage/yr (PhP) | 42,339 | 35,615 | 21,795 | 99,346 |
| | Less SD/yr [i] | 32,869,828 | 51,458,885 | 6,693,644 | 25,897,862 |
| | Cost or incentive/yr [j] (PhP) | 17,634,943 | 97,192,216 | 10,483,321 | 140,320,017 |

[a] Source: Fish Cage Operator Survey 2002

[b] Reduction in the number of cages

[c] Reduction in feeding ration

[d] Reduction in stocking density

[e] Net revenue per cage x no. of cropping cycle per year

[f] Net revenue x total reduction in the no. of cages

[g] Reduction in feeding ration per cage x cropping cycle per year x total no. of cages

[h] Change in net revenue x cropping cycle per year x total no. of cages

[i] Reduction in stocking density (SD defined as net stocking density + mortality based on survey average) x cropping cycle per year x total no. of cages

[j] Change in net revenue x cropping cycle per year x total no. of cages

Note: negative sign denotes cost.

Table 33. Ranking of Options $Z_1$, $Z_2$ and $Z_3$ at 5 %, 10 %, and 15 % reduction in nutrient loadings in Agoncillo, Laurel, San Nicholas, and Talisay, Philippines based on net revenue per cage per year.

| Municipality | 5 % reduction in nutrient loading | | | 10 % reduction in nutrient loading | | | 15 % reduction in nutrient loading | | |
|---|---|---|---|---|---|---|---|---|---|
| | $Z_1$ | $Z_2$ | $Z_3$ | $Z_1$ | $Z_2$ | $Z_3$ | $Z_1$ | $Z_2$ | $Z_3$ |
| Agoncillo | 2.5 | 2.5 | 1 | 2.5 | 2.5 | 1 | 2.5 | 2.5 | 1 |
| Laurel | 2 | 1 | 3 | 2 | 1 | 3 | 2 | 1 | 3 |
| San Nicholas | 2 | 1 | 3 | 2 | 1 | 3 | 2 | 1 | 3 |
| Talisay | 2 | 1 | 3 | 3 | 1 | 2 | 3 | 2 | 1 |

$Z_1$ - Reduction in the number of cages

$Z_2$ - Reduction in feeding ration

$Z_3$ - Reduction in stocking density

Table 34. Ranking of Options $Z_1$, $Z_2$ and $Z_3$ at 5 %, 10 %, and 15 % reduction in nutrient loadings in Agoncillo, Laurel, San Nicholas, and Talisay, Philippines based on cost or incentive per year.

| Municipality | 5 % reduction in nutrient loading | | | 10 % reduction in nutrient loading | | | 15 % reduction in nutrient loading | | |
|---|---|---|---|---|---|---|---|---|---|
| | $Z_1$ | $Z_2$ | $Z_3$ | $Z_1$ | $Z_2$ | $Z_3$ | $Z_1$ | $Z_2$ | $Z_3$ |
| Agoncillo | 1 | 3 | 2 | 3 | 1 | 2 | 3 | 1 | 2 |
| Laurel | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 |
| San Nicholas | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 |
| Talisay | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 2 | 1 |

$Z_1$ - Reduction in the number of cages

$Z_2$ - Reduction in feeding ration

$Z_3$ - Reduction in stocking density

### Waste Management in the Fish Cage Industry

Improved waste management entails additional costs to reduce the impacts of nutrient pollution in Taal Lake fish cage industry. The options are: (1) the single-line positioning of cages (Option $Z_4$) and (2) the use of an aerator during problem situations (Option $Z_5$). Options $Z_4$ and $Z_5$ do not reduce the nutrient loadings but rather mitigate harm to fish production. The relationship of these options to fish output is difficult to measure; hence, only costs are reported. In the implementation of single-line positioning of cages, individual operators will incur additional cost of at least PhP 1,430 per cage per year. This option could result in a better water exchange inside and outside the surface area in cages. Properly spaced cages could make nutrient concentration more diluted. An estimate of PhP 176,256 per year for each municipal government is needed in implementing Option $Z_4$ (Table 35). The success of this strategy lies with the participation of all operators in Taal Lake and strong 'political will' of the LGU officials.

Table 35. Annual municipal government cost with the implementation of single-line positioning of cages (Option $Z_4$).

| **Item** | **Cost (PhP)** |
|---|---|
| Administrative and Employee Cost (Govt. labor) | 96,000 |
| Government operating expenses (GOE) | 72,960 |
| Contingency (10 % of GOE) | 7,296 |
| Total | 176,256 |

An aerator can be employed during critical condition when the dissolved oxygen level dip below the acceptable level (5 mg/L). An aerator costs about PhP 30,000 per unit and is replaced after 9 years with a salvage value of 20 % of the initial cost. An estimate of PhP 6,000 per year on operating and maintenance costs is needed. Given the high cost of this strategy, many operators are hesitant in employing this strategy. They believe that it is only applicable in ponds and not in a deep lake.

# CHAPTER 7

# SUMMARY, CONCLUSION, AND POLICY IMPLICATIONS

## Summary and Specific Findings

The major purpose of this study was to determine the cost-effectiveness of potential solutions to the nutrient pollution in Taal Lake, Philippines. The first specific objective focused on describing the nutrient pollution dynamics in the lake and the impacts on fish cage production and operators. The second specific objective focused on the evaluation and estimation of the physical efficiency in the fish cage production as influenced by the municipal jurisdictions and ownership arrangements. The third specific objective focused on the estimation of the costs of reducing the nutrient loadings from the fish cage production by reducing the number of cages, reducing the feeding ration, reducing the stocking density, and reducing the impacts of nutrient loadings on production by the introduction of single-line positioning of cages and the use of an aerator. These options were based on expert recommendations.

The study site is in Taal Lake, Batangas, Philippines, where the cage culture production of tilapia, bangus, and maliputo is one of the most important economic uses of the lake next to open water fishery and tourism (Chapter 2). The trend in production is towards increased stocking density and intensive feeding. The cage production activities are limited to the municipalities of Agoncillo, Laurel, San Nicholas, and Talisay. It was relevant that each municipality has a different management regulations towards cage culture. This situation is one of the ramifications of the Local Government Code of 1991, which placed the management of all municipal waters under the authority of municipal and city governments. The lower fees in Agoncillo and Laurel may be one of the reasons why cages are sprawling in these areas. The fish cage sprawl started in 1990s. Thereafter, fish kill occurrences began to haunt operators. After massive fish kill incidences during 1999-2001, some operators in Agoncillo and Laurel exited the industry and/or transferred productions to other municipalities. With the increased fish cage production, open water fish catch began to decrease. The initial expectation of the study was that cage production activities in the four municipalities would not vary much. However, analysis of the production data showed wide variations among operators in the four municipalities.

Implementation of national and local legislation passed to manage the lake is not strictly enforced. For example, the Fisheries Administrative Order 118 in 1975, that established the fish sanctuary area, prohibits the establishment of any structure and intensive fishery utilization; however, in 2002, it was filled with cages. Non-registration of fish cage businesses was prevalent in the four municipalities.

Another factor that influences fish cage production is the type of ownership arrangements existing in the area. The two types of ownership arrangements are: (a) an owner as the operator and (b) an owner hires a caretaker. In Taal Lake, a majority of the local residents act as caretakers of absentee owners. Local residents have the legal right to own at most 5 cages but, in general, have limited capital to finance their own fish cage business. The additional labor provided by the caretakers in tending the cages and feeding the fish is essential in reducing the physical inefficiencies in the use of inputs, specifically feed. The owners and caretakers do not share common views and perceptions about each other's role and performance.

The conceptual framework, discussed in Chapter 3, introduced the bio-economic approach to efficient allocation of inputs to produce output, linking physical inefficiency with negative externalities. Important factors of production include feeding ration, stocking density, labor, environmental factors, and the cage culture technology. In the model, operators determine the rational range of inputs used to maximize profits. This is achieved when the value of the marginal product is equal to the input price or the cost of added input. Of the different inputs employed, nutrient loss is directly related to the amount of feed used.

The focus on the fish cage industry as the main source of nutrient enrichment in the lake emphasized the inherent characteristics of the cage technology as very polluting in nature and that of the lake as a congestible, common pool resource. Externalities occur when inputs employed exceed the assimilative capacity of the cage and its surrounding environment. There is incompatibility in the lake's resource uses since operators rely on water both as an input into the production and as a place to put waste. The characteristics of the lake's uses and the water quality itself make it very costly to exclude others. Indeed, a negative feedback loop exists in the current nutrient pollution problem in Taal Lake. The use of inputs, specifically feed, results in water quality impairment, which, leads to fish kill incidences and financial losses. With the water quality impairment and increasing intensity of production, operators are prompted to increase the use inputs and extend the cropping cycle.

The current management options for reducing the nutrient loss are limited to controlling the intensity of fish cage production. With cost-effectiveness analysis, the relationship between inputs and output relative to the goal of reducing the amount of nutrient loss was discussed. Cost-effectiveness offers a practical approach of finding the lowest-cost means of accomplishing the objective.

The data used in the estimation of the fish production function were gathered through face-to-face survey interviews of 50 fish cage operators (Chapter 4). The survey process also involved community familiarization and field reconnaissance. The survey elicited information on the fish cage operations and costs, community feedback, and perceptions on the nutrient pollution problem. The data gathered served as input in the estimation of the Cobb-Douglas production function. The C-D estimation provided estimates of the production coefficients and the relative physical efficiency in the use of inputs under ownership arrangements and difference in locations.

Chapter 5 summarized the results of the fish cage operator survey. The 2002 survey revealed that the majority of the operators are married male operators having the role of caretakers. Likewise, a majority of the operators are engaged in the grow-out cage business and employ feed and stocking density beyond the recommended levels. There were variations in feeding ration employed per cage per cropping cycle and total number of existing cages, signifying different amounts of nutrient loss per location. The grower and finisher feed types are often used higher quantities than the other types. The majority of operators believed that increasing the amount of feed would result in increased harvests. Agoncillo and Laurel are expected to have the most localized effects of nutrient pollution. The use of fish medicine or anti-stress medication by operators in these two municipalities supports such claim.

The physical environment in Taal Lake also influences the productivity of the fish cage culture. Operators observe that natural food in the lake increases during the months of June to October resulting in better harvests. However, fish kill incidences occur in the months of June and July. A cropping cycle between late August and early May may be the best period to culture fish in Taal Lake.

Nutrient pollution is not the sole problem confronting operators in Taal Lake. Other pressing concerns are bad weather, fluctuating and/or low price of fish in the market, fish diseases, slack caretakers, mismanagement of waste disposal in the lake, etc. Many solutions have been proposed to address these problems. Changes in the intensity of production activities are central to the suggestions elicited through the survey. Emphasis is given to the strict implementation of municipal fishery ordinances coupled with improvements in institutional support structures, e.g. provision of credit facilities for operators.

Income of operators is very sensitive to feed cost, yield, and the price of fish. Notable in the data was high feed cost of operators in San Nicholas and low productivity exists in Laurel. Based on the production function estimated in Chapter 4, an 'owner as operator' is more rational in the use of feed and is closer to production efficiency than the 'owner hires a caretaker' arrangement. Net returns to production are not statistically different among municipalities and types of ownership arrangements based on the sampled data. In the estimation of optimal input-output of the fish cage production, it was found that the dummy variables, ownership arrangement and location (at least for Laurel), affect the physical efficiency in the culture system. The explanatory variable, labor, was not statistically significant at 10 % level. Stocking density was found to be not statistically significant; hence, the net stocking density was used in the regression. Likewise, it appears that operators are over-utilizing net stocking density relative to feeding ration. Feeding ration was statistically significant only at 12 % level. Estimation of optimal input levels using marginal analysis revealed that inputs could be reduced dramatically. Net revenue increases seven fold compared with the baseline average net return per cage per cropping cycle. However, even at the optimal level, nutrient loss is still inevitable in the current production technology.

Analysis of the cost-effectiveness of pollution reduction options shows that the reduction in feeding ration (Option $Z_2$) to achieve 5-15 % nutrient loadings is suggested for Laurel and San Nicholas operators. It was also recommended for Talisay operators, except at 15 % reduction in nutrient loadings, where reduction in stocking density (Option $Z_3$, i.e. with proportional reduction in feeding ration) is the best choice. For Agoncillo operators, Option $Z_3$ is advised, if based on net revenue of fish production per cage per year, while Option $Z_1$ is recommended at 5 % reduction in nutrient loadings and Option $Z_2$ at 10-15 % reduction in nutrient loadings, if based on cost or incentive per year. These cost-effectiveness findings are predicted on the finding that reducing inputs would increase net revenue.

## Conclusion

Externalities are inevitable with the current fish production technology, and the choice left is to accept a certain level of pollution as a trade-off for the benefits gained from use of the lake for fish cage production. Even at the optimal level of inputs and output, nutrient losses are certain. Also, the open-access problem is predictable with the inherent characteristics of the Taal Lake ecosystem. Thus, enforcement of fishery rules and regulations incurs high exclusion costs, which is undesirable to most LGUs. For this reason, exclusion through prices and transaction costs may be necessary. A change in the municipal regulations may change the unreceptive behavior of many operators towards changing to sustainable production practices. Developments in the institutional structures may lead to future technological changes in the fish production system.

Production output differs with locations and ownership arrangements. While output is influenced partly by feeding ration employed, increasing this input does not necessarily mean a corresponding increase in profits. In areas of low water quality, operators are led to stock fingerlings beyond the recommended level. It seems an irrational decision but some operators don't have much choice. There may be other pressing reasons why operators continue to practice high stocking density and feeding ration. Operators may not be fully aware of applying the marginal principle in their production. Certainly, there's a lot of uncertainty in the fish cage production. The estimated production function and the optimal input levels may not be representative of the entire Taal Lake fish cage industry. Analyses could be improved if a measure of water quality could be put into the production function.

Based on the estimated production function, owners are more rational than caretakers in the use of inputs, specifically feed. The 'owner as operator' may be a better ownership arrangement in cage production in Taal Lake than the 'owner hires a caretaker,' at least in the perspective of lower nutrient losses. However, in terms of equity or benefit distribution, local residents may be at a disadvantage if policy makers solely advocate this type of ownership arrangement.

Results show differences in the cost-effectiveness of the nutrient pollution reduction options across the four locations. The recommendations among locations may differ because of the differences in the actual practices in cage production. The reduction in feeding ration and stocking density are cost-saving options that operators could further investigate in their own production. The estimated production function did not include water quality due to its unavailability. Thus, caution for these results is warranted because in areas of low water quality, employing these two options may not result in expected harvests. Changing the location of cages may help address the problem of fish mortality. Allowing a certain area devoted to cage production to 'rest' is one possible option to look into. Practicing production on a rotation basis may be a solution to explore.

Other measures are needed to solve the problems confronting the fish cage industry. An intensive information and education campaign is needed. Caretakers may need more training on proper cage culture practices to the extent that production inefficiencies may be attributed to the operator's lack of technical know-how. The success of pollution reduction options requires LGU interventions through sound policy measures and strong political will. Environmental risk could be managed more effectively by increasing emphasis on training programs. A critical issue is the attitude of operators towards adoption of existing and new techniques in cage culture and policy changes. Continuous lake-wide research and the creation of institutional channels for better dissemination of information to operators are also necessary.

## Policy Implications

The devolution of power to the local government units has both positive and negative ramifications concerning the condition of Taal Lake and its environment. Managing the lake holistically calls for a single unified institution. The local government policies greatly influence the use of Taal Lake as an input in fish cage production. The role of operators also would be critical in addressing the institutional changes needed in the industry. Given an intensive production system in a situation of incompatible-use and a common pool resource, a community-based lake management approach is a better management strategy for recognizing the equal rights and income distribution among stakeholders.

With the high density of cages in Laurel and Agoncillo and the frequent incidences of fish killings, it is likely that more owners will exit or transfer productions in Talisay. The establishment of 'entry and exit procedures' in the four municipalities would provide LGUs with information on the status of the fish cage industry in each location.

## Limitations of the Study and Future Research Needs

The paper focused mainly on point source pollution contributed by the fish cages. Estimates of the nutrient loading rates from various sources suggest that fish cages contribute substantially more than the other non-point sources. No study has fully documented the pollution brought about by the 38 rivers draining into Taal Lake. Incorporating detailed research data on the nutrient contributions from the different non-point sources, *i.e.* watershed, agricultural run-off, industry, and household sewage, is necessary to validate the suggested pollution reduction options.

LGUs will have the final decision on the pollution reduction scenarios, weighing the choices of who shoulders the costs and whose interests count. It is also interesting to know the effects of the pollution reduction option on variables such as price levels, consumption, investment, and employment.

The contribution of the open catch fishery is also important in the general management of the Taal Lake ecosystem. Studies on the technical relationship between the growth of endemic species (e.g. *tawilis*) and tilapia and the varied levels of nutrient input loading would be useful for future studies of the effects of nutrient enrichment and tilapia dominance through fish caging on the declining harvest of *tawilis*. Knowing the lake carrying capacities for cage culture would also be useful for allocating the future expansion or limitation in the industry.

The following research questions can also be considered for future studies. The first research question is, "why do some operators continuing to invest in the cage business despite the uncertainties and risks of negative net revenue during harvests?" A study incorporating risks in the decision-making process of the operators would help address this. The second research question is, "how could one model a cooperative game between operators who are confronted with the choice of cleaning the waste collectively and continually producing the fish?" There is a need to investigate the choice of actions that operators face and model the interactions among stakeholders. The third research question is, "what are the effects of implementing the pollution reduction strategies on the productivity of fish in cages?" Knowing the feedback mechanisms of applying the pollution reduction options would be useful in evaluating their 'real' cost-effectiveness. In addition, if water quality and economic rents increase after pollution reductions are done, how can the LGUs prevent the entrance of additional operators, and more cages, into the lake?

# APPENDICES

## APPENDIX A. APPENDIX TO CHAPTER 4

***Survey Questionnaire (Translated from Tagalog)***

### COST- EFFECTIVE SOLUTION TO NUTRIENT POLLUTION ABATEMENT IN TAAL LAKE, PHILIPPINES: A CASE STUDY

### CONSENT STATEMENT

**Dear ______________________,**

*I am Arvin B. Vista, a graduate student of Michigan State University. I am conducting a study to better understand the fishing industry in Taal Lake. The information that you provide will be used to document how to improve the management of fishery in Taal Lake. The information that I collect from you and other fishermen in the area will be used to complete my M.Sc. thesis.*

Your participation in the interview will be VOLUNTARY. Your refusal to participate in or to withdraw from the study carries no penalty or loss of any benefits. This interview is estimated to last for an hour and a half. You will be asked to respond to questions related to your fishing activities in the lake. You are free to NOT ANSWER any of the questions that I will ask. The information that you provide will be kept CONFIDENTIAL and will not be released to any other entity that is not involved in the study. No one will know your answers but me, and your identity will be protected in any report based on the data. Your privacy will be protected to the maximum extent allowable by law.

If you have any questions or concerns that may be raised by participating in the study, please send us a letter through these addresses:

| | |
|---|---|
| **Mr. Arvin B. Vista**<br>**122 Mabini Street**<br>**Barangay Tala**<br>**Rizal, Laguna 4003**<br>**Telephone Number (63-49) 809 0383**<br>**E-mail: vistaarv@msu.edu** | **Dr. Patricia E. Norris**<br>**Dept. of Agricultural Economics**<br>**Michigan State University**<br>**211B Agriculture Hall**<br>**East Lansing, MI 48824**<br>**Telephone no. (517) 353-7856**<br>**E-mail: norrisp@msu.edu** |

If you have questions or concerns regarding your rights as a study participant, or are dissatisfied at any time with any aspect of this study, you may contact – anonymously, if you wish – Ashir Kumar, M.D., Chair of the University Committee on Research Involving Human Subjects (UCRIHS) by phone: (517) 355-2180, fax: (517) 432-4503, e-mail: ucrihs@msu.edu, or regular mail: 202 Olds Hall, Michigan State University, East Lansing, MI 48824.

Thank you!

Are you willing to participate? [ ] Yes [ ] No

*If yes, proceed to Section 1.*

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General instructions and reminders:

1. For each question, record only one answer. For questions with pre-coded responses, circle the interviewee's answer and then enter the pre-coded response number/letter in the blank on the right side of the questionnaire. Do not read the pre-coded responses to the respondent. If the respondent does not know an answer, enter zero (0).

2. A corresponding ID will be used for each respondent.

3. The following codes will be used for all questions.

   Coding: [77] = Not Applicable
   [88] = None

4. Do not leave any box blank, use appropriate codes for none or not applicable answers.

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CERTIFICATION

I certify on my honor that this interview was conducted by me honestly and completely and if found guilty of falsifying the interview, will be subject to forfeiture of allowances.

____________________ Date of Interview

____________________ Signature Over Printed Name of Interviewer

## SURVEY QUESTIONNAIRE FORM

### Section 1. BACKGROUND INFORMATION

*[Instruction for the interviewer: Please answer the following questions honestly]*

| | | | | |
|---|---|---|---|---|
| 1.1 Time started (hh:mm): | Q1.1 | | | AM PM |
| 1.2 Time finished (hh:mm): | Q1.2 | | | AM PM |
| 1.3 Date: | Q1.3 | | | |
| 1.4 Name of respondent: | Q1.4 | | | |
| 1.5 Age, Civil Status, Sex | Q1.5 | | | |
| 1.6 Education | Q1.6 | | | |

**Code**

1.7 Municipality/Barangay: ______________________________ Q1.7 [ ]

## SECTION 2. INFORMATION ON FISH CAGE OPERATION

2.1 *What is your role in the cage culture business?*.................... Q2.1 [ ]

Code: [1] = Owner-operator
[2] = Caretaker
[3] = Owner-operator/caretaker

(*Definition: Owner-operator/caretaker – a person who operates their own cage while at the same time serving as caretaker to absentee-owners*)

2.2 *When did you start the fish cage business?*................ Q2.2 [ ]

2.3 *How many years of experience do you have in cage operation in Taal Lake?*.................................................... Q2.3 [ ]

2.4 *How may years of experience do you have in cage operation in other area?* ..................................................... Q2.4 [ ]
*(What specific place/area?)* ______________________________

2.5 *Is your family very dependent on fish cage business, i.e. is it the primary source of income?*.......................................... Q2.5 [ ]

Code: [1] = Yes
[2] = No

*Describe why?*

______________________________________________

______________________________________________

______________________________________________

*Source of household income:*

| *Types of Livelihood Q2.6* | *Daily Income Q2.7a* | *Monthly Income Q2.7b* |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| Total (Q2.7) | | |

2.8 *Are you a member of any organization*? ............................ Q2.8 [ ]

Code: [1] = Yes, name of organization: ______________________________
[2] = No (*Proceed to question 2.11*)

2.9 *What is your position in the organization*?...................... Q2.9 [ ]

Code: [1] = President/Head
[2] = Vice President
[3] = Member
[4] = Others, specify: ______________________________

2.10 *Are you benefiting from your involvement in the organization/ cooperative?*........................................................ Q2.10 [ ]

Code: [1] = Yes
[2] = No

Describe.

______________________________________________________________________

______________________________________________________________________

______________________________________________

2.11 *What was your occupation before engaging in the fish cage operation*? ........................................................ Q2.11 [ ]

Code: [1] = Farmer
[2] = Always been a fisherman
[3] = Professional, specify: ______________________________
[4] = Others, specify: ______________________________

2.12 Do you still need to attend any training course on fish cage farming?........................................................ Q2.12 [ ]

Code: [1] = Yes, specify: ______________________________
[2] = No

## SECTION 3. INFORMATION ABOUT THE FISH CAGE STRUCTURES

3.1 *What type of fish cage business do you have?* ………………… Q3.1 [ ]

Code: [1] = Grow-out
[2] = Nursery/ hatchery
[3] = Both grow-out and nursery/hatchery

3.2 *How many fish cage units do you have in total?* ………………… Q3.2 [ ]

3.3 *What is the distance between fish cage units (m)?* ……………… Q3.3 [ ]

3.4 *What is the state of ownership of the fish cage business?* ……… Q3.4 [ ]

Code: [1] = Owned
[2] = Renting/lease
[3] = Caretaker

3.5 *What method of fish cage culture do you use in Taal Lake?* ….. Q3.5 [ ]

Code: [1] = Floating
[2] = Fixed
[3] = Submerged

3.6 *What is the typical depth of the fishnet from the surface water (m)?* …………………………………………………… Q3.6 [ ]

3.7 *What is your preferred fish cage size?* ………………………… Q3.7 [ ]

Code: [1] = 10 X 10 (100 $m^2$)
[2] = 10 X 12 (120 $m^2$)
[3] = 10 X 17 (170 $m^2$)
[4] = Other, specify: ____________________

3.8 *What is the distance of fish cages from the shoreline?* ………… Q3.8 [ ]

3.9 *For how many cropping cycles have you already used your fish cages?* …………………………………………………… Q3.9 [ ]

3.10 *For how many more cropping cycles can you use the fish cage structures?* …………………………………………………… Q3.10 [ ]

3.11 *If you will be changing your fish cage structures, what kinds of material will you be using and how much do they cost?* ........ Q3.11 [ ]

| Materials | Quantity | Price/quantity | Total | Remarks |
|---|---|---|---|---|
| Net | | | | |
| | | | | |
| | | | | |
| Bamboo | | | | |
| Nylon twine | | | | |
| | | | | |
| | | | | |
| Others: | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | TOTAL (Q3.11) | | | |

*[Instruction: If the fish cages are bought 'ready-made', proceed to Section 4.]*

3.12 *What is the type of net used in your cage (s) ?* ........................ Q3.12 [ ]

Code: [1] = # 17 (Nursery/Grow-out)
[2] = # 14 (Grow-out)
[3] = # 12 (Grow-out)
[4] = # 10 (Grow-out)

3.13 *Who built your fish cage's net structure?* ............................ Q3.13 [ ]

Code: [1] = Family labor
[2] = Hired labor (How much is paid per unit? ____________________)
[3] = Volunteer [free labor] (Other costs: ________________________)
[4] = Others, specify: ________________________________________

3.14 *Who set-up the bamboo and net structure in the lake?* .............. Q3.14 [ ]

Code: [1] = Family labor
[2] = Hired labor (How much is paid, if contractual ______, if per day _______?

If hired labor, what is the contract arrangement? Describe below:

______________________________________________________________

______________________________________________________________

3.15 *How long does it take to construct the fish cage (days)?* ......... Q3.15 [ ]

## SECTION 4. INFORMATION ABOUT THE FINGERLINGS

4.1 *How many months is the culture period?* .............................. Q4.1 [ ]

4.2 *How many cropping cycles per year?* .............................. Q4.2 [ ]

4.3 *What species do you rear in the fish cages?* .............................. Q4.3 [ ]

Code: [1] = tilapia [*Oreochromis nilotocus*]
[2] = bangus [*Chanos chanos*]
[3] = maliputo [*Caranx ignobilis*]
[4] = Other, specify: ______________________________

4.4 *If tilapia, what kind of fingerlings variety is stocked in your cages?*.............................. Q4.4 [ ]

Code: [1] = GIFT – genetically improved farmed tilapia
[2] = GMT – genetically male tilapia
[3] = Sex-reversed tilapia
[4] = Don't know

4.5 *How many fingerlings are stocked in your cage (s)?* ........... Q4.5 [ ]

*[Instruction: Summarize the respondent's answers in Questions 3.2, 3.7 and 4.5].*

| *Cage size* | *Quantity per cage* | *Number of fingerlings stocked* | *Remarks* |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| *TOTAL* | | | |

4.6 *Where do you get your fingerlings?*.............................. Q4.6 [ ]

Code: [1] = Own fish cage
[2] = Purchased from other sources, specify place (Province/ Municipality/ Institution):
______________________________
(Laguna, Bulacan, Pampanga, Nueva Ecija, Batangas)
[3] = Government (BFAR), specify office: ____________________
[4] = Others, specify: ______________________________

4.7 *What is the typical fingerling size stocked in your cage(s)?.......* Q4.7 [ ]

Code: [1] = Size 8 [5] = Size 17
[2] = Size 10 [6] = Size 20
[3] = Size 12 [7] = Size 22
[4] = Size 14

4.8 *What is the price of fingerlings per piece (depending on the size)? ..........................................................................* Q4.8 [ ]

Code: [1] = ________ [5] = ________
[2] = ________ [6] = ________
[3] = ________ [7] = ________
[4] = ________

4.9 *How do you transport the fingerlings from the source to its designated place?.........................................................* Q4.9 [ ]

Code: [1] = Placed in plastic bag with oxygen
[2] = Hauling box with agitator
[3] = Other, specify: ______________________________

Describe:

______________________________________________________________

______________________________________________________________

______________________________________________

4.10 *Estimate in percent, how many fingerlings die after stocking in cages (2- 7 days)?.................................................* Q4.10 [ ]

## SECTION 5. INFORMATION ABOUT FEED AND FEEDING MANAGEMENT

5.1 *What type of fish feeds do you use?*……………………………… Q5.1 [ ]

Code: [1] = Commercial
[2] = Natural
[3] = Home made feeds
[4] = Commercial & natural (Specify: % ____ Commercial, % _____ Natural)
[5] = Other, specify: ______________________________

5.2 *What is/are the feeding ration you use?* ………………………… Q5.2 [ ]

Code: [1] = Thrice a day, what time? ______________________
[2] = Twice a day, what time? ______________________
[3] = Once a day, what time? ______________________
[4] = Other, specify: ______________________________

5.3 *How much do you spend on feeds per cage per cropping cycle, i.e. from the first day of stocking the fingerlings & onwards?*… Q5.3 [ ]

| Feed Type | Brand | Price/bag (PhP) | Number of bags/day | Total days of feeding (or total bags used) | Cost (PhP) |
|---|---|---|---|---|---|
| Fry mash | | | | | |
| Starter Crumble | | | | | |
| Starter Pellet | | | | | |
| Grower | | | | | |
| Finisher | | | | | |
| | | | | TOTAL (Q5.3) | |

5.4 *What feeding method do you employ?* ................................. Q5.4 [ ]

Code: [1] = Hand feeding/Broadcasting
What position? [ ] Seated) [ ] Standing [ ] Bended-knee
[2] = Feed tray
[3] = Demand feeder
[4] = Automatic feed blower
[5] = Automatic feed spreader
[6] = Other, specify: ____________________

5.5 *Where do you get/buy the feeds?* ......................................... Q5.5 [ ]

Code: [1] = The financier delivers them directly to caretaker's house
[2] = Bought in local store, specify: ____________________
[3] = Through credit in local store, specify ____________________
[4] = Other, specify: ____________________

Describe the details of contract, if any:

____________________

____________________

____________________

5.6 *Does your harvest increase as you increase your feeding ration?* ......................................... Q5.6 [ ]

Code: [1] = Yes
[2] = No

5.7 *How do you decide on the amount of feeds given to the fish?* ... Q5.7 [ ]

Code: [1] = Personal knowledge/opinion
[2] = Common practice
[3] = Check fish weight/appetite by inspection
[4] = Other, specify: ____________________

5.8 *How much does it cost to transport the feeds from the store to the cages?* ......................................... Q5.8 [ ]

How do you know when fish need more food? Describe: ____________________

____________________

How you decide on feed adjustment? Describe: ____________________

____________________

When do you need to add the amount of feed given to fish? ____________________

____________________

## SECTION 6. FISH FARMING PRACTICES AND MANAGEMENT

6.1 *Where do you get the information on the recommended cultural management practices for fish cage operation?* ....................... Q6.1 [ ]

Code: [1] = Personal experience
[2] = Co-fishermen
[3] = Training programs and seminars
[4] = Government technicians
[5] = Others, specify: ____________________

6.2 *What factor(s) do you consider in selecting the site of a cage?*... Q6.2 [ ]

Code: [1] = Water depth is 6 meters or more
[2] = Water temperature is from 25 °C – 29 °C
[3] = Other, specify: ____________________
[4] = Don't know

6.3 *Who decides about the size, quantity, and other expenses of the cage operation?* ............................................... Q6.3 [ ]

Code: [1] = Owner
[2] = Caretaker
[3] = Owner and caretaker
[4] = Other, describe: ____________________

6.4 *Do you use air compressors or aerators?*.......................... Q6.4 [ ]

Code: [1] = Yes, when do you use them? ____________________
[2] = No, why? ____________________

6.5 *Do you use any vitamin/anti-stress medicine for your fish?*....... Q6.5 [ ]

Code: [1] = Yes, how much is the cost? ____________
[2] = No

| *Item* | *Age of fish* | *Frequency of application* | *Amount used* | *Price/unit* | *Total Cost* |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | TOTAL (Q6.5b) | | |

6.6 *What system of harvesting do you employ?* …………………….. Q6.6 [ ]

Code: [1] = Partial harvest
[2] = Total harvest
[3] = Selective, when fish weigh 175-225 grams
[4] = Other, specify: ______________________

6.7 *What is the mode of fish disposal?* …… ………………………….. Q6.7 [ ]

Code: [1] = Wholesale/ Direct buyer
[2] = Middlemen
[3] = Contract
[4] = Other, specify: ______________________

6.8 *If sold to a direct buyer, what is the mode of payment?* ………… Q6.8 [ ]

Code: [1] = Cash
[2] = Advance payment
[3] = Credit, describe the agreement: ______________________
[4] = Other, specify: ______________________

6.9 *Where are the "market" areas of the harvested fish??* …………. Q6.9 [ ]

Code: [1] = Metro Manila
[2] = Nearby municipalities within Batangas, specify: ____________
[3] = Within the municipality only
[4] = Other place, specify: ______________________

6.10 *What is/are the conditions of fish when they are sold in the markets?* …………………………………………………………………….. Q6.30 [ ]

Code: [1] = fresh
[2] = frozen or with ice
[3] = Other, specify: ______________________

6.11 *Is there an ice store in your municipal area?* …………………….. Q6.11 [ ]

Code: [1] = Yes
[2] = No, where do you get your ice? ______________________
Cost of ice/per block? ______________________

6.12 *How much was the total sale from your last harvest?* ………… Q6.12 [ ]

6.13 *How much is the household consumption of fish from a given cage (Kg.)?* ............................................................ Q6.13 [ ]

| Cage # | Number /kilo | Amount of Production (Kg) | Price/ Kg | Sale (PhP) (Q6.12) | Household consumption (Kg) (Q6.13) | Amount of fish that died (grow-out) |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | TOTAL | | | | |

6.14 *Do you observe any changes in the harvest size per cage area compared to previous years of operation?* ........................ Q6.14 [ ]

Code: [1] = Yes
[2] = None

*If yes, what could be the reasons behind these changes? Describe.*

________________________________________________

________________________________________________

________________________________________________

6.15 *How frequently do you change and clean the net in cages?* ...... Q6.15 [ ]

Code: [1] = Once per cropping cycle
[2] = Once per year
[3] = Other, specify: ______________________________

6.16 *How many hours are spent on changing and cleaning the nets?* Q6.16 [ ]

6.17 *How much did it cost you to clean and change the net?* .......... Q6.17 [ ]

6.18 *Where do you dispose your wastes (plastics, etc.) from cage activities?* ....................................................................... Q6.18 [ ]

Code: [1] = Collect and burned in the land.
[2] = Thrown into the water
[3] = Other, specify: ______________________________

## SECTION 7. OTHER PRODUCTION INPUTS AND EXPENSES

7.1 *What other production inputs do you employ and what are the costs incurred in these inputs?* ……………………………………… Q7.1 [ ]

| *Item* | *Quantity* | *Price* | *Cost* | *Life expectancy* | *Remarks* |
|---|---|---|---|---|---|
| *Raft* | | | | | |
| *Container* | | | | | |
| *Weighting scale* | | | | | |
| *Sinkers* | | | | | |
| *Battery/Electricity* | | | | | |
| *Gasoline and other transportation costs* | | | | | |
| *Fees (application, mayor's permit, fishery rental, plate fee, BIR)* | | | | | *Annually* |
| *Harvesting* | | | | | |
| *Marketing cost* | | | | | |
| *Others:* | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | *TOTAL (Q7.1)* | | | | |

7.2 *What is/are your source(s) of financing?* ………………………… Q7.2 [ ]

Code: [1] = Financier
[2] = Own capital, amount (PhP) ________________________________
[3] = Borrowed, amount (PhP) _______ , source: __________, interest: _______
[4] = Other, specify: ____________________________________________

7.3 *If sourced out from the financier, what is the income-sharing scheme (%)?*…………………………………………………… Q7.3 [ ]

Code: [1] = 50% to financier, 50% to caretaker
[2] = Other, specify: _______________________________________

## SECTION 8. POLLUTION PROBLEM AND FISH PRODUCTION

8.1 *What is/are the problem(s) you experience in your operation?* ............................................................ Q8.1 [ ]

Code: [1] = Bad weather, e.g. typhoon
[2] = Theft and escape of fish from the cages
[3] = Slack caretakers
[4] = Low quality fingerlings
[5] = High mortality in fingerlings
[6] = Dirty water, pollution
[7] = Dying fishes in grow-out cages
[8] = Diseases, specify: ______________________
[9] = Fluctuating and low fish price in the market
[10] = Other, specify: ______________________

8.2 *Do you observe any changes in the quality of water compared to previous years of cage operation?* Q8.2 [ ]

Code: [1] = Yes
[2] = None

*If yes, what could be the reasons behind these changes? Describe.*

______________________________________________

______________________________________________

______________________________________________

8.3 *How many times did you experience fish kill?* ........................ Q8.3 [ ]

| *Year/Month* | *Cause of Fish Kill* | *Quantity of Mortality (Kilogram)* | Remarks |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | TOTAL (Q8.3) | | |

8.4 *What measures do you employ to minimize or prevent the fish kill?* ............................................................... Q8.4 [ ]

Code: [1] = Reducing the number of cages
[2] = Removal of abandoned cages
[3] = Use medicine
[4] = Use of aerator during problem situation
[5] = Nets are routinely cleaned
[6] = Early harvesting of fishes
[7] = Others, specify: ________________________________

Describe why and how you employ such measures.

________________________________________________

________________________________________________

________________________________________________

8.5 *What can you say about the operation these days, in terms of culture period, compared with the last 5-10 years?* ............... Q8.5 [ ]

Code: [1] = Shortened
[2] = Lengthened, how many months were added in the culture period? __
[3] = The same
[4] = Other, specify: ________________________________

Describe why?

________________________________________________

________________________________________________

________________________________________________

8.6 *What do you think are reasons for such change(s)?* ............... Q8.6 [ ]

Code: [1] = Too much wasted feeds
[2] = Fish kill occurrences
[3] = High demand of fish in the market
[4] = Other, specify: ________________________________

8.7 *Who are the potential actors to solve the problem in Taal Lake?* ............................................................... Q8.7 [ ]

Code: [1] = Researchers from BFAR
[2] = Ourselves
[3] = Local Government Units
[4] = Other, specify: ____________________________________

Other comments

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

**THANK YOU FOR YOUR PATIENCE IN PROVIDING ANSWERS TO THE QUESTIONS.** In case we have additional question, we may request another interview time not to exceed 30 minutes. If you have some comments or questions, you may write to:

| | |
|---|---|
| **Mr. Arvin B. Vista**<br>**122 Mabini Street**<br>**Barangay Tala**<br>**Rizal, Laguna 4003**<br>**Telephone Number (63-49) 809 0383**<br>**E-mail: vistaarv@msu.edu** | **Dr. Patricia E. Norris**<br>**Dept. of Agricultural Economics**<br>**Michigan State University**<br>**211B Agriculture Hall**<br>**East Lansing, MI 48824**<br>**Telephone no. (517) 353-7856**<br>**E-mail: norrisp@msu.edu** |

## APPENDIX B: APPENDIX TO CHAPTER 5

Number of fingerlings during stocking and the actual number of fish harvested.

| ID no. | SD at stocking | SD mortality at stocking | Net SD | Fish Sold (kg) | Home consumption (kg) | Total Product (kg) | Actual no. of fingerlings that are harvested |
|---|---|---|---|---|---|---|---|
| | A | B | C=A-B | D | E | F=D+E | G=F/(no. of fish per kg) |
| 1 | 60,000 | 3,000 | 57,000 | 1,500 | 3 | 1,503 | 6,012 |
| 2 | 3,000[a] | 100 | 2,900 | 3,003 | 0 | 3,003 | 12,012 |
| 3 | 40,000 | 4,000 | 36,000 | 3,600 | 5 | 3,605 | 14,420 |
| 4 | 40,000 | 4,000 | 36,000 | 3,600 | 5 | 3,605 | 10,815 |
| 5 | 60,000 | 6,000 | 54,000 | 4,000 | 40 | 4,040 | 16,160 |
| 6 | 50,000 | 5,000 | 45,000 | 4,000 | 40 | 4,040 | 16,160 |
| 7 | 45,000 | 4,500 | 40,500 | 5,000 | 6 | 5,006 | 20,024 |
| 8 | 80,000 | 8,000 | 72,000 | 2,500 | 15 | 2,515 | 10,060 |
| 9 | 150,000 | 140,000 | 10,000 | 2,000 | 10 | 2,010 | 8,040 |
| 10 | 35,000 | 3,500 | 31,500 | 2,143 | 100 | 2,243 | 8,973 |
| 11 | 35,000 | 3,500 | 31,500 | 3,000 | 11 | 3,011 | 12,044 |
| 12 | 50,000 | 5,000 | 45,000 | 3,000 | 5 | 3,005 | 12,020 |
| 13 | 60,000 | 20,000 | 40,000 | 3,500 | 20 | 3,520 | 14,080 |
| 14 | 12,000 | 1,200 | 10,800 | 3,000 | 5 | 3,005 | 12,020 |
| 15 | 40,000 | 2,000 | 38,000 | 3,000 | 3 | 3,003 | 12,012 |
| 16 | 50,000 | 10,000 | 40,000 | 1,200 | 5 | 1,205 | 4,820 |
| 17 | 40,000 | 4,000 | 36,000 | 3,800 | 5 | 3,805 | 11,415 |
| 18 | 40,000 | 4,000 | 36,000 | 4,500 | 10 | 4,510 | 13,530 |
| 19 | 30,000 | 3,000 | 27,000 | 3,300 | 5 | 3,305 | 13,220 |
| 20 | 40,000 | 2,000 | 38,000 | 3,800 | 10 | 3,810 | 15,240 |
| 21 | 40,000 | 4,000 | 36,000 | 3,700 | 5 | 3,705 | 11,115 |
| 22 | 40,000 | 4,000 | 36,000 | 3,600 | 5 | 3,605 | 14,420 |
| 23 | 30,000 | 3,000 | 27,000 | 3,300 | 5 | 3,305 | 13,220 |
| 24 | 35,000 | 3,500 | 31,500 | 2,200 | 10 | 2,210 | 8,840 |
| 25 | 100,000 | 30,000 | 70,000 | 2,215 | 0 | 2,215 | 8,860 |
| 26 | 54,000 | 14,000 | 40,000 | 3,000 | 2 | 3,002 | 12,008 |
| 27 | 40,000 | 4,000 | 36,000 | 2,500 | 5 | 2,505 | 10,020 |
| 28 | 40,000 | 4,000 | 36,000 | 1,017 | 10 | 1,027 | 10,270 |
| 29 | 100,000 | 30,000 | 70,000 | 4,000 | 0 | 4,000 | 16,000 |
| 30 | 100,000 | 50,000 | 50,000 | 2,800 | 100 | 2,900 | 11,600 |
| 31 | 30,000 | 15,000 | 15,000 | 1,000 | 10 | 1,010 | 3,030 |
| 32 | 50,000 | 10,000 | 40,000 | 2,300 | 60 | 2,360 | 9,440 |
| 33 | 40,000 | 4,000 | 36,000 | 1,000 | 5 | 1,005 | 4,018 |

[a] Stocking density added to the fish left from the previous harvest

| 34 | 40,000 | 30,000 | 10,000 | 600 | 12 | 612 | 2,448 |
|---|---|---|---|---|---|---|---|
| ID no. | SD at stocking | SD mortality at stocking | Net SD | Fish Sold (kg) | Home consumption (kg) | Total Product (kg) | Actual no. of fingerlings that are harvested |
| | A | B | C=A-B | D | E | F=D+E | G=F/(no. of fish per kg) |
| 35 | 91,000 | 10,000 | 81,000 | 6,000 | 2 | 6,002 | 24,006 |
| 36 | 50,000 | 1,000 | 49,000 | 1,500 | 15 | 1,515 | 6,060 |
| 37 | 30,000 | 3,000 | 27,000 | 1,700 | 3 | 1,703 | 6,812 |
| 38 | 50,000 | 5,000 | 45,000 | 2,500 | 3 | 2,503 | 10,010 |
| 39 | 50,000 | 5,000 | 45,000 | 2,503 | 0 | 2,503 | 10,010 |
| 40 | 50,000 | 5,000 | 45,000 | 2,500 | 3 | 2,503 | 10,012 |
| 41 | 30,000 | 3,000 | 27,000 | 1,300 | 5 | 1,305 | 5,220 |
| 42 | 30,000 | 1,000 | 29,000 | 1,800 | 6 | 1,806 | 7,222 |
| 43 | 50,000 | 1,000 | 49,000 | 1,951 | 5 | 1,956 | 7,825 |
| 44 | 30,000 | 500 | 29,500 | 2,400 | 5 | 2,405 | 9,620 |
| 45 | 25,000 | 3,000 | 22,000 | 1,800 | 7 | 1,807 | 7,228 |
| 46 | 30,000 | 2,000 | 28,000 | 2,000 | 3 | 2,003 | 8,012 |
| 47 | 40,000 | 3,000 | 37,000 | 2,500 | 3 | 2,503 | 10,012 |
| 48 | 15,000[a] | 1,500 | 13,500 | 5,000 | 6 | 5,006 | 20,024 |
| 49 | 50,000 | 5,000 | 45,000 | 2,000 | 10 | 2,010 | 8,040 |
| 50 | 45,000 | 4,500 | 40,500 | 2,500 | 15 | 2,515 | 10,060 |

[a] Stocking density added to the fish left from the previous harvest.

## APPENDIX C. APPENDIX TO CHAPTER 5

### Computation of the Estimated Nutrient Input Loading Rates in 2001.

This section presents an indirect estimate of organic and inorganic N and P loading associated with wastes from the fish cages, watershed/agriculture, and the household sewage.

**Fish cages**

| | Unit | Nitrogen [a] | Phosphorus |
|---|---|---|---|
| Percentage nutrient loss into the surface water | % | 76.56 | 85.00 |
| Amount of nutrient per metric ton of feed used | kg | 47.33 | 9.00 |

[a] Amount varies with the type of feed used. The reported value is based on the average of the five feed types. Likewise, the amount of nutrient loss to the environment increases with increasing FCR.

The amount of N present per ton of feed = 1000 kg * 0.04733 kg = 47.33 kg

$N\ loss_{2001}$ $= \sum_{i=1}^{4}$ (N loss per cage per cropping cycle$_{kg}$*no. of cages $_{2001}$* no. of cropping cycle per year) $_{per\ municipality}$

$$= \frac{\begin{bmatrix}(302*2{,}362*2)+(184*2{,}729*2.71)+(353*481*2)+\\(198*1{,}861*2)\end{bmatrix}}{1000kg}$$

$= 3{,}758\ mt$ N

The amount of P present per ton of feed = 1000 kg * 0.009 kg = 9.00 kg

$P\ loss_{2001}$ $= \sum_{i=1}^{4}$ (P loss per cage per cropping cycle$_{kg}$*no. of cages $_{2001}$* no. of cropping cycle per year) $_{per\ municipality}$

$$= \frac{\begin{bmatrix}(64*2{,}362*2)+(39*2{,}729*2.71)+(75*481*2)+\\(42*1{,}861*2)\end{bmatrix}}{1000kg}$$

$= 816\ mt$ P

**Agriculture/watershed** (after Clemente and Wilson, 2000)

Assuming an average nutrient loss of 6.48 kg N per hectare per year, 0.96 kg P per hectare per year and a 10% filtration of nutrients by the watershed vegetations, the estimated total nutrient loading rates in 2001 are shown below.

$$\text{N loss}_{2001} = \frac{\frac{6.48}{\cancel{ha}/\cancel{year}}\cancel{kg}N * 0.9 * 41006\cancel{ha}}{1000\cancel{kg}/1mt}$$

$$= 239.15\ mt\ \text{N}$$

$$\text{P loss}_{2001} = \frac{\frac{0.96}{\cancel{ha}/\cancel{year}}\cancel{kg}P * 0.9 * 41006\cancel{ha}}{1000\cancel{kg}/1mt}$$

$$= 35.43\ \text{m}t\ \text{P}$$

**Household Sewage** (after Jacinto *et al.*, 1998)

A 90 % approximation of the total catchment population in 2001 (equal to 494,221) directly discharge into the system. Assuming an effluent load factor of 20 kg per person per year of BOD to estimate the household sewage input and taking the CNP ratio of the organic matter to be 190:15:1 of carbon, nitrogen and phosphate, the per capita organic carbon loading is about 21 kg per year or 1800 moles C per person per year, while the inorganic discharge associated with this load is about 9.5 moles P per person per year and 140 moles per person per year. BOD measures the ability of naturally occurring microorganisms to digest organic matter.

Using N and P estimate discharge per person per year and multiplying it with the population directly discharging into the lake, which is 494,221, we then get the following results.

$$\text{N loss}_{2001} = \frac{\frac{140}{person/year} moles * 0.9[535{,}323 + 535{,}323(0.0258)] persons * \frac{14}{mole} gN}{\left(\frac{1000g}{1kg} * \frac{1000kg}{1mt}\right)}$$

$= 968.67\ mt$ N

$$\text{P loss}_{2001} = \frac{\frac{9.5}{person/year} moles * 0.9[535{,}323 + 535{,}323(0.0258)] persons * \frac{31}{mole} gP}{\left(\frac{1000g}{1kg} * \frac{1000kg}{1mt}\right)}$$

$= 145.45\ mt$ P

Annual population growth rate

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