POLLUTION-INDUCED FISH KILLS IN BOLINAO: EFFECTS OF EXCESSIVE AQUACULTURE STRUCTURES AND OVERSTOCKING

Zenaida M. Sumalde, Karen Lou A. Francisco and Mildren Peñales

September, 2002

Comments should be sent to: Zenaida M. Sumalde, Department of Economics, College of Economics and Management, University of the Philippines Los Baños, 4031 College, Laguna, Philippines. Telephone No. (63-49) 536 2505; Fax No. (63-49)536 3641

Email: zeny@laguna.net

EEPSEA was established in May 1993 to support research and training in environmental and resource economics. Its objective is to enhance local capacity to undertake the economic analysis of environmental problems and policies. It uses a networking approach, involving courses, meetings, technical support, access to literature and opportunities for comparative research. Member countries are Thailand, Malaysia, Indonesia, the Philippines, Vietnam, Cambodia, Lao PDR, China, Papua New Guinea and Sri Lanka.

EEPSEA is supported by the International Development Research Centre (IDRC); the Swedish International Development Cooperation Agency (Sida); and the Canadian International Development Agency (CIDA).

ACKNOWLEDGEMENTS

This study was made possible through a research grant from the Economy and Environment Program for Southeast Asia (EEPSEA). Thanks to Dr. David Glover and the management of EEPSEA for their support.

Deep appreciation goes to Dr. Herminia A. Francisco, Dr. Jack Ruitenbeek and Dr. Nancy Olewiler, EEPSEA resource persons for endorsing the study; and the EEPSEA panel of experts for their suggestions and constructive crtiticism from the conceptualization towards the completion of this study. The valuable suggestions of Dr. Herminia A. Francisco on the revision and refocusing of the report are highly appreciated.

The technical advices of Dr. Perry A. Aliño and Dr. Zeny Catalan on the link between aquaculture and fishery and Dr. Ma. Lourdes SD McGlone on water quality are gratefully recognized.

Lastly, the assistance of Mercy A. Gagalac, Rusyan Jill Mamiit, Kirby Tardeo, Jun Castrence, Leilani Verceles, Glory Ranches, Mr. Florante Garcia, the enumerators, boatmen, barangay officials during the field work and water quality analysis, and the cooperation of the respondents are greatly acknowledged.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

POLLUTION-INDUCED FISH KILLS IN BOLINAO: EFFECTS OF EXCESSIVE AQUACULTURE STRUCTURES AND OVERSTOCKING

Zenaida M. Sumalde[1], Karen Lou A. Francisco[2] and Mildren Peñales[2]

EXECUTIVE SUMMARY

In the Philippines, Lingayen Gulf is one of the main producers of aquaculture. In 1992, the Lingayen Gulf Coastal Area Management Plan (LGCAMP) was formulated to regulate aquaculture industry. Bolinao was one of the municipalities surrounding the Gulf identified to be suited for coastal or marine aquaculture production. Since 1995, the number of aquaculture structures in Caquiputan Channel, Bolinao continued to increase to the point that it exceeded the carrying capacity of the Channel. Despite the ordinances, aquaculture operation was not regulated. Overstocking and excessive feeding practices have been reportedly done in the area. These practices, together with excessive number of structures, were claimed to have caused deterioration in water quality that, in turn, have caused fish kills in the area.

This study was conducted to assess the effects of excessive aquaculture structures and overstocking on water quality and aquaculture production in the area.

Water quality analysis done in the sample fishpens revealed that on the average, the DO levels in areas with aquaculture structures were below the critical value of 5 mg/L for fish growth. TSS values were also reasonably high in aquaculture sites compared to the non-aquaculture areas. Stocking density was found to be negatively correlated with DO values.

Cost and return analysis revealed that aquaculture operation is a lucrative business but the at the same time, the management practices have negative effects on the industry itself.

Aquaculture production analysis showed that stocking density tends to have negative effects on production if stocking density exceeded 1,693 frys/100 m^2 fish pen area. Water quality dummy also indicate that the poorer the water quality in terms of DO value, the more likely that production will decrease.

Among the policy implications forwarded from the results of the study include: strict enforcement of the ordinances, provision of resources for activities toward sustainable aquaculture, and enactment of legislation. Suggestions for further researches are also included.

[1] Associate Professor and Project Leader, Department of Economics, College of Economics and Management, University of the Philippines Los Baños.
[2] Research Assistants for the study.

I.0 INTRODUCTION

1.1 Background

Aquaculture or cultivating edible fish and other marine species in an artificial system in both freshwater and marine environment has been practiced to meet the growing demand for fish. Historically, aquaculture production followed the traditional extensive method with low-yielding "natural ponds" where harvests are low but sustainable over long period (Hagler, 1997 as provided in www.greenpeace.org). During those times, aquaculture has been considered a clean and environmentally friendly activity since most aquaculture operation was extensive and made use of natural feed production in water bodies (Anderson and de Silva, 1997).

However, as the world progressed and population increased, the increasing demand for food resulted into the transformation of aquaculture production from the extensive system into intensive culture. In the latter method, aquaculture species are grown using commercial feeds, fertilizer and pesticides. The problem with the intensive approach now is the practice of giving excessive feeds to the cultured fish that has been claimed to cause severe environmental damage due to water pollution it causes. For example, in Taiwan, the overuse of fertilizer and veterinary products to increase shrimp production contributed to water pollution and resulted in the decreasing resistance to disease of shrimp stock (Lin, 1989 as reported in www.unrisd.og.engindex/). Intensive aquaculture also causes environmental damages. In Ranot district in Thailand, the average ground water level in 1989 decreased from three meters to seven meters below the surface due to heavy pumping of water to supply the needs of the intensive aquaculture farms. In Taiwan and the Philippines, sinking water tables due to intensive aquaculture farming have been reported to cause sinking land levels that resulted in rice fields flooding and buildings to collapse (Chiang, Lin and Kuo, undated). In addition to environmental damage, aquaculture also poses health hazards, land conversion, social conflicts and losses in biodiversity. As such, as the world tries to supply food to the growing population, aquaculture, which is acclaimed as the fastest, growing food production and with potential of alleviating poverty, has come under increasing scrutiny (Craig, 1999). Its sustainability and impact on the environment has been questioned.

The Philippines has been listed as the world's third largest producer of aquaculture species (Craig, 1999). In Luzon, one of the main aquaculture producers is Lingayen Gulf. The industry started as early as the 1970s through the brackishwater fishponds where the semi intensive form of milkfish culture was adopted. Milkfish was given natural food. Supplemental food, in the form of breadcrumbs and commercial feeds, was given only when the natural food got exhausted. To maximize income, shrimps and other fishes entering the pond during inflow of seawater were grown out together with the milkfish (Verceles, McManus and Aliño, 2000). This was accelerated in 1980s by converting mangrove areas into fishponds. However, the prohibition of mangrove conversion to fishpond in the early 90s pushed milkfish operation to shift to the construction of fishpens and fishcages in the coastal water and rivers.

In 1992, the Lingayen Gulf Coastal Area Management Plan (LGCAMP) was formulated which provided for the identification of the zones within the Gulf area that are suitable for aquaculture. Based on the criteria, the bulk of aquaculture activity in the area is concentrated on the coastal and inland waters in four municipalities namely:

Bolinao, Anda, Dagupan and Binmaley. Along with this, the Bolinao Local Government Unit (LGU) issued an ordinance in 1995 and formulated the Coastal Development Plan (CDP) that aim to regulate aquaculture operation. As an implementing guideline of the CDP, the Municipal Fishery Ordinance (MFO) was passed in 1999 (Aliño, undated).

Despite the passage of the MFO, fishpens and fishcages have continued to be constructed and operated illegally. In 1997 and 1998 intense aquaculture operation was reported in Bolinao especially at the Caquiputan Channel. In 1997, 703 permits covering 88 hectares were issued to individuals to operate fishpens and fishcages. Although it was reported that the number of permits issued decreased to 476 in 1998, ocular inspection made by the Marine Fisheries Resource Management Program (MFRMP) revealed that in 1999 there were 797 units of fish pens and fish cages installed covering 165 hectares excluding those inaccessible by boat. These figures are beyond the estimated carrying capacity of 544 units (130 hectares) of the Caquiputan Channel (Verceles, McManus and Aliño, 2000).

In addition to the excessive number of units, the operators have been reported to practice high stocking density and overfeeding with supplemental feeds that have both direct and indirect effects. Timing and method of feeding also contributed to these effects. The milkfish fingerlings (3-5 cm) were stocked at 15 to 50 individuals/m^2, which is considered to be highly intensive or overstocking. The recommended stocking density for milkfish is 1,250 pcs – 1,500 pcs per 100 m^2 (12 – 15 pcs/m^2. In high stocking density, fish excreta is high in ammonia, nitrate and nitrite, the latter binds with the hemoglobin of blood and can be fatal (www.twnside.org.sg/title/paccct-ch.htm) thus resulting in fish kills. An increasing significance of intensive fish culture, which is now being practiced in Bolinao, has both positive and negative effects. On the positive side, leftover commercial feeds will decompose and induce the growth of algae, which can serve as feed for milkfish. The leftover feeds can also serve as extra food for non-cultured species, thus hastening their growth. For the adjoining reefs, the algal growth may also be favorable as it may be absorbed by the coral polyps thereby increasing their growth. Fish excreta and fecal wastes combined with nutrients released from the breakdown of excess feeds raises the nutrient level well above the normal. This situation creates an ideal environment for algal blooms to form that leads to reduction in dissolved oxygen (DO) or high biological oxygen demand (BOD). Up to a certain extent, high BOD and growth of algae are beneficial to non-cultured species particularly the herbivores (personal communication with Dr. Z. Catalan). However, very low DO (less than 5 mg/l) is detrimental to fish growth especially the cultured species. Accumulation of excess leftover commercial feeds also results in sedimentation resulting in water turbidity that causes deterioration in health and quality of reefs. As overcrowding due to overstocking and excess commercial feeds become intense, the condition may result in eutrophication of the water surrounding rearing pens and the bodies of water or rivers receiving aquaculture effluent. In the case of Bolinao, it has been reported that the poor water quality reached the adjacent waters of Dewey and Tambac Bay.

Results of the water quality monitoring done by the Marine Science Institute, University of the Philippines in 1999, showed that DO of the waters of Caquiputan Channel in Bolinao ranged from 2.9 - 4.5mg/l. These values were below the critical value of DO (5mg/l) for fish survival (Boyd and Lichtkoppler, 1979. The same study reported that the operators tend to overfeed the milkfish such that the excess feeds consume DO during decomposition thus compete with the oxygen needs of the growing fish. According to Rosenthal (1994), cited by Verceles, McManus and Aliño, (2000), "these factors subsequently overloads the ecosystem causing benthic enrichment, and reduction in macrofauna biomass leading to anoxic and azoic benthic conditions and the reduction of dissolved oxygen (DO)".

Excessively low DO (below 3mg/L) is already detrimental for milkfish growth. Sporadic fish kills have been periodically reported in the aquaculture areas. These occurred in specific fishpens that are usually densely constructed and with high stocking density. Unfortunately, these fish kills are considered minor and are left undocumented to serve as basis for the formulation of policy towards sustainable aquaculture.

On the positive side, the municipality is earning revenues from permits issued and renewal fees and tax payments of the operators. For example, in 1998 the aquaculture industry in Caquiputan Channel in Bolinao was reported to have contributed P2.3 M to the municipal revenue. In addition, the industry provided additional employment to the community and source of livelihood of the operators. Employment figures however, are not recorded at the municipal office since the workers are hired on as per need basis and not as regular workers in the aquaculture areas.

1.2 Statement of the Problem and Significance of the Study

The role of aquaculture in satisfying the world's protein requirements, at least in reducing the gap between supply and demand of aquatic products has been clearly identified.

In Bolinao, it is apparent that the aquaculture industry provides additional income to the municipality and the community. However, it cannot be denied that the industry contributed to the water quality deterioration in the Caquiputan Channel. For example, the water quality monitoring done by the University of the Philippines – Marine Science Institute (UP – MSI), revealed that water quality at the Caquiputan Channel, where aquaculture structures are densely constructed, has indeed deteriorated since the start of coastal aquaculture operation (Verceles, McManus and Aliño, 2000). Other identified sources of water pollution in the area include household sewage and agricultural run off, but since the intensive aquaculture operations started, water quality deteriorated further. Aquaculture operation has been claimed to reduce water quality by at least 20% (personal communication with the aquaculture technician and CRM manager of Bolinao). While the municipal government has passed ordinance to regulate the industry, the implementation of such has not been effective. It was reported that contrary to the provisions of the ordinance, permits have been granted without regard for the carrying capacity of the channel. Despite the income of the municipality from taxes, issuance of permits and renewals, no budget has been allocated for the conservation of the water quality (Verceles, McManus and Aliño 2000). As a result, the number of pens and cages that are beyond the carrying capacity coupled with excessive feeding and high stocking density have been blamed for the continuous decline of water quality of the Channel.

Government oversight on the effects of aquaculture industry is increasingly common especially on the basic problems of pollution generated by aquaculture operations. Questions related to these, include: “What are the effects of excessive structure and overstocking on water quality?", "on milkfish production?" "Shall we trade off sustainability with shortsighted benefits?" "Up to what extent is aquaculture damaging the coastal resources?" Answers to these questions are not readily available due to lack of consolidated information about such effects. There is a need for an economic analysis of the damage due to excessive aquaculture structure and overstocking. This will push the municipal officers/decision makers to allocate resources to fully enforce the implementation of the municipal fishery ordinance (MFO) which is related to sustainable aquaculture.

1.3 Objectives of the Study

In general, the study aimed to assess the effects of excessive aquaculture structures and stocking density on water quality and aquaculture production in Bolinao, Northern Philippines.

Specifically, the study was conducted to:

a. describe the current status of the aquaculture industry in Bolinao, specifically, at the Caquiputan Channel;

b. determine the level of water pollution in terms of DO and TSS in the Channel;

c. estimate the change in production due to overstocking;

d. identify the link between aquaculture production and management practices such stocking density and quantity of feeds given ; and

e. identify policy options and recommend directions for further research related to aquaculture industry.

1.4 Theoretical and Conceptual Framework

Water pollution in Lingayen Gulf has been attributed to various sources, including upstream factory wastes, salt farms, household sewage, agricultural run off, sedimentation, and lately, the intensive aquaculture industry. However, in Bolinao the main sources of pollutants in the Caquiputan Channel have been identified to include household sewage, agricultural run-off from fertilizer and chemicals, and aquaculture industry. The last is claimed to contribute at least 20% to water pollution.

Intensive aquaculture may be beneficial to fishery up to a certain extent when the excess feeds serve as additional food to capture-species. The decomposing left over feeds may provide good medium for algal bloom that serves as food to both the aquaculture and capture-species. However, excessive wastes from aquaculture species contribute to deterioration of water quality that is detrimental to fish growth. For the study, the indicators of water quality deterioration include Dissolved Oxygen (DO) and Total Suspended Solids (TSS).

Like any production function, aquaculture production in the short run is affected by the utilization of variable inputs. That is, an increase in the variable input will increase production up to a certain extent, but beyond which, further increases in the variable input will cause total production to decrease. This is explained by the law of diminishing marginal productivity of the variable input.

If there are **n** variable inputs, the production function is expressed as:

$$Y = Y(X_1, X_2, \ldots\ldots X_n)$$

In equation form, this can be expressed as:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots + \beta_n X_n$$

Where:

Y = total production
X_1 = variable input 1
X_2 = variable input 2
:
:
X_n = variable input n
α = intercept of the production function, the value of Y when all the variable inputs are set to zero
β_i = coefficients of the variable input I

To determine the level of variable input that will give maximum total production, the explanatory variables are expressed in parabolic terms. Considering one variable input, the resulting equation would be:

$$Y = \alpha + \beta_1 X_1 - \beta_2 X_1^2$$

Setting the first order condition of the equation and equating it to zero, the maximum value of variable X_1 that will give maximum output can be estimated.

1.5 Research Methodology

Place and Scope of the Study

There are four municipalities along the Lingayen Gulf that operate aquaculture industry. These are the municipalities of Bolinao, Anda, Dagupan and Binmaley in Pangasinan and Aringay in La Union. However, this study focused on the municipality of Bolinao. The area was chosen due to the intense operation of the industry in seven barangays in the Caquiputan Channel.

Unit of Analysis and Sampling Procedure

From the information obtained in November 2000, there were 120 multi-unit aquaculture operators in Bolinao. The study aimed for total enumeration of the aquaculture operators however, during the fieldwork some difficulties were encountered. Majority of the operators were not residing in Bolinao. Despite the meeting conducted by the team with the members of the Bolinao Aquaculturist Association and the assurance of the president to cooperate, some members of the Association could not be interviewed for some reasons. To remedy the problem, letters and survey-questionnaires were sent to the members of the Association through the CRM officer. However, not all the questionnaires were returned or recovered. After going through the filled-in questionnaires only 34 were found to be complete and considered in the analysis. However, sample fish pens/cages (two units per barangays) were chosen to get sample for water quality. These fish pens/fishcages were chosen based on the willingness of the owners to cooperate with the study.

Variables Collected and Methods of Data Collection

The study used both primary and secondary information. Primary information included the following:

a. For the fish pen/cage operators. Socio economic characteristics, information about fish pen/cage operation including number and size of fish pens/cages, aquaculture practices, production and expenses, problems related to aquaculture operations and related information were obtained from the sample operators using interview schedule.

b. Water quality assessment was conducted with the help of the UP-MSI technical group. Samples of water were taken from the fish pens and fish cages of the sample aquaculture operators, stations 200 meters away from the structures and a barangay without aquaculture structures. Samples were taken using the Niskin sampler three times a day for four months to determine the effect of the growth of fish on water quality. Water quality analysis was done at the UP-MSI Laboratory.

c. Key informants survey was also done to get qualitative information related to aquaculture industry in the area.

Secondary information related to aquaculture operations, water quality studies, fishery guidelines and other information were gathered from various sources.

Aquaculture Production Analysis

The production function for aquaculture production is expressed as:

$$Ya = Y(SD, F, WD)$$

Where: Ya = aquaculture production (kg per 100 m^2 area)
SD = stocking density (pcs per 100 m^2)
F = quantity of feeds per production cycle (bags per100 m^2 area)
WD = water quality dummy
1 if DO level inside the pen is =< 4mg/L
0 if DO level inside the pen is > 4mg/L

To determine the effect of overstocking and excessive feeding on production, square values of SD and F were included in the equation.

In equation form, this is expressed as:

$$Ya = \alpha + \beta_1 SD - \beta_2 SD^2 + \beta_3 F - \beta_4 F^2 - B_5 WD$$

The negative signs of the coefficients for SD^2 and F^2 was expected since it is hypothesized that there are levels of stocking density and amount of feeds where total production is maximum, beyond which, production will decrease.

The stocking density that will give maximum production was estimated by getting the first order condition of the equation and equating it to zero. This is expressed as:

$$\delta Y / \delta SD = O$$

To determine the effect of water quality, dummy was included in the equation. It was hypothesized that if the undesirable situation exists, that is, DO level =< 4mg/L, milkfish production is likely to decrease and vice versa. As an intercept shifter, if DO =<4 mg/L, the intercept of the production function will be $\alpha - \beta 5WD$.

Correlation between stocking density and DO was computed to determine the relationship between the two variables.

2.0 DESCRIPTION AND STATUS OF AQUACULTURE OPERATION IN BOLINAO

2.1 Background

Aquaculture operation in Lingayen Gulf started sometime in 1970s. During that time operation was through the semi-intensive brackish water fishponds where cultured fish were given natural food (lab-lab) and supplementary food in the form of breadcrumbs and commercial feeds were given only when the natural food gets exhausted (Verceles, McManus and Aliňo, 2000). To maximize income, shrimps and other fishes entering the pond during the inflow of water were grown out together with the milkfish. Due to increase in demand for milkfish, coupled with the desire to earn higher income, aquaculture operation was accelerated in 1980s by converting mangrove areas into fishponds. However, similar with other aquaculture sites in the Philippines conversion grew rapidly resulting in depletion of mangrove areas, thus, in 1995, mangrove conversion was prohibited. This policy pushed aquaculture operation to shift to the construction of fishpens and fishcages in coastal marine waters and rivers.

Prior to the prohibition of mangrove conversion, the Lingayen Gulf Coastal Area Management Plan (LGCAMP) was formulated. The plan provided for the identification of the zones within the Gulf area that are suitable for aquaculture. Based on the criteria and guidelines set for aquaculture operation, four municipalities namely: Anda, Binmaley, Bolinao and Dagupan were identified as suitable areas. However, aquaculture operation in Bolinao is the one being closely monitored since 1995 partly because of the presence of the UP-MSI Marine Laboratory in the area.

On October 5, 1995, Bolinao LGU issued an ordinance aimed to regulate the establishment and construction of fishpens and fishcages in the municipal water and issued permits for their operation. It was in 1997 when aquaculture was reported to be intensified in the area. It was also in this year when the LGU of Bolinao formed the technical committee composed of representatives from the local government, non-government organization (NGO), the University of the Philippines Marine Science Institute (UP-MSI), fishers and residents to formulate the ten-year (1997 – 2007 Coastal Development Plan (CDP) of Bolinao. In fact, “Bolinao was the first municipality in the Philippines to have formulated a CDP in a community-based and participatory manner” (Jacinto, 2002). The CDP contained the technical considerations for sustainable management of fishpens and fishcages and also designated areas for fishpens and fish cage operations. As an implementing guideline of the CDP, the Municipal Fishery Ordinance (MFO) was passed and finally approved in 1999 (PDI, Feb. 6, 2002).

The MFO classifies the waters of Bolinao into four zones namely: eco-tourism (Zone 1); multiple-use zone (Zone II); fishery management (Zone III); and navigational zone (Zone IV). Aquaculture is specified under the multiple-use zone covering nine (9) barangays (villages) along the Caquiputan Channel. The maximum size of fishpens and fishcages and distance between them are also specified in the plan. (Fishery Ordinance No. 01 Series of1999, Article II, Section 7).

2.2 Number of Fish pen/Fish cage Structures

Despite the regulation, fish pens and fish cages have continued to be constructed and operated both legally and illegally. From 242 fish pen units listed at the Coastal Resource Management (CRM) Office during the start of coastal aquaculture in 1995, the number of units continuously increased. In 1997, 703 permits covering 88 ha were reportedly issued by the municipality. However, ocular survey reported that there were 1076 units constructed during this time, the figures excluded those not accessible by boat. Although it was reported in 1998 that the number of permits issued decreased to 476, ocular inspection done by the MFRMP revealed that in 1999 there were actually 797 units of fish pens and fish cages installed covering 165 hectares. These figures exceeded the carrying capacity of 544 units (130 hectares) estimated for the Caquiputan Channel (Aliño, undated). The number continued to increase so that in 2000 and 2001, there were already 993 and 1170 structures, respectively It should be noted that in most of the periods, the number of permits issued was way below the actual figure in ocular survey or inspection made, an indication that indeed there were illegally constructed structures (Table 1). Based on the records gathered from the CRM office of Bolinao, the maximum number of structures that an operator registered for 2000 – 2001 was 10 units. This was already beyond the provision in the municipal fishery ordinance of five units per operator.

Compared with other aquaculture municipalities around Lingayen Gulf, Pangasinan, it was reported that in 2001, Bolinao had the highest number of fish pens/cages of about 1170 units, Dagupan with 1139 units and Aringay, La Union with 561 units. However, report of MFRMP study indicated that compared to the two other municipalities Bolinao has the lowest density of 32 units/sq km, Aringay and Dagupan had intensity of 432 units/sq km and 325units/sq. km, respectively. The report also indicated that there were frequent fish kills in the two denser municipalities. However, these fish kills maybe minor such that it never reached nationwide attention compared to the recent one that hit Bolinao. Also as indicated earlier, Bolinao is more closely monitored such that whatever happen in the area it will be caught by media. In fact, it was reported that since 1997, there were minor fish kills in Bolinao but not enough

Table 1. Number of aquaculture structures in Bolinao, 1995 – 2001.

YEAR	NUMBER OF STRUCTURE
1995 [a]	242
1997 [a]	1076 (ocular survey); 703 (permits officially issued)
1998 [a]	476 (permits officially issued)
1999 [b]	797 (ocular survey)
2000	993[c] (MFRMP, 2000); 371[d] (permits officially issued)
2001 [b]	1170 (AFMA-DMEQCMA study)
January 2002 [e]	1067 (LGCAMC physical count); 621 (permits officially issued)

[a] Verceles, Macmanus and Aliño, 2000
[b] MFRMP (on going study)
[c] AFMA-DMEQCMA (on going study)
[d] CRM office, Bolinao
[e] PDI, Feb. 9, 2002.

enough to make a dent on the profit of operators (PDI, February 6, 2002). The relatively low density in Bolinao maybe misleading since the estimates were based on the total area of the municipal water and not on the area where the fishpens and fishcages were actually constructed and are highly concentrated. Take note that fishpens are installed only in shallower parts near the shore hence getting the density based on the total area of the channel may mask the real picture. As indicated earlier, the aquaculture operation had exceeded the biological carrying capacity of the Caquiputan Channel.

3.0 WATER QUALITY ANALYSIS

Generally, there are eight parameters used to test water quality. This includes the following: temperature, pH, salinity, turbidity, total suspended solids (TSS), dissolved oxygen (DO), Chlorophyll-a, and fecal coliform bacteria. The parameters that are of interest in this study are *Dissolved Oxygen* and *Total Suspended Solids* due to their importance on the growth of aquatic and marine species.

Four aquaculture barangays (Luciente 2, Luna, Tara and Pilar) in Bolinao were chosen to be the sample areas. Barangay Victory, which does not have aquaculture structures, served as the control site. In each barangay, designated fish pens or fish cages (2 each), as well as a designated point "outside" (~200 meters away from the aquaculture structures) were monitored for four months. This means three stations for each barangay except for Tara, which has five points (two each for fish pens and fish cages, and an outside station). Corresponding codes were assigned for the sample points (Table 2). Sampling was done three times a day: early morning (5:20 – 9:00 AM); noontime (11:00 AM – 3:00 PM); and late afternoon (3:20 – 7:00 PM).

Water samples were obtained, depending on the station's depth, using a Niskin sampler. About 500 ml of each water sample was filtered through a filter paper aided by a pump to obtain the TSS. Part of the water sample was placed in two DO bottles to determine its DO value. Water samples were analyzed for the DO and TSS values at the UP-MSI Marine Laboratory. Data presented here are results of the analysis for DO and TSS for July, August, September and December.

3.1 Dissolved Oxygen (DO)

This is a universal and critical indicator of the presence and health of aquatic life in a body of water. A high DO value means that there is no oxygen demanding stresses present, thus, the aquatic life there can be considered of "good health". A low DO value, on the other hand, means that stress-inducing conditions are occurring. There are two processes in which oxygen is continually being introduced into the water column: through simple re-aeration (mechanical agitation) and photosynthesis. Aside from this, oxygen is constantly diffusing into the water at the air-sea interface. The amount of DO in the water is also dependent on several other factors such as temperature, water turbulence, atmospheric pressure and the presence of oxygen-demanding compounds and organisms.

Table 2. Number and station codes for water quality study, by barangay, Bolinao, Pangasinan, 2001.

BARANGAY	STATION CODE			TOTAL
	Fish pen	Fish cage	Outside of (or without) aquaculture structure	
Luna	LUN1 LUN2		LUNO	3
Luciente	LCT1 LCT2		LCOT	3
Tara	TAR1 TAR2	TRC1 TRC2	TROT	5
Pilar	PLR1 PLR2		PLOT	3
Victory (non aquaculture barangay)			VICT1 VICT2	2
TOTAL	8	2	6	16

DO by time of sampling and sampling month

Results of the water quality analysis showed varying levels of DO throughout the day and across barangays and stations. On the average, low DO values were observed during the early part of the day, increasing towards the late afternoon (Table 3). This could be due to the fact that at night and early morning, respiration dominates, thus consuming most of the dissolved oxygen present in the water. DO level steadily decline during the night, and is thus lowest just before dawn. All the sampling months showed this trend (except for September), with most of them attaining a value higher than 5mg/L during the late afternoon. According to Boyd and Lichtkoppler (1979), 5 mg/L is the amount of oxygen that is needed by a fish in order to attain normal growth. A value lower than this is already stressful to most vertebrates and causes mortality to some invertebrates. In fact, at a DO value of <1.0mg/L, milkfish already stops feeding and continues only when the DO is maintained at >3.0mg/L (Chiu et al. 1986).

By month, DO values on the average were found to be relatively highest during August (Table 3.), and lowest during December (Dec < Sept < July < August). This trend could be due to several factors such as weather condition, age of fish culture, occurrence of fish kills in some fish pens, and possibly human errors. The onset of rains[1] in most of the sampling period (particularly in August and September) must have also affected the DO values obtained.

[1] the onset of typhoons during the latter part September till November delayed the sampling period for two months

DO by sampling station (inside and outside of the structure, and without aquaculture structures)

Analyzing the values obtained during the sampling period, one could see a striking difference between the average DO values inside the fish pen/fish cage and those 200 meters away from the structure. The DO values obtained outside the structures were found to be significantly higher than those of the inside (Table 3 and Figure 1). It appears that wastes from aquaculture have minimal or no effect at all outside the structure. The reason for this is that since they were about 200 meters away from other structures, the effect of aquaculture on its water quality were little or not felt. This implies that there is "confinement" of the wastes inside the structures and if ever wastes are carried outside these are diluted by the freely and continuously flow of water at the outside station (no impeding structures). The average DO value inside the structure did not even reach the critical 5mg/L value for DO through out the sampling period, indicating the high DO demand of fishes. As for the outside station, DO level was able to reach the critical value of 5mg/L only for the months of July and August. The low DO value during September, may be attributed to the 1-meter decrease in water level during the noontime sampling time at Luciente 2 and Luna. Waters at this level could have high temperatures, decreasing the solubility of oxygen, and thus accounting for low DO. In December, the occurrence of fish kills in some of the stations was evidence of the low DO during this month and could have also influenced the outside stations. This was marked with whitish water and a large number of dead fish (mostly small pufferfish) floating in and out of the pen. In fact, it was during this month where the lowest DO values were obtained among all of the sampling months.

Comparing the DO values inside and outside the structure, with those without aquaculture operations showed that the overall average DO value for all sampling months in the latter was higher than those from both the inside and outside stations (Table 3). Moreover, it was found to be beyond the critical value for DO or nearing that value for all the sampling months, an indication that indeed, aquaculture operation affects water quality. Among all the sampling months, the average DO in August was found to be the highest, which could be attributed to the varying weather conditions that took place, ranging from calm and sunny to rainy and windy, brought about by the monsoons. The wind in some of these stations could have accounted for the increase in DO as it can allow the 're-introduction' of oxygen into the water through mechanical agitation.

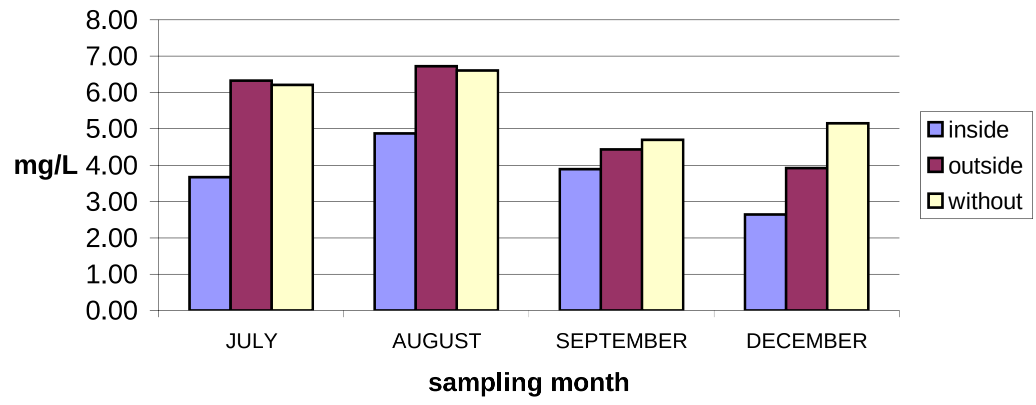
3.2 Total Suspended Solids (TSS)

TSS are solids that are found "suspended" in a water column, and can be trapped by a filter. The mineral constituents of these solids can be organic or inorganic by nature, sources of which can be silt brought about by soil erosion, domestic and industrial waste discharge, plankton, excessive algal growth, and decaying plant and animal matter. High presence of this in an aquatic ecosystem can cause several problems for both the aquatic environment and its organisms. Content of some solids (i.e. pesticides and other industrial wastes) can cause great damage to the physiology of the fish. These suspended solids can clog fish gills, reduce growth rates, decrease resistance to disease, and prevent egg and larval development (possibly through suffocation) (Mitchell and Stapp, 1992; GREEN Hands-On Center website). Also, it provides a place for harmful microorganisms (i.e. bacteria) to live on and breed.

Table 3. Average DO values (mg/L) inside and outside of (or without) structures, by month and time of the day, July, August, September and December 2001.

MONTH/TIME OF SAMPLING	INSIDE THE STRUCTURE	OUTSIDE OF THE STRUCTURE	WITHOUT STRUCTURE	ALL
July				
Early morning	2.99	6.00	5.94	4.11
Noontime	3.73	5.96	5.61	4.14
Late afternoon	4.31	7.03	7.08	5.33
Average	**3.68**	**6.33**	**6.21**	***4.53***
August				
Early morning	3.73	5.31	5.72	4.37
Noontime	5.18	7.47	7.08	5.99
Late afternoon	5.73	7.41	7.05	6.31
Average	**4.88**	**6.73**	**6.61**	***5.56***
September				
Early morning	3.00	2.86	1.34	2.66
Noontime	4.53	5.55	5.97	4.96
Late Afternoon	4.12	4.88	6.80	4.65
Average	**3.88**	**4.43**	**4.70**	***4.09***
December				
Early morning	1.98	2.68	4.43	2.46
Noontime	2.80	4.15	5.28	3.50
Late Afternoon	3.16	4.92	5.75	3.92
Average	**2.65**	**3.92**	**5.15**	***3.29***
For Four Months				
Early morning	2.91	4.30	4.36	3.46
Noontime	3.93	5.78	5.98	4.65
Late afternoon	4.33	6.06	6.67	5.05
Average	**3.72**	**5.38**	**5.67**	***4.39***
Overall Average	3.76	5.36	5.67	4.37

Figure 1 Average DO obtained inside and outside, and without aquaculture



Aside from these, higher amount of suspended solids can greatly reduce the feeding activity of fishes. High amount of suspended solids in the water can block the sunlight, limit plant, algal and plankton growth, and thus reduce the food supply of most fishes. It also reduces the visibility of the water, preventing predators to see and catch their prey.

TSS is directly proportional to turbidity. A high TSS value means that the water is extremely turbid. This can lead to a low DO value due to reduced photosynthetic activity of plants. Chemically, the relationship can be written as:

$$CO_2 + H_20 \xrightarrow{\text{light}} (CH_2O)_n + O_2$$

The reduction of light will also cause some of the bottom-dwelling plants to die. The decomposition of these plants will further reduce oxygen due to bacterial action that consumes oxygen. As TSS and turbidity increases, DO level decreases and eventually leads to the occurrence of fish kills.

Another consequence of the presence of high amount of TSS is the increase in water temperature caused by the absorbance of heat (from sunlight) by the suspended solids (Mitchell and Stapp, 1992; KanCRN website). Dissolved oxygen and temperature have an inverse relationship. Thus, when the water temperature becomes high, the dissolved oxygen in the water becomes less soluble. Most aquatic organisms are affected directly by temperature levels. Milkfishes in tropical waters require optimum temperatures of 25-32°C and <32ppt (Boyd and Lichtkoppler, 1979).

TSS by time of sampling and sampling month

In general, average TSS values were higher in stations inside aquaculture structure than those outside or without aquaculture structures except for afternoon sampling in July and December (Table 4). This may have been due to the leftover feeds and wastes from milkfish culture. It was also observed that TSS increases by time of day, that is, the values were higher during the afternoon sampling, perhaps due to the accumulation of wastes from the cultured fish. Among all the months, December was observed to have the highest TSS values and, except for the non-aquaculture barangay, exceeded the critical limit of 13 mg/L on the average. This may be due to high quantity of feeds given as the fish grew older but are left unconsumed. An increase in TSS can be correlated to a decrease in DO, especially if it exceeds the critical value for TSS (13mg/L) set for aquaculture . Other factor that can influence the amount of suspended solids in the water column include the occurrence of rain, leading to siltation.

Table 4. Average TSS values (mg/L) inside and outside of (or without) structure, Bolinao, Pangasinan, July, August, September and December 2001

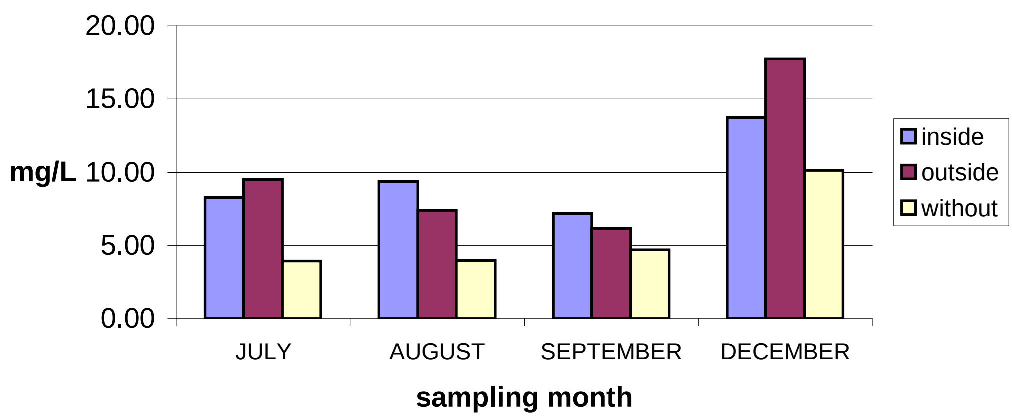
MONTH/TIME OF SAMPLING	INSIDE THE STRUCTURE	OUTSIDE OF THE STRUCTURE	WITHOUT STRUCTURE	ALL
July				
Early morning	5.58	6.40	**2.20**	5.25
Noontime	10.57	5.30	**4.95**	8.55
Late afternoon	8.64	16.88	**4.65**	10.20
Average	**8.26**	**9.53**	**3.93**	**8.00**
August				
Early morning	9.17	7.15	**3.80**	7.99
Noontime	6.50	7.35	**3.55**	6.34
Late afternoon	12.45	7.73	**4.60**	10.29
Average	**9.37**	**7.41**	**3.98**	**8.21**
September				
Early morning	4.90	3.67	3.55	4.32
Noontime	7.17	7.00	3.45	6.66
Late afternoon	9.45	7.78	7.15	8.74
Average	**7.17**	**6.15**	**4.72**	**6.57**
December				
Early morning	7.64	8.55	3.70	7.38
Noontime	18.78	21.13	2.80	17.37
Late Afternoon	14.83	23.60	23.85	18.15
Average	**13.75**	**17.76**	**10.12**	**14.30**
For Four Months				
Early morning	6.38	6.64	3.31	6.01
Noontime	10.76	10.19	3.69	9.73
Late Afternoon	11.34	13.99	10.06	11.85
Average	**9.49**	**10.28**	**5.69**	**9.20**
Overall Average	**9.61**	**10.22**	5.69	**9.26**

TSS values by sampling station

As mentioned earlier, average TSS values were found to be higher inside the aquaculture structures than outside or 200 meters away from it during the months of August and September (Figure 2). This may be due to the feeds and wastes that could have accumulated inside the structure, building up the amount of suspended solids in the water column. As mentioned before, weather condition could also have some effect on the TSS value. Rain that occurred during most of the sampling time in August could have resulted in high siltation that was manifested by flood-like water and could have influenced the TSS value. Such is the case with LUNO, with TSS values of 12.3mg/L value, which may be attributed to the rain that occurred early in the morning during the sampling period.

TSS values obtained during the month of December were the highest among all the sampling months, possibly contributing to fish kills and influencing not only the water quality inside the aquaculture structure but outside the structure as well. In fact, some of the stations outside the aquaculture structures had TSS values greater than 13mg/L during this month. This could have influenced the average values obtained during this month, wherein a higher average TSS value was obtained outside of the structure rather than inside the aquaculture structures. The TSS values during this month were significantly higher especially during noon and late PM where average values on all the sampling stations exceeded the critical value of 13mg/L. High value of TSS was correlated with very low average DO values (Figure 1), indicating that an increase in TSS can lead to a decrease in DO since the former decreases photosynthetic activities and increases water temperature. As for the non aquaculture barangay, average TSS values obtained during the sampling months were significantly lower than those with aquaculture structures (Figure 2). This could be attributed to its huge distance from the shore making it less prone to heavy siltation, and may be because there are no aquaculture structures in the area.

Figure 2. Average TSS obtained inside and outside, and without aquaculture

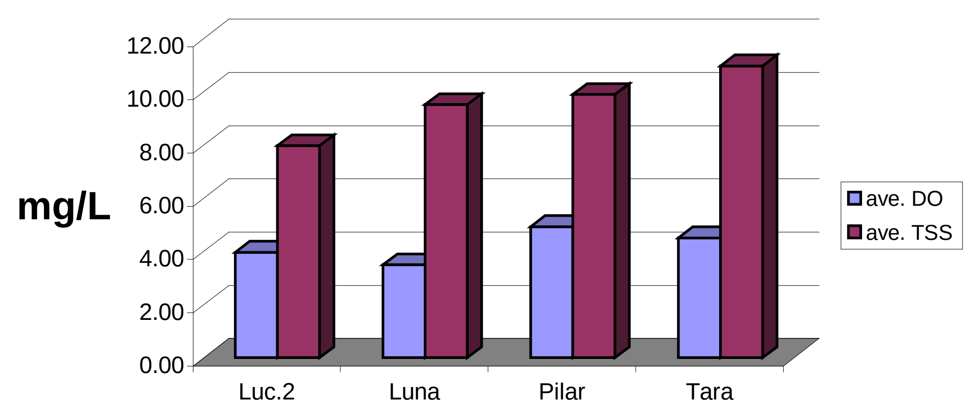


3.3 Water quality and number of aquaculture structures

Based on the records at the CRM office of Bolinao, there were about 70 aquaculture structures in Luciente 2, 36 units in Tara, 23 units in Luna, and 22 units in Pilar for the year 2000-2001. It is hypothesized that the greater the number of structures in an area, the lower the DO value (and possibly the higher TSS) since it is more congested, thus more structures contributing more wastes and lowering the water quality of that area. In addition, congestion restricts the flow of water thus, limiting the inflow of new oxygen-rich water. Luciente 2 is considered as an area that is highly impacted by aquaculture activities. But in spite of this, it only ranked 2nd to the lowest (Luna) in terms of DO values during the whole sampling period. However, reports in light of the February 2002 fish kill event revealed that there were around 353 units in Luciente 2 where the massive fish kill started. Luna obtained an average DO value of 3.49 mg/L, which is below the critical value. In fact, except for the control barangay, average DO values in most of the sampling stations throughout the sampling period did not reach 5 mg/L (Figure 3).

The relatively lower DO value in Luna compared to Luciente 2 could have been attributed to mismanagement. One of the sample fish pens in this barangay had 74,000 stocks (excessive compared to the 50,000 – 60,000 stocks recommended for a 4000 m^2 fish pen) that were already at the 4th month of growth and ready to be harvested. However, the operator added 75,000 new frys thus, increasing the load of the fish pen to 149,000 fishes. This resulted in overcrowding and competition of space and eventually depleting the oxygen level inside the pen. As a result, the operator suffered from 25,000 mortality of the new stock. In the case of the other sample fish pen, the fishes were newly harvested, but the operator practiced cleaning the net on the site instead of removing and hauling it to the shore for washing. This contributed also to wastes that resulted in low DO and high TSS values.

Figure 3. Average DO and TSS values per site



For TSS, sampling points in Tara recorded to have the highest values 10.96 mg/L. This was followed by Pilar (9.90 mg/L), Luna (9.51mg/L), then Luciente 2 (7.97 mg/L). Tara obtained the highest TSS value primarily because of its location where flushing rate and current flow is strong. High turbidity is often observed in these areas, especially where substantial inputs of silt and fine-grained particles from erosion-prone areas exist (Maaliw et al., 1989). It was surprising though that sampling points from barangay Pilar got higher average TSS value than Luna and Luciente 2 given that it was low impacted by aquaculture activities. This may be due to the rains that occurred during most of the sampling time, causing heavy siltation. All of the aquaculture stations however, obtained an average TSS value below the critical limit of 13 mg/L.

It should be noted however that the records of the municipal office do not give the actual number of structures present per area. Ocular inspection showed greater number of aquaculture structures than that recorded. For example, Luciente 2 was reported to have 353 structures during the massive fish kill last February 2002 but only 70 units were recorded at the CRM office.

3.4 Stocking Density and Water Quality

Another factor that affect water quality is stocking density. Too many fishes occupying a given confined area, like fish pen and fish cage, lessen the movement of fish thereby resulting in low oxygen. Overcrowding due to high stocking density also result in excessive excretion of fish wastes including ammonia, nitrate and nitrite, the last binding with hemoglobin in the blood and probably causing fish kills.

The stocking density recommended by INTAQ, 2000 for a 4000 m^2 fish pen ranges from 50,000 – 60,000 frys or 1,250 – 1,500 frys per 100 m^2. In the water quality sampling areas, the sizes of fish pens varied in size hence, stocking density. However, except for the sampling points in Pilar, the stocking densities in the sample fish pen structures were above the recommended values. Highest stocking densities were recorded for both the sample fish pens in Luna. One of the sample structures in this barangay even practiced double stocking, that is, at the 4th month of the first stock (74,000 frys in a 4000 m^2 fish pen) new stock of 75,000 were added. As a result, 25,000 of the new stock died.

Result of the correlation analysis showed negative relationship between stocking density and DO level. This was manifested by correlation value of –0.81 indicating high and negative relationship between the two variables. This means to say that as stocking density increases DO level decreases. In Pilar, both the sample fish pen structures followed the recommended stocking density and had relatively higher DO levels compared with the other sample sites (Table 5). Nevertheless, the DO levels in both sampling points were below the critical value of 5mg/L. The fish cage samples in Tara, were also within the recommended stocking density and were recorded to have higher DO levels, with one exceeding the critical limit. This may be attributed to the low stocking density and location of fish cages wherein the structures are situated in deeper water, hence wastes are diluted by water flows. It was also evident that although the DO levels in sampling points 200 meters away from the fish pen structures were higher than those samples taken inside the aquaculture structures, the values were still below 5mg/L. The trend showed positive correlation between the DO values inside the aquaculture structures and the DO values outside the structure. This implies that if the DO levels inside the aquaculture structures decline further, the water body closer to it will also suffer from low DO level.

For the non-aquaculture barangay, the DO levels were higher compared with those in the aquaculture barangays. This suggests that the presence of aquaculture operation in the area affected the DO level and, consequently, coastal water quality.

From the foregoing discussions, it appears that there are indications of deteriorating water quality due to mismanaged aquaculture operation, specifically overstocking. Although poor water quality are normally confined within the aquaculture structures, if the situation gets worse, adjacent water bodies would also suffer from water quality deterioration.

Table 5. Stocking density and DO levels in different sampling points, aquaculture and non aquaculture areas, Bolinao, Pangasinan, 2001

SAMPLING POINT	AREA (m^2)	STOCKING DENSITY ($pc/100m^2$)*	DO LEVEL (mg/L)				
			July	Aug.	Sept.	Dec.	Ave.
LCT1	1,600	1563	3.51	4.84	3.15	2.46	3.49
LCT2	2,800	1786	4.69	4.57	2.89	2.09	3.56
LCTOT	**	**	6.71	6.58	3.35	2.66	4.83
LUN1	4,000	1850	2.88	4.47	3.51	1.71	3.14
LUN2	2,000	2250	2.98	2.58	3.03	1.53	2.53
LUNO	**	**	6.87	6.46	3.07	2.75	4.79
PLR1	2,800	1250	4.03	5.77	4.12	3.74	4.41
PLR2	4,000	1500	3.44	6.02	4.84	3.61	4.48
PLOT	**	**	5.68	6.92	5.68	5.31	5.90
TAR1	1,200	1667	2.99	5.02	4.54	2.68	3.81
TAR2	1,600	2188	1.06	4.02	4.22	2.05	2.84
TRC1(cage)***	3,000cum	1333	4.48	5,17	4.95	2.85	4.36
TRC2(cage)***	4,000cum	1575	4.66	6.33	6.24	4.01	5.31
TROT	**	**	6.05	6.96	7.0	4.95	6.24
VICT1	non aquaculture	non aquaculture	6.46	6.51	4.91	5.39	5.82
VICT2	barangay	barangay	5.95	6.71	4.50	4.91	5.52
Correlation r between stocking density and average DO level was -0.81.							

Note:

* recommended stocking density for fish pen is 1250 – 1500 $pc/100\ m^2$

** sampling point in each aquaculture barangay 200 m away from the aquaculture structure

*** recommended stocking density for milkfish in fish cage is 3,700 $pc/100\ m^3$

4.0 THE AQUACULTURE OPERATORS

4.1 Survey of Operators

A total of 34 fish pen operators were surveyed on information related to aquaculture operation. More could have been interviewed but most of the operators/ owners were not from Bolinao and names could not be obtained from the CRM office in Bolinao. There were also informal reports that there are dummy operators hence, it was difficult to locate the real owners. For those whose names were listed, only 34 cooperated with the study.

4.2 Socio-Economic Characteristics of the Respondent-Operators

The respondent-operators were on the middle age category with average age of 44 years. Those from Pilar were considered the oldest with average age of 51 years. Those from Luciente, Luna and Tara had average age ranging from of 43 – 47 years (Table 6). Majority (82 %) of the respondents were male. In fact, all the operators from Tara were males. Of all the barangays, Luna had the most number of female operators (44% vs 56% males). Most of them were married with average household size of five. Those from Tara had the least number of household members of four while the biggest family size with six members were those from Luna. The respondents were either secondary school or college graduates (29% each on the average) and 12 % had vocational degrees. Seventy four percent of all respondents were members of organizations related to fishery, civic and environment. More than one third (38%) of the respondents were full time operators and a great majority (62%) were part time aquaculture operators. Almost two thirds of them had been operating aquaculture in Bolinao for more than four years, hence they were among the pioneers in coastal aquaculture operation.

4.3 Physical Information About Aquaculture Operation

On the average, each operator owned two units of fish pen/cage. However, there were those who owned 11 units (Table 7). This is a clear violation of the municipal ordinance, which specifies that an operator can own only five units at the maximum. The average size of fish pen is 3,208 m^2 although the range was 1,200 – 6,000 m^2. As indicated in the MFO, the minimum size of fish pen should be 1,200 but should not exceed 4,000 m^2. hence, in terms of minimum size the ordinance had been followed but not when it comes to maximum size. This maybe explained by the fixed license fee of Php10,000 per unit per year such that the operator tried to maximize his return from the fixed license cost. Average depth of the structure is four m from the water surface although this varied from 0.60 m to nine m, the deepest being in Luciente 2 and Luna. The average distance of the structure from the shore is 279.50 m which is closer to the ordinance of at least 300 m. However, by specific operator, there were those whose structures were located just four m away from the shore. Luciente 2 and Luna had average distance of only 137.50 m and 101.25 m, respectively while Pilar and Tara had structures located within the provision of the ordinance. Aquaculture structures in Tara had average distance of 541 m while Pilar had 377.50 m on the average (Table 7). The relatively closer distance to the shore of the structures in Luciente 2 and Luna may be explained by the desire of the operators from these barangays to minimize the cost of operation. However, this has some implications on water quality that were discussed earlier. Fish pens are usually situated in shallower water since the nets and structures are anchored at the bottom.

Table 6. Socio-economic characteristics of the respondent-operators, by barangay, Bolinao, Pangasinan, 2001

CHARACTERISTIC	BARANGAY				ALL
	Luciente 2	Luna	Pilar	Tara	BARANGAYS
	n=8	n=9	n=8	n=9	n=34
Average age(in yr)	43	47	51	44	44
Gender					
Male (% of respondents)	88	56	75	100	82
Civil Status					
Married (% of respondents)	88	78	100	89	85
Educational Attainment					
Elementary (% or respondents)	12.5	11	50	0	12
Secondary (% of respondents)	25	11	25	44	29
College (% of respondents)	25	33	25	33	29
Vocational (% of respondents)	12.5	11	0	11	12
No Answer (% of respondents)	25	33	0	11	18
Average Household Size	5	6	5	4	5
Membership in Organization (%)	75	67	50	89	74
Type of Organizational					
Membership (%)					
Civic	25	11	0	0	12
Fishery	50	56	25	67	53
Environmental	0	0	25	0	3
Others	0	0	0	22	6
None	25	33	50	11	24
Type of Operation (%)					
Part time	62	67	25	67	62
Full time	38	33	75	33	38
Years Operating in Bolinao (%)					
< 4 years	38	33	25	44	35
> 4 years	62	67	75	56	65

Reported mortality during the study period was 16% which was relatively higher compared to the mortality of 14% experienced in 1998 and earlier. Highest mortality was reported by operators in Pilar whose fish pens were hit by fish kill and oil spill that occurred in January 2000. Accordingly, they experienced huge losses in their operation prior the study (Table 7). These operators were also among those who reported 50% mortality rate in 1998.

Given optimum stocking and proper management, potential yield of a 4000 m^2 pen could be from 22,000 – 30,000 kg of fish (at an average of 2 pc per kg). (INTAQ, 2000). Based on the responses given by the operators, they were able to produce 29,967 kg of fish on the average for a 4000 m^2 fish pen which was within the potential yield (Table 7). There are even those who were able to harvest more than 56,000 kg. Thus, it may appear that the operators were operating efficiently. However, there were also those whose harvest was only 9,000 kg, a figure far below the potential yield. These were the operators from Luna who suffered 60% mortality in their recent operation. Compared to 1998, the operators were able to produce more in 2001. This maybe attributed to the fish kill that hit the area in 1998 due to proliferation of excessive number of structures.

Another important information gathered from the respondents was the longer grow out period in the recent years compared to that of 1998. Accordingly, the average grow out period (from stocking of frys to harvest) lately was 5.17 mo (21 wk) compared to 4.6 mo (18.5 wk) in 1998 (Table 7). This longer grow out period was attributed by the operators to the deteriorating water quality and to some extent cold weather.

4.4 Management Practices

Management practices related to aquaculture operation include stocking density, feeding practices, use of pest and disease control, use of air compressor or aerator, and to a certain extent water quality testing.

Stocking Density

This refers to the number of frys place per unit area of the fish pen. For fish pen, the recommended stocking density for a 4,000 m^2 fish pen was 50,000 – 60,000 per unit (INTAQ, 2000). This translates to stocking density of 1,250 – 1,500 frys per 100 m^2. Since the size of fish pens varied, the stocking density based on per 100 m^2 was done to compare operators with different fish pens areas and determine if there was overstocking.

For the sample operators, the average stocking density during the time of the study was 1,119 frys per 100 m^2 and was a bit short of the recommended number. A closer look at the individual operators, however, revealed that the average masked the true situation in the area. There were those who had relatively low stocking density of only 625 frys per 100 m^2. The reason given was the limited capital to buy the milkfish frys. However, there were also those whose stocking density reached up 2,971 frys per 100 m^2 which was twice that of the recommended rate. Results of the survey showed that in all sample areas, there were operators who overstocked their pens. Lowest average stocking density of 988 frys per 100 m^2 was computed for operators from

Luciente while the higher average stocking of 1,242 frys per 100 m^2 was recorded for Tara. (Table 7).

Feeding Practices

The information related to feeding practices included the following: kind of feeds; quantity of feeds given and frequency of feeding.

Different types/kinds of commercial feeds are given to milkfish at different stages of growth. For the sample operators, production cycle of milkfish lasted for five months and in extreme cases up to seven months. They lamented that lately, production cycle was longer compared to the three to four months grow out cycle during the earlier period. During the 1st month of the growing cycle, the most common type of feeds given consisted of fry mash and starter/crumble. Fry mash was used by all the respondents from Luna and Pilar and by 62 % of the respondent operators from Luciente 2. In Tara, the most common feeds given were starter mash or crumble. For the 2nd month, the most common feed was starter except for Tara where the fish were fed with grower up to the 4th month of growth (Table 8). During the 5th month, all the operators used finisher. This were given continuously especially in cases where the growth cycle extended until the 6th or 7th month.

The frequency of feeding affects the capacity of the fish to absorb/ingest the feeds given. Cultured species can absorb/take in only so much feeds at a time such that if feeds are given in bulk and less frequent most of the feeds will just go to waste. Frequency of feeding varies by stage of growth. In Luciente, the feeds were given four times a day from the 1st to the 3rd month and five times from the 4th month onwards. In Luna, feeds were given less frequent during the same stages of growth. In Pilar, the feeds were given continuously but smaller quantities from the 4th month onwards while in Tara, the operators practiced continuous feeding from the 2nd month onwards. However, it is difficult to say whether the operators are over feeding the milkfish. The recommended feeding rate was based on the weight and not on the age of fish. For example, the feeding rate for fish weighing 1 – 5 g should be 15 – 20% of body weight while for bigger fish weighing 500 g, the feeding rate is 3% of body weight. However, overfeeding maybe implied since the caretakers were reportedly feeding the fish continuously especially from the 3rd month of fish growth. This practice is very inefficient and may lead to wastes especially during cold weather when the fish culture requires less feeds. As suggested by INTAQ, 2000, it is better to underfeed than overfeed the fish since the last may only contribute to poor water quality. In addition, when fishes are stressed, due to poor water quality, low DO and poor handling of fish during transfer, they have no appetite and continuous feeding will only contribute to waste and poorer water quality (INTAQ, 2000).

Table 7. Information related to fish pen/cage operation by barangay and selected variables, Bolinao, Pangasinan, 2001

VARIABLE	BARANGAY				ALL
	Luciente 2	Luna	Pilar	Tara	BARANGAY
Average number of fish pen units	1	4	2	2	2
Range	*(1 - 2)*	*(1 – 11)*	*(1 - 3)*	*(1 - 3)*	*(1 - 11)*
Average area of fish pen unit (m^2)	3556	3400	3280	2822	3301
Range (m^2)	*(2,000 – 6,000)*	*(1,200 - 4,000)*	*(1,200 - 4,800)*	*(1,200 - 4,000)*	*(1,200 – 6,000)*
Average depth of net from the surface (m)	4	4.5	4.75	3.8	4
Range (m)	*(1.83 - 9)*	*(2.6 – 8)*	*(4 - 6)*	*(0.60 - 7)*	*(0.60 - 9)*
Average stocking density (pcs/100 m^2)	988	1,187	1,035	1,242	1,119
Range (pcs/100 m^2)	*(625 - 2,000)*	*(875 – 1,416)*	*(375 - 2,174)*	*(750 - 2,971)*	*(625 – 2,971)*
Average number of structure near the operator's	7	4	13	3	6
Range	*(2 - 30)*	*(1 – 10)*	*(4 - 20)*	*(1 - 10)*	*(1 - 30)*
Average distance of structure from the shore (m)	137.5	101.25	377.5	541.13	279.5
Range (m)	*(40 - 500)*	*(17.5 - 400)*	*(30 - 1,000)*	*(4 - 4,000)*	*(4 - 4,000)*
Average mortality 2001 (% of stocking density)	7	18	22	21	16
Range(% of stocking density)	*(12 - 18)*	*(4 – 60)*	*(7 - 24)*	*(0.33 - 34)*	*(0.33 - 60)*
Average mortality 1998 (% of stocking density)	8	18	50	8	14
Range (% of stocking density)	*(1 - 20)*	*(4 – 43)*	*(1 - 50)*	*(0.17 - 30)*	*(0.17 - 50)*
Average Production (kgs/4000 m^2) 2001	17,454	19,293	18,607	17,208	17,930
Range(kgs/4000 m^2)	*(10,000 – 39,850)*	*(9,000 – 24,072)*	*(13,825 – 34,783)*	*(10,974 – 56,667)*	*(9,000 – 56,667)*
Average Production (kgs/4000 m^2) 1998	13,516	12,869	6,157	17,992	14,293
Range (kgs/4000 m^2)	*(7,167 - 26,667)*	*(9,524 - 16,000)*	*(3,356 - 7,517)*	*(9,333 - 38,502)*	*(3,356 - 38,502)*
Average grow out period (mo/cropping) 2001	5.38	5.14	6	5.22	5.17
Range (mo/cropping)	*(5 - 6)*	*(4 - 6)*	*(5 - 7)*	*(3.5 - 7)*	*(3.5 - 7)*
Average grow out period (mo/cropping) 1998	4.64	5.07	4.17	4.21	4.6
Range (mo/cropping)	*(4 - 6)*	*(4 - 6)*	*(4 - 4.5)*	*(3.5 - 6)*	*(3.5 - 6)*
Average price paid for fingerlings/fry (Php/pc)	2.61	2.61	2.69	2.4	2.46
Range (Php/pc)	*(2.4 - 3.1)*	*(2.3 – 3)*	*(2.5 - 2.9)*	*(1.5 - 2.75)*	*(1.5 - 3.1)*
Average price received by the operators (Php/kg)	51	57	59	58	56
Range (Php/kg)	*(50 - 56)*	*(50 - 60)*	*(45 – 78)*	*(55 - 65)*	*(45 – 78)*

Table 8. Responses of aquaculture operators by barangay and feeding practices, Bolinao, Pangasinan, May 2001

INFORMATION	LUCIENTE2 (n=8)	LUNA (n=9)	PILAR (n=8)	TARA (n=9)
Kind of Feeds on Different Stage of Growth				
1st Month	Fry Mash (62)	Fry Mash (100)	Fry Mash (100)	Starter/Crumble (55)
2nd Month	Starter/Crumble (50)	Crumble (50)	Crumble (100)	Grower (44)
3rd Month	Starter (62)	Starter (50)	Crumble Pellets (60)	Grower (67)
4th Month	Grower (75)	Grower (50)	Grower (100)	Grower/Finisher (75)
5th Month	Finisher (100)	Finisher (71)	Finisher (80)	Finisher (55)
Number of Feeding per Day				
1st Month	4	3	3	3
2nd Month	4	3	3	Continuous
3rd Month	4	3	4	Continuous
4th Month	5	4	Continuous	Continuous
5th Month	5	4	Continuous	Continuous

Note: Figures in parentheses are percent of respondents

Use of Pest and Disease Control and Air Compressor or Aerator

The usual chemicals applied to control pests and diseases include Blue Water, Vitracin and Vitamins. More than half (54%) of the respondents reported using these types of chemical for pest and disease control (Table 9). Those that did not use chemicals claimed that it will just entail additional costs and once the disease is there, the chance of controlling it is very small.

Another important management practice in aquaculture industry is water quality testing. This is necessary to monitor the DO levels so that appropriate measures can be done in case of low DO. Only 25% of the respondents said they performed water quality testing. No one of the operators from Luciente II and Pilar did water quality testing (Table 9). Highest percentage (75%) from Luna and some 22% from Tara did the activity through the help of the UP-MSI. These operators were among those trained on water quality testing by UP-MSI as part of their participatory approach to aquaculture management program. However, during the interview, the operators mentioned that the laboratory part is to technical, laborious and expensive and unless UP-MSI provides for funds and assistance, they could not do the water quality testing continuously.

Table 9. Percentage distribution of operators by barangay and techniques used in aquaculture, Bolinao, Pangasinan, 2001

TECHNIQUE	BARANGAY				ALL
	Luciente 2	Luna	Pilar	Tara	BARANGAY
	(n = 8)	(n = 8)	(n = 5)	(n = 9)	(n = 30)
Use of chemicals					
Yes	62.7	57.14	100	44.4	53.57
No	37.5	28.57	0	55.6	42.86
No answer	0	14.29	0	0	3.57
Water quality testing					
Yes	0	71.43	0	22.2	25
No	100	14.29	100	77.8	71.43
No answer	0	14.29	0	0	3.57
Who does the testing					
UP-MSI	0	71.43	0	22.2	25
None	100	28.43	100	77.8	75
Use of air compressor/aerator					
Yes	75	71.43	50	66.7	67.86
No	25	28.57	50	22.2	28.57
No Answer	0	0	0	11.1	3.57
Reason for using aerator					
Fishkill/low DO	50	14.29	75	11.1	32.14
When catching fish	12.5	0	0	11.1	7.14
When checking the net	37.5	42.86	25	44.4	28.57
No answer	0	28.57	0	33.3	32.14
Harvesting technique					
Cast net	62.5	57.14	25	88.9	64.29
Seine	0	14.29	0	0	5.57
Others	37.5	28.57	75	0	28.57
No answer	0	0	0	11.1	3.57
Post harvest activity					
Icing	37.5	85.71	50	11.1	42.86
Wash and ice	62.5	14.29	50	66.7	50
No answer	0	0	0	22.2	7.14

Use of air compressor or aerator is resorted to facilitate continuous flow of air. This is a usual practice in aquaculture fishponds. It is surprising that the operators had been using aerators also in their pens and cages. Two-thirds of the respondents were reportedly heavy user of air compressor (Table 9). Thirty two percent said they used aerator when there is fish kill and when DO is low. They believed that growth is facilitated if air circulation is aided by the aerator. However, for coastal pens and cages, use of aerator is not needed since there is continuous flow of oxygen due to water current

(Jacinto, 2002). Other operators said they used aerator when catching fish and changing net to assure that flow of air is regulated. Use of cast net was the usual method of harvesting milkfish. The harvested fishes were usually iced in a 25-kg capacity vat before transporting to Metro Manila and nearby municipalities.

4.5 Net Income from Aquaculture Operation

Net income is the difference between total revenue and total costs from the operation. Total Revenue (TR) is obtained by multiplying the quantity harvested with the average price of milkfish received by the operators. Total Cost (TC) consisted of all the costs incurred in production. This included the Total Fixed Costs (TFC) and Total Variable Costs (TVC). Price of milkfish received by the individual operator ranged from Php 45 – Php 78 per kg with average values of Php 51 – Php 59 per kg. Since the operators reported varied sizes of fish pens, net income was expressed in terms of a 4000 m^2 fish pen area for uniformity.

Details of Costs incurred by an operator. On the average, TC incurred by the operators for a 4000 m^2 fish pen amounted to Php 694,129 per cropping cycle. TFC consisted of license fee, permit to operate and interest on borrowed capital. TVC included expenses for frys or fingerlings, feeds, labor of the caretaker, and other material inputs. TFC per cropping amounted to Php13,900 and contributed only a measly two percent of the TC. It appeared that TVC amounting to Php 680,229 per cropping dominated the cost of milkfish operation (Table 10). Among the variable inputs, feeds accounted for the majority (72%) of the TVC while frys contributed 18 percent.

Net Income from a 4000 m^2 fish pen. TR from fish pen operation was obtained by multiplying total production by the price of per kg of milkfish received by the operators. TR during the 1st operation cycle in year 2001 ranged from Php 500,000 – Php 3,116,667 with an average of Php1,004,098. The average was obtained by getting the sum of the TRs of all operators divided by the total number of sample. Highest average TR of Php 1,093,274 was realized by the operators from Luna. This maybe attributed to the high average production per pen. For an individual operator, highest TR of Php 3,116,667 was estimated for an operator from Tara where highest production of 56,667 kg was also reported(Table 6.6). This high productivity in Tara was way above the estimated production of 22,000 – 30,000 kg by INTAQ, 2001.

TC ranged from Php 220,775 – Php2,037,202 with an average of Php 309,969 (Table 11). Highest total costs of Php 810,466 was estimated for the operators from Tara where highest costs and lowest TCs by an individual operator were also recorded. The lowest total cost per barangay was that of Pilar.

Table 10. Details of costs incurred by a fish pen operator for a 4000 m^2 pen , per cropping, Bolinao, Pangasinan, 2001

TYPE	AMOUNT (PHP)
Fixed Costs	
License fee*	5,000
Permit	75
Interest on borrowed capital	8,825
Total Fixed Cost	13,900
Variable Costs	
Changing/washing of net	2,768
Rope/nylon cord	2,190
Bamboo	15,000
Raft	1,500
Miscellaneous	4,500
Net	20,540
Fry/fingerlings	120,895
Feeds	491,664
Labor	21,172
Total Variable Costs	680,229
Total Cost	694,129

* License fee is P10,000 per unit per year and the operator has two cropping per year

For all the sampled operators, the average net income was derived by getting the sum of the individual net incomes and dividing it by the number of respondents. On the average, net income from a 4000 m^2 fish pen was Php 309,969. On per site basis, highest average net income of Php 534,840 was computed for Pilar and the lowest of Php 227,104 was in Luciente. The relatively lower net income in Luciente compared to the other barangays maybe attributed to lower production, lower price per kg of fish and high production costs. These net income values, however, were within the range of the computations of Php 217,824 - Php 355,798 done by INTAQ, 2001 for different prices of milkfish.

Form the results of the study it appeared that milkfish culture is a lucrative business and the operators, in general, are earning fairly well in aquaculture operation. Had the industry been managed properly, it would be sustainable. However, as reported earlier, construction of aquaculture structures was not monitored properly such that the number of structures reached beyond the capacity of the area which was claimed to have caused the fish kill event last February 2002.

4.6 Perception and Problems Related to Aquaculture Operation

The operators also observed change in the grow out period from their operation. Fifty nine percent of the respondents reported to have experienced this change. Sixty eight percent of the respondents said that they had experienced longer grow out period or slow growth of fish lately (Table 12). Reasons cited for the change included effect of the aquaculture industry itself (71%), poor quality fingerlings (3%), weather condition (7%) and others. They believed that growth of milkfish is slow during cold weather and this was coupled by deteriorating water quality.

Even the operators themselves admitted the low quality of water within the fish pens. Forty eight percent of the respondents mentioned that they are faced with low quality water. In fact, 75 % of the respondent-operators in Pilar, reported water quality as their main problem (Table 13). Other pressing problems expressed by the respondents included operation losses due to fish kill (still related to low water quality), theft and weather. Pollution had been expressed also by more than one-fourth of the respondents. Since pollution and low water quality are almost synonymous, the problems expressed by the respondents affirmed that indeed aquaculture operation contributed to water pollution in the area. This problem on water quality was also shared by the key informants and fisherfolks from the study sites.

Varied answers were given when asked for measures taken to minimize losses. These included use of aerator, early harvesting, net management, change sources of fingerlings, adjust price of milkfish, etc. (Table 13). To minimize pollution, operators said that they have to do net management that involves cleaning of nets to remove the wastes from aquaculture. However, it seems that they were not aware that their practice of cleaning the net on the aquaculture sites can only add up to water pollution. There were also those who mentioned that they reduced the number of structures. However, it is apparent that the last measure was just lip service for the number of structures continued to proliferate and had been blamed to have contributed the massive fish kills that occurred last February 2002.

Table 11. Average Costs and Returns from a 4000 m^2 fish pen operation per cycle, by barangay, Bolinao, Pangasinan, 2001

ITEM	BARANGAY				ALL
	Luciente 2	Luna	Pilar	Tara	BARANGAY
Total Revenue (TR)					
Qty Harvested (kg per 4000 m^2 area)	17,454	19,293	18,607	17,218	17,930
Range(kg/4000 m^2 pen)	*(10,000 – 39,850)*	*(9,000 – 24,072)*	*(13,825 – 34,783))*	*(10,974 – 56,667)*	*(9,000 – 56,667)*
Ave price of Fish (Php/ kg)	51	56	53	58	52.5
Range	*(50 - 56)*	*(55 - 60)*	*(45 - 57)*	*(55 - 60)*	*(45 - 60)*
Total Revenue (TR) in Php	**894,519**	**1,093,274**	**1,088,528**	**996,738**	**1,004,098**
(Range)	*(500,000-2,072,200)*	*(522,000 – 1,440,000)*	*(697,500 – 1,913,043)*	*(636,463 – 3,116,667)*	*(500,000 - 3,116,667)*
Total Costs (TC) in Php	**735,054**	**595,442**	**633,349**	**810,466**	**694,129**
(Range)	*(422,040-1,556,835)*	*(340,155-1,045,575)*	*(432,992-1,050,945)*	*(220,775 – 2,037,202)*	*(220,775 – 2,037,202)*
Net Income (TR less TC) in Php	**227,104**	**509,015**	**534,840**	**344,386**	**309,969**
(Range)	*(77,960 – 518,875)*	*(36,495 – 805,941)*	*(220,055 – 862,099)*	*(59,428 – 1,079,465)*	*(36,495 – 1,079,465)*

Table 12. Percentage distribution of operators by barangay, perceived change in growth period and reasons for the change, Bolinao, Pangasinan, 2001

ITEM	BARANGAY				ALL
	Luciente 2	Luna	Pilar	Tara	BARANGAY
	(n = 9)	(n = 8)	(n = 8)	(n = 9)	(n = 34)
Change in grow out period					
Yes	67	62	50	56	59
No	11	37	50	33	29
No answer	22	0	0	11	12
Nature of change					
Longer period/slow growth	89	62	50	67	68
Fish size				11	3
Shorter period/faster growth		12		11	6
No answer	11	26	50	11	23
Reason for the change					
Aquaculture	89	75	50	67	71
Fingerlings				11	3
Weather				22	6
Technology used		12			3
Fishkill	11				3
No answer		12	50		14

Table 13. Distribution of respondents by perceived problems related to aquaculture and measures taken by barangay, Bolinao, Pangasinan, 2001.

VARIABLES	BARANGAY				ALL
	Luciente	Luna	Pilar	Tara	
	n=9	n=8	n=8	n=9	n=34
Problems related to water quality					
None	38	29	0	67	33
Fish kill	25	43	25	11	26
Water pollution, turbidity and changes in consistency	63	43	75	11	48
Others	0	0	0	11	3
Losses or damages in fish farm					
None	25	29	0	56	27
Fish kill	50	29	100	22	50
Natural calamities/typhoon	13	29	25	22	22
Fish diseases and pests	0	14	0	0	4
Low quality or malnourished fries	0	14	0	0	4
Market factors (price)	0	14	0	11	6
Theft	13	0	0	11	6
Measures taken to minimize loss					
None	38	29	25	67	39
Use aerator	25	14	25	0	16
Harvest early	0	14	0	0	4
Net management	25	29	0	22	19
Change fingerling source	0	0	25	0	6
Decrease volume of fries	0	0	50	0	13
Observe and count fries for first three days	0	14	25	11	13
Adjust price of milk fish	25	0	0	22	12
Measures taken to minimize pollution					
None	78	71	25	89	66
Net management and sea clean-up	0	29	25	11	16
Reduce number of cages and pens	25	0	0	0	6
Use aerator	0	0	50	0	13
Use blue water	0	0	25	0	6
Decrease stocking density	0	0	25	0	6

5.0 EFFECTS OF AQUACULTURE ON PRODUCTION

Effects of aquaculture industry can be evaluated based on the following: a) socio-economic aspect; b) environmental aspect and c) ecological aspect. For this study the socio-economic effect was evaluated based on income from aquaculture production, which was discussed in the previous chapter. Environmental aspect was captured on the water quality analysis portion. In this chapter the focused will be on the analysis of the effects of intensive aquaculture operation on the aquaculture industry itself and losses from fish kills and other damages due to aquaculture operation.

5.1 Aquaculture Production Analysis

The discussions about water quality and aquaculture operation in Chapter 3 suggest that there are indicative relationships between aquaculture practices and water quality, particularly DO levels. Specifically, results of the water quality testing showed that overstocking is negatively related to DO level, that is, the higher the stocking density the lower the DO level, hence poor water quality. Although poor water quality are normally confined within the aquaculture structures, if the situation gets worse, adjacent water body also suffer from water quality deterioration. In this case, poor water quality may also affect aquaculture production itself.

Technically, aquaculture production is a function of variable inputs used to produce the fish. For this study, stocking density and feeds were considered as important factors that affect production. This is so because, overstocking and overfeeding are claimed to contribute to water quality that caused fish kills and eventually reduced yields. In addition, these two inputs accounted for the high production costs. To determine whether water quality (which is perceived to be caused by aquaculture operation) affects yield, water quality dummy using DO values was included in the fish production equation.

Results of the regression run for aquaculture production are as follows:

$$Ya = 141.29^{**} + 2.542SD^{*} - 0.00075SD^{2**} + 2.999F^{ns} - 0.0205F^{2ns} - 40.78WD^{***}$$

$R^2 = 0.93$ F = significant at 0.01

*** significant at 0.01 level
** significant at 0.05 level
* significant at 0.10 level
ns = not significant at 10% level

Where:

Ya = milkfish production of operators (kg/100 m^2 area)
SD = stocking density/100 m^2 area
F = quantity of feeds used for the whole operation in bags
WD = water quality dummy
1 if DO level in the sampling fishpens in the area is equal to or less than 4mg/L
0 if DO level in the sampling fishpens in the area is greater than 4mg/L

The water quality dummy is interpreted as an intercept shifter. It implies that, holding other factors constant, if the undesirable condition, that is, water quality deterioration exists, productivity will decrease, thus shifting the production function downward.

The 4mg/L cut off value for DO was based on the study on DO and marine life conducted by the US Environmental Protection Agency's Environmental Research Laboratory (US-EPAERL) in Rhode Islands. Results of the study showed that if DO level is 4mg/L, survival rate of planktonic larvae of crabs may be reduced by 30% and growth of summer flounder by 25%. This study was used as basis in the absence of available information on the relationship between different DO levels and mortality or milkfish survival in the Philippines.

The signs of the variable inputs coefficients conformed to a priori economic expectation. For the stocking density, as stocks increases so will yield up to a certain level, beyond which, yield will start to decline. However, the coefficient of the feed variable appeared to have no significant effect on production. This non-significance of feeds on production may imply that there is no significant variation in feed level used by the operators such that yield differences do not depend on quantity of feeds.

Results for the stocking density show that yield increases as stocks increases but up to a certain extent. There is a maximum stocking density beyond which, production will start to decrease. This is exactly what a short run production analysis tells us. That is, because of the law of diminishing productivity, further increases in the variable input will cause production to decrease. For the aquaculture production, this maybe explained also by the nature of the fish as a resource, that is, as more stocks are put in a given space, overcrowding occur, which result in the competition for space and eventually lead to slow growth, if not mortality. In addition, overcrowding also lessen the movement of fish thereby reducing the oxygen level that result in low DO. Moreover, if stocks were beyond the optimum, fish excreta and wastes became excessive that may result in fish kill. .From the equation above, if stocking density per 100 m^2 of fish pen area exceeded 1,693 frys, production will start to decline. This is manifested by the negative sign of the coefficient of the squared stocking density. This result is quite close to the recommended stocking density of 1,250 - 1,500 frys/100 m^2 fish pen area that was identified by INTAQ (2001).

The coefficient of the water quality dummy is – 40.78. This means that holding other factors constant, if the DO level within the fish pen area fell below 4mg/L, the intercept of the milkfish production function will decrease and the production frontier will shift downward. This could be interpreted to mean that those aquaculture structures with DO levels less than 4mg/L are likely to suffer from lower productivity compared to those structures with DO levels higher than 4mg/L. Data on water quality analysis in the sample barangays showed that there were variations in DO levels in specific sampling points; with some points having DO values greater than 4mg/L.

5.2 Losses from Fish Kills Due to Overcrowding

"A 'fish kill' is a significant and sudden death of fish or other aquatic animals. Such event is characterized by large numbers of aquatic animals dying over a short time usually in a clearly defined area" (Jacinto, 2002). There are several factors that may contribute to fish kill including weather factors, hydrological factors and aquaculture mismanagement. The latter includes high stocking density, excessive feeding and too much structure in the area. If there is excessive feedings, large amount of feeds are not eaten by the fish and settled at the bottom. This favored algal growth that competes for oxygen with the fish. Fish excreta also mixed with the other nutrients thereby increasing the nutrient loading that results in euthropication and eventually fish kills.

Occurrences of fish kills had been common in Bolinao. But these were undocumented since the occurrences are site specific, that is, by specific pens or cages and not the whole aquaculture area. For example, results of the monitoring done by the MFRMP mariculture (coastal aquaculture) component showed that fish kills had been experienced in specific fish pens in Bolinao and two other aquaculture municipalities (Dagupan and Anda) year round with peaks during the months of April, May and June. These fish kills were not sufficient enough to cause alarm among the local officials who apparently are fish pens and fish cages owners, themselves (PDI, Feb 9, 2002). Fish kills occur along with algal blooms and poor water quality, the latter aggravated by irresponsible coastal aquaculture practices such as overstocking, excessive feeding practices and overcrowding or excessive number of fish pen structures. Accordingly, aquaculture structures have exceeded the maximum number allowed in the area, which hindered the flow of water in order to maintain good water quality (MFRMP, on going study).

The fish kills in Bolinao last February 1-3, 2002 can be considered the worst fish kill event that happened in the country. This started on the evening of February 1, which was a neap tide, meaning tidal currents were slow and so less 'new', oxygen-rich waters were flowing from offshore areas. Few days before the event, the operators had been reported to be using aerator, a practice of introducing oxygen into the fish pens or cages. This practice is usual for fishponds where water is not flowing but not in coastal waters where water currents introduce oxygen. It is also an indication that there was high oxygen demand in the area. Two days before the fish kills, the milkfishes were noted to crowd in the surface, evidently gasping for air and eventually dying due to low DO. Water quality testing performed by the Regional Director of the Bureau of Fisheries and Aquatic Resources (BFAR), Region 1 a day after the massive fish kill, recorded a 1.2 - 2.3 mg/L DO value, which was indeed very low for fish survival. . This was not only below 5mg/L but also below 3mg/L, a value where fish is still capable of surviving. DO values less than 2mg/L can cause gill-suffocation, thus, the fish kills. The losses to this event were estimated to be PhP 600 million (PDI, Feb. 9, 2002). The incident affected not only Bolinao but also other villages near it. Greatly affected barangays are those part of our sampling areas (Luciente 2, Luna and Tara), as well as the other barangays with aquaculture operation (Luciente I, Salud, Lucero). Records at the municipal CRM office showed a listing of 173 fish pens and 448 cages (621 units in all) with permits issued, but ocular inspection done by BFAR showed otherwise (600 fishpens and 467 fishcages or a total of 1067 units). Both counts were way above the estimated carrying capacity of 544 units (130 hectares) of the water. Of this number, 353 can be found in Guigiwanen and Luciente 2 where the fish kills started. It should be noted that Luciente 2 and Luna were also among the areas affected by fish kills last September 2001.

But it was not only the aquaculture industry that was affected. Even the fishing industry felt the effect of this massive fish kill. Many of the fishes in the wild were also observed to be gasping for air. In fact many of them also died, while others may had moved away from these oxygen-depleted areas. As a result, some fishers ended up having no or less catch compared than usual. A resident said that children who usually caught five kilos of fish per day near the beach, came home with no fishes in their nets (PDI, February 8, 2002). Unfortunately, there are no hard evidences that will enable the estimation of damage to capture fishery.

What really caused the massive fish kills? The damage due to fish kill event was so huge that the inquiry reached national attention. The event had been on the headlines of major dailies. On February 5, 2002, the UP-MSI issued a press statement on the massive fish kills in Bolinao. Excerpts of the press statement are as follows:

"The fish kill events coincided with a bloom of a dinoflagellate identified as Prorocentrum minimum that has been reported to be associated with eutrophied waters and was reported to have caused human poisoning through shellfish consumption, in other countries. A high density of the plankton cells was found in the water column as well as gills of the fish. This accumulation of cell in the gills result in asphyxiation of the fish. It must be noted that this is the first time that a P. minimum bloom occurred in the Philippines."

"Another important fact is the low dissolved oxygen (DO) levels in the municipal waters of Bolinao. Several days before the February 1 fish kills, measured DO levels is already below the limit of 5 mg/l set by the DERN for class Sc waters or water suitable for the propagation of fish and other aquatic organisms. Low DO levels less that 2 mg/l can cause suffocation of gill breathing aquatic organisms, and is one of the most common causes of fish kills. Moreover, several days before the incident, a number of fish cage operators reported that fish were aggregating at the surface of the water, an indication that the fishes were already deprived of oxygen"

This decreased in DO is not a sudden event. As had been discussed before, the great increased in number of fish pens and fish cages in Bolinao exceeded the number of structures set in the MFO. Large amount of organic matter were released from unconsumed feeds and fish wastes. According to the Regional Chief of BFAR in Region 1 "around 30% of the feeds given are not consumed by the fish culture and are eventually thrown out into the water and seabed" (PDI, Feb 6, 2002). The build-up of organic matter eventually led to eutrophication. This caused a phytoplankton bloom, or in this case a bloom of a dinoflagellate identified as *Prorocentrum minimum,* the first time to be recorded in the Philippines, which led to an increase in die-off thus, resulting further to more organic matter in the bottom, the decomposition of which consumed the dissolved oxygen in the water that caused further stress to the confined fish.

In light of this event, Bolinao's mayor Jesus Celeste said that the coastal development plan would be strictly implemented, and that they might do away with the fish pens but continue with fish cages. It is believed that fish pens releases more pollution than fish cages (PDI, Feb. 5, 2002) since feeds and wastes that settle at the bottom cannot be removed like in fish cages. But UP-MSI believed that for the Bolinao's water to recover from this disaster, aquaculture operation would have to be stopped for quite sometime. On February 17 the local government had suspended aquaculture operations as well as issuance of permits. (PDI, Feb 17, 2002). If the moratorium on aquaculture operation is to be continued, there is a chance that aquaculture operation in Bolinao will again be optimum. These actions, however, will undoubtedly encounter many objections since many people derive their livelihood from it. Reports from BFAR also cited that the fish kill event affected coral fishes like slipmouth, rabbit fish and mullet Further water quality analysis conducted by BFAR found out that hydrogen sulfide, a toxic gas, was high in the aquaculture areas. This toxic gas was caused by amino acids in the uneaten fish feeds that settled at the sea bottom (PDI, April 14, 2002). Despite this however, many operators re stocked their cages and pens but most of the newly stocked milkfish floated dead. This indicated that indeed the water of Bolinao is not yet fitted for aquaculture production. This will cripple the economy of Bolinao for sometime and this is where political will should come in. Will the local officials trade off long term and sustainable industry against the short term gains?

This major aquaculture event became a national issue. A month after the fish kill event, a Senate inquiry on the matter was conducted. Senate Resolutions 238 and 241 authored by Senators Loren Legarda-Leviste and Manuel Villar urged "The Senate Committee on Agriculture and Food and the Senate Committee on Local Government to conduct an inquiry, in aid of legislation, into the massive fish kill of milkfish which occurred at Caquiputan Channel in Bolinao, Pangasinan valued at Php 600 million, with the intent of introducing remedial measures to prevent its spread to other waters and to ensure that there would be no reoccurrence of the same fish kill in Bolinao, Pangasinan and in other waters of the Philippine archipelago" (PDI, March 14 , 2002). To date, there is no concrete legislative action passed by the Senate nor resolutions from the local officials and administrative order from BFAR to address the fish kill issue.

The above discussions pointed some indicative relationships between excessive number of structures, water quality and fish kills. However, there is no empirical study that will establish the direct link between aquaculture operation and the extent of its contribution to water quality deterioration and eventually mortality and fish kills.

5.3 Other damages and problems due to aquaculture

In addition to the value of milkfish losses from fish kills, there are associated social and environmental hazards caused by the aquaculture operation. Related to the fish kill event last February was the health impact to the community. In the wake of the fish kill events, 75 persons were hospitalized due to allergy after eating dried milkfish, which was believed to have been affected by the fish kill (PDI, Feb. 9, 2002). Affected people reportedly complained of headache, dizziness, vomiting, difficulty in breathing, abdominal pain, nape pain, itchiness, chest pain and skin redness. In addition, the laboratory and experiments of the UP-MSI had been suspended so as not to be contaminated by the polluted waters. Moreover, there is now a moratorium on the construction of fish pens in the affected area hence, there will be foregone earnings on the part of the operators. However, directly affected are household surrounding the coastal areas. Before the fish kill, even children can catch up to five kilos of fish a day near the beaches, but since the fish kill event, their nets have been empty. The effect on the total marine resources could also be "unquantifiable" for the accumulated decaying marine fauna and flora spread continually to the adjacent coastal areas. Its effect on the sea grasses and coral reefs may also be detrimental. Furthermore, the economy of the town would also be losing in term of taxes from the operators and the value of the damaged resources.

Other problems related to aquaculture operation were mentioned by the key informants from the study sites. For the KIs from aquaculture barangays, they mentioned water pollution or deterioration of water quality that resulted in fish kills as one of the main problems caused by aquaculture operation. This was also the perception of the CRM Officer who pointed out that wastes from aquaculture operation must have contributed 20% to the degradation in water quality at the Caquiputan Channel. It was also pointed out that MFO guidelines were not followed. These included the one line set up of structures and the number of units that an operator can own. Perhaps, the local executives had been lenient in allowing more structures due to the prospects of income that could be derived by the municipality from the industry. Or perhaps, they do not see yet the problems that may arise from the excessive number of structures.

Other commonly mentioned problems by the KIs included limited access to fishing areas, navigational hazard, small fishing areas and displacement of small fishers who need to go to far distance to fish (Table 14). These are also the main problems mentioned by the fisherfolks (Table 15). In addition, the fisherfolks also cited that there were disagreements between the operators or caretakers and fisherfolks. There were also reports of the presence of dummy operators wherein the owners were foreigners, notably from Taiwan, but were listed under the names of Bolinao residents. This maybe one of the reasons why other operators did not want to share information about the operation. Again, this is in conflict with the MFO which states that qualified applicants to construct and operate aquaculture activities are as follows: "1) Residents of Bolinao, of legal age and a registered voter of Bolinao and/or 2) Accredited people's organizations and other organizations in Bolinao with at least sixty (60) percent of their members are residents of Bolinao" (MFO No O1, Series of 1999, Article VIII Section 38). In Luna, the KIs specified that the 20-meter off fishing limit from the fish pen resulted in conflict among resource users. For the municipality, the problem associated with aquaculture industry was that the produced are not sold in Bolinao but in other municipalities and Metro Manila.

Table 14. Results of key informants survey on the perceived problems related to aquaculture operation in Bolinao, Pangasinan, May 2001

INFORMATION	PILAR	LUCIENTE 2	TARA	LUNA	VICTORY	CRM OFFICER
None					X	
Water pollution or deterioration of water quality,	X	X	X			Degradation of water quality in areas where there are fishpens/ fish cage structures but the entire area is not totally polluted
Result in limited access of fishers			X	X (result in conflict		
due to structures				due to 20 m off fishing limit from		
Navigational hazard due to garbage	X	X	X	X fish pen structures)		
Non implementation of regulation						
(realignment of structures, very						milkfish are sold outside Bolinao; brought to Metro Manila and other municipalities
close to each other like mosaic)						
Existence of dummy operators		X				
Small fishing area and displacement	X		X	X		
of small fisherfolks and lapulapu						
culture						
Disapperance of important fish species	X	X	X	X		

Table 15. Percentage distribution of fishers by barangay and perceived problems* related to aquaculture industry, Bolinao, Pangasinan, 2001

PROBLEM	BARANGAY		
	Aquaculture	Non-Aquaculture	All
None	28%	26%	29%
Water pollution	48%	69%	53%
Navigation hazards	23%	14%	21%
Displacement of fishermen (fishing sites)	3%	2%	3%
Less catch for small fishermen	6%	0%	5%
Disagreements between operators/ caretakers and fishermen	6%	0%	5%

* multiple responses

6.0 SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

6.1 Summary

Introduction and Methodology

Aquaculture is the method of cultivating edible fish and other marine species in an artificial system. Historically, aquaculture production in the Philippines followed the traditional extensive method and is environment friendly since the operation made use of natural feed production in water bodies. However, the increasing demand for food brought about by world progress and increasing population resulted into the transformation of aquaculture production from the extensive system into intensive culture where cultured fish are given commercial feeds.

In Luzon, Lingayen Gulf is one of the main producers of aquaculture. Bolinao had been identified as among the municipalities with potential areas for coastal and inland water aquaculture operation together with the municipalities of Anda, Binmaley and Dagupan. Bolinao was also the first municipality in the country that formulated the municipal fisheries ordinance (MFO) to regulate aquaculture operation. In 1997 and 1998 intense operation was reported in Bolinao resulting in sporadic fish kills in the area. Despite the MFO, the number of aquaculture structures had been reported to be constructed and operated both legally and illegally thus, exceeding the carrying capacity of the area. As such, while the industry provides benefits to the community in terms of revenues from permits, licenses and taxes and additional employment, it had been blamed for the deteriorating water quality in the coastal area. In additional to excessive number of aquaculture structures, overstocking and overfeeding practices resulted in low dissolved oxygen (DO) that became detrimental to the growing milkfish.

This study was conducted to assess the effects of excessive aquaculture structures and stocking density on water quality and aquaculture production. Survey and interviews were conducted among sample operators and key informants from both the aquaculture and non-aquaculture barangays. Monitoring of water quality was done in aquaculture areas as well as a non-aquaculture site to determine the deterioration in water quality due to aquaculture operation. With the recent fish kill event in Bolinao, result of this study is expected to provide inputs in formulating policies to rationalize aquaculture operation in the area.

Water quality analysis was done in sample fish pens from the survey areas for four months to capture the effect of aquaculture operation on water quality using DO and TSS are parameters. Aquaculture production analysis was done to determine the effect of stocking density, feeding and water quality on milkfish production. Correlation analysis was also done to determine the relationship between stocking density and DO values. Descriptive analysis on the effects of water quality deterioration on fish kills and other damages was also highlighted.

Description and Status of Aquaculture Operation

Aquaculture operation in Bolinao was concentrated at the Caquiputan Channel. Despite the regulation, fishpens and fishcages continued to be constructed and operated both legally and illegally. While the Coastal Resource Management (CRM) Office maintained record of aquaculture permits issued, the number recorded were inconsistent with the actual counts, the former way below the latter. From 242 fish pen units listed at the start of coastal aquaculture in 1995, the number of units continuously increased. In years 2000 and 2001, there were 993 and 1170 aquaculture structures, respectively, that were way above the carrying capacity of 544 units estimated for the Channel. While the MFO provided for a maximum of five units per operator, survey results showed that there were operators with 11 units. Interview with caretakers and key informants revealed that there were operators who owned 40 units. With the worst fish kill that occurred in February 2002, a moratorium on fish pen operation was put in place. However, there were reports that as of April, there were some operators who restocked their structures.

Water Quality Analysis

DO and TSS were the parameters used to evaluate water quality. Results of the analysis showed that DO levels in areas with aquaculture sites were below the critical value of 5mg/L for fish growth at all time during the sampling period. Water quality in terms of DO was relatively lower in aquaculture sites than those areas without aquaculture structures. On the average, DO level within the structures was 3.76 mg/L and was below the critical value of 5mg/l for fish growth. Correlation analysis between stocking density and DO values revealed high and negative relationship between the two variables This implies that aquaculture negatively affects water quality. No definite relationship was established between aquaculture operation and TSS values. At some points, TSS values were high inside the fish pen structures but there were also cases where TSS values were high outside of the structures. The analysis might have been complicated by the heavy rains towards the last month of sampling period and that the TSS values might have been affected by siltation.

The Aquaculture Operators

On the average, an operator owned two units of fish pen. However, there were respondents of the study who reported to own at most 11 units. From the 34 sample operators, 30% reportedly owned more than five units of fishpens. This is again a violation of the MFO guidelines that stated an operator could own at most five units only. The size of pens on the average was within the recommended area of 4,000 m^2. except for an operator who had 6,000 m^2 pen. Although in general, stocking density was within the recommended biological optimum number of 1,250 - 1,500 frys/100 sq m. there were operators whose stocking density was as high as 2,971 pcs/100 m^2, which was almost double that of the recommended. Cost and return analysis revealed that milkfish culture is a lucrative business and that the operators are earning fairly well in the operation. Average net income before tax from a 4000 m^2 fish pen was Php 309,969 per harvest with highest value up to Php 534,840.

The operators themselves admitted that aquaculture contributed to deterioration of water quality. It was mentioned that they experienced longer grow out period, such that they had only two harvests at the maximum compared to three or four harvests three years ago. Other problems mentioned by the operators included fish kill, losses due to theft and weather condition.

Effects of Aquaculture Operation on Production

Regression analysis for the aquaculture production showed that stocking density is positively related to increase in yield but up to a certain extent. Similar with other production function, further increase in variable input will eventually lead to decrease in production. Estimate showed that if stocking density, a variable input, exceeded beyond 1,693 frys per 100 m^2 area, production will start to decline. Feeds however, seem not to have significant effect on productivity as manifested by the non significant coefficient. This may imply that there is no significant variation in feed level used by the operators such that yield differences do not depend on quantity of feeds. The water quality dummy also showed negatively significant effect on yield. Result of the analysis on water quality dummy implies that if DO level fell below 4mg/L production will likely to decrease such that the production function will shift downward.

The worst effect of excessive aquaculture structures and overstocking is fish kills. There were reports of sporadic fish kills in Bolinao commonly occurring during the months of April, May and June. However, the massive fish kills that occurred in February 2000 was recorded to be the worst, not only in Bolinao but also for the country as a whole. Value of aquaculture losses from this catastrophe was estimated to be around Php600 million. Two days before the fish kills, the milkfishes were reported to crowd in the water surface, evidently gasping for air and eventually dying due to low DO. Recorded DO values a day after the massive fish kill range from 1.2 mg/L – 2.3 mg/L. These values were indeed very low for fish survival. While record at the CRM Office showed a total of 621 units (172 fishpens and 448 cages), ocular inspection showed otherwise a total of 1067 units, two times that of the 544 units carrying capacity of the area.. But it was not the aquaculture industry only that had been affected for even the fishes in the wild were observed to be affected. Unfortunately, there were no hard evidences that will enable the estimation of damage to capture fishes.

Other damages associated with fish kills due to aquaculture were social and environmental hazards. Few days after the fish kills, 75 people from Bolinao were hospitalized due to allergy allegedly from eating dried milkfish. In addition, laboratory and experiments of the UP-MSI were suspended for fear of polluted water contamination. Effects on the total marine resources are also unquantifiable because the decaying marine fauna and flora spread continually to adjacent coastal areas. Long term effects on the sea grasses and coral reefs and the species inhabiting them could be detrimental.

6.2 Conclusions

From the results above the following conclusions can be drawn:

a. The MFO guidelines were not followed. This was manifested by increasing number of structures that went way above the carrying capacity of the area. The inconsistencies between the actual number of structures and those listed or recorded at the CRM office of Bolinao indicated that most of the structures were illegally constructed. In addition, the number of structures that an operator can own also manifests the ineffectiveness of the ordinances if not inefficiencies of the administrators in implementing the guidelines.

b. Aquaculture operation is a lucrative business and the operators are earning fairly well from the operation.

c. The aquaculture industry in Bolinao can be classified as intensive. Although the average stocking density fell within the optimal value, there were operators whose stocking densities were more than double that of the optimum.

d. Results of the water quality analysis showed that aquaculture indeed affect the water quality in the area. The high and negative correlation between stocking density and DO values in the sampling areas implies that overstocking contributed to water quality deterioration. Despite the fluctuations in DO levels within the day, the average value in areas with aquaculture structures fell below the 5 mg/l critical limit for fish growth. TSS values were also high in most of the sampling sites. However, no definite link between aquaculture operation and TSS values was established.

e. Results of the aquaculture production analysis showed that stocking density had negative effects on production. Beyond a certain level, further increases in stocks would result in decreasing productivity. Water quality dummy also indicate that production is likely to decrease if DO level fell below 4mg/L.

f. Excessive number of structures and overstocking may lead to fish kills and other associated damages that are detrimental not only to the aquaculture industry itself but the community as well.

6.3 Policy Implications and Suggestions for Further Research

From the results of the study, the several policy implications can be forwarded:

a. As a lucrative business, there must be a need for regulation of coastal aquaculture operation. The problems associated with mismanaged coastal aquaculture, imply that strict enforcement of the MFO should be in place. Penalty that should be high enough compared to the gains from violation of the ordinances may be considered. Incentives for compliance to the ordinance such as tax holiday, technical assistance, etc may be considered by the LGU.

b. Since coastal aquaculture has been operating in other coastal areas of the country, legislative actions aim to regulate the industry may be called for.

c. Since aquaculture is contributory to water quality deterioration, LGUs may consider the provision, out of the revenue from the industry, of resources for activities towards sustainable aquaculture. Periodic monitoring of the number of structures may be done to make sure that the carrying capacity of the area is met.

d. Polluters-pay-principle may be applicable to the aquaculture sites. This will serve as incentive for the operators to practice effective and efficient coastal aquaculture operation.

For further research, the following can be considered:

Technical inputs are important in any economic analysis. Based on the above results the following are among the priority activities for research:

a. Studies on the technical relationship between growth of fishes, both captured and aquaculture species, and varied levels of DO. The technical coefficients on this aspect would be useful for valuation studies on the effect of water quality and fish growth.

b. Further study on the optimal stocking density for aquaculture in coastal or marine environment shall be considered.

c. Longitudinal or time series study on water quality, hydrologic characteristics, weather condition and fish growth would also be very useful.

d. Technical study on the effects of aquaculture wastes on water quality, coral reefs and spawning grounds of captured fish species to determine the survival of fish larvae and juveniles would also provide valuable input especially in assessing the effect of aquaculture on captured species.

e. Lastly, comparative study on the socio economic and environmental effects of different types of aquaculture operations (fishpond, freshwater aquaculture, coastal and inland aquaculture, concrete tanks, etc) can give important information about aquaculture management.

The above studies would be very useful for valuation and assessment studies related to aquaculture.

REFERENCES

Aquinaldo, M. M. S., P. M. Aliño, L. Talue-McManus and M.A. Juinio-Meñez. 2001. "Coastal Development Planning." Coastal Resources Management Tools. Marine Environment Resources Foundation, Inc. The Marine Science Institute, University of the Philippines. The Royal Netherlands Embassy and International Development Research Center. 45 pages.

Anderson, T. and S. de Silva. 1997. "Strategies for low-pollution feeds and feeding." www.agri-aqua.ait.ac.th/naca/aquaasia/3vol2_1_18.htm

Barbier, E.B. and I Strand. 1998. "Valuing Mangrove-Fishery Linkages: A Case Study of Campeche, Mexico." Environmental and Resource Economics. 12:151 – 166.

Boyd, C. and F. Lichtkoppler. 1979. Research and development of International Center for Aquaculture. Agricultural Experiment Station, Series No. 22 pp 3 – 10.

Craig, E. 1999. "Aquaculture Impacts on the Environment. Cambridge scientific Abastracts." www.csa.com/hottopics/aqaucult/oview.html

Cruz, P. 2001. "Tips for Optimizing Feed Use in Marine Cage Culture." Seminar on Sustainable Aquaculture and Water Quality Monitoring. Integrated Aquaculture Specialist, Inc. and the Marine Science Institute, University of the Philippines.

Dela Vega, A. 2000. "Milkfish farming in the Philippines." INTAQ Technical Bulletin.

FRMP. 2001. Resource and Social Assessment of Lingayen Gulf. An Opportunity for Better Adaptive Management. (mimeographed)

Jacinto, G. 2002, "Fish kill in Bolinao, Pangasinan: A Case Study" Paper presented at the National Forum on Aquaculture. Feb. 14, 2002. UP MSI, Quezon City, Philippines.

Fuentes, Y. "Bolinaoans on thw warpath again." Jan. 23, 2002. Phil Daily Inquirer.

____________. "Another Fish kill hits Bolinao." Feb. 5, 2002. Phil Daily Inquirer.

___________."Bolinao Fish kill: what went wrong?" Feb. 6, 2002. Phil Daily Inquirer.

___________. "UP agency proposes suspension of Bolinao fish pen operations." Feb. 7, 2002. Phil Daily Inquirer.

___________. "Bolinao fish kill spreads, emergency state declared." Feb. 8, 2002, Phil Daily Inquirer.

___________. "Local execs own fish pens, cages." Feb. 9, 2002. Phil. Daily Inquirer.

___________. "Bolinao recovery plan. Fish pen operations suspended." Feb 17, 2002. Phil Daily Inquirer.

___________. "27 hospitalized after eating bad 'daing na bangus'". Feb. 19, 2002. Phil Daily Inquirer.

Doyo, M. C.P. Fish pens, fish cages, and drowned fish. Human face. March 14, 2002. Phil Daily Inquirer.

Hagler, M. 1997. Shrimp – The devastating delicacy." www.greenpeace.org/~oceans/shrimpaquaculture/srimreport.html

McManus, L.T. and T.E. Chua (ed). 1990. The Coastal environment profile of Lingayen Gulf, Philippines." ICLARM Technical Reports 22, 69 p. Manila, Philippines.

Municipality of Bolinao. 2000. Updated Socio-Economic Profile of Bolinao.

_____________. 1997. The Proposed Coastal Development Plan (CDP) of Bolinao.

_____________. 1995. Ordinance No 1 S – 1995. Regulating the establishment, erection or construction of fish corral such as fish pens and fish cages in the municipal waters of Bolinao, Pangasinan and granting permits for their operations prescribing payments and penalties thereof.

Press Statement of the UP Marine Science Institute on the Massive Fish Kill in Bolinao, Pangasinan. Feb. 5, 2002.

Rosenthal, H. 1994. Aquaculture and the Environment. World Aquaculture. 25(2):9.

Rosser, J. Barkley, Jr. 2000. "Implications for Fisheries Policy of Complex Ecologic-Economic Dynamics." http://cob.jmu.edu/rosserjb

Tedesco, M. "How Low Dissolved Oxygen Conditions Affect Marine Life in Long Island Sound." www.epa.gov./regiono1/eco/lis/

Unknown. (n.d.) "The negative impact of aquaculture." www.twnsid.org.sg/title/paccct-ch.html

Verceles, L. F. L. T McManus and P.M. Aliño. 2000. "Participatory Monitoring and Feedback System: An Important Entry Towards Sustainable Aquaculture in Bolinao, Northern Philippines. Science Diliman, 12 (2): 78 – 87.

APPENDIX

LIST OF ACRONYMS

BFAR	Bureau of Fisheries and Aquatic Resources
BOD	Biological Oxygen Demand
CRM	Coastal Resource Management
CDP	Coastal Development Plan
DO	Dissolved Oxygen
KI	Key Informants
LGU	Local Government Unit
LGCAMP	Lingayen Gulf Coastal Area Management Plan
MFO	Municipal Fishery Ordinance
MFRMP	Marine Fishery Resources Management Plan
MSI	Marine Science Institute
PDI	Philippine Daily Inquirer
TC	Total Cost
TFC	Total Fixed Cost
TR	Total Revenue
TSS	Total Suspended Solids
TVC	Total Variable Cost
UP	University of the Philippines