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MANAGING TROPICAL MULTISPECIES FISHERIES
WITH MULTIPLE OBJECTIVES

by

Jose E. Padilla
M.Sc., Universiti Pertanian Malaysia, 1985

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
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in the Department
of
ECONOMICS

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June 1991

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ABSTRACT

The fishery is an important sector for most tropical developing countries. However, the fishing industry is, in most cases, poorly managed resulting in overcapitalization and stock depletion. Tropical fishery resource systems are difficult to manage because of their complexity and the limited information of the nature of interactions between multispecies and multiple gears involved. Moreover, many governments tend to view the fishery as a growth sector and sometimes are unmindful of the need to sustain the resources. The objective of this thesis is to develop a model that takes into account the interrelationships of biological, technological, economic and social factors in a typical tropical fishery. The model is estimated using data collected during a survey of the small pelagics fishery of Guimaras Strait and the Visayan Sea in the central Philippines.

The analysis of the fishery proceeds in three steps. First, a biological model of the fish stocks is developed. A dynamic pool model is assumed to represent fishery population dynamics. The status of the fish stocks is evaluated by looking at the yield-per-recruit for the major small pelagic species groups. The analysis then proceeds by determining the optimal allocation of the fish catch across competing gears or fleets. The allocation process explicitly considers the technological interactions in harvesting and the simultaneous optimization of several conflicting objectives in the fishery. The final step is the analysis of alternative management schemes. The regulatory schemes considered are those potentially enforceable given the economic, social and institutional environment for the fishery.

The results showed that the efficient or optimal fleet may amount to only a small fraction of the existing fleet. It is also shown that sizable fishing profits can be generated by rationalizing the fishery. However, the displacement of a large number of vessels and fishermen represents an enormous social problem. Increasing target yields through regulation of fishing selectivity does not increase significantly the efficient or optimal fleet size. This is because the current level of exploitation is close to that yielding the maximum yield-per-recruit. The results thus show the extent of overemployment and overcapitalization in the fishery.

To my parents ...

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Several individuals and institutions were instrumental in the completion of this dissertation and my doctoral program at Simon Fraser University. Their contributions, which I truly appreciate, are hereby acknowledged.

I am most grateful to Professor Parzival Copes for his guidance and full support throughout my graduate studies. As Senior Supervisor, his comments improved this thesis immensely. Professor Terry Heaps spent much time over the drafts of this thesis. His insightful comments helped me tie the loose ends together.

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The Institute of Fisheries Analysis was a very accommodating "home base" at SFU. Many thanks to the IFA colleagues specially to Chris Wright for many "fruitful" discussions and also to Eleanor Oxton for providing access to the IFA computer. Discussions with Prof. Lampe (formerly of ICLARM) and Dr. Eng Choo (SFU) at various stages of the research were also very helpful.

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Chapter 1

Introduction

1.1 Background

The fishery resources have greater importance to the economies of many tropical coastal developing countries than the value or the quantity of fishery landings would suggest. In the Philippines, for instance, the total catch (marine and freshwater) was about 2.3 million tons in 1988. This was valued at 42.12 billion pesos[1] representing 5.11% of the gross national product (GNP) in that year. However, the employment contribution of the fishery is a little higher. Directly employed in the fishery are an estimated 1.3 million fishermen, or 5.54% of the total labor force. On top of this number are those indirectly employed in capture fisheries and in allied industries, but there is no available estimate of their number. Exports of fishery products have risen dramatically in the past decade and in 1988, the 9.6 billion pesos in fishery exports was 6.44% of total exports. Moreover, fish is the cheapest and the primary source of protein in the Filipino diet. The importance of fishery resources, notwithstanding, there is not much done to manage them. There are indications that Philippine fisheries are overcapitalized and overexploited.

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[1] In 1988, the exchange rate was around 16 pesos per Canadian dollar (CAD).

This endangers the fish stocks and the livelihood of those who depend on them.

One reason why there has been no serious attempt to manage the fishery resources in the Philippines is that not much is known about them. The fishery is multispecies and the number of commercially important finfishes alone is in the hundreds. This makes it very costly and difficult to study the biological characteristics and interrelationships of the various species. The fishery is also technologically interrelated whereby all gears have limited selectivity in the harvesting process; every haul of the net yields a mixture of species. Moreover, the number of fishing gears exploiting the fishery is numerous. All these contribute to the complexity of the fishing industry and the limited understanding of the fishery.

While fishery regulations have been initiated, enforcement has been very lax. This can be attributed to the obvious lack of an enforcement mechanism and more importantly, to the inadequate scientific basis in the design of these regulations. Even where data is available, the complexity of the fishery resource system imposes upon fishery managers an enormous difficulty in the selection of appropriate tools in managing the fishery. Regulations vary in terms of their costs (enforcement included). Likewise, regulations may impact more on a specific group of fishermen, hence, the pattern of resource distribution may change.

Another factor that contributes to poor management of the fishery resources is the lack of political will on the part of the government in the light of enormous social implications of fisheries rationalization. In fact, a number of conflicting objectives have to be observed in the exploitation of fishery resources in the Philippines. The objectives include food production, resource conservation, improving the economic condition of those in the fishery and increasing employment. The conflict in these objectives lies, for instance, in the income-employment trade-off. Average fishing income will inevitably go down as more fishermen are allowed into the fishery. This is an inevitable consequence as development rather than management has been the focus of most fishery related government programs. Thus, the multi-objective nature of fisheries exploitation presents a difficult dimension in the management of the fishery.

This thesis looks at the small pelagic fishery of Guimaras Strait and the Visayan Sea in the Philippines, a fishery that has all the characteristics described above. It is a multispecies multi-gear fishery and the biological characteristics of the fish stocks have barely been documented. This fishery is one of the most productive in the country and a main contributor to the economy of the region, particularly to the provinces of Iloilo and Negros Occidental in the central Philippines.

An important component of this thesis is the documentation of the characteristics of the fishery as this is the first step in attempting to manage it. An extensive survey and monitoring was conducted to collect biological and economic data pertaining to the fishery. The data include length frequency distributions of various small pelagic species and information on the operations of fishing gears exploiting these fish stocks. The monitoring period lasted one year -- from November 1988 to October 1989. The empirical testing of the model developed in this thesis relies mainly on the primary data collected.

The complexity of the fishery resource system and the limited data that are available dictate the level of analysis that can be done. However, the following are the pressing issues that need to be addressed in the analysis of the small pelagics fishery of Guimaras Strait and the Visayan Sea:

- the multispecies nature of the fishery and the technological interactions in harvesting;
- the large number of gears exploiting the small pelagics; and
- the pursuit of multiple objectives in exploitation.

The analysis of the fishery in this thesis proceeds in three steps. First, a biological model of the fishery resources is developed. A dynamic pool model is assumed to represent fishery population dynamics. The yield-per-recruit for each of the various small pelagic species groups is looked into and target yields are computed. The analysis then proceeds by determining the optimal allocation of the fishery yields across competing gears or fleets. The allocation process explicitly considers the technological interaction in harvesting and the simultaneous optimization of several conflicting objectives in the fishery. The final step is the analysis of alternative management schemes. The regulatory schemes considered are those potentially enforceable given the social, economic and institutional environment for the fishery.

1.2 Outline of the thesis

The fishery is described in chapter 2 using available secondary data and the primary data collected in the survey and monitoring. The chapter highlights the biological and technological complexities of the fishery and the pressing social, political and institutional issues that should be considered in the management of the fishery. The third chapter presents the theoretical bases for fisheries management by reviewing the literature on three areas deemed important in the case of the small pelagics fishery in the Philippines. These are on the evolution of fisheries policy, the approaches made in modeling multispecies and multi-gear fisheries and the common fisheries management regulations.

The development of the fishery model is in chapter 4. An adaptation of the dynamic pool model developed by Beverton and Holt was chosen to represent fish population dynamics. A framework is also presented in determining optimal fleet size when several conflicting objectives are pursued in the exploitation of the fishery. The derivation of numerous parameters required by the model is described in chapter 5. The methodologies employed in the estimation are described including the procedure for the construction of a fishing effort index. The discussion of results is in chapter 6. The impacts of alternative management strategies that are applicable to the fishery are analyzed in this chapter. The regulation of fishing mortality and age at first capture are among the regulations considered. The final chapter presents a summary of the empirical results of the model as well as some concluding remarks.

Chapter 2

Description of the Fishery Resource System

This chapter gives a detailed description of the various components of the fishery resource system. This thesis deals with a tropical fishery in a developing country where conditions, in many respects, are radically different from those in developed countries. Hence, this chapter provides an understanding of the entire gamut of the fishery, which is the initial step in attempting to manage it.

The status of the fishery is described by presenting secondary and primary data. The secondary data are time-series of catch, effort and demographic information and are presented in sections 2.1, 2.4 and 2.5. The primary data consist of biological and economic information collected during a survey and monitoring in the central Philippines from November 1988 to October 1989[1]. The biological data include length-frequency distributions of the major small pelagic species caught as well as weekly records of catch and effort of the various fishing gears. The economic data were gathered during the bimonthly monitoring of the operations of various fishing gears in the

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[1] The field expenses of the survey and monitoring project were funded by the Asian Fisheries Social Science Research Network (AFSSRN) which is coordinated by the International Center for Living Aquatic Resources Management in Manila, Philippines. The survey was implemented by the University of the Philippines in the Visayas (UPV)-AFSSRN research team. The project was conceptualized by the author who led the research team in conducting the research, managing and processing the data and in writing the preliminary results.

study area. A preliminary analysis of the primary data are presented throughout this chapter.

2.1 Resource characteristics and catch statistics

The Philippines constitute an archipelago consisting of 7,107 islands extending about 2,000 km in a north-south direction between 4°30′ and 21°20′ N. It has a total coastline of 17,460 km along which 65% of total municipalities, 82% of all provinces are located and where 55% of the population resides. The study area[2], Guimaras Strait and adjacent waters (specifically the Visayan Sea), is located about 10°15′ N latitude and 122°45′ E longitude (Figure 2.1). The Strait is bounded by Panay Island in the northwest and by the island of Negros on the southeast. It has an area of about 7,119 sq.km. with an average depth of 18 meters. Like the Philippine archipelago, the two provinces bordering on the study area are primarily coastal with 87 of 131 cities and municipalities facing the sea.

The tropical Philippine waters possess a great diversity of marine life but not a great abundance of any single species (Warfel and Manacop 1950). Over 2,000 fish species grouped in 205 families and 716 genera have been recorded (Herre 1953), several hundreds of which are of commercial value. Seventy-one

---

[2] The survey and monitoring areas are also indicated on the map. Six sites were selected, three in each province. The sites on Negros island (Negros Occidental side) are Himamaylan, Silay City and Cadiz City and on Panay island (Iloilo side) are Guimbal, Banate and Estancia. Cadiz City and Estancia border on the Visayan sea while the rest face Guimaras Strait.

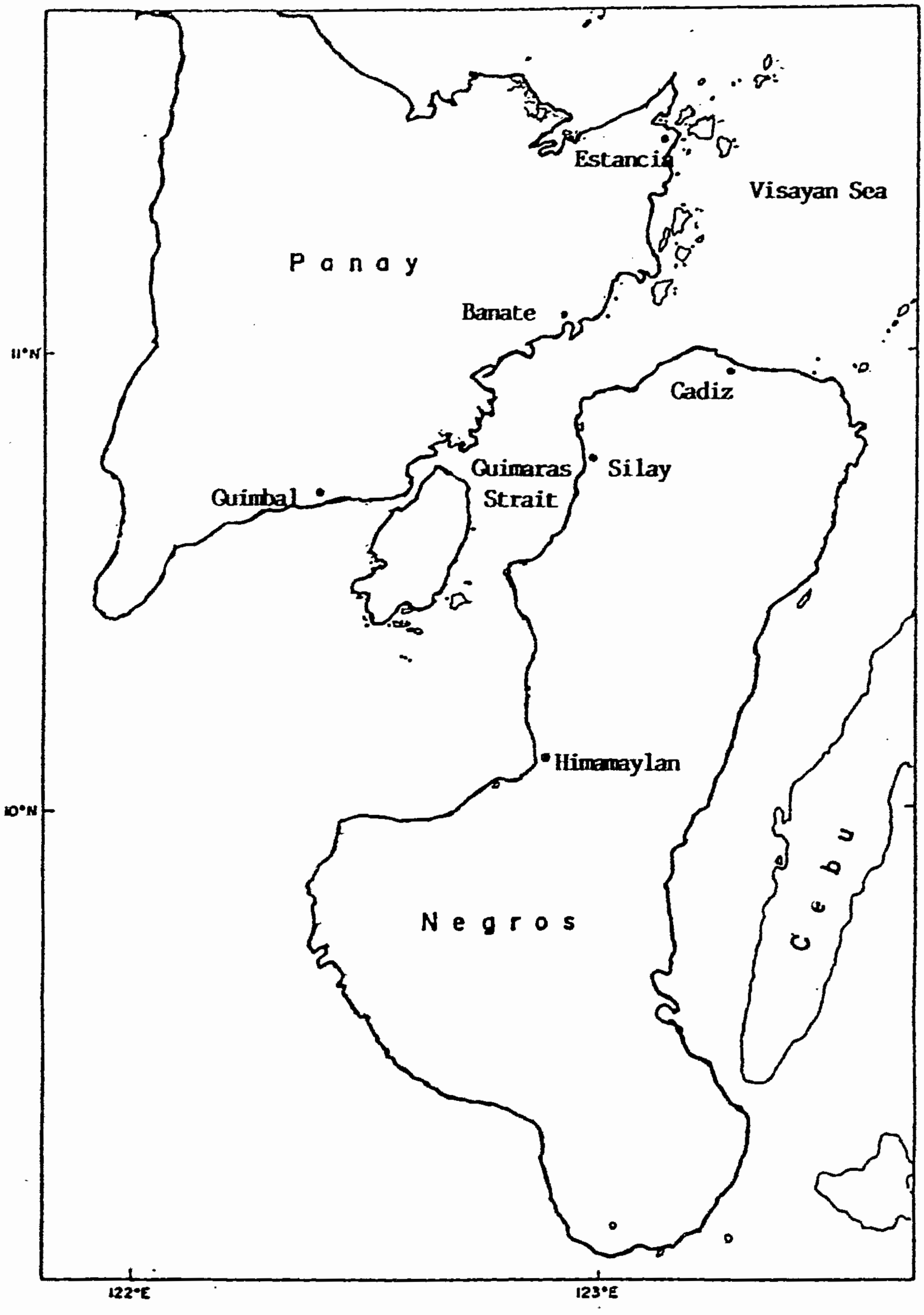


Figure 2.1. Map showing the study area and the six survey sites

(71) species or species groups are listed in the catch statistics. The catch data in the official fishery statistics are divided into municipal and commercial. The municipal-commercial classification is made on the basis of vessel gross tonnage. Catches of fishing boats below 3 gross tons are municipal landings while those for vessels 3 gross tons and above are commercial landings. Records of fish catches are collected by gear type, by vessel category and by species groups.

The Philippines lie in the tropics and marine fish and invertebrates in this environment differ from their temperate counterparts by having, generally, smaller asymptotic sizes, shorter life spans, reduced intensity of seasonal oscillations in a number of cyclical features (growth, fat content, migratory behavior, etc.), higher fecundities, and higher natural mortality (Pauly 1989). The small pelagic fishes which are the subject of this thesis have the above characteristics. The term "small pelagic fishes" is an arbitrary classification of a diverse group of fishes that share a common habitat - the upper surface layers of the water column. The above-mentioned characteristics, the greater degree of interaction between species and the diversity of the ecological environment in tropical fisheries often create difficulties for stock assessment or for population dynamics studies. Further discussion of this and the biological characteristics of the small pelagics may be found in chapter 5.

The total marine catch[3] from Guimaras Strait and the Visayan Sea from 1978 to 1987 amounted to 12.89% of total Philippine production. Guimaras Strait and the Visayan Sea ranked fourth and first, respectively, in terms of productivity among 24 statistical fishing grounds in the country in 1987. Average yield per sq.km. in the same year was 12.38 tons in the Visayan Sea and 9.71 tons in Guimaras Strait. Meanwhile, the national average was 2.69 tons/sq.km. in that year.

Marine fisheries in the two fishing grounds are primarily based on pelagic fishes as the contribution of these species to total marine fishery production in 1978-1987 ranged from 41.89% to 55.35% (Table 2.1). Of the total pelagic landings, small pelagic fishes formed over 90% of the catch in the same period, equivalent to about 50% of the total marine catch. The proportion of small pelagic landings in Guimaras Strait is smaller (about 41%) than in the Visayan Sea (52%) while the national figure stands at 44% from 1978 to 1987.

The landings of small pelagics are confined to only a few species or species groups. Landings of each species group are added from 1978 to 1987 for Guimaras Strait and the Visayan Sea. The figures show that ten of the top twenty species groups landed are small pelagics. During this period, the cumulative landings of sardines, a group of small pelagic species, was highest among all species groups (Table 2.2).

---

[3] In the Philippines, records of marine landings by statistical area (or by fishing ground) started only in 1978. This ended in 1987 after which data collection reverted back to the original system of reporting only estimates of catch for the entire country. The remaining part of this section discusses mainly the secondary data.

Table 2.1. Marine fishery production in Guimaras Strait and the Visayan Sea, by species group, 1978-1987 (in metric tons)

Year	Total Prodn.	Pelagics		Total Pelagics	Demersal and Invertebrates	Percentage of small pelagics to	
		Small Pelagics	Big Pelagics			Total Prodn.	Total Pelagics
1978	195,573	81,922	7,208	89,130	106,443	41.89	91.91
1979	242,518	105,285	15,310	120,595	121,923	43.41	87.30
1980	250,796	135,543	14,220	149,763	101,042	54.05	90.50
1981	221,632	114,371	13,806	128,177	93,455	51.60	89.23
1982	229,572	127,064	15,643	142,707	86,865	55.35	89.04
1983	268,769	140,523	13,312	153,835	114,391	52.28	91.35
1984	266,933	131,204	15,756	146,960	119,973	49.15	89.28
1985	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1986	254,112	122,039	13,427	135,466	118,646	48.03	90.09
1987	260,140	134,826	8,445	143,271	116,869	51.83	94.11

n.a. = not available

Source: Fisheries Statistics of the Philippines, various years.

Table 2.2. Important fish species groups in Guimaras Strait and the Visayan Sea, 1978-1987.

Rank	Species group		Total landings (m.t.)	% share to total prodn	Cumulative percentage
1	Sardines	SP	325,764	14.87	14.87
2	Slipmouths	DM	214,002	9.77	24.64
3	Roundscad	SP	205,825	9.40	34.04
4	Threadfin breams	DM	128,441	5.86	39.90
5	Goatfishes	DM	78,696	3.59	43.49
6	Anchovies	SP	78,558	3.59	47.08
7	Indo-Pacific mackerel	SP	78,119	3.57	50.65
8	Squid	DM	71,634	3.27	53.92
9	Indian mackerel	SP	70,563	3.22	57.14
10	Crabs	DM	66,520	3.04	60.18
11	Crevalles	SP	63,453	2.90	63.08
12	Shrimp & prawns	DM	63,103	2.88	65.96
13	Eastern little tuna	SP	59,814	2.73	68.69
14	Lizard fishes	DM	59,658	2.72	71.41
15	Frigate tuna	SP	56,915	2.60	74.01
16	Round herring	SP	55,215	2.52	76.53
17	Big eye scad	SP	47,136	2.15	78.68
18	Croakers	DM	34,010	1.55	80.23
19	Spanish mackerel	BP	31,655	1.45	81.68
20	Sillago	DM	31,056	1.42	83.10

Legend: SP - Small pelagic
BP - Big pelagic
DM - Demersal

Source : Fisheries Statistics of the Philippines, various years.

Other small pelagic species groups caught in order of their importance were round scads, anchovies, mackerels, crevalles, frigate tuna, round herring and big-eye scads.

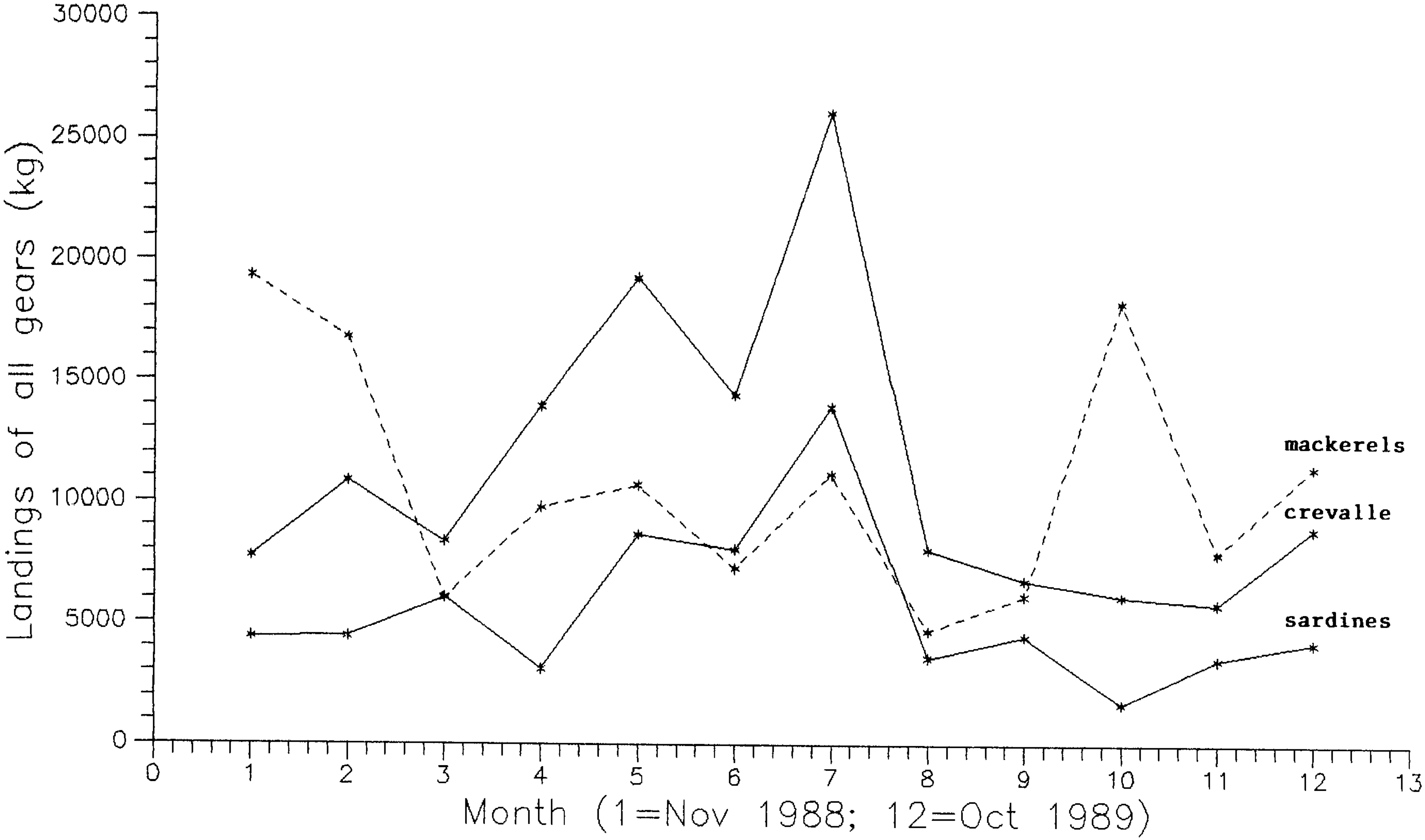
Monitoring of marine fish production for one year at 6 sites along Guimaras Strait showed wide monthly fluctuations in the landings of small pelagic fishes. Figure 2.2 shows the three top species groups in terms of landings, namely: crevalle, mackerel and sardines. Peak landings occur early in the year from February to May for crevalle, from August to December for mackerel and from March to May for sardines. These peaks are not very noticeable since the monthly landings fluctuated by a wide degree.

The distinction between municipal and commercial fishery sectors is important because of their performance differences. The official fishery statistics show a 60/40 split of total landings in favor of the commercial sector in Guimaras Strait and Visayan Sea. The monitoring that was conducted reveal a more disparate sharing of total landings with the commercial sector accounting for about 80% of total landings[4]. Since the number of municipal fishermen is far greater than that of commercial fishermen, the above implies a very wide difference in productivity between the two sectors. This is discussed further in the succeeding section.

---

[4] The data collected during the survey and monitoring are more reliable than the official fishery statistics. The collection of the latter data was plagued with implementation problems due to budget and manpower shortages faced by the Philippine Bureau of Fisheries and Aquatic Resources, which was the responsible agency at that time.

Figure 2.2. Monthly landings of major small pelagic species groups in six survey sites in Iloilo and Negros Occidental, Philippines (Nov. 1988 to Oct. 1989)



2.2 The fishing fleet: technical and economic profile

The fishery resources of the Philippines are exploited by numerous gears -- from a simple hand line to a modern purse seine to fixed gears such as a fish corral. About 23 different types of municipal gears are in operation in the study area. The number of gears would be 50% higher if the commercial counterparts of some of the municipal gears are counted as separate gears.

Table 2.3 lists selected technical and economic characteristics of the major fishing gears. Only the large purse seines with their mechanically-powered catcher and carrier vessels complemented by a large crew and other fishing paraphernalia conduct large-scale fishing operations. These fishing units are large by developing-country standards but may still be small by Western standards. Modified Danish seine and encircling gill nets fall in the middle range while the rest are purely artisanal using small boats and sails to propel the vessel. Thus, the fishing fleet in the study area employs harvesting technologies that cover a wide technological continuum.

The above may be deduced from the amounts invested in fishing equipment, from which the level of fishing technology that is used can be inferred. Purse seines require the biggest capital outlay. On the other hand, average investment in Danish seines and encircling gill nets, although sizable, are much smaller than those in purse seines. The rest, the

Table 2.3. Technical and economic description of major gears in Iloilo and Negros Occidental, Philippines, 1988-1989

Craft-gear combination	Average gross tonnage	Average crew size	Average investment (pesos)	Share to total investment (%)				Capital-labor ratio
				Boat	Engine	Net	Other assets	
A. Gill nets								
Drift gill net	1.40	2.8	18,492	30.0	25.3	44.3	0.4	6,557
Bottom gill net	1.05	2.1	6,184	34.1	3.7	59.0	3.1	3,017
Encircling gill net	2.57	5.5	46,490	24.7	24.4	48.5	2.5	8,515
B. Seines								
Purse seine	33.16	32.0	329,804	42.8	9.9	46.5	0.8	10,306
Baby purse seine	3.65	16.6	93,610	46.6	14.5	38.0	0.9	5,636
Beach seine	0.77	8.5	12,195	24.6	36.9	37.9	0.6	1,435
Tuck seine	0.18	4.6	1,745	54.6	0.0	44.7	0.7	379
Danish seine	4.95	8.0	59,208	46.6	32.1	15.4	5.9	7,392
C. Trawl	2.40	2.3	29,395	24.5	63.4	11.6	0.5	12,670
D. Fish corral	0.59a	3.1	13,572	10.1	9.6	36.4	43.9	4,450
E. Squid jigger	0.41	1.8	4,761	22.9	65.2	0.1	11.8	2,660
F. Longline	0.23	1.6	1,726	93.1	0.0	0.0	6.8	1,065
G. All gears	3.42	4.6	42,371	37.5	24.4	32.6	5.5	9,231

a = average gross tonnage for the collecting vessel in fish corral

Exchange rate: 1 CAD = 16 pesos (1988-1989) artisanal gears, involve minimal investments. Normally, the biggest chunk of investment is for the boat structure and the engine to propel the boat although in some remote fishing villages dug-out canoes with no mechanical power are employed.

In Philippine fisheries where labor has low opportunity costs and capital is scarce, one would expect that a labor-intensive fishing technology would evolve. Labor would be substituted for capital where possible. Several observations support the above. In municipal fishing man or wind-power takes the place of motors. In commercial fisheries, however, boat and net specifications dictate power requirements in propelling the vessel; hence in this respect, there is a lower degree of substitutability between labor and capital. Nevertheless, in other fishing tasks such as the hauling of the net, manpower takes the place of motors and winches.

Hence, the capital-labor ratio is lower for gears which are primarily artisanal, such as tuck seine and long line, and higher for commercial gears such as trawl and purse seine (Table 2.3). The capital-labor ratio indicates more importantly, in addition to the level of fishing technology employed, the amount of investment required to generate a job in fisheries. Municipal fisheries involve much lower investment than commercial fisheries per unit of gainful employment.

The proliferation of many types of fishing gears in the area is consonant with the multiplicity of both pelagic and demersal (bottom fish) species being harvested. Most gears are designed to target on certain species or groups of species according to where the fish thrive along the water column. Drift, encircling and surface gill nets, for instance, are for catching primarily pelagic species while trawls and bottom seines such as beach seines take mostly demersal species. However, it is the usual case even for selective gears, that every haul of the net produces significant by-catches of non-targetted species. Moreover, modifications on the design or operation of some gears allow them to catch both pelagic and demersal species. Trawling in mid-water or increasing the opening or "mouth" of trawls or of Danish seines enable these gears to operate along a wider range on the water column.

In the small pelagics fishery, the more important gears in terms of biological impact, i.e., the volume of catch, are modified Danish seine, purse seine including baby purse seine, trawl, and gill nets (encircling, drift and bottom-set). In terms of the proportion of small pelagics to total catch, however, encircling gill net, purse seine and drift gill net are the most dependent on these species (Table 2.4). The contribution of the small pelagics to total fishing revenue does not deviate much from the physical composition of catch because of the small price differences across species groups.

Although the share of small pelagics to total catch of modified Danish seines ranges from only about 24% to 40%, they account for the largest absolute quantity of small pelagic landings considering the large number of units of this gear in the study area. This is the dominant gear in both the demersal

Table 2.4. Relative abundance of small pelagic fishes in Guimaras Strait and the Visayan Sea: composition of catch (%) of major commercial and municipal gears, 1988-1989.

	COMMERCIAL GEARS					
Species group	Enc'ling gill net	Baby purse seine	Danish seine	Trawl	Fish corral	Purse seine
Small pelagics	98.86	87.67	39.21	10.64	41.56	87.73
Sardines	95.96	63.00	2.24	1.01	2.21	1.81
Mackerels	1.66		12.58	1.54	0.31	69.81
Anchovies		23.34	0.16	1.66	31.73	0.19
Big-eye scads			0.01	0.25		0.13
Roundscads	0.09		1.20	1.60		6.61
Round herring	0.15		0.02			
Crevalle	0.19	0.09	15.94	3.59	1.29	5.73
Fusilier				0.03		
Mixed small pelagics	0.80	1.24	7.06	0.96	6.02	3.45
Other species	1.14	12.33	60.80	89.35	58.44	12.28

	MUNICIPAL GEARS						
Species group	Drift gill net	Enc'ling gill net	Baby purse seine	Danish seine	Trawl	Fish corral	Bottom gill net
Small pelagics	75.06	96.55	96.90	23.68	17.43	63.78	29.27
Sardines	62.74	80.66	73.21	1.12	3.10	30.3	9.15
Mackerels	0.55	2.70		5.09	4.31	1.09	7.73
Anchovies	3.79	12.05	23.69	0.17	5.40	21.76	0.28
Big-eye scads		0.13		0.03	0.02		0.05
Roundscads	3.24			0.40	1.34		0.02
Round herring	4.04	0.24		0.02	0.04		0.19
Crevalle	0.17	0.31		9.29	1.75	4.64	2.7
Fusilier				0.02			0
Mixed small pelagics	0.52	0.45		7.55	1.45	5.99	9.15
Other species	24.94	3.45	3.10	76.32	82.57	36.22	70.74

and pelagic fisheries. Danish seine will remain the major gear in the future as it is gaining popularity not only in the study area but in other parts of the Philippines.

The catch per unit of effort indicates the efficiency of the fishing operation measured in physical terms. These figures, as listed in Table 2.5, are computed from the catch and effort data collected during the survey and monitoring. For the purpose of comparison, effort[5] is measured by actual fishing hours. Drift net, the simplest gear that targets on small pelagics caught an average of 2.53 kg/hr. The highest recorded catch was for baby purse seines at over 40 kg/hr. Considering the length and frequency of fishing trips using drift nets, the annual catch per fishing unit comes to about 2.28 tons, equivalent to 0.81 ton/fisherman/yr. This is within the estimate of Smith et al. (1980) who placed the catch rate in the municipal sector (nationally) at 0.27 - 2.13 tons per fisherman per year. On the other hand, the highest annual catch for primarily commercial gears is by modified Danish seine at about 4.95 tons/fisherman/yr.

The average duration of a fishing trip varies among gears from a few hours to several days. Gill netters usually set out at daybreak and then again at dusk, thereby fishing twice on a good day. The large purse seiners and trawlers are able to spend several days at sea with the carrier vessels ferrying supplies and bringing in the catch. As such, these two gears

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[5] In chapter 5, a more thorough definition of fishing effort is made. Also, an index of fishing effort across gears is constructed.

Table 2.5. Technical details of fishing operations for selected fishing gears in Iloilo and Negros Occidental, Philippines, 1988 - 1989

Gear	CPUE (kg/hr)	Fishing hours/ trip	No.of hauls per trip	Number of trips per month	Effective fishing days/yr	Distance of fishing ground (km)
A. Gill nets						
Drift gill net	2.53	3.43	1.06	21.90	75.12	9.65
Bottom gill net	2.06	4.84	2.55	20.90	101.16	9.27
Encircling gill net	12.74	3.70	1.32	17.10		
B. Seines						
Purse seine	36.20	13.52	3.53	15.20	205.50	19.43
Baby purse seine	44.02	4.79	3.02	20.30	97.24	n.a.
Beach seine	9.31	5.20	3.39	20.22	105.04	n.a.
Tuck seine	9.17	5.04	4.92	n.a.	n.a.	n.a.
Danish seine	14.34	9.00	2.52	25.57	230.13	22.23
C. Trawl	21.95	10.96	7.92	17.30	189.61	33.09
D. Fish corral	27.34	9.15 a	1.62	31.48	288.04 b	0.86 c

a The interval length (hrs) the fish corral is emptied.
b Average days the corral is in operation.
c The distance from shoreline the fish corral is constructed.
n.a. = not available (not monitored)

have the highest number of effective fishing days in a year, at over 200 days (Table 2.5). The distance the fishing boat can travel in search for fish depends on the source of power and the size of the boat itself. The smaller vessels are limited to operating within several kilometers from the shore. Fish corrals, a fixed gear, are constructed right after the typhoon months of July, August and September and last until destroyed by natural forces.

2.3 Costs and earnings

A cross section analysis of fishing operations by type of gear is made in this section. The unit of operation that is considered is the fishing trip. For each gear, an average is given for all trips made during the survey. The analysis pertains to the fishing enterprise and hence, the costs included are those incurred by the fishing operator while the earnings include only the value of the catch. Table 2.6 gives a summary of costs, earnings and profits.

There are two categories of costs considered: fixed and variable costs. Fixed costs are primarily allocations for depreciation and government fees in the form of resource access fees and permits. There is no insurance coverage for fishing boats included in the analysis. Variable costs include expenses for material inputs (fuel, oil, ice, food, etc.), crew remuneration and repairs and maintenance. The biggest cost item under material expenses is fuel, followed by food. The

Table 2.6. Costs and earnings per fishing trip and measures of profitability for major gears, Iloilo and Negros Occidental, Philippines, 1988-1989 (amounts in pesos)

Market category	Drift gill net Amount	Drift gill net %	Bottom gill net Amount	Bottom gill net %	Enc. gill net Amount	Enc. gill net %	Purse seine Amount	Purse seine %
A. Total catch value	145	100.0	147	100.0	576	100.0	7,497	100.0
Sold	100	69.0	126	85.9	528	91.7	6,794	90.6
Small pelagics	77	53.5	37	25.3	472	82.1	4,910	65.5
Other species	22	15.5	89	60.6	56	9.7	1,884	25.1
Consumed, given away, etc.	45	31.0	21	14.1	48	8.3	703	9.4
B. Costs	137	100.0	119	100.0	445	100.0	4,206	100.0
Variable costs	109	79.3	109	91.4	345	77.6	3,953	94.0
Material expenses	58	42.2	20	16.7	105	23.6	1,517	36.1
Labor expenses	38	27.6	75	62.9	174	39.1	2,094	49.8
Other	13	9.5	14	11.8	66	14.8	341	8.1
Fixed costs	28	20.7	10	8.6	100	22.4	253	6.0
C. Profitability								
Gross profit	36		38		231		3,544	
Net profit	7		28		131		3,291	
Return on investment (%/yr)	4.4		19.7		19.5		54.7	

Market category	Danish seine Amount	Danish seine %	Trawl Amount	Trawl %	Fish corral Amount	Fish corral %	All boats Amount	All boats %
A. Total catch value	2,370	100.0	1,705	100.0	307	100.0	1,384	100.0
Sold	2,242	94.6	1,645	96.5	271	88.3	981	70.9
Small pelagics	1,253	52.9	519	30.5	109	35.5	588	42.5
Other species	989	41.7	1,126	66.0	162	52.8	392	28.4
Consumed, given away, etc.	128	5.4	60	3.5	36	11.7	403	29.1
B. Costs	1,823	100.0	1,087	100.0	183	100.0	1,116	100.0
Variable costs	1,788	98.1	1,048	96.4	173	94.4	1,059	94.9
Material expenses	939.6	51.6	371	34.1	43	23.3	194	17.4
Labor expenses	704.6	38.7	610	56.2	91	49.7	777	69.6
Other	144	7.9	66	6.1	39	21.5	88	7.9
Fixed costs	34	1.9	39	3.6	10	5.6	57	5.1
C. Profitability								
Gross profit	582		657		134		324	
Net profit	548		618		124		267	
Return on investment (%/yr)	27.2		50.3		56.5		20.8	

Notes:

Gross profit = Total catch value - variable costs

Net profit = Total catch value - total costs fishing industry, especially the commercial fisheries sector, is a big user of imported fuel and its financial performance is greatly affected by fuel price fluctuations.

Total catch value is the sum of receipts from catch that is sold and the imputed value of catch that is not sold[6]. The portion of catch that is not sold consists of that consumed while fishing and that given to the crew as part of remuneration. The part consumed by fishermen's (operator and crew) families primarily satisfies their basic nutritional requirements. On the average, about 29% of total catch value per trip for all gears is not sold but is given to the crew or consumed at sea. Meanwhile, the contribution of small pelagics to cash revenues ranges from just 25% (bottom gill net) to over 82% (encircling gill net) with the average at 42.5% (all gears).

The monetary indicators of profitability suggest that both the short-run and long-run participation of the sample gears in the fishery are assured. In all cases both gross profit and net profit are positive. In terms of absolute figures, purse seine yields the largest profit per trip. However, a more meaningful indicator of profitability is the return on

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[6] The disposal of catch was tracked down during the monitoring period. The usual practice was to pay the crew with cash and/or in kind (fish and other provisions). This and other parts of catch that does not reach the market are valued at the market price and imputed to total revenue. These are in turn included in the fishing costs. For example, the value of fish given to the crew is added to total catch value but is also included in the crew remuneration.

investment[7] (ROI). Three gears, namely, fish corral, purse seine and trawl registered an annual ROI of over 50%. The ROI figures would explain the extent of use of the gears in the study area.

Trawl is one of the most popular gears particularly in Himamaylan. In fact, one fishing operator owned as many as 20 municipal trawlers. However, the employment of fish corral and purse seine was not as widespread as that of trawl because of barriers to entry in the use of these gears. The number of fish corrals that can be constructed is limited and the "rights" are usually auctioned by the municipal governments. In the case of purse seine, the investment requirement (about 329,800 pesos per fishing unit) is quite prohibitive for the average fisherman. On the other hand, the increasing popularity of Danish seine in the study area may be explained by the moderate returns on investment on this gear and the relatively affordable capital requirement.

2.4 Socio-demographic aspects

The fishery resource system is not only composed of the fishery resources and the harvesting technology but also includes people - primarily the fishermen. The demographic

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[7] Investment, as measured here, includes the value of fishing equipment and working capital. No value was imputed for the time spent by operators (who are not crew members) in managing the fishing enterprise. Thus, the ROI measures the returns on the operator's monetary and temporal investment in the fishing enterprise.

aspects, labor dynamics and the socioeconomic conditions in the fishery are discussed in this section.

As of 1980, the population of the Western Visayas region, which includes the provinces of Iloilo and Negros Occidental, stood at 4.526 million, about 9.4% of the national population (NEDA 1989). The number of residents in Iloilo and Negros Occidental in the same year were respectively, 1.434 and 1.930 million. Annual population growth rate for the region over 1980-1985 was estimated at 2.4%, hence the population of the two provinces in 1989 should be around 1.780 million for Iloilo and 2.389 million for Negros Occidental.

The number of municipal fishermen in the two provinces moved in opposite directions over the years. In Iloilo, it increased from 23,322 to 27,863 between 1983 and 1988 while in Negros Occidental it decreased from 49,671 to 39,964 (Provincial Development Planning Office, 1988; BFAR 1988, 1986). The decrease in municipal fishermen in Negros Occidental may be attributed to the absorption of fishermen by the booming shrimp aquaculture business in Negros Occidental. Hence, it may be concluded that the fishery is an employer of last resort; the fishery absorbs those who cannot find employment in other sectors as is happening in Iloilo. At the same time, fishermen move to other jobs, if available, as was the case for those in Negros Occidental.

The Philippine capture fisheries are classified into the municipal and commercial sectors but the socioeconomic conditions in the fishery cannot be adequately described following such classification. The level of operation, and hence earnings vary greatly within each sector and within each gear category. For instance, in municipal fisheries, an artisanal fishing unit using a simple hand line would catch much less than a municipal trawl. Similarly, in the commercial sector, a purse seine boat with a 3 gross-ton catcher vessel would be small compared to an ocean-going purse seine vessel. In addition to the level of operations of the fishing unit, the earnings of those in the fishery (the operator, the master fisherman and the crew members) are also determined by the compensation structure which is described in the succeeding paragraphs.

The small artisanal fishing units are usually owner-operated. For the larger and more costly municipal vessels however, there are, in addition to owner-operated vessels, fishing units which are managed by capitalists who are non-fishermen. As noted earlier, some capitalists own and manage several fishing units. The pattern of ownership and the management of commercial vessels are also mixed although a smaller number of vessels are owner-operated compared to the municipal vessels. Where the owner is the operator of the commercial vessel, he is usually the master fisherman.

Labor dynamics in fishing villages exhibit the social values of the communities. Employment arrangements in Philippine capture fisheries are very informal. Verbal agreements between the operator and the crew suffice and both parties freely inform each other of their employment decisions.

Many fishing enterprises in the municipal sector are a family affair whereby immediate family members compose the fishing crew and take charge of vertical integration activities (e.g., selling of catch). Where out-of-family hiring is necessary, employment decisions show clannish and regionalistic tendencies whereby relatives and community members are given priority although skill also counts. The explanation for this hiring practice is that it reduces information and screening costs.

The compensation structure in capture fisheries is as diverse as the number of gears. Remuneration is a strict sharing system in gill netting while in the bigger fishing activities, it is a combination of fixed wage and shares. In a share system, remuneration is a certain percentage (or share) of the divisible earnings which are left after deduction of common expenses from sales. For all fishing vessels in the study area, about 44% of the divisible earnings goes to the boat (capital owner) while the rest is divided among the crew whose share depends on fishing skill. It should be noted here then that for an owner-operated vessel, the owner receives compensation as member of the crew and, at the same time, collects the boat share.

In most of the large commercial fishing enterprises, the crew members, particularly the master fishermen, are given additional perks and bonuses if a pre-specified and agreed upon catch level is met. The system of rewarding bonuses is quite complex. The minimum catch is either specified in terms of quantity or value on a per trip basis and the perks and bonuses increases for catches much higher than the minimum. For example, the bonus may be computed in the following manner. If total catch in a given trip is greater than 20 tubs (about 40 kg/tub), the bonus is 10 pesos per tub but if total catch exceeds 30 tubs, the bonus is 15 pesos per tub plus an additional compensation in kind, e.g., one sack of rice per month. The perks and bonuses are additional compensation but only to the highliners in the fishery.

Thus, the actual compensation received by the fisherman is primarily a function of the compensation structure adopted as well as the productivity of the fishing operation. The average crew remuneration for one year was computed from the survey data and is listed in Table 2.7. The nature of remuneration is also specified for the various positions in the fishing unit. For some gears, the distinction between the various positions is not very clear as some crew members perform several functions during the fishing operation. For most gears, the average yearly income of the crew members varies greatly across positions in the same gear category and in the same position but different gear category. The netman of an encircling gill net received, on the average, only 1,126 pesos per year, the smallest fishing income received by a crew member during the survey. On the other hand, the master fisherman of a Danish seine received over 140,000 pesos per year.

There are crew members who are able to generate large incomes from the fishery. They are mostly the master fishermen (skippers) of primarily commercial fishing gears such as purse

Table 2.7. Average crew remuneration for one year, by position and by type of gear, Iloilo and Negros Occidental, 1988-1989 (amounts in pesos)

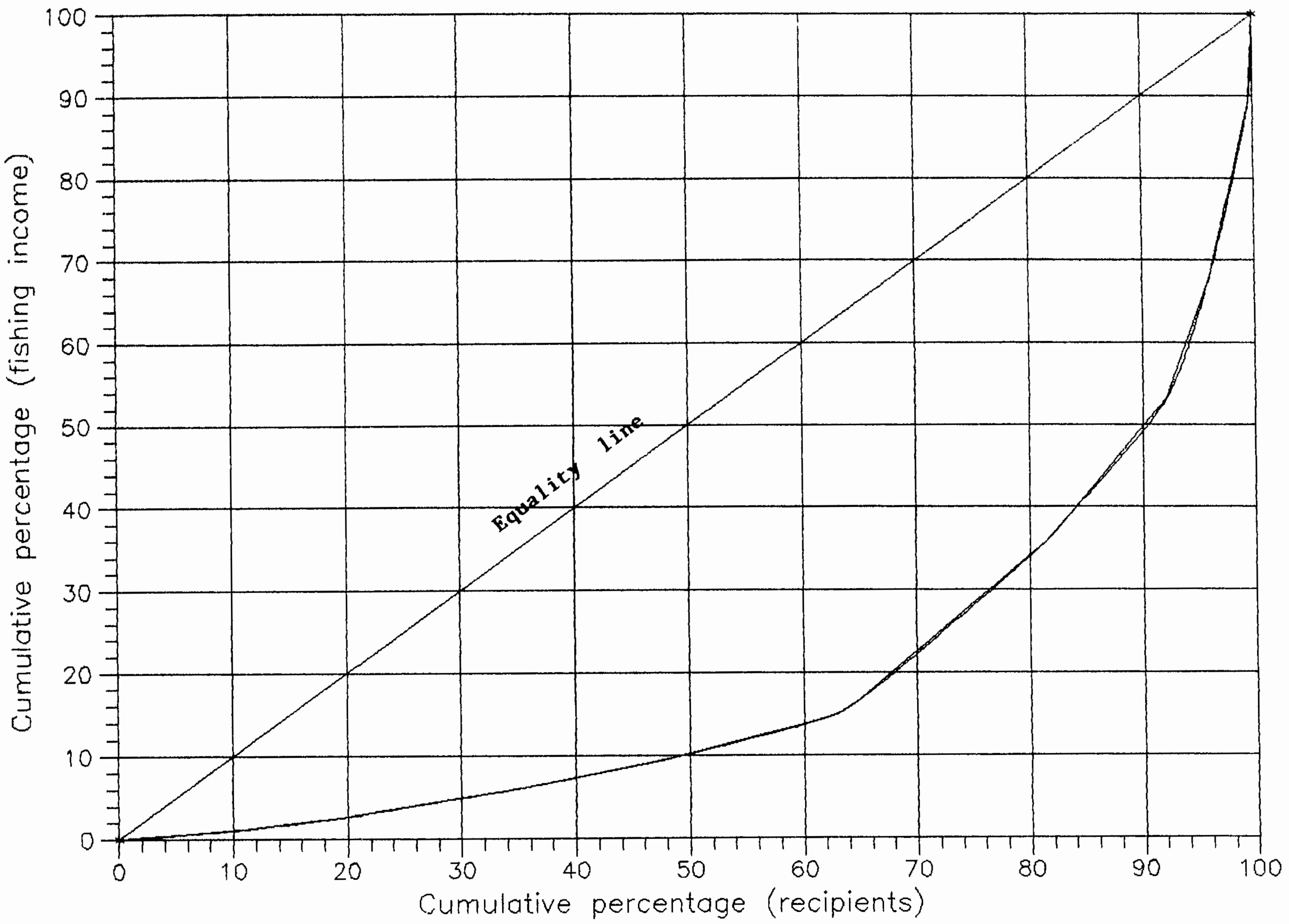
Position/remuneration	Drift gill net	Bottom-set net	Encirc. gill net	Trawl	Fish corral
A. Cash remuneration					
Master fisherman					
Share from divisible earnings (D.E.)	3,188	9,232	19,177	70,110	15,244
Fixed salary/bonuses	-	-	-	-	-
Total	3,188	9,232	19,177	70,110	15,244
Mechanic/machinist					
Share from D.E.	-	-	9,132	33,593	-
Fixed salary/bonuses	-	-	-	-	1,183
Total	-	-	9,132	33,593	1,183
Netman					
Share from D.E.	2,664	7,059	1,126	25,594	26,267
Fixed salary/bonuses	-	-	-	-	-
Total	2,664	7,059	1,126	25,594	26,267
Other crew					
Share from D.E.	2,664	7,059	3,184	57,112	7,312
Fixed salary/bonuses	-	-	-	-	-
Total	2,664	7,059	3,184	57,112	7,312
B. In-kind (sum for all positions)	1,472	1,215	249	440	148
Per crew member	945	593	46	190	48

Position/remuneration	Purse seine	Baby p. seine	Beach seine	Tuck seine	Danish seine	All gears
A. Cash remuneration						
Master fisherman						
Share from D.E.	107,498	44,990	18,677	1,480	140,933	47,230
Fixed salary/bonuses	4,161	482	-	-	78	148
Total	111,660	45,472	18,677	1,480	141,011	47,378
Mechanic/machinist						
Share from D.E.	27,246	15,233	-	-	58,755	17,841
Fixed salary/bonuses	6,384	723	-	-	2,403	2,270
Total	33,630	15,956	-	-	61,158	20,111
Netman						
Share from D.E.	1,059	1,866	3,467	941	18,081	12,657
Fixed salary/bonuses	39	-	-	-	-	49
Total	1,098	1,866	3,467	941	18,081	12,707
Other crew						
Share from D.E.	5,990	4,568	7,863	-	8,730	20,704
Fixed salary/bonuses	740	51	-	-	2	130
Total	6,729	4,620	7,863	-	8,732	20,834
B. In-kind (sum for all positions)	165,086	19,043	2,266	746	1,122	2,385
Per crew member	5,159	1,146	267	162	140	520

seine, Danish seine, trawl and baby purse seine. Their large incomes may be attributed to their superior fishing skills which are adequately rewarded by the compensation system adopted in the fishery. As mentioned earlier, some boat skippers receive bonuses and perks in addition to their shares from divisible earnings. Also, the operators of trawls, fish corrals and purse seines realize relatively high returns on investment (see Table 2.6). The high ROI may be partly attributed to the fact that some fishing operators have tied-in other income-generating activities such as fish processing and trading or brokerage with fish capture. In effect, there is a vertical integration of activities around fish capture.

The fishing income figures are an indication of the disparate socioeconomic conditions in the fishery. There are fishermen who receive large incomes but the majority of the participants in the fishing industry -- the netmen and the ordinary crew members get very meager incomes. To determine the distribution of fishing income to the various direct participants in the fishery, a Lorenz curve is constructed (Figure 2.3). The income received by the crew members is indicated in Table 2.7, while the fishing income of the boat owner is computed from Table 2.8, which is then converted to annual figures. The Lorenz curve is for only the 583 sample gears surveyed.

Figure 2.3. A Lorenz curve showing the distribution of fishing income for the sample respondents (fishing operators and crew members)



Income group	Percent of income received	
	The fishery	Philippines[8]
Lowest 20 percent	2.7	3.7
Second 20 percent	4.7	8.2
Third 20 percent	6.5	13.2
Fourth 20 percent	20.4	21.0
Top 20 percent	65.7	53.9
Top 10 percent	50.3	36.9

Thus, there are two sides of the socioeconomic picture in Philippines fisheries. The more prosperous side is represented by a smaller group consisting mostly of fishing operators and master fishermen of commercial gears. On the other side is the majority of fishery participants whose absolute income levels may be lower than the poverty line income. They are mostly ordinary crew members of all fishing vessels (commercial and municipal) and the master fishermen and operators of gill nets, beach seine and tuck seine (primarily municipal vessels). The figures below support this statement. The top 10% of income earners capture over 50% of the income while the bottom 20% capture only 2.7% of the fishery income. The distribution of income in the fishery is more skewed, i.e., farther away from the equality line, than that for the entire economy as the figures above show.

In spite of the dire situation for the majority of fishermen, most remain in the fishery because their occupational mobility is very limited. There are barriers to entry to self-employment, primarily, capital requirements.

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[8] This is the latest data available for the Philippines which reflect conditions in 1971 (World Bank 1976).

Moreover, most fishermen have undergone formal education only up to the sixth grade with only a few of them able to enter high school or beyond. This contributes to their low opportunity costs and in turn, the attendant poverty for most in fishing communities.

The sources and flow of household income for the respondents[9] were recorded during the survey. Fishing was the primary source of income for the households included in the survey; it contributed an average of 90.2% of household income (Table 2.8). The figures also show that households with low fishing income (those employing gill nets and fish corral) have a higher proportion of total income derived from non-fishing sources. This should be expected as there is pressure on these households to augment meager fishing income. In fact, the proportion of households having other sources of income (last column in Table 2.8) is relatively high for households with low fishing income (with the exception of those employing encircling gill net).

Even considering non-fishing incomes, the household income for some groups is still very small. What is not captured in the survey is income in kind from other sources and debts incurred by the household. Although the income data pertain only to a small sample, these shed some light to the alleged endemic poverty in fishing communities in the Philippines.

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[9] The surveyed respondents are either the operators or master fishermen and no ordinary crew members. The income figures for the ordinary crew members, albeit from capture fishing only, are included in Table 2.7.

Table 2.8. Flow and sources of household income for sample fishing operators and and master fishermen, Iloilo and Negros Occidental, Philippines, 1988-1989

Gear used	Total household income (pesos/yr)	Income breakdown (%) other sources	Income breakdown (%) fishing	Size of sample	Percent with other income source
A. Gill nets					
Drift gill net	8,636	55.79	44.21	60	56.67
Bottom gill net	12,204	25.18	74.82	115	71.30
Encircling gill net	27,085	28.30	71.70	46	28.26
B. Seines					
Purse seine	126,974	15.70	84.30	29	55.17
Danish seine	142,687	1.59	98.41	96	29.17
C. Trawl	70,205	2.18	97.82	106	16.04
D. Fish corral	21,902	31.35	68.65	22	59.09
All gears	44,318	9.78	90.22	583	34.13

Notes:

The respondent was usually the operator or master fisherman except for the fish corral category, in which case it was usually the caretaker who was interviewed.

Sources of other income

- Agriculture/livestock (farming and poultry raising)
- Carpentry
- Electrical and welding services
- Commerce/trading
- Fishery-related (fish and prawn trading, fish retailing and brokerage)
- Non-fishery (hog trading, vegetable vending, etc.)
- Transport services (public utility vehicle driving)
- Practice of profession/salaried employment (both private and public sectors)
  - salaried jobs
- Domestic/personal services

Exchange rate: CAD 1 = 16 pesos

While the survey did not measure household income for the ordinary crew members, their average household income would be expected to be lower than that for the survey respondents as may be indicated by the estimated fishing income of the crew members in Table 2.7.

2.5 Fishery laws, management goals and institutions

Fishery legislation and the institutions created to oversee the fishing industry provide direction to the fishing industry and influence the behavior of fishermen. The basic fishery law in the Philippines is Presidential Decree 704 proclaimed in 1975. Embodied in this decree and in related fishery legislation are the goals for managing the fishery resources. Considering that fish is the primary and cheapest source of protein in the Filipino diet, the fishery is viewed more for its production role than for anything else. Hence, one of the goals of fishery management as stated in P.D. 704 is the attainment of fish self-sufficiency through increased production and import substitution. At the same time, a conservation-oriented utilization of resources is also advocated as another goal. Alleviation of pervasive poverty is also targeted through integrated development. Nevertheless, fishery managers exploit the labor absorptive capacity of the fishery sector and this works against poverty alleviation as such calls for a reduction of fishing intensity.

At the time P.D. 704 was proclaimed it was believed that "... the vast resources of the Philippines have remained largely untapped due to unnecessary constraints brought by existing laws and regulations and by failure to provide an integrated development program for the industry." Accordingly, the fishery was declared a preferred area of investment in order to achieve maximum economic utilization of fishery resources. Numerous incentives were designed to spur expansionary activities and the burden was put on the fishery to increase export earnings.

Recently, however, conservation has taken center stage in view of the depletion of marine resources and the degradation of the coastal ecosystems. (For the entire small pelagic fishery of the country, it was estimated by Dalzell et al. (1987) that effort should be reduced by 45% from its present level to achieve maximum economic yield.) The dire situation in the fishery can be attributed to the failure to strike a balance among the conflicting objectives as stated above. Smith (1981) pointed out potential conflicts between community objectives and national goals. Investment programs directed to the least capitalized fisheries "may distribute incomes more equitably among individual fishermen and communities, but to the extent that they decrease the sustainable yield they make the pie to be divided much smaller, thus conflicting with the national goals of resource conservation and management."

Fishery laws and regulations in the Philippines are usually in the form of fishery administrative orders (FAO) in addition to those explicitly stated in other statutes. Fishery regulations being enforced in the study area include the following:

a. The seven-km ban on commercial vessels as provided for in P.D. 704. This allots the area within 7 km. from the shore (also designated municipal waters) exclusively for municipal fishing by prohibiting fishing operations by commercial vessels.

b. FAO 155 prohibits the use of fine-meshed nets (mesh size less than 3cm) in fishing.

c. FAO 164 governs the use of modified Danish seine in Philippine waters. It sets a mesh size limit in accordance with item b and limits operation of commercial modified Danish seiners following item a.

d. FAO 167 establishes a closed season for protection and conservation of herrings, sardines and mackerels (all small pelagics) in the Visayan Sea. The closed season is from November 15 to March 15 of each year. It went into effect in 1989.

The above fishery regulations are primarily geared toward conservation and protection of the fishery by indirectly controlling fishing effort. A closed season is a period during which any or all of the following is prohibited: fishing in a specified area, the catching or gathering of certain species of fish or aquatic products, or use of specified fishing gear to catch or gather fish or fishery/aquatic product. Mesh size restrictions determine the age at first capture or the recruitment age of the fish but the lower limit of 3 cm is well below the 5.5 cm optimal mesh size indicated by some studies (as cited in PCAMRD 1990). The seven-km ban on commercial vessels is primarily designed to reduce conflicts between commercial and municipal fishermen but may also effectively protect the spawning and nursery grounds for the fish.

In addition to the above fishery administrative orders, licensing is implemented in the Philippines more as an administrative activity than as a means to control fishing effort. Municipal fishing is regulated by local governments and such governments in the study area are supposed to issue licenses to municipal fishermen and to monitor the extent of municipal fishing. Commercial fishing, on the other hand, is the domain primarily of the Bureau of Fisheries and Aquatic Resources (BFAR), the Philippine Coast Guard and the Maritime Industry Authority. Both the commercial fishermen and commercial fishing vessels are required to obtain a license. However, compliance to the licensing guidelines has been very limited. Records of the number of fishermen and vessels in the study area are unreliable.

As mentioned, the licensing scheme in Philippine fisheries is not a means to control fishing effort in the fishery. This is evident in the fact that there is no ceiling on the number of licenses. Moreover, the access fees charged to commercial fishing are too low to be deterrents to fishing. A commercial fisherman's license can be purchased at 13 pesos inclusive of application fee. A 250-ton commercial fishing boat, a large vessel by industry standards, would be assessed at most 2,030 (about 130 CAD) pesos in fees (license and clearance fees and cash bond deposit). A further discussion of the licensing scheme and other fishery regulations is found in the next chapter.

P.D. 704 gave jurisdiction and responsibility in the management, conservation, development, protection, utilization and disposition of all fishery and aquatic resources of the country to the BFAR. The BFAR is now a staff bureau under the Department of Agriculture (DA), and its functions are mainly advisory in nature. It was downgraded from a line agency with a network of field offices reaching all fishing municipalities. Fisheries concerns at the field level are now integrated in the functions of the DA personnel who are assumed to be generalists, i.e., able to deal with agriculture and fishery issues. The DA, however, does not have police power and the enforcement of fishery laws and regulations is the responsibility of the coast guard and local governments.

An evaluation of compliance with fishery laws illustrates the performance of the present fishery institutions. Compliance to the seven-km ban on commercial fishing vessels is first evaluated. Table 2.9 shows the total number of vessel-fishing-observations which is the number of times the sample vessels were in the process of fishing. The times the sample vessels were in the process of fishing were counted during the biweekly monitoring from November 1988 to October 1989. The

Table 2.9. Compliance with the 7 km. ban on commercial vessels: distance of fishing areas from nearest coastline, Iloilo and Negros Occidental, 1988-1989

Gear (Commercial vessels only)	Number of vessel-fishing-observations	7 km. or less (violation)		over 7 km. (compliance)	
		No.	Percent to total	No.	Percent to total
Encircling gill net	219	204	93.15	15	6.85
Purse seine	778	704	90.49	74	9.51
Danish seine	462	343	74.24	119	25.76
Trawl	117	93	79.49	24	20.51
All gears	1656	1404	84.78	252	15.22

Table 2.10. Compliance with the 3-cm mesh-size limit by type of gear, Iloilo and Negros Occidental, 1988-1989.

Gear	Total # of boats surveyed	3 cm. or less (violation)		over 3 cm. (compliance)	
		No.	Percent to row total	No.	Percent to row total
A. Commercial vessels					
Encircling gill net	16	16	100.00	0	0.00
Purse seine	6	5	83.33	1	16.67
Danish seine	54	54	100.00	0	0.00
Trawl	37	37	100.00	0	0.00
Other commercial gears	5	5	100.00	0	0.00
Sub-total	118	117	99.15	1	0.85
B. Municipal vessels					
Drift gill net	58	58	100.00	0	0.00
Bottom gill net	131	126	96.18	5	3.82
Encircling gill net	31	31	100.00	0	0.00
Purse seine	5	3	60.00	2	40.00
Danish seine	41	41	100.00	0	0.00
Trawl	89	89	100.00	0	0.00
Other municipal gears	35	24	68.57	11	31.43
Sub-total	390	372	95.38	18	4.62
Total boats	508	489	96.26	19	3.74

vessel-fishing-observations were then grouped in terms of distance from the nearest coastline. The figures show that intrusion into municipal waters (7-km or less) by commercial vessels was frequent; close to 85% of the vessel-fishing-observations were within seven km from the shore. Compliance to the mesh size regulation was also evaluated. Violation of the 3-cm limit on mesh size for all fishing nets is also widespread (Table 2.10). Of the 583 fishing units surveyed, 508 employed fishing nets and 489 were violators. Almost all commercial vessels used fine-meshed nets. The degree of violation by municipal vessels is almost equally serious. Fisheries law enforcement in thus largely inadequate in the area. The same may be said for the entire country.

Chapter 3

Theoretical Basis for Fisheries Management

The small pelagics fishery of Guimaras Strait in the Philippines illustrates the complexities of a fishery in a tropical country setting. There has been no serious attempt to manage the fishery primarily because not much is known about the fishery resource system. The brief description of the important components of the fishery resource system in the preceding chapter indicates that the following are the important characteristics of the small pelagics fishery that should be taken into account in any attempt to manage it:

a. the pursuit of multiple objectives in exploitation,
b. the multispecies and multi-gear nature, and
c. the limited capability of the government in enforcing fishery regulations.

The following sections discuss each of the above by reviewing the theoretical and applied literature on these subjects. A summary is provided at the end of the chapter. The literature review highlights the approaches so far made in tackling the above issues in fisheries analysis. At the same time, an evaluation of their applicability to the fishery resource system under study is made. Thus, this chapter provides the justification for the employment of an analytical model such as that developed in chapter 4. From this analytical model various fishery management strategies may be analyzed.

3.1 The evolution of fisheries policy: objectives of fishery management

FAO (1983) classifies the objectives of fishery management into three groups -- maintaining the resources, economic performance and equity (or social needs). In addition to the above, other authors (Charles 1988; Regier and Grima 1985; and Lawson 1984) include, among others, the following: food production, maintaining employment for fishermen and the well-being and viability of fishing communities. In the Philippines, fishery management objectives as mentioned in section 2.5 fall in the same FAO classification.

Fishery management objectives in the fisheries literature evolved from the goal of obtaining the maximum sustainable yield (MSY), the maximum economic yield (MEY) and more recently, the optimum sustainable yield (OSY). MSY is primarily a biological goal of targeting fishery yields equivalent to the maximum productivity of the resource without endangering the biological status of the stocks. On the other hand, MEY and OSY, in the context of their use in the literature, include economic and social considerations in addition to setting the biological objective. Further discussion of these fishery management goals (MSY, MEY, OSY) is done in the succeeding sections. What should be emphasized at this point is that the lumping of several valid objectives into one indicator (MEY or OSY) shrouds the existing tradeoffs among the objectives. Before dealing with this, however, the rationale for fisheries management should first be established. Afterwards the evolution of fisheries policy is traced.

A convenient starting point is the Gordon-Schaefer[1] model of the fishery. A logistic growth function that exhibits the commonly observed density dependent growth of fish stocks is often employed to represent the biological relationships in a fishery (Schaefer 1954). A sustainable yield-effort curve showing the effect of fishing activity is derived from the logistic growth function. Primary economic variables, fishing costs and output prices, are incorporated in the model by assuming, for simplicity, constant unit prices and costs. This line of analysis was first applied in fisheries by Gordon (1954). Subsequent fisheries literature shows a fisheries model that integrates the work of Gordon and that of Schaefer (1957), which is often called the Gordon-Schaefer model of the fishery. A graphical representation of this fishery model is in Figure 3.1.

The Gordon-Schaefer model is a long-run and steady-state analysis of the fishery. In the long-run, fishing effort in an open-access fishery expands until there are no incentives for entry, i.e., at the industry level total revenue equals total costs. (Total costs include the normal returns to labor and capital inputs which are the opportunity costs of such inputs.)

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[1] This is a static bioeconomic model of the fishery. A dynamic model with the same basic assumptions is found in Clark and Munro (1975).

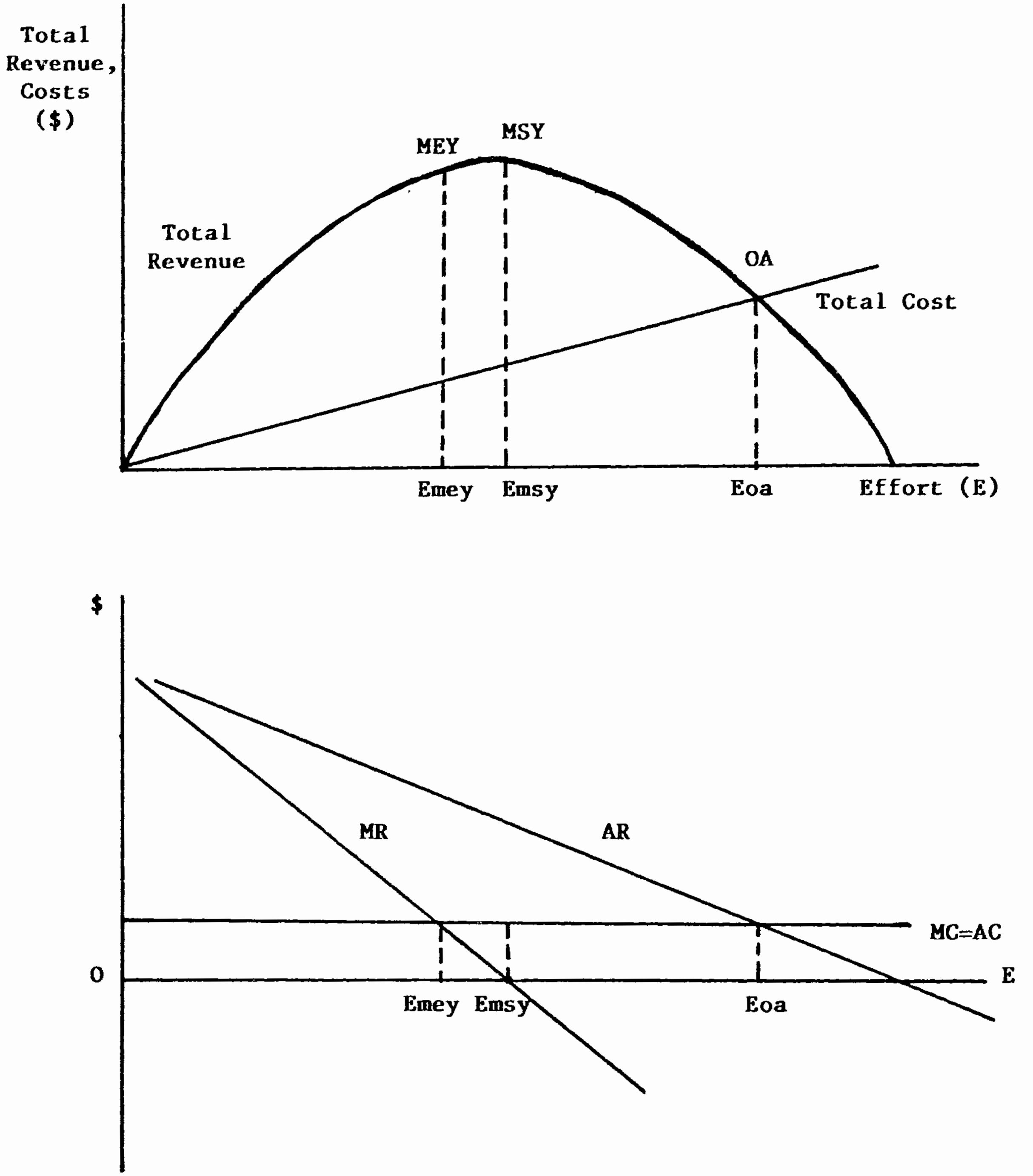

Figure 3.1. A simple bioeconomic fishery model: the Gordon-Schaefer model

The fishery gravitates to such a point because there is no system of property rights that allows for optimal use of the resource. This point represents an equilibrium where biological forces and economic factors affecting fishermen are in balance. This point is often called the open-access equilibrium (E_{oa}).

In Figure 3.1, the total cost curve intersects the total revenue curve to the right of MSY. It should be noted that the two curves may intersect to the left of MSY, for instance, in fisheries where the fish species are low-valued or where fishing costs are quite high. However, the discussion will focus on the former case (the textbook case) where the point of intersection is to the right of MSY as in Figure 3.1. At the open access equilibrium the yield of the fishery is smaller[2] than the maximum sustainable yield. Also, the population level corresponding to E_{oa} is smaller than that which yields the MSY and would be much smaller if average cost of fishing is lower than is illustrated. The biological implication of the open-access equilibrium with a low unit cost of effort then is a low level of fish biomass. At the open-access equilibrium, the rents attributable to the resource are fully dissipated by the uncontrolled entry of fishing vessels. The dissipation of resource rents, the low stock level and yields below MSY at the open-access equilibrium are often the stated rationale for fisheries management.

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[2] The population level is higher if the total cost curve intersects the total revenue curve to the left of MSY.

The model illustrates two points where the fishery may be exploited with proper regulation, namely: MSY and MEY. MSY is a biological optimum whereby the physical sustainable yield of the fishery is maximized and the corresponding effort is at E_{msy}. Harvesting at effort levels beyond E_{msy} constitutes biological overfishing while below E_{msy} involves biological underfishing as the biological potential of the stocks is not fully captured. The maximum sustainable yield dictum guided fisheries management in many countries for many decades. This objective originated in the early work of Hjort *et al.* (1933) which showed the existence of maximum sustained yields for fishery stocks. There are, however, several shortcomings of the MSY objective and its applicability to multispecies fisheries. These shortcomings are discussed in section 3.2.

While moving the fishery to the level of MSY may be an improvement over the open-access equilibrium, it does not correspond to the economic optimum. There are factors of production in the fishery other than the fish stock and, hence, the rates of exploitation at E_{msy} and E_{oa} constitute an economic overfishing as economic benefits from the fishery are not maximized. Economists then prescribe a rate of fishing equivalent to E_{mey} that would maximize the difference between the catch value and fishing costs (MR=MC). The economic criterion of optimality is more conservation oriented than the biological goal of MSY as it requires a lower level of fishing effort and the maintenance of a larger fish stock. While the economic prescription limits fish supply and may be thought undesirable in the face of food shortages, economic calculations show that resources of labor and capital released by moving from E_{msy} to E_{mey} would normally be able to make a greater contribution to food supply through expansion of agriculture and aquaculture (Copes 1989).

In the early 1970s, another concept was advocated as the proper goal of fisheries management. It was argued that MSY and MEY leave out other equally important aspects of fisheries management such as social, political and cultural factors (Alverson and Paulik 1973; Rothschild 1973). Specifically, the scope of economic benefits as usually embodied in the MEY objective is perceived to be too narrow. The concept of optimum sustainable yield (OSY) incorporating all the above considerations came about and is distinct from MEY (Roedel 1975). Maximization of economic benefits as an objective of fisheries management becomes a special case of the broader goal of optimum sustainable yield. Economists could argue, however, that if MEY is interpreted on the basis of a social cost-benefit analysis, then the OSY definition is a duplication of the MEY concept. Nevertheless, in the succeeding paragraphs, MEY and OSY are discussed separately.

So far, three possible objectives of fisheries management have been enumerated, namely, the attainment of: MSY, MEY or OSY. However, there remains a lot of confusion about the OSY concept and its actual estimation. A fundamental issue is how to take jointly into account the biological, economic, social and political factors embodied in this concept. Akin to this is which of the above should take precedence in defining and estimating the OSY. Unlike the case of MEY where the biological and economic considerations are successfully webbed into the analysis, this is not achieved in the actual definition of the OSY as the plethora of methods to estimate it suggests (e.g. Roedel 1975; Larkin 1977).

The OSY concept may be looked at differently as consisting of different objectives rather than a single objective. Recognizing its multi-objective nature would reduce the confusion as this paves the way to the realization that the various objectives are non-complementary. The trade-offs in the objectives become apparent when considering social issues such as minimizing unemployment in fisheries-dependent communities, the economic goal of maximizing resource rent, or the biological objective of resource conservation. Hence, fishery resource utilization should be viewed as one of maximizing a set of conflicting objectives and the task of the manager is to strike a balance among the objectives. At this point, fisheries management ceases to be a science and becomes an art.

To date, the applications of multi-objective analysis to fisheries analysis are rather surprisingly few despite the existence of a well-developed methodology (Keeney and Raifa 1976). One of the earlier works is by Bishop *et al.* (1981) although they just outlined the procedure. Kendall (1984) outlined a multi-objective approach to regional resource management planning but without an empirical application.

Healey (1984) developed a multi-objective fisheries model by considering conservation, economic development and social development goals. He used multi-attribute analysis, specifically, a linear utility model to assess the optimality of alternative yield strategies. He then applied the model to the New England herring fishery and the Skeena River salmon fishery. More recently, Krauthamer *et al.* (1987) included social and cultural variables that may affect the fishing process particularly in the determination of fishing power. Charles (1989) was able to explicitly incorporate labor dynamics into the fishery model and then employed control theory to solve for the optimal pattern of fishery exploitation. The "trick" was to define the various objectives in such a way to hide the tradeoffs and form a single objective functional. No study, however, has addressed simultaneous optimization of several objectives.

Fisheries management goals as embodied in fisheries policies evolved following closely the theoretical development in the fisheries disciplines. For instance, Canadian marine fisheries policy followed largely the biological criterion until 1965, while economic considerations became more explicit from 1965 to 1976 (Copes 1980). From 1976 onwards, the pursuit of an optimum sustainable yield was evident in the goal of maximizing the sum of net social benefits (personal income, occupational mobility, consumer satisfaction and so on) derived from the fisheries and the industries linked to them

(Department of Environment, Fisheries and Marine Service, 1976).

3.2 Multispecies and multi-gear fisheries

Until recently, approaches to fisheries management in terms of stock assessments and management policy have been cast in terms of single species models. These approaches assume ecological independence between or among species, that is, biological interactions such as competition and predation do not matter. Likewise, the traditional models ignore technological interactions whereby the harvesting of one species results in appreciable by-catch of other species. Even for obviously multispecies fisheries, these are treated as single species with the specification of global production models and the subsequent estimation of a global MSY. Examples of such models are Brown *et al.* (1979) and Panayotou (1982). The main advantages of this approach are its simplicity and the subsequent tractability of the mathematical manipulations and the relatively slight data requirements. The concept of MSY, however, loses its utility in multispecies fisheries unless the harvested stocks can be regarded as a single, isolated population (May *et al.* 1979).

Several researchers (e.g., Mercer 1982) have noted that the inadequacies of single-species modeling are becoming of more consequence in view of the tremendous expansion in the intensity of fishing operations and in the variety of trophic levels of species harvested. More importantly, the single-species models may lead to erroneous advice when dealing with multispecies fisheries. Thus in the past decades, models of multispecies fisheries were developed. These are based mainly on and are extensions of the surplus production model (Schaefer 1954; Fox 1970), the stock-recruitment relationship (Ricker 1954) or the yield-per-recruit calculation (Beverton and Holt 1957). The rest of this section discusses these groups of models.

The multispecies extensions of the single-species Schaefer model assume a variety of biological interactions involving two or more species. Elementary multispecies modeling procedures show a different result from models that lump together all species in terms of the optimal harvesting strategy. Horwood (1976) considered an interactive model of two species in direct competition with each other and noted that fishing species in proportion to their relative numbers does not necessarily take the fishery to its maximum sustainable yield. More specifically, Pope (1976) concluded, from an analysis of mixed fishery models which include biological interactions, that these models give total yields lower than the sum of individual species MSYs.

More recent multispecies models assume a variety of biological interactions and harvesting scenarios involving two or more species. An example is Flaaten (1988) who derived the maximum sustainable frontier (MSF); the shape of which depends on the biological interaction(s) between species. In the case of two species, a point on the MSF gives the maximum yield that can be harvested from one species given the desired yield from the other species. Another example is that of May *et al.* (1979) which considered the harvesting of: a) a prey and predator, b) one prey along with two predators, and c) bottom and top species with three trophic levels. In each of the assumed biological interactions, they noted that the simple considerations of MSY species by species are insufficient for enunciating management principles in multispecies situations.

The use of the above models in economic studies that compare open-access harvesting and the socially-optimal harvesting of multispecies fisheries are numerous. Among the earlier works are Quirk and Smith (1970) and Anderson (1975). More recent dynamic models are by Clark (1976) and Silvert and Smith (1977) and more recently by Flaaten (1989) and Clark (1990). The introduction of economic variables particularly in a dynamic analysis gives remarkable results. For instance in Clark (1990), non-selective harvesting of individual species may call for the elimination of those species or populations whose biotechnical productivity is relatively low. This may be an optimal result although the eliminated population is, in itself, valuable.

Another method of biological assessment employed follows from the relationship between stock and recruitment. Ricker (1958) considered graphically the case of several stocks exploited by a common fishery. An analytical treatment of the problem of determining the common rate of exploitation that produces the maximum total equilibrium yield from a mixture of stocks (up to 20 stocks) was given by Paulik *et al.* (1967). Hilborn's (1976) approach is basically the same as that of Paulik *et al.* although the former is more general and less restrictive with his relaxation of some of the latter's assumptions. However, basically the same conclusions are derived in the two approaches. While maximizing total fishery yields, the potential for recruitment overfishing and/or the extinction of one or more component stocks exists.

Extensions of the traditional single-species yield-per-recruit analysis of Beverton and Holt to mixed fisheries with technological interactions have been done, although sparingly. Technological interaction results when there is co-occurence of fishing gear when species are exploited concurrently in time and space. Most of these models assume away biological interdependence in favor of focusing more on the technological linkage among species. Nevertheless, the determination of the optimal yield remains a difficult problem. Murawski (1984) derived a single-fishery, mixed-species, yield-per-recruit model. More recently, Pikitch (1987) explored the use of the yield-per-recruit model in the multispecies flatfish fishery of Oregon. The works so far done in this area, i.e., the multispecies extensions of the single-species yield-per-recruit model are intended for fishery systems where biological interactions are unclear or negligible but technological interactions are obvious.

Most of the literature so far reviewed deals with single-fishery multispecies/multiple stocks whereby a single gear or a technologically homogeneous group of gears exploit several species/stocks. The case of multispecies multi-gear fisheries has also been addressed. Most studies solve the problem of allocating total allowable catches (by species) to various fisheries (or fleets) competing for the same resources (Fukuda 1976; Brown *et al.* 1979; Murawski and Finn 1986). The allocation problem (mostly solved by linear programming) is the focus of the papers with the biological constraints taken as given. A simulation model developed by Murawski (1984) incorporates a yield-per-recruit model and then determines the optimal exploitation patterns. The results emphasize the potential for growth underfishing or overfishing of individual species/stocks when total system yield is the optimization criterion. In other words, some species need to be exploited at a point below or above the maximum sustainable yield.

Each of the above multispecies models have a large number of biological parameters to be estimated. Provided data are available, analytical models (stock-recruitment and yield-per-recruit models) present several advantages over the production models in the following respects (Greboval 1985):

- They are biologically more sound to the extent that they reflect fish growth, mortality and age-class dynamics.
- They allow for explicit representation of stock-recruitment relationships.

- They are less dependent upon the ability to measure effort in a dynamic, multispecies context.
- They are statistically more robust than production models (Schnute 1977).

A major problem in any fishery is the measurement of fishing effort even for single-species, single-gear fisheries considering the variety of vessel classes and specifications. The appropriate notion of fishing effort is of greater bearing in multispecies multi-gear fisheries as effort needs to be standardized for several gears and then disaggregated for each species. Likewise, sensible interpretation of catch and effort data requires separation of directed catch and by-catches in each fishery but determining target catches is difficult when there is a number of potential target species.

The common solution to the problem of standardizing effort in fisheries with directed and non-directed catches is to examine the distribution of catch for every fishing trip. Trips yielding an arbitrarily set percentage of a particular species will be classified as directed effort for that species, otherwise the fishing trip is non-directed effort. This approach, however, introduces several biases in the following respects (FAO 1976). It generally underestimates effort as trips that do not meet the cut-off are not included. Effort may actually be directed at several groups of species with no single species accounting for a significant share, or fishermen may be hunting for target species but end up catching other species. Moreover, an attendant difficulty in this procedure is the evaluation of effort applied to the non-targeted species.

Akin to the above, especially in technologically-interrelated fisheries, is the difficulty of estimating the catchability coefficients -- the mortalities generated on each species from a unit of fishing effort in each fishery (or gear). There should be a vector of catchability coefficients in each fishery and the number of parameters increases multiplicatively as the number of fisheries and when the number of fishing grounds and fishing strategies are taken into account. Murawski *et al* (1983) used cluster analysis to estimate the catchability vectors associated with each strategy and fishing ground by grouping catch and effort data by area, time and vessel size. The data requirements, however, are enormous.

3.3 Evaluation of fisheries management alternatives

In an open access fishery, fishing effort would inevitably expand beyond that which is optimal as shown in section 3.1. The excessive effort is what dissipates the potential resource rents in the fishery. There are several ways of introducing regulations that limit fishing effort to the desired level: controlling inputs and/or outputs. Currently, the primary regulations in fishery rationalization schemes are limited entry licensing (may be interpreted as controlling input) and the granting of individual boat quotas (may be interpreted as controlling output). Additional regulations may be instituted to "fine-tune" the primary regulations to conform with other management considerations, e.g., conservation of stocks. Such regulations may include the control of fishing inputs such as the specification of boats, gears and the length of the fishing time through seasonal closures.

Thus, there are several alternatives with which to regulate effort in the fishery. The choice of a control measure should be influenced by enforcement costs, flexibility of the management tool and the efficiency of the resulting pattern of resource utilization. Hence, the following evaluation of alternative management tools follows these criteria. Economic efficiency of a regulation is its capability to ensure the largest possible contribution of fishery exploitation to the economy and to induce the adoption of new and more efficient fishing technology. Thus, efficiency has both a static and dynamic dimension. The dynamic requirement leads to a second criterion for the evaluation of regulations, which is flexibility. The instability of fishery ecosystems require a flexible management tool. Moreover, flexibility is needed to address possible loopholes such as the substitution of unregulated fishing inputs for restricted ones.

The notion of flexibility relates to a third criterion - that of enforcement or implementation. Since regulations constrain the behavior of fishery participants, these should be acceptable to fishermen and other vested interest groups so that agreements can be reached. Likewise, a regulatory system should be implementable without costly adjustments in the existing fishery institutions. Perhaps, this is one of the most important considerations in the design of fishery management regimes in developing countries. The institutional structure for fisheries in most Third World countries are inadequate to monitor the fishing industry, and more so to enforce fishery laws. Oftentimes, the inadequate institutional set-up becomes a constraint on the design of efficient and flexible management tools.

3.3.1 Quantity controls on output: total allowable catch and individual boat quotas

Regulations that directly control the quantity of fish to be harvested include the setting of total allowable catch (TAC) and/or dividing the TAC into individual boat quotas. The determination of TACs is directly based on the biological potential of the resource.

TACs are highly flexible management tools. Perturbations in the level of population may be allowed for by setting a preliminary TAC at the start of the fishing season, which is revised accordingly as more information about the fishery is obtained as the season progresses. However, this feature of TAC is not applicable when the TAC is divided into individual boat quotas as each vessel should be guaranteed that quota for the entire duration of the fishing season. With regard to the determination of the TAC, a fishery-wide TAC is normally set but difficulties arise when dealing with multispecies fisheries and with technologically-interdependent fisheries.

In terms of economic efficiency, a purely TAC-based management regime does not prevent the dissipation of rent. In an attempt to increase the share of the TAC, boats "race for fish" as soon as the fishing season opens. The pattern of fishing is not optimally spread during the entire season and the TAC may be filled up very quickly. Even though the fishery's productive potential may improve through the years with a successfully enforced TAC, biological gains are not matched by economic improvement unless entry into the fishery is also restricted. A well-documented case is the Pacific halibut fishery in which, with the introduction of TACs in 1933, catches rose from 47 million pounds to 58 million pounds in 1950. The number of vessels, however, increased proportionately more during the same period and the fishing season needed to be shortened accordingly (Crutchfield & Zellner 1962).

Economic improvement comes about if the TAC is apportioned into individual boat quotas as was first advocated by Christy (1973). As the individual quota establishes a system of quasi-property rights in the fishery, it aids in solving the problems associated with the absence of property rights (Scott 1985). An entitlement to a portion of the catch induces individual boats to harvest that share at the least cost. Further gains may accrue if the quotas are made transferable. When a market for quotas emerges, the more efficient operators may buy out the quotas of less efficient fishing units with the prospect of increasing aggregate rent. A market for quotas also permits these vessels to buy out quotas that would be optimal for their level of operations, *i.e.*, taking into account the size of the fishing vessel and the length of the fishing season. Consequently, an individual transferable quota (ITQ) system facilitates rationalization of the fishery by making exit and entry into the fishery easier as is the case of New Zealand (Clark *et al.* 1989). More recent advocates of the ITQ base their arguments on the generation of management rents (Anderson 1989) and the possibility of a minimum information fishery management (Arnason 1989).

As mentioned earlier, the determination of the TAC is difficult if there is joint harvesting of several species. This problem filters through when dividing the TAC into individual quotas. Moreover, Copes (1986) noted that the chances that a fishing operator's catch would conform precisely to the proportions of various species quotas are almost nil. In addition to the multispecies problem, Copes also mentioned the problem of quota busting and high-grading. This is a most difficult problem where there are numerous fish landing points and the number of vessels is large which make checking of catches impractical. Other problems mentioned by Copes with an ITQ system are: residual catch management, unstable stocks, short-lived species, flash fisheries, real time management, high grading, seasonal variations, spatial distribution of effort, TAC setting, transitional gains trap, and industry acceptance. Most of these problems do not exist when the TAC is not complemented by an individual quota scheme.

3.3.2 Quantity controls on fishing effort: restriction on fishing gear and technology

Among the wide range of management tools available, controls on fishing effort and technology appear to be the most widely adopted regulations. Restrictions imposed on the mesh size of fishing gears and the prohibition of certain kinds of gear, notably and most recently the prohibition of *muro-ami*[3] in the Philippines, are examples. Also, the ban on commercial fishing vessels operating in municipal waters in the Philippines may be classified under this category of regulations. The popularity of these measures lies in their relative ease of implementation and effectiveness in preventing stock depletion albeit they are very inflexible tools of management.

Objections to these restrictions on fishing gear and technology arise from the fact that these limit the freedom of fishermen and their acceptability is thus at stake. Moreover, a gear which may turn out to be economically efficient may be ruled out in favor of equity considerations in order to avoid conflicts between interest groups. The ban on commercial vessels from fishing within seven kilometers from the shore in

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[3] Muro-ami is a fishing gear of Japanese origin which is employed in catching coral reef fishes. Fishes are driven to the net by pounding the coral reefs. The fishing operation is considered destructive to the reefs and its environment.

the Philippines gives priority to improving the economic plight of municipal fishermen. The complete ban on trawling operations in Indonesian waters also illustrate this point although this regulation was premised on biological grounds.

There are, however, situations which call for this category of regulations. Waugh (1984) enumerated three conditions that justify such regulations on economic grounds, namely: a) to ensure optimal age-at-first-capture, b) to suppress the rapid rate of change in technology in the industry, and c) to prevent dissipation of rent in the fishery through overcapitalization of individual vessels.

The first justification is related to the concept of eumetric fishing of Beverton and Holt who argued that there is a rate of fishing that produces the optimal yield. Further, at each rate of fishing mortality, there is an age of first capture that maximizes yield and this should be the target of mesh size regulation. In the absence of a regulation to this effect, fishermen tend to use the finest mesh possible resulting in recruitment and growth overfishing -- both are cases of intertemporal externality. However, the theory of eumetric fishing raises a number of policy issues. Turvey (1964) stated the necessity for mesh size regulation to in order to achieve the economic optimum. A larger mesh size initially decreases catch but may ultimately raise it by increasing the stock. Boyd (1966) countered that the above argument follows

> "... only if the decreased costs associated with increased steady-state fish stock at least offset the increased production costs due to the larger mesh size, however, will a larger mesh size be Pareto-superior. If, and only if, this is indeed the case will external diseconomies due to larger fish size available in the future exist, and then, and only then, will some sort of regulation of mesh size be necessary for Pareto-optimum."

The regulation of technology may be justified in times of rapid change during which time, fishermen may be forced to adopt new technologies prematurely under threats of a price disadvantage and a possible decline in their share of the catch. The third justification for technology regulation is related to the second. As mentioned earlier, with other primary regulations which establish partial property rights only, competition for catch induces fishermen to resort to capital stuffing by upgrading vessels and equipment. All these possible courses of action for fishermen dissipate rents from the fishery unless proper fine tuning of regulations is done through regulation of gears and technology.

3.3.3 Limitation of entry through licensing

Until recently with the introduction of individual boat quotas, the foundation of most complex fishery management regimes has been the limitation of the number of fishing boats in the fishery through the issuance of licenses. These boats should deliver the optimal amount of fishing effort. Limited entry licensing is a relatively flexible tool for managing the fishery but raises some difficulties in terms of implementation. Several questions need answers: How many licenses are to be issued? How will they be allocated? Which is to be licensed - the fishermen, the gear, the boat or all of these? Will licenses be transferable? Should a fee system accompany a licensing scheme?

The upper limit on the number of boats to be allowed in the fishery should produce approximately the desired amount of fishing effort. However, the relationship between total fishing effort and the number of vessels is nebulous as the former is a multidimensional variable. Vessel configuration, crew skill, fishing time and area of operation determine the aggregate amount of effort or catching power of a vessel (for instance, Hilborn and Ledbetter 1982). Nevertheless, approximations may be done based on the relationship between vessel characteristics and past data on participation in the fishery.

When dealing with a multi-purpose fishing fleet, however, the problem of setting the number of licenses is compounded as such vessels move from targeting one species to another depending on profitability. Meany (1977) suggested the issuance of licenses for the entire fishery and allowing fishermen to catch all species. This should be accompanied by a fee schedule that is adjusted to encourage fishing of underfished species and vice versa. The case of a heterogeneous fishing fleet exploiting a common fishery, e.g. trawls, gill nets and seines sharing the small pelagic fishery in the Philippines has another difficulty. In determining the number of licenses to be issued, differences in gear productivity and in the capacity of vessels need to be accounted for.

The multidimensional nature of fishing effort precludes economic improvement in the harvesting process through limited entry alone. In most licensing schemes, the following are licensed - the fisherman, the boat, the gear. Normally, however, the license for the vessel does not specify the tonnage, the horsepower rating of the motor or other equipment that the vessel can carry, all of which can be adjusted to increase fishing effort. Hence, licensing by itself may not effectively reduce fishing effort. Even where the vessel configuration is specified by the license, the possibility of substituting one vessel attribute for another leaves room for increasing fishing effort. Hence, overcapitalization remains a potential problem even in fisheries where limited entry has been instituted and the dissipation of resource rents may still occur.

The above situation is illustrated clearly by the evolution of limited entry in the British Columbia salmon fishery (Fraser 1979). Licensing brought down the number of vessels in the fishery. However, significant improvements were made on the remaining vessels. These were equipped with more powerful motors or with more sophisticated fishing equipment thereby increasing fishing power or capacity in an attempt to capture a larger share of the expected rents. This process is termed "capital stuffing" in the fisheries economics literature (Crutchfield 1979). Hence, the potential gains from a reduced number of vessels were offset by increased capacity and capital intensity of individual vessels. The higher costs of fishing resulting from "capital stuffing" dissipated much of the rent created by the limited entry program.

Wilen (1988) mentioned other problems that would not be remedied with a limited entry regime alone, which may also dissipate fishery rents. There would still be excess mobility and movement of vessels as they take advantage of openings in the fishery at different places. Consequently, there would be congestion and interference as a large number of vessels converge on a small area where the fishery opening was located. Wilen further noted that this instance occurred in the British Columbia roe herring fisheries in the late 1970s whereby the fishery was transformed from one where the fleet was spread over relatively longer openings in several areas to one where a significant fraction of the fleet converged on each opening. Hence, while average catch may increase with limited entry, the average cost of fishing may, likewise, increase.

A highly controversial issue with license issuance is transferability. The arguments in favor of transferability are very similar to those for the individual quota. Meany (1978) discusses the nature of these advantages. If a licensing scheme establishes property rights in the fishery, then it should be made transferable as it is an important characteristic of such a right. In addition, Crutchfield (1979) argued that the efficiency in use, continuity in operation and ease of operation are the important arguments for relatively free and costless transferability of limited fishing rights.

However, there are advantages to a non-transferrable licensing scheme. The number of licenses may be reduced through attrition because the license expires when the fisherman retires. If a faster rate of license withdrawal is desired, a buy-back program may be introduced. A license holder may be induced to retire his license at a lower price than it would have obtained if the license had been transferrable. The reason is that with a non-transferrable license the fisherman could demand a price for his license that is equivalent only to the expected rents it would yield during his remaining years of fishing. Hence, the "expectations trap" may be avoided entirely when licenses are non-transferrable (Copes 1991). The "expectations trap" occurs in a transferrable licensing scheme when license holders demand a price for their licenses (when selling) equal to the present value of all future higher returns expected from rationalization of the fishery.

Moreover, if an objective of a licensing scheme is to bring about a lasting improvement in fishing incomes, licenses should not be transferrable. Copes (1990) noted that

> "If the license limitation succeeds in raising industry incomes above open-access equilibrium returns, and boat owners are allowed to sell their licenses at free market prices, the anticipated stream of additional earnings (rents) attributable to license limitation will become capitalized in the value of the licenses".

If this comes about, the result is a "transitional gains" trap whereby only the first generation of license holders will benefit. The succeeding license holders, in buying the license, will have paid in advance for any resource rents the license is expected to earn; they will be no better off than if they had been working in an open access fishery. Transferable licenses, in this case, will not increase fishing incomes in the long-run.

A licensing scheme may also be used to resolve conflicts between artisanal and commercial fishermen by designating areas of operation of the license. This scheme is called restrictive area licensing. The granting of exclusive fishing privileges to artisanal fishermen to municipal waters in the Philippines is an example. A more elaborate scheme is the division of Malaysian waters into fishing belts (Abdul Majid 1983). Fishing rights within 5 miles from the shore are reserved for traditional fishing, from 5 to 12 miles from shore to owner-operated trawlers of less than 40 gross tons, from 12 to 30 miles from shore to larger-sized vessels operated by Malaysians, 30 miles and beyond to foreign fishing and international joint ventures. As in the Philippines, the Malaysian area licensing program is beset with enforcement problems. However, restrictive area licensing may improve the economic picture in the fishery to the extent that it reduces gear conflict externality and by restricting mobility and movement of vessels. These are the points elaborated on by Wilen (1988). Specifying the area of operation for certain gears reduces congestion in the fishing grounds, hence, a smoother fishing operation is achieved. However, since the primary consideration of the above regulations is the resolution of conflicts among groups of fishermen, the economic consequences are just incidental benefits.

3.3.4 Territorial use rights in fisheries[4]

The most commonly adopted rights based regulation in fishing, i.e., limited entry licensing, bestows rights upon individuals. In the process the fishery is transformed from open access or unowned resource (*res nullius*) to a common property resource (*res communes*) for those possessing the rights.[5] Limited entry by itself does not solve the prisoner's dilemma in fishing and some of the problems associated with open access fishing still persist as mentioned above. It is only when fishermen have an individual sense of exclusivity to the harvest that they have the incentive to work together. The granting of territorial use rights in fisheries (TURFs) is one route toward this end. As will be described below, the nature of fishing rights in TURFs may be considered basically similar to those bestowed by a license but over a smaller fishing area only.

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[4] A discussion of this management alternative is prompted by the inclusion of the concept in the pending bills that revise the basic fishery law, Presidential Decree 704.

[5] The distinction between res nullius and res communes follows from Ciriacy-Wantrup & Bishop (1975). This deviates from the literature where, in most cases, an open access fishery is referred to as a common property resource. The terminology used by Ciriacy-Wantrup and Bishop appears to be more applicable since in open-access fishing, no form of rights are bestowed on anyone.

One of the earlier works on TURFs is by Christy (1982) and now the concept is defined as community held rights of use (or tenure) and exclusion over the fishery resource within a specific area and for a period of time (Panayotou 1983). The following are the important descriptive elements of TURFs: community, territory, a set of rights and responsibilities. Maintenance and proper management of the resource base and restrictions on the exercise of the rights of use and exclusion are some of the responsibilities.

TURF is not entirely new in fisheries as traditional TURFs are known to have existed for centuries in Brazil, Japan, Sri Lanka, Papua New Guinea, Oceania and Ivory Coast (as cited in Panayotou 1983). The increasing interest in TURF stems from its potential advantages in fisheries management. The biggest benefit, being that the government is able to turn over to the local community many of the functions and responsibilities of management and enforcement. These include the determination and distribution of benefits, the acquisition of information and resolution of conflicts within and between fishing communities - tasks which are often costly and politically difficult for a central authority.

TURFs are seen to be of most utility in tropical fisheries in developing countries. The multispecies multi-gear nature of fisheries and the scattered and remote fishing villages on a long coastline makes monitoring and enforcement of fishery laws extremely costly if not impossible. Management of the resource by the users themselves is less costly and more effective.

While the establishment of TURFs is an attractive management tool for open-access fisheries, its applicability appears limited. Rettig (1989) concluded that the less mobile the fish stock, the greater the success with TURFs. This is supported by the more successful application of TURFs in these species. Ancient forms of TURFs in Japanese villages were associated with cultural traditions that favored the emergence of rights in fisheries. This socio-cultural requisite may not exist in contemporary society which is undergoing rapid changes with the pressure of population growth, technological improvement and commercialization of subsistence fishing. Thus the introduction of TURFs in communities accustomed to unregulated fishing may be met with resistance.

3.4 Summary

The existing fisheries literature on the following areas was reviewed in the previous discussion: the evolution of fisheries policy, the treatment of multispecies and multi-gear fisheries and the implications of alternative management strategies. A general observation is that in almost all aspects, the literature dealt mainly with temperate fisheries in developed countries while only a handful tackled tropical fisheries in developing countries. This points to the need for changes in adapting existing theory in the analysis of multispecies fisheries in the Third World. Moreover, the commonly accepted tools or regulations in managing the fishery may need to be re-examined as far as their applicability to developing countries is concerned.

The preceding review of literature identified an important gap in most analytical approaches which needs to be addressed. Most studies focusing on multispecies fisheries deal with the biological interactions between species or the occurrence of technological relationships between species in the harvesting process. This is quite adequate in representing the biological and technological aspects of fisheries, however, it fails to consider the social and economic dimensions which may be more important considerations in some fisheries. More specifically, there was no explicit treatment of the multi-objective nature of fisheries resource harvesting. On the other hand, where the multi-objective exploitation issue was dealt with satisfactorily, the multispecies problem was assumed away. In the case of Third World fisheries where resources are multispecies and there are pressing social and economic issues, an analytical approach that incorporates all these important considerations needs to be developed. An applicable model is presented in the next chapter.

Chapter 4

Mathematical Specifications of the Model

This chapter presents a model of the small pelagic fisheries of Guimaras Strait and the Visayan Sea in the Philippines. The important considerations in modeling the fishery are its multispecies multi-gear nature and the need to address various goals of fishery management. The model that is formulated consists of 3 sub-models that accomplish the following tasks: the estimation of fishery yields, the allocation of these yields to competing fishing fleets and the analysis of alternative management schemes for the fishery. Each sub-model is discussed below.

4.1 Population dynamics

The biological model used to describe stock dynamics is an adaptation of the dynamic pool model developed by Beverton and Holt, which was discussed in passing in chapter 3. The exploited fish stock can be viewed as a pool with continuous inflows and outflows. The harvestable population (in terms of weight or number) increases with recruitment and from growth of individual fish already in the fishery. Total outflows (Z) consist of natural mortality (M) and fishing mortality (F), thus $Z=F+M$.

The life stages of the fish may be divided into two parts for the purpose of fisheries management. The first stage is the pre-exploited phase while the second stage is the exploited phase which commences at t_p, the time the fish becomes vulnerable to the fishing gear until $t_\varphi - 1$, t_φ being the maximum age after which no fish is assumed to survive. Consider a year-class of fish whose biomass (in terms of number) is R, that is added to the fishery. These new recruits of age t_r grow in size following the von Bertallanfy growth function (VBGF) without being liable to harvest until they reach t_p. During this time, the decrease in the number of recruits is due only to natural mortality. The number of recruits that reach the fishable stage, as denoted by R_{tp}, is

$$R_{tp} = Re^{-M(tp-tr)} \qquad (4.1)$$

In the exploited phase, the number of fish declines due to fishing and natural mortality (F+M). Fishing mortality is a constant instantaneous coefficient which is assumed to be invariant with age of the fish and stock abundance. It is also assumed that F is directly proportional with fishing effort. During the exploited phase the number of recruits remaining in time t, N_t, is

$$N_t = R_{tp}e^{-(M+F)(t-tp)} \qquad (4.2)$$

The Beverton-Holt model assumes the growth of fish in length to follow the VBGF. The VBGF incorporates two biological processes affecting growth, namely, anabolism and catabolism which are the building and breaking down of tissue, respectively. Defining growth as the difference between anabolism and catabolism, von Bertallanfy derived a simple equation predicting the length of the organism as a function of age. The length of fish at time t (L_t) is expressed as

$$L_t = L_\infty [1 - e^{-K(t-t_0)}] \qquad (4.3)$$

where L_∞ is the asymptotic length towards which the fish is growing, K is the growth constant that embodies anabolism and catabolism and t_o is the age at which the length of fish is theoretically zero.

Fish are assumed to grow isometrically in which case the weight of the fish is proportional to the cube of any linear dimension. Hence, the VBGF (equation 4.3) may also be used to express growth in weight. This transformation permits the estimation of the yield of a cohort in terms of weight. The growth in weight is given by

$$W_t = W_\infty [1 - e^{-K(t-t_0)}]^3$$

or in expanded form

$$W_t = W_\infty \sum_{n=0}^{3} \Omega_n e^{-nK(t-t_0)} \qquad (4.4)$$

where W_∞ is the maximum weight of the fish and Ω_n is equal to +1, -3, +3, -1 for n equal to 0,1,2,3, respectively.

From the instantaneous fishing mortality $dY_t/dt = FN_tW_t$, the total yield during the entire exploitable lifespan ($\varphi = t_\varphi - 1$ to t_p) of the fish is

$$Y_t = F \int_{tp}^{t\varphi-1} N_t W_t dt \qquad (4.5)$$

From (1), (2) and (4), (5) may be expressed in integrated form as

$$Y_t = FRe^{-M(tp-tr)} W_\infty \sum_{n=0}^{3} \sigma(n) \qquad (4.6)$$

where $$\sigma(n) = \frac{\{\Omega_n e^{-nK(tp-to)}\}\{1 - e^{-(F+M+nK)(t\varphi-1-tp)}\}}{F + M + nK}$$

Assuming further that there is no upper limit to lifespan (t_φ is ∞) and that t_0 is zero[1], the above may be further simplified as

$$Y_t = FRe^{-M(tp-tr)} W_\infty \sum_{n=0}^{3} \frac{\Omega_n e^{-nKtp}}{F+M+nK} \qquad (4.7)$$

Equation (4.7) gives the yield for each species over the exploitable lifespan of a given year-class. For multispecies fisheries, the total yield over all species is the sum for individual species. Assuming that recruitment is yearly and constant[2], the total annual yield from a given fish population is also equal to the equation 4.7.

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[1] This assumption is due to difficulty of estimating the value of this parameter from available data. It is discussed further in section 5.1.

[2] The assumption of constant recruitment is not critical. Recruitment may vary from year to year provided that recruitment varies randomly around a certain mean but without a trend. In this case, R would refer to mean recruitment and that yield, Y, is expected yield. The important assumption here with regard to recruitment is that there is no stock-recruitment relationship. This assumption is due to inavailability of time-series data on recruitment and stock size.

The yield-per-recruit is a function of the parameters specified in the equation, namely: R, M, F, t_p, t_r, K and W_∞. The estimation and values of these parameters from data collected in this research are presented in chapter 5. Only t_p and F are policy variables while the rest indicate the technological and biological characteristics of the fish stocks. Equation 4.7 is further analyzed in sections 6.3.3 and 6.3.4 in the assessment of regulations on fishing mortality (F) and mesh sizes (as implied by t_p).

Equation 4.7 was used by Lee and Al-Baz (1989) in their assessment of the fish trap fishery of Arabian Gulf and by Mennes (1984) on Moroccan fisheries. Greboval (1985) used a similar specification for the New England groundfish fishery. Other authors, e.g., Pikitch (1987) and Murawski (1984) derived a variant of equation (4.7) in their work on the flatfish and groundfish fisheries of the U.S., respectively.

Most of the applications of the Beverton-Holt model of stock assessment as enumerated above are on temperate and sub-temperate fishery stocks. Pauly (1989) noted that the M/K ratio is generally lower for temperate stocks than for tropical stocks. He pointed out that this has implication with regard to the kind of management advice that can be designed for the fishery when using yield-per-recruit stock assessment models in tropical environments. This becomes clearer in section 5.1 where technological and biological parameters are presented and discussed and in section 6.4.3 where fishing mortality regulations are analyzed.

4.2 Effort allocation among competing fisheries

The small pelagic fisheries of Guimaras Strait and the Visayan Sea in the Philippines currently support a number of fishing fleets using different scales of operation. For example, there are both commercial and municipal fishermen in the purse seine, Danish seine and trawl fleets. While the previous section provides a methodology for estimating the yearly yield of the fishery resources (the application is in chapter 5), this section resolves the following question. What is the optimum size of each fleet that can be supported by the yields in the fishery? The optimal fleet size may then be compared to the number of vessels currently in the fishery and from this, management alternatives for the fishery can be designed.

In the process of determining the optimal fleet size the goals of fishery management need to be considered. The explicit and implicit objectives pursued in the exploitation of fishery resources as stated in Philippine laws were discussed in section 2.6. The main objectives include the maximization of fishery production and conservation of resources, the alleviation of poverty through the generation of economic rent, the maximization of employment in the fishery sector and the attainment of a more equitable distribution of benefits. The objectives may be classified into four categories, namely: catch optimization subject to conservation of stocks, economic efficiency, employment generation and equity. The management problem is viewed here as a multiobjective programming problem whereby the pursuit of several conflicting objectives is tackled explicitly.

Following Evans (1984), the allocation problem is that of selecting the values of a vector of decision variables $f = (f_1, f_2, \ldots, f_n)$ in order to optimize p ($p \geq 2$) objective functions $h_1(f), h_2(f), \ldots, h_p(f)$ subject to a constraint matrix imposed on the decision variables expressed as $f \in B$. Mathematically, the allocation problem is stated, in general form, as

$$\text{Max } h(f) = [h_1(f), h_2(f), \ldots, h_p(f)] \qquad (4.8)$$
$$\text{subject to } f \in B$$

Here f is the vector of standardized fishing efforts for the n fishing fleets and B is represents the set of feasible values of f. It is implicit in the constraint matrix that f should be nonnegative.

Of the fishery management objectives being considered, economic efficiency and employment generation remain as objective functions while the others are in the constraints. The rationale is that these two objectives (catch optimization and equity) may be more conveniently expressed as constraints. Catch optimization is supplanted by constraints that limit catch to the biological potential of the resource while equity in the distribution of benefits is interpreted as maintaining the current proportion of catch by the municipal and commercial sectors in each fleet and for the entire fleet. These are further discussed below, however, the remaining two objectives

-- economic rent and labor use maximization are discussed first.

Economic rent or surplus is commonly quantified in monetary terms as the difference between fishery revenues and fishery costs.[3] The economic objective of maximizing economic rents from the fishery is specified as follows:

$$\text{Max} \quad h_1(f) = \Sigma_i \Sigma_j \Sigma_s \, p_i q_{ijs} f_{js} - \Sigma_j \Sigma_s \, c_{js} f_{js} \qquad (4.9)$$

where *i* denotes species of fish, *j* the fleet (gear) and *s* is the sector (municipal and commercial). P_i is the unit price of *i*th species and c_{js} is the unit cost of standardized effort for gear *j* in sector *s*. The above expression states that rent is equivalent to the difference between the value of catch of all small pelagic species caught and the cost of harvesting those species across all fleets. The concept of economic rent is further clarified in chapter 5 where specifying the components of fishing costs and fish prices are specified.

The objective of maximizing employment in the fishery may be expressed as

$$\text{Max} \quad h_2(f) = \Sigma_s \, \Sigma_j \, l_{js} f_{js} \qquad (4.10)$$

where l_{js} is the labor component for every unit of standardized fishing effort for fleet *j* and sector *s*. Hence, the objective

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[3] Economic benefits from the fishery do not only include monetary commercial benefits but also the rents arising from "social overhead capital" and infrastructure developed in fishing communities (Christy and Scott 1965) and Charles (1989). However, due to difficulties in measuring other components of economic rent, only the direct monetary benefits are considered. The concept of rent is further discussed in the next chapter.

is to maximize labor input across all fleets (gear) noting that the crew component for each fishing gear varies. Considering that there is high economy-wide unemployment, it is desirable to permit entry into the fishery sector of the highest number of fishermen possible.

The two objectives of rent and employment maximization are in conflict with each other. As indicated by the costs and earnings figures described in chapter 2 and will be discussed again in chapter 5, the more profitable gears are not necessarily those employing labor-intensive fish harvesting technologies. This fact should be considered in the modeling process.

While fishery catches should be maximized these have to be within the biological potential of the resource. The catch optimization objective is thus subject to conservation objectives. In the model, however, catch optimization is not considered as an explicit objective. Instead, it is expressed as a set of constraints specifying an upper limit on the catch of each species. The reason is that, in the application of the model, only a section of the entire fleet harvesting the small pelagics is considered. Hence, any part of the target catch allocated but not harvested by the fleets under study may be caught by the other fleets.

In the application of the model, catches are first set equal to the historical trend in landings which constitute the base case model. The catches are then equated to the yield that maximizes yield-per-recruit for each species in the analysis of management alternatives for the fishery. This allows for the comparison of the optimal fleet compcsition given by alternative target yields for the fishery.

The set of constraints specifying limits on catches by species group is given below. Total catches (H) for a given species, *i*, expressed as the summation of the catches (or fishing mortalities) generated by all fleets 1,2,...,*j* in each of two sectors *s* (commercial and municipal) must be less than or equal to Y_i, the annual historical catch (and eventually the catch that maximizes yield-per-recruit).

$$H_i = \Sigma_j \Sigma_s q_{ijs} f_{js} \leq Y_i \tag{4.11}$$

The parameter q_{ijs} is the catchability coefficient for species *i* taken in fishery *j* and by sector *s*. H_i may be also interpreted as fishing mortality in discrete time (one year) for species *i*, thus, the above equation indicates the proportionality of fishing mortality with fishing effort (f_{js}).

In a mixed species fishery, the q_{ijs} or the coefficient of proportionality between landings and fishing effort will vary across species and fleets due to differences in the availability of the various species and their vulnerability to the gear. Furthermore, the effects of fishing power and area of operation which differ between the commercial and municipal fishing sectors are to be accounted for. Hence, the catchability coefficient should pertain to a given species, a specific gear and the sector catching it[4]. In matrix form, equation (4.11) is represented as

$$\underset{(n\cdot 1)}{\mathbf{H}} = \underset{(n\cdot 2m)}{\mathbf{q}} \cdot \underset{(2m\cdot 1)}{\mathbf{f}} \leq \underset{(n\cdot 1)}{\mathbf{Y}} \qquad (4.12)$$

where

$$\mathbf{H} = \begin{vmatrix} H_1 \\ H_2 \\ H_3 \\ \cdot \\ \cdot \\ \cdot \\ H_n \end{vmatrix} \qquad \mathbf{q} = \begin{vmatrix} q_{111} & \cdots & q_{1m1}, & q_{112} & \cdots & q_{1m2} \\ \cdot & & \cdot & \cdot & & \cdot \\ \cdot & & \cdot & \cdot & & \cdot \\ \cdot & & \cdot & \cdot & & \cdot \\ q_{1n} & \cdots & q_{nm1}, & q_{n12} & \cdots & q_{nm2} \end{vmatrix}$$

$$\mathbf{f} = \begin{vmatrix} f_{11} \\ \cdot \\ \cdot \\ f_{m1} \\ f_{12} \\ \cdot\cdot \\ \cdot \\ f_{m2} \end{vmatrix} \qquad \mathbf{Y} = \begin{vmatrix} Y_1 \\ Y_2 \\ Y_3 \\ \cdot \\ \cdot \\ \cdot \\ Y_n \end{vmatrix}$$

Each row in the **q** matrix gives the catchability coefficients across all gears and sectors for a single species of fish.

Fishing effort which is captured in the f vector is typically represented as some variant of fishing time multiplicatively adjusted by fishing power which is a productivity measure specified as a production function of fishing inputs, labor and capital inputs (Squires 1987). Hence standardized fishing effort may be stated as a function of fishing time (t), labor (L) and capital (K).

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[4] The literature reviewed by Peterman and Steer (1981) shows that catchability varies with population abundance for both pelagic and demersal species. Gates and Norton (1974), on the other hand, specified a catchability coefficient that is a decreasing function of fleet size, that is, there are congestion effects. For simplicity and also due to their inavailability the effects of vessel interference and stock intensity are not considered in this model.

$$f = f(t,K,L) \qquad (4.13)$$

with the partial derivatives f_t, f_K, and f_L all positive. The specification of the production function of effort is in section 5.2.2.

Equity in fishery resource exploitation in the Philippines is viewed as that of providing equal resource access, where possible, to all groups of fishermen. In this case the two groups are the municipal and commercial fishermen. Since management of the fishery entails an inevitable displacement of vessels and fishermen, an important issue to resolve is from which fleet and sector this reduction should come. Equity considerations then take on entirely the opposite perspective of determining who should leave the fishery. In Philippine fisheries the conflict between the commercial and municipal fishermen should be taken into account; any attempt to manage the fishery should not favor either group. Hence, in the allocation process the current proportion of fishing effort exerted by the two sectors (f_1 and f_2) in each fleet (CR_j) and for the entire fishery (CR) should be maintained. These are then constraints to the allocation model which can be expressed mathematically as follows

$$\begin{aligned} f_{j1}/f_{j2} &= CR_j \quad \text{for all } j, \text{ and} \\ \Sigma_j f_{j1}/\Sigma_j f_{j2} &= CR \qquad (4.14) \end{aligned}$$

The values of CR_j and CR are estimated in the next chapter.

One characteristic of programming models is that the allocation process jumps from one extreme point to another in the maximization of the objectives. The optimal solution may call for the elimination of one or more fleets. This (and any displacement of existing capital from the fishery) may not be acceptable politically given that the opportunity cost of fishing assets in the Philippines is very limited if non-existent, i.e., the possibility for productive disinvestment is essentially nil. More fundamentally, the elimination of any fleet reduces the flexibility in adapting to changes in the course of managing the fishery in the future. The equity constraint should include a minimum fleet size for all fleets (implying a minimum fishing effort) which can be expressed as follows

$$f_j \geq \min\,(f_j) \qquad (4.15)$$

The right-hand side is the vector of minimum levels of fishing effort for each fleet and is estimated in the next chapter. Setting a lower minimum level of effort in this constraint will allow for a larger amount of effort to be freely allocated across fleets in a manner that will maximize the values of the two objectives. This still makes possible the specialization of one fleet which has comparative advantage over the other fleets in the small pelagics fishery.

With the foregoing simplifications, the effort allocation problem is reduced to a bicriteria modeling problem with catch and equity constraints. The fishery management problem is summarized below[5]

$$\text{Max} \quad [h_1(f)] = \Sigma_i \Sigma_j \Sigma_s \, p_i q_{ijs} f_{js} - \Sigma_j \Sigma_s \, c_{js} f_{js}$$

$$[h_2(f)] = \Sigma_j \Sigma_s \, l_{js} f_{js}$$

subject to

$$\begin{array}{lcl} \Sigma_j \Sigma_s \, q_{ijs} f_{js} & \leq & y_i \\ f_{j1}/f_{j2} & = & CR_j \\ \Sigma_j f_{j1}/\Sigma_j f_{j2} & = & CR \\ f_j & \geq & \min \{f_j\} \end{array}$$

4.3 Some concepts in multiobjective programming

The introduction of several goals which are conflicting and attempting to maximize them simultaneously presents new dimensions in the areas of modeling and mathematical programming. The notion of an optimal solution in single-objective modeling is no longer applicable in multiobjective programming. Instead, the concept of a set of nondominated solutions[6] is introduced.

The set of efficient solutions is a subset of the feasible region. An efficient solution is one for which there does not exist another feasible solution which does as well on every single objective, and better on at least one objective.

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[5] Appendix A gives the mathematical programming model with all the parameter values estimated.

[6] In the literature, a nondominated solution is also termed an efficient or Pareto solution. These terms are used interchangeably in this manuscript.

Mathematically, $f^E \epsilon B$ is an efficient solution to equation (8) if there does not exist any other feasible solution $f \epsilon B$ such that $h_i(f^E) \leq h_i(f)$ for all $i = 1,2,\ldots,p$ and $h_i(f^E) < h_i(f)$ for some $i = 1,2,\ldots,p$.

A solution which maximizes each of the objective functions simultaneously is called a superior solution (f^S), i.e., and is the case if $f^S \epsilon B$ and $h_i(f^S) \geq h_i(f)$ for $i = 1,2,\ldots,p$ of all $f \epsilon B$. A superior solution is an efficient solution but the reverse is not necessarily true. Since at least two objectives in a multiobjective programming problem are typically conflicting in nature, a superior solution rarely exists. Hence, the concern is on generating the set of efficient or nondominated solutions.

There are several methods of generating the set of nondominated solutions. Two methods are reviewed here, namely the weighting and ϵ-constraint method[7]. The two methods transform the multiobjective problem into a single objective programming format and then, by variation of the parameters used to effect the transformation, the set of nondominated solutions can be generated.

The weighting method is expressed mathematically as

$$\text{Max } h(f) = \Sigma_i w_i h_i(f) \qquad (4.16)$$
$$\text{subject to } f \epsilon B$$

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[7] A more complete listing and description of methods that generate the nondominated set is found in Goiceochea et al. (1982).

where w_i are the weights attached on the ith objective function. The multiobjective problem has been transformed into a single optimization problem for which solution methods exist. The weights may be interpreted as the relative worths of the objectives and may reflect the decision maker's preferences. However, here subjectivity is avoided by looking at the process as simply generating the nondominated solutions set. The efficient region is derived by varying the w_is assigned to each objective function.

The ϵ-constraint method allows the specification of bounds on the objectives in a sequential manner. The setting of maximum or minimum levels for p-1 objectives transforms the problem into a single-objective problem. The multiobjective problem in equation (4.8) is reduced to

$$\begin{aligned} &\max \quad g_u(f) && (4.17)\\ &\text{subject to:} \quad f \in \beta \\ &\qquad\qquad\qquad g_k(f) \geq \epsilon_k \\ &\text{for} \quad k = 1,2,\ldots, u-1, u+1,\ldots,p \end{aligned}$$

Appropriate parametric variation of the ϵ_k specified for the p-1 objectives generates the nondominated set.

It may be that the number of efficient solutions is large and that narrowing the set down to a more manageable number of alternatives is necessary. However, the methods for reducing the efficient solutions set involve an articulation of the preferences of the decision maker. To avoid any subjectivity in the modeling process, an evaluation of a number of extreme points will be done and their characteristics will be compared. Some sort of menu may be prepared from which the decision maker chooses the "desired" allocation.

4.4 Towards the analysis of fishery management schemes

The central part of the model is the allocation of fishing effort to competing fleets subject to target catch levels and equity constraints. There are two ways whereby one may proceed with the analysis of various management schemes with respect to the above model. One is *ex-post*, i.e., after the effort allocation process is completed. This does not involve the changing of model parameters which means that the same optimal solution is being considered. Another is through sensitivity analysis by varying the values of the estimated parameters.

The output from the effort allocation process is the optimal fishing effort for each of the fishing fleets under consideration. Fishing effort is standardized across fleets and the methodology used is described in section 5.2.2. Since effort is an index involving the following inputs: fishing time, labor and capital, the determination of the actual number of vessels would entail the assumption of the values of these inputs. Several of these inputs or components may be regulated. For example, fishing time may be regulated through seasonal closures and capital through controls on vessel tonnage. Analyzing the effects of such controls on fishing effort is an *ex-post* exercise with respect to the effort allocation problem; the same set of optimal level of standardized fishing effort is being considered. What is being changed is the configuration of the vessels and/or fishing time. This is discussed further in chapter 6 when considering the effects of seasonal closures.

Sensitivity analysis, on the other hand, is carried out by running the effort allocation model again to determine the effects on the results of the base case model. This may alter the original set of optimal points and hence lead to a different optimal allocation of effort. There are two general types of regulations that can be analyzed in this manner with respect to the population dynamics model. These are changes in fishing mortality (F) and mesh size regulations which imply targeting different ages at first capture (t_p) for the small pelagic species. The regulation of fishing mortality (F) and mesh sizes (t_p) involve changes in the target catch levels (Y_is) specified in the biological constraints. This aspect is discussed further when considering specific management alternatives for the fishery in chapter 6.

Chapter 5

Application of the Model and Preliminary Analysis

The analytical framework developed in the preceding chapter is applied to the small pelagic fisheries of Guimaras Strait and the Visayan Sea. The procedure for estimating the parameters required by the analytical model is described in this chapter. Likewise, the estimated parameters are analyzed where applicable. The number of required parameters is quite large and since secondary data pertaining to the fishery are very limited, the estimation of parameters relies largely on the data collected in the survey. Fortunately, most parameters can be derived from the primary survey data.

There are two important points that should be noted in the applied model. First, parameters are estimated from data collected over a 12-month period. The basic assumption is that the period (November 1988 - October 1989) is a representative year, biologically and in terms of meteorological conditions, for the small pelagics fishery in the study area. The biological parameters estimated in this chapter reflect the dynamics of the fishery regardless of any management applied to the fishery. The technical and economic parameters, on the other hand, pertain to the "current" pattern of exploitation where fishery regulatory schemes have been instituted but were not successful or effective. Sensitivity analysis will be performed on the parameters to determine the effects on the results of any error that may have been committed in estimation.

Second, the model is based on a regional approach to the management of the small pelagic fisheries in Guimaras Strait and Visayan Sea. It is assumed that the resources are independent stocks and that their pattern of distribution in the fishing grounds is fairly constant over time. Although pelagic species are known to be migratory, it is further assumed here that the study area is a major part of that migratory route where fish come in contact with fishing activities. This assumption is plausible as catches of small pelagics in the study area are one of the highest among statistical fishing grounds in the entire country. One observation during the monitoring period confirmed that small pelagics move around Guimaras Strait and Visayan Sea and the adjoining areas. Encircling gill nets which target mostly on small pelagics changed ports (within the study area) at certain times of the year as they followed the migrating fish. Moreover, fishermen indicated that their movement around the fishing grounds is about the same from year to year.

5.1 Biological sub-model

The basic biological parameters were estimated for dominant species in each category. As shown by weekly samples of landings of all gears during the monitoring period the following species accounted for the largest share in each category of small pelagics:

Category	Dominant species	Percent share to total in the category
Sardines	*Sardinella gibbosa*	23.70
Mackerels	*Rastrelliger brachysoma*	72.00
Crevalles	*Selaroides leptolepis*	51.00
Anchovies	*Stolephorus indicus*	43.80
Round scads	*Decapterus macrosoma*	34.70
Round herring	*Dussumieria acuta*	82.40
Big-eye scads	*Selar crumenupthalmus*	95.50.

The parameters required by the Beverton-Holt model are listed in Table 5.1 and such parameters refer to the above dominant species in each category. Estimates of the parameters were derived from length-frequency data collected during the survey. The data were analyzed using a computer package called Electronic LEngth Frequency ANalysis (ELEFAN). (A brief description of the ELEFAN package is in Appendix B.) The biological parameters would be accurately estimated if the sampling gear has a wide selectivity, i.e., it catches both small and big fish for each species. On the basis of wider selectivity of Danish seine and trawl over other gears and their predominance in the study area, the two gears were selected as the sampling gears for the purposes of the ELEFAN package.

Natural and fishing mortalities are instantaneous rates as described in section 4.1. The natural mortality (M) figures for all species are quite high, which is usually the case for tropical fishes and more specially so for short-lived species

Table 5.1. Estimates of biological and technological parameters for small pelagic fish species of Guimaras Strait and the Visayan Sea, Philippines

	Sardine	Mackerel	Crevalle	Anchovy	Round-scad	Round herring	Big-eye scad
Mean asymptotic length (cm)	20.00	23.10	20.50	14.72	24.50	22.00	21.00
Mean asymptotic weight (yr)	106.65	217.52	148.76	29.05	205.15	135.43	102.19
Body growth coefficient (K)	1.00	1.00	0.55	0.90	0.96	0.80	0.89
Age at recruitment (yr)	0.470	0.393	0.630	0.249	0.511	0.251	0.779
Age at first capture (yr)	0.776	1.038	1.023	0.765	0.790	0.817	1.650
Natural mortality (M)	2.00	1.92	1.34	2.05	1.84	1.68	1.83
Fishing mortality (F)	3.76	3.06	0.84	0.45	3.81	3.01	3.58
Yield-per-recruit (gm)	8.72	13.79	6.00	0.49	18.38	6.01	7.12
No. of recruits (million)	3,267	1,646	2,682	12,537	377	775	720

as the small pelagics (Table 5.1). The ratio of M to K ranges from 1.92 for round scads to 3.06 for mackerels, which is, again, typical for tropical stocks (Pauly 1989). Fishing mortality (F) is proportional to fishing effort. The intensity of fishing is quite high for most species as shown by the exploitation rates (the ratio of F to sum of the two mortalities) which is over 50% except for anchovy and crevalle. Hence, the high exploitation rate as well as the high rate of natural mortality result in a small absolute biomass level for each species in relation to the number of recruits. If the current intensity of fishing increases further over time, in the long run this may lead to the collapse of the fish stocks if recruitment is density-dependent. The implications of the biological characteristics of the fishery stocks and the current exploitation patterns on the management of the fishery are discussed further in section 6.4.3 where the effects of fishing mortality regulations are analyzed.

The parameter t_o specified in Equation 4.1 is a factor used to adjust the growth curve to an absolute age scale. Length frequency data, by themselves, never allow the estimation of t_o (Pauly 1987). With t_o remaining unknown, all growth curves refer to chronological time; they indicate what size the fish of a given cohort had at a certain time but do not indicate the absolute ages of the fish, i.e., they do not give the age corresponding to a given size (Ingles and Pauly 1984). However, in this thesis the parameter t_o is assumed to be zero (as in Lee and Al-Baz 1989) to be able to interpret the age data listed in Table 5.1 as absolute ages.

The age-at-first-capture is indicative of the retention characteristics of the gear. It corresponds to the mean selection age if the selection range of the gear is above the size at which fish are recruited to the exploited area (Beverton and Holt 1957). The mean selection length can be derived from ELEFAN output which is then converted to age using equation (4.3) by setting t_o to zero. The recruitment age (t_r), on the other hand, is derived for the smallest fish length captured by the sampling gear as was done by Lee and Al-Baz (1989). It is obtained from the length frequency distribution of the catch of the sampling gear for each fish species. Such distribution may be indicative of the retention characteristics of the sampling gear.

The above parameters are used to estimate the yield-per-recruit for each species. It should be emphasized that the yield-per-recruit figures are computed under current patterns of exploitation implying that the values of F and t_p are those listed in Table 5.1. The estimates of yield-per-recruit are shown in the bottom part of Table 5.1 and will serve as the base target yield in the analysis in chapter 6. Further analysis of these figures will be done in chapter 6 when these are compared with the yield-per-recruit under various levels of fishing mortality and age-at-first-capture.

While recruitment data are not directly available, a procedure used by Pauly (1982) is also used to estimate recruitment. Given estimates of yield-per-recruit from equation 4.7, the number of recruits produced each year can be estimated using the relationship

$$R = Y/(Y/R) \tag{5.1}$$

where R is annual recruitment and Y is the annual yield from the fishery. Here, Y^1 is the average annual catch (over 10 years) for each species group as reported in the official fishery statistics hence, the computed R is the mean recruitment for each species. The estimates of mean annual recruitment are given in Table 5.1. The mean recruitment figures will be of use in determining alternative target yields for the fishery in chapter 6.

5.2 Economic sub-model

5.2.1 Fleet characteristics[2]

The small pelagics fishery is exploited by a large number of gears. Five fleets/gears were selected for analysis on the basis of their large contribution to small pelagic landings. These are modified Danish seine, encircling gill net, purse seine, trawl and drift gill net fleets. (Refer to Appendix C for an illustration of these gears.) Each fleet was further

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[1] See the next section for further clarification of the average annual catch. It should be mentioned at this point that the catch figures listed are the shares of the gears considered in the study to total landings by species group. These are listed in Table 5.2. It follows that the recruitment estimates correspond to these yields.

[2] A description of the various gears employed in the small pelagics fishery was already done in chapter 2. This section, however, emphasizes the differences between the municipal and commercial sectors in each fleet which was not done in chapter 2. Moreover, only the characteristics of the five sample fleets are discussed.

divided into two sectors, namely: commercial and municipal. This followed the official classification of vessels in the Philippines which is based on the gross tonnage of the catcher vessel. Those with gross tonnage below 3.0 belong to the municipal category and those with 3.0 and above are in the commercial category. A discussion of the implications of this classification is in chapter 2.

The five sample gears account for a majority of small pelagic landings in the study area. The share of the five gears of total landings by species group ranged from 75.96% for round herring to 99.23% for round scads. To obtain the total quantity of fish to be allocated among the competing fleets (gears), the average annual landings for each species group is multiplied by the respective percentage contribution of the sample gears. The figures are given in Table 5.2.

The description of the various fishing fleets and information on their operations during the survey period are given in Table 5.3. The largest vessels are found in the purse seine fleet which are constructed with wooden or steel hulls, are powered by large diesel engines and are equipped with fish finders, sonars, etc. All commercial fishing vessels are mechanically powered. However, the same cannot be said for municipal vessels particularly the drift gill net fleet which is largely artisanal. Most are very small vessels with the following average length-width-depth dimensions in feet: 29.83-1.75-1.87. About 4% have no mechanical power source and hence rely on sails.

Table 5.2. Estimation of yearly catch of major small pelagic species groups for the sample fishing gears

Species group	Total landings over 9 years 1978 - 1987 (a) (m.t.)	Average annual landings (m.t.)	Percent landed by sample gears	Total catch/yr (m.t.)
Sardines	325,764	36,196	78.70	28,486
Roundscad	205,825	22,869	99.23	22,693
Mackerels	148,682	16,520	97.33	16,079
Anchovies	78,558	8,729	70.70	6,171
Crevalle	63,453	7,050	98.31	6,931
Round herring	55,215	6,135	75.96	4,660
Big eye scad	47,136	5,237	97.90	5,127

a 1985 data is not available

Table 5.3. Characteristics of the sample fishing gears exploiting the small pelagic fisheries of Guimaras Strait and the Visayan Sea

Fleet/gear	Average gross tonnage	Average crew size	Percent of vessels motorized
Danish seine			
Commercial	5.07	8.00	100.00
Municipal	1.52	6.21	100.00
Encircling gill net			
Commercial	3.65	5.44	100.00
Municipal	1.96	5.88	100.00
Purse seine			
Commercial	18.03	28.24	100.00
Municipal	1.95	19.00	100.00
Trawl			
Commercial	5.10	2.76	100.00
Municipal	1.73	2.47	100.00
Drift net			
Municipal	0.59	2.75	96.54

The number of persons employed in the fishing unit depends on the type of fishing gear and the scale of operations. The latter may be gleaned from the tonnage of the vessel; in a given fleet, the larger the vessel the bigger the crew to carry out the fishing operation. This is the case only if larger vessels are not equipped with motors that substitute for human power. However, except for the purse seine fleet the size of the crew tends to be about the same. The reason is that in the other fleets, average vessel size across sectors is not significantly different. Given this situation, the municipal sector in general employs more labor-intensive fishing technologies than the commercial sector.

5.2.2 The measurement of fishing effort

Effort is an aggregate index of the use of individual factors of production. The measurement (and standardization) of fishing effort in this thesis identifies three important inputs in the fishing process, namely: capital, labor and fishing time as is specified in equation 4.13. There are, however, important considerations in the specification and estimation of the effort function. The first is that several species (pelagic and non-pelagic) are simultaneously harvested hence, there is technological interaction in the harvesting process. This implies that technology is joint-in-inputs and a single function must be estimated for both pelagic and non-pelagic catches. A separate effort function will be estimated for each fleet hence, the effort function is defined for the respective fleet operations.

Second, the estimation of equation 4.13 assumes that technology is separable. The components of effort can only be consistently aggregated into a composite index with this assumption[3]. Separability makes it possible to meaningfully rank alternative levels of effort (represented by isoquants) without knowing the levels and mixes of species harvested. The ranking of isoquants is independent of the composition of catch. Hence, monotonicity is still maintained as more inputs yield higher effort (catches). The type of separability imposed is input-output separability which implies that fishermen make their decisions on optimal species independently of their decisions on factor combinations. The importance of these assumptions is emphasized in the succeeding discussions.

In the specification of equation 4.13, the gross tonnage was taken as the proxy for capital and crew size for labor. In cross-section data the two proxy variables tend to be correlated which may give rise to multicollinearity. Labor and fishing time are then combined to form the aggregated input crewdays. Thus, two variables constitute fishing effort, namely: gross tonnage (GRT) and crewdays (CD). Fishing effort corresponds to total catch[4] (pelagic and non-pelagic) per

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[3] A detailed discussion of the various restrictions on technology and their implications is found in Squires (1987).

[4] This is in consonance with the restriction joint-in-inputs production technology which is discussed earlier.

fishing trip as the latter is an indicator of the effectiveness of the fishing process. While stock size is an important determinant of catch, it is not included as it is assumed constant considering that the data is cross-sectional. Hence, the fishing effort function may also be interpreted as a production function.

It was observed during the survey that there were significant variations in terms of catch and length of fishing trips across seasons for all fleets. The specification of fishing effort is revised to incorporate seasonal variations. The identification of seasons was based on wind direction and wind velocity in the fishing grounds. The Philippine meteorological bureau identifies four seasons prevailing in the study area, namely: pre-monsoon (May-June), peak-monsoon (July-September), post-monsoon (October-November) and calm (December-April).

A Cobb-Douglas specification is selected for equation 4.13 as it incorporates the restriction of separability in the production technology. Dummy variables are added to include seasonal effects. The final specification of the fishing effort index is:

$$f = e^{\beta o}(GRT)^{\beta 1}(CD)^{\beta 2}e^{\Sigma i \sigma i Si} \qquad (5.2)$$

or in log-linear form

$$\ln f = \beta_o + \beta_1 \ln(GRT) + \beta_2 \ln(CD) + \Sigma_i \sigma_i S_i \qquad (5.3)$$

where f is standardized effort, β_is and σ_is are the parameters to be estimated and S_is are the seasonal dummies. As mentioned, the actual estimation of Equation 5.3 makes use of cross-section data collected during the survey..

The coefficients of the effort index equation are listed in Table 5.4. As expected, the relative importance of vessels tonnage and crewdays in producing effort varies across fleets/gears and between the municipal and commercial sectors in each fleet. This is so because each fleet involves a different fishing operation and the scale of operations may vary across sector in each fleet. It appears, however, that the number of crewdays is a significant explanatory variable in almost all fleets. The signs of the coefficients for CD and GRT are positive[5] indicating that the effort index increases for higher values of either variable. More specifically, a bigger vessel, *ceteris paribus*, would have a larger catch per trip than a smaller vessel in a given sector. The effect of a longer fishing trip that is equivalent to a higher number of crewdays is interpreted in the same manner.

The nature of effects of changing seasons/monsoons on catch and effort is two-fold. The first is that sea conditions affect the effectiveness of fishing operation. In particular, municipal vessels would be expected to be more negatively affected by inclement weather and sea conditions during the peak monsoon. However, this is not clearly shown by the sign of S_2 in Table 5.4 as other factors are captured by the seasonal coefficients. The other factor is the availability of

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[5] This satisfies monotonicity of the effort (production) function in terms of the inputs.

Table 5.4. Specification of fishing effort for the sample fishing gears: coefficients of the Cobb-Douglas fishing effort function (per fishing trip)

	Regression	Coefficients					R-squared
Gear	Constant	Tonnage	Crewday	S1	S2	S3	
Danish seine							
Commercial	1.4060*	0.9218*	1.3222*	-0.1016	0.0447	-0.1552	0.7439
Municipal	2.3577*	0.0890	1.3384*	0.1511	0.2335*	0.2118**	0.6140
Encircling gill net							
Commercial	-3.3224	4.8243**	0.8076*	1.4806*	1.0728*	0.6169	0.2990
Municipal	3.3481*	0.0689	0.4669*	0.3604**	0.5059*	0.3757***	0.1287
Purse seine							
Commercial	4.3210*	0.0676	0.2464*	0.5828*	0.7415*	0.6076*	0.1796
Municipal	2.3777*	1.5250	0.6103*	0.4519***	1.2691*	1.4013*	0.4759
Trawl							
Commercial	1.9844	1.1531	0.4268*	0.3049	-0.5567***	0.0570	0.2194
Municipal	2.8361*	0.1236	1.2839*	0.2036	0.1929	0.4708**	0.2329
Drift net							
Municipal	2.1685*	0.1907	0.4865	-0.6230	-0.0960***	-1.0630*	0.2222

Notes: * - significant at 1% level
** - significant at 5% level
*** - significant at 10% level
S1 - refers to the pre-monsoon season
S2 - refers to the peak-monsoon season
S3 - refers to the post-monsoon season

target species which changes from one season to another. For most fleets, the seasonal effects tend to be significant indicating that the impact of fishing inputs on fishing mortality varies from one season to another. Such effects are most pronounced in the encircling gill net and purse seine fleets as the coefficients generally take on higher values and are significant.

The average impact of a fishing trip on fishing mortality cannot be adequately represented by the simple average of the effort index for the four seasons/monsoons. For one the length of each season varies from 2 to 5 months. Moreover, the frequency of trips over the monitoring interval of two weeks also varied from season to season. Hence, to obtain the average standardized fishing effort for any one trip during the year, the seasonal fishing effort values are weighted by the number of trips (in percent) made for each season.

The average fishing effort per trip for the various fleets are listed in Table 5.5. Inter-gear comparisons make intuitive sense due to the standardization of fishing effort. The biological impact of fishing activities significantly differs from one gear to another. As expected the purse seine fleet produced the highest standardized fishing effort per trip as they registered the largest catch per trip. It is noteworthy also that each drift gill net operation is equivalent to only a small fraction of the rest of the fishing operations on a fishing trip basis.

Table 5.5. Calculation of fishing effort index by season for the sample fishing gears (per fishing trip)

Gear	Fishing Effort				Weighted Average
	Season1	Season2	Season3	Season4	
Danish seine					
Commercial	173.25	148.80	178.38	246.78	194.83
Municipal	54.52	87.75	101.23	58.05	71.34
Encircling gill net					
Commercial	113.06	57.65	37.78	26.48	49.91
Municipal	60.15	62.42	58.90	42.78	53.98
Purse seine					
Commercial	324.85	374.85	351.78	179.73	281.50
Municipal	292.00	636.35	626.75	156.06	403.21
Trawl					
Commercial	111.44	38.55	56.29	59.92	63.64
Municipal	37.86	42.87	54.42	42.60	43.85
Drift gill net					
Municipal	3.78	6.46	2.24	6.08	5.20

Table 5.6. Calculation of minimum fishing effort for the sample fishing gears

Gear	Average effort per trip	Average number of trips per year	Annual effort per year per vessel	Minimum fleet size	Minimum effort level/year (000)*
Danish seine					
Commercial	194.83	243	47,314	208	9,804
Municipal	71.34	291	20,780	651	13,496
Encircling gill net					
Commercial	49.91	330	16,491	12	192
Municipal	53.98	251	13,572	16	218
Purse seine					
Commercial	281.50	231	64,939	17	1,110
Municipal	403.21	262	105,649	13	1,354
Trawl					
Commercial	63.64	270	17,195	31	533
Municipal	43.85	271	11,865	187	2,217
Drift gill net					
Municipal	5.20	249	1,292	177	228

* May not correspond exactly to the figures given due to rounding off.

Intra-gear comparisons in some gears do not support the *a priori* expectations; effort index on the average is higher for the municipal sector for the purse seine and encircling gill net fleets. The reason is that the municipal-commercial classification is rather tenuous as it is based solely on vessel tonnage and as indicated by the regression results this is not a significant variable in most fisheries. Moreover, there are other factors, e.g., fishing skill, which explain fishing effort but were not captured in the fishing effort equation.

The equity constraints require the estimation of the minimum fleet size for each sector. This, however, requires information on the number of vessels by gear type in the study area. What is available from secondary sources is the total number of commercial and municipal fishing units in Iloilo and Negros Occidental, but without breakdown by type of gear. The number of fishing units by gear category was estimated following the distribution of fishing trips (by gear category and by sector) that were monitored. It was assumed, for example, that the existing number of municipal Danish seine vessels is indicated by the ratio of the number of fishing trips recorded for this vessel category to total municipal fishing trips recorded. There may be important implications of this estimation procedure when comparing the estimates to the optimal number of vessels. Such are discussed in sections 6.1.3 and 6.1.4.

In the context of the effort allocation model, the minimum fleet size has to be converted into the equivalent standardized units of effort. The effort level per fishing trip for the average fishing vessel in each sector is already derived. The annual effort exerted by the average vessel is equal to the product of the effort per trip and the average number of trips in one year. The equivalent effort level of the minimum fleet size is computed by setting the minimum at 10% of the existing number in each fleet. The equity constraints also require the estimation of the ratio, in terms of effort, of the commercial and municipal sectors in each fleet. These are readily computed from the minimum effort levels.

To explain the figures in Table 5.6, the dynamics of fishing operations need to be discussed. The number of trips a fishing vessel can make per unit of time is affected by weather conditions and equipment reliability as well as the nature of fishing operation. Gill nets (drift and encircling) are used for only a few hours in the early evening and at dawn while purse seines are laid out at night but only during the dark phases of the lunar cycle. Whereas, the other fishing gears (trawl and Danish seine) are employed both during night and day times. Hence, gill nets and purse seines tend to have much shorter effective fishing days, on the average, than trawls and Danish seines. The average number of fishing trips made during the year varies significantly between the municipal and commercial sectors in the Danish seine and encircling gill net fleets. The annual number of trips explains the differences in the annual effort per vessel from one sector to another. The minimum effort level by sector is given in Table 5.2. The proportionality constraints, which are the ratio of commercial fishing effort to municipal fishing effort by fleet are: 0.7265 (Danish seine), 0.8800 (encircling gill net), 0.8195 (purse seine), 0.2405 (trawl) and 0.6644 (all fleets).

5.2.3 Estimation of catchability coefficients

The parameter q_{ijs} as specified in equation 4.10 determines the fishing mortality (or catch) generated on species *i* from a unit of standardized fishing effort in fishery *j* and sector *s*. Within a mixed-species system, q_{ijs} should vary across species and fleet (gear) due to differences in availability of the species and their vulnerability to the gear. Within the same fleet but for different sectors, the proportionality between fishing effort and fishing mortality should also vary because of the differences in the fishing grounds exploited by each sector.

Using catch data per fishing trip over one year and given corresponding estimates of standardized fishing effort for each fleet, the catchability coefficient is computed as follows

$$q_{ijs} = H_{ijs}/f_{js} \qquad (5.4)$$

where H_{ijs} and f_{js} are respectively, the actual average catch of species *i* and total standardized fishing effort in fishery *j* and sector *s*. The basis of computations is the fishing trip although the final figures are on a per unit of standardized fishing effort. It should be emphasized that the sum of q_{ijs}

is not equal to one even including the q for non-pelagic catches since H_i is actual catch while effort is standardized.

As with the standardized fishing effort, the catchability coefficients are weighted by the number of trips during each season for reasons mentioned previously. The estimates of catchability coefficients by season in each fishery and sector are listed in Table 5.7. The last part of the table contains the seasonally-weighted q_{ijs} which will be used in the effort allocation model.

5.2.4 Other economic parameters

Price of fish

The market for fish at the ex-vessel level involves a large number of buyers (brokers, vendors, retailers) and an equally large number of sellers (fishing units), hence the market is competitive. Prices, however, are not solely determined by local demand and local supply. Although the study area is geographically separated, the local market for fish is integrated with other bigger markets. Fish caught in Guimaras Strait and the Visayan Sea not only supplies local demand but a considerable quantity is shipped to Metro Manila markets as is the case of catches from other fishing grounds. Therefore, landings of fish from Guimaras Strait represent a very small share of the overall market. It is on this basis that fish prices in the study area are considered exogenous and supply is assumed to adjust based on this exogenous price level.

Table 5.7. Estimates of catchability coefficients by season for the sample fishing gears

Gear/season	Species						
	Sardine	Mackerel	Crevalle	Anchovy	Round-scad	Round-herring	Big-eye scad
A. Pre-monsoon season							
Danish seine							
Commercial	0.0782	0.1185	0.5139	0.0000	0.1510	0.0000	0.0000
Municipal	0.0706	0.2368	0.2740	0.0000	0.0742	0.0000	0.0000
Encircling gill net							
Commercial	2.0952	0.0072	0.0000	0.0000	0.0000	0.0000	0.0000
Municipal	0.8967	0.4924	0.0021	0.0000	0.0000	0.0000	0.0000
Purse seine							
Commercial	0.2684	0.5531	0.0434	0.2520	0.1562	0.0000	0.0044
Municipal	0.0848	0.2828	0.0532	0.2894	0.0379	0.0000	0.0000
Trawl							
Commercial	0.4711	0.4756	0.0000	0.3343	0.0000	0.0000	0.0000
Municipal	0.0000	0.7189	0.0972	0.2587	0.0000	0.0613	0.0000
Drift gill net							
Municipal	2.3696	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
B. Peak-monsoon season							
Danish seine							
Commercial	0.0847	0.1578	0.4324	0.0000	0.0513	0.0000	0.0036
Municipal	0.1155	0.3209	0.2525	0.0000	0.0263	0.0000	0.0032
Encircling gill net							
Commercial	1.9921	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Municipal	1.0646	0.2911	0.0000	0.0000	0.0000	0.0000	0.0000
Purse seine							
Commercial	0.1147	0.9014	0.2510	0.3774	0.0467	0.0000	0.0000
Municipal	0.0074	0.8562	0.2136	0.0000	0.0416	0.0000	0.0000
Trawl							
Commercial	0.0000	0.0000	0.0000	0.4208	0.0000	0.0000	0.0000
Municipal	0.0000	0.0000	0.0216	0.4777	0.0000	0.1046	0.0000
Drift gill net							
Municipal	1.2605	0.0000	0.0000	0.0000	0.0000	0.2171	0.0000
C. Post-monsoon season							
Danish seine							
Commercial	0.0501	0.2412	0.1752	0.0000	0.0265	0.0000	0.0000
Municipal	0.0398	0.5953	0.2822	0.0000	0.0100	0.0000	0.0141
Encircling gill net							
Commercial	1.2361	0.0000	0.0000	0.0000	0.0000	0.1439	0.0000
Municipal	1.6234	0.0000	0.0051	0.0000	0.0000	0.3073	0.0000
Purse seine							
Commercial	0.3189	0.4275	0.2495	0.0298	0.0000	0.0000	0.0000
Municipal	0.1666	0.2744	0.1615	0.0508	0.0000	0.0000	0.0000
Trawl							
Commercial	0.0000	0.0000	0.0000	0.3035	0.0000	0.0000	0.0000
Municipal	0.0000	0.0000	0.0000	0.2759	0.0000	0.0229	0.0000
Drift gill net							
Municipal	0.9241	0.0000	0.0000	0.0000	0.0036	0.5893	0.0000

Table 5.7 continued..

Gear/season	Species						
	Sardine	Mackerel	Crevalle	Anchovy	Roundscad	Roundherring	Big-eye scad
D. Calm season							
Danish seine							
Commercial	0.0241	0.2090	0.3009	0.0000	0.0334	0.0000	0.0041
Municipal	0.0444	0.2572	0.3500	0.0000	0.0437	0.0000	0.0091
Encircling gill net							
Commercial	1.6872	0.0140	0.0000	0.0000	0.0000	0.0000	0.0000
Municipal	1.0335	0.0460	0.0000	0.0000	0.0000	0.0161	0.0000
Purse seine							
Commercial	0.4333	0.3980	0.1295	0.0130	0.1411	0.0046	0.0887
Municipal	0.4012	0.4420	0.0630	0.0135	0.0875	0.0099	0.0000
Trawl							
Commercial	0.0000	0.0000	0.0000	0.5379	0.0000	0.0000	0.0000
Municipal	0.0301	0.0663	0.0175	0.5156	0.0000	0.0000	0.0000
Drift gill net							
Municipal	0.8826	0.0000	0.0000	0.0742	0.0280	0.0111	0.0000
E. Average for all seasons							
Danish seine							
Commercial	0.0548	0.1849	0.3512	0.0000	0.0585	0.0000	0.0024
Municipal	0.0654	0.3220	0.3023	0.0000	0.0398	0.0000	0.0068
Encircling gill net							
Commercial	1.7162	0.0055	0.0000	0.0000	0.0000	0.0364	0.0000
Municipal	1.1259	0.1808	0.0013	0.0000	0.0000	0.0627	0.0000
Purse seine							
Commercial	0.3060	0.5570	0.1624	0.1506	0.0988	0.0019	0.0376
Municipal	0.1935	0.5056	0.1229	0.0609	0.0503	0.0037	0.0000
Trawl							
Commercial	0.0876	0.0884	0.0000	0.4358	0.0000	0.0000	0.0000
Municipal	0.0124	0.1501	0.0292	0.4219	0.0000	0.0405	0.0000
Drift gill net							
Municipal	1.1282	0.0000	0.0000	0.0423	0.0165	0.1346	0.0000

The average ex-vessel prices (pesos per kg) of fish for each market category during the monitoring period are 9.52 for sardines, 16.07 for mackerels, 15.22 for crevalle, 10.96 for anchovy, 11.27 for round scads, 10.21 for round herring and 8.20 for big-eye scads.

Fishing costs and profits

The costs of fishing include both variable and fixed costs. Variable expenses are mainly fuel, oil, food and provisions, repairs and maintenance and crew remuneration while fixed costs are largely depreciation allowances for the use of the fishing assets. (Chapter 2 partly discussed this aspect and Appendix D shows a detailed computation of costs and earnings for the average fishing trip for the various sectors and fleets included in the model.)

Inasmuch as the various fleets catch both small pelagic fishes and other species (big pelagics and demersal species), the total cost of fishing need to be apportioned between these two groups of species. In a multi-species fishery, relative prices determine how fishermen allocate effort across species, hence, the basis of apportioning costs is the relative contribution of each group of species to total revenue rather than to total catch. The contribution of small pelagics to total revenue ranges from 36.86% for the municipal trawl fleet to 91.17% for the municipal encircling gill net fleet (Table 5.8). The costs attributable to small pelagics is divided by

Table 5.8. Computation of fishing costs, revenue and expected profit per unit of standardized fishing effort for the sample fishing gears

Gear	Share of small pelagics to total revenue (%)	Costs attributable to small pelagics (Pesos/trip)	Unit cost of fishing effort (Pesos/trip)	Unit revenue of fishing effort (Pesos/trip)	Unit profit of fishing effort (Pesos/trip)
Danish seine					
Commercial	56.25	1,498.06	7.69	9.52	1.83
Municipal	55.16	567.53	7.96	10.90	2.95
Encircling gill net					
Commercial	87.28	437.58	8.77	16.80	8.03
Municipal	91.17	419.54	7.77	14.28	6.51
Purse seine					
Commercial	75.87	2,341.78	8.32	17.43	9.11
Municipal	73.92	1,716.59	4.26	13.11	8.85
Trawl					
Commercial	41.58	226.18	3.55	7.03	3.48
Municipal	36.86	219.83	5.01	8.01	3.00
Drift net					
Municipal	65.16	56.76	10.92	12.76	1.85

Notes: Fishing costs include variable and fixed costs the standardized fishing effort to obtain the unit cost of fishing effort. Again the basis of calculation is the average fishing trip for each fleet.

The unit cost figures are not indicative of cost efficiency as total costs are allocated between small pelagics and other catches and the amount of catch per unit of effort differs across sectors. Unit costs should be compared with the unit revenue to arrive at the unit profit. The unit profit of fishing effort is related to the first objective (equation 4.12) which may be alternatively written as follows

$$\Sigma_j \Sigma_s \left(\Sigma_i p_i q_{ijs} - c_{js}\right) f_{js} \qquad (5.5)$$

in which form, the expression inside the parenthesis is the unit profit and the terms refer, respectively, to the unit revenue and unit cost of fishing effort in a given fishery j and sector s. The unit revenue is the sum of the value of all small pelagic fishes caught by each unit of effort.

The interpretation of the unit profit of effort can proceed by examining the economic returns and benefits in fisheries. Copes (1972) identified three net benefits, namely: consumer surplus, resource rent and producer surplus. Consumer surplus is not included in the analysis as this would require demand functions which are not available. In an open-access fishery, resource rent would be non-existent in the long-run, though in good fishing years the existing fishing operators obtain an extra short-run return. In the main, remuneration in the fishery consists of the normal returns to the factors of production such as labor and capital plus a producer surplus captured by the crew members and the owners of those fishing units having a superior performance. Producer surplus accruing to the crew is included in crew remuneration but is not computed given the difficulty in estimating the opportunity costs of labor.

The computed unit profit of effort includes only the normal returns to capital and a portion of the producer surplus. The normal returns to capital in the fishery must include the opportunity costs of capital and some premium for risks faced by this input in the fishing industry. The unit profit for each fleet is listed in Table 5.8. In general, the commercial fleet realizes more profit than its municipal counterpart (with the exception of the Danish seine fleet) and no fleet is in the red. The purse seine fleet is the most profitable while the drift gill net fleet is the least profitable.

Labor utilization

The second objective in the effort allocation model is the maximization of employment in the small pelagics fishery. Employment is interpreted here in terms of labor utilization. The objective therefore has two dimensions: labor and fishing time. The coefficient l_{js} in equation 4.13 is the average number of crewdays per unit of standardized fishing effort. It is computed by taking the ratio of the average number of crewdays per trip and the average fishing effort per trip in each of the fishing sectors under study[6].

Estimates of the number of this variable are listed in Table 5.9. As with the other parameters, it is seasonally-adjusted. Across the seasons, the length of the fishing trip as well as the number of persons involved in the trip varies. The reason for the former is already explained earlier. Although there is a specific number of crew hired by the operator, the actual crew size is not constant for all trips. It may be less as some crew members are unavailable or it may be more if the master fisherman accepts apprentices.

Labor use intensity varies from one fleet to another. Expectedly, the drift gill net fleet recorded the highest labor use utilization as more fishermen are involved in the fishing process relative to the standardized fishing effort or the scale of operations. Except for the purse seine fleet, the municipal sector in each fleet showed higher labor use intensity than their commercial counterparts. This indicates that the municipal sector in most fleets employs a more labor-intensive fishing technology than the commercial sector.

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[6] As will be explained in the succeeding chapter, the fishing effort allocated to each sector will be converted into actual number of vessels by dividing this by the fishing effort exerted by the average fishing vessel in that sector. Hence, the conversion of total fishing effort into the estimated number of vessels is consistent with the procedure for estimating the (average) unit labor utilization and the standardization of fishing effort.

Table 5.9. Average number of crewdays by season for the sample fishing gears (per fishing trip)

Gear	Crewdays (per trip)					Standardized fishing effort/trip	Crewdays per unit effort/trip
	Season1	Season2	Season3	Season4	Average		
Danish seine							
Commercial	6.105	4.739	6.081	7.175	6.120	194.83	0.0314
Municipal	2.954	3.985	4.480	3.472	3.650	71.34	0.0512
Encircling gill net							
Commercial	1.452	1.216	1.114	1.503	1.308	49.91	0.0262
Municipal	2.079	1.653	1.942	2.162	1.969	53.98	0.0365
Purse seine							
Commercial	16.679	16.493	18.703	15.127	16.254	281.50	0.0577
Municipal	18.190	34.072	17.447	13.235	20.768	403.21	0.0515
Trawl							
Commercial	3.247	2.037	1.708	1.620	2.035	63.64	0.0320
Municipal	1.509	1.678	1.623	1.932	1.739	43.85	0.0397
Drift net							
Municipal	0.750	0.761	0.662	0.604	0.652	5.20	0.1253

Chapter 6

Results and Discussion

The Interactive Mathematical Programming System (IMPS) (Love and Stringer 1987) was used to generate initial results from the effort allocation model and for subsequent analysis of management alternatives for the fishery. The allocation model is a special case of multi-objective programming in the sense that there are only two objectives, hence it may be called a bicriteria programming model. The generation of efficient solutions is conveniently handled in IMPS by applying the weighting method principle discussed in section 4.3.1. The corner or pivot points of the feasible region in decision space, i.e., in terms of the composition of fleet, are first identified. From these pivot points, the set of nondominated solutions is derived in objective space, i.e., in terms of the values of the objective functions. The mathematical programming problem in numerical form is given in Appendix A. The values of the various parameters indicated in this appendix constitute the base case model.

This chapter is divided into three sections. The first section analyzes the optimal allocation of effort under current conditions, i.e., no regulation is imposed on the fishery and the target yields are the historical level of landings for each species group. This constitutes the base case for the analysis. The trade-offs between the two objectives of employment and profit maximization are noted and the implied distribution of key fishery variables across fleets are examined. The second section, which is an extension of the first, assesses the effects of changes in parameters on the effort allocation process. Changes in the values of the following parameters are considered: fish prices, costs of fishing inputs and catchability coefficients. The last section, on the other hand, deals with alternative management schemes that are applicable to the fishery, which include among others the regulation of fishing effort and mesh size. Throughout this chapter, the optimal fleet composition is compared to the existing fleet size to determine the extent of adjustment in the fishery.

6.1 Optimal effort allocation: base case results

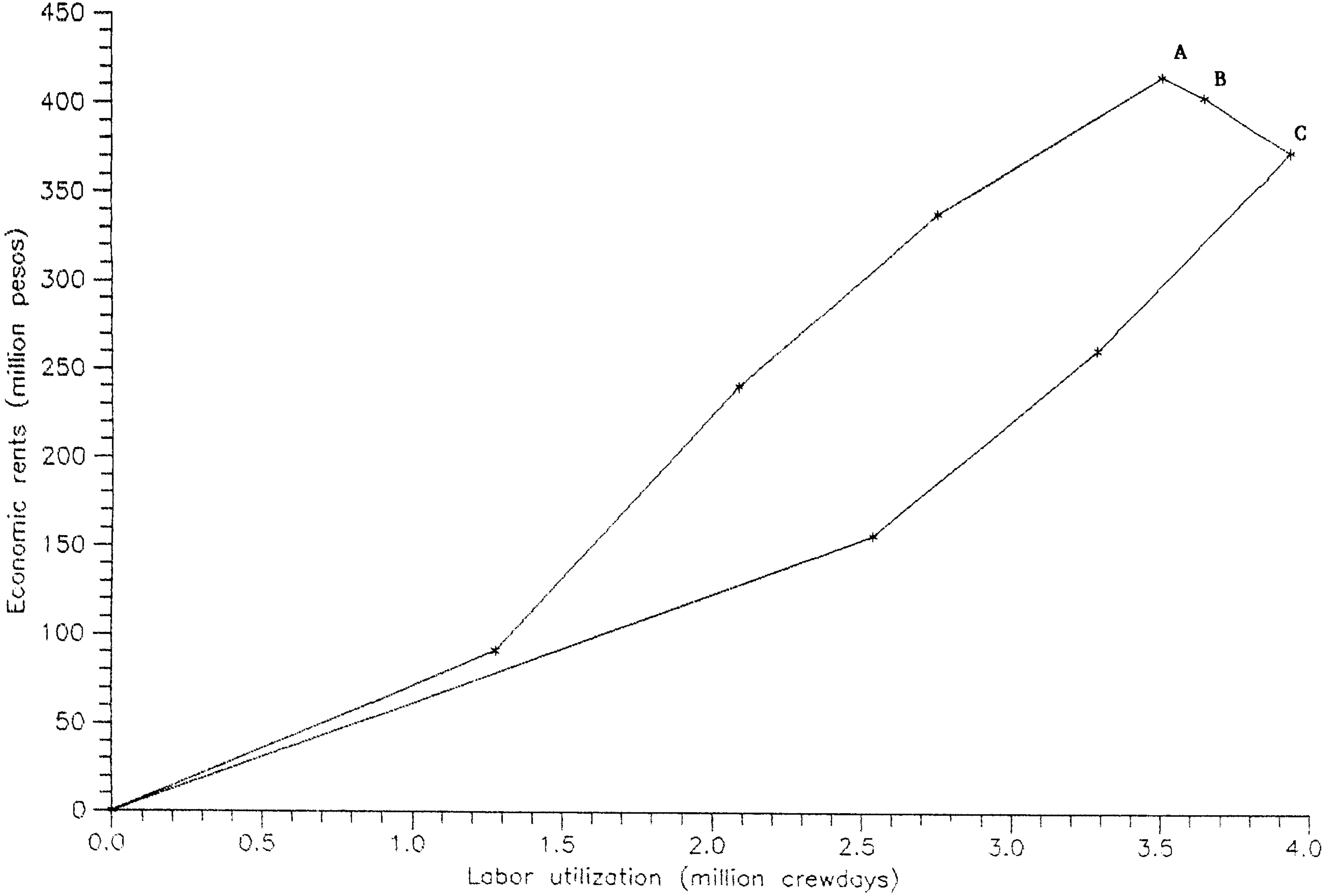
The optimal allocation of effort is first determined under existing exploitation patterns particularly in terms of the physical configuration of the fleet and prevailing economic conditions. The target yield for each species is the average annual landings for the past 10 years (1978-1987). The focus of the analysis is on the explicit management objectives, profits and employment maximization and the constraints, catch limits and equity implied at the pivot points of the feasible region. Specifically, the level and distribution of interrelated fishery variables such as fishery profits, vessels, fishermen and catch both at the industry and firm levels are discussed.

6.1.1 Trade-offs between objectives and constraints

Typically, multi-objective programming does not result in a unique optimal solution as in single-objective problems. Instead, it yields a range of efficient solutions in cases where objectives are non-complementary. Such a range may be called the efficiency frontier. In the present model, it is implied that maximizing fishery profits as a management objective is not consonant with simultaneously maximizing employment in the small pelagics fishery of Guimaras Strait and the Visayan Sea, Philippines. The efficiency frontier, more conveniently drawn in objective space, shows clearly the trade-off between the two objectives (Figure 6.1). The frontier indicates where the fishery can operate optimally depending on the desired combination of profits and employment. No specific point, however, will be suggested as such decision is best considered a political one. Instead, a "decision menu" will be presented to the decision maker from which a desired point may be chosen. The extreme points of the efficiency frontier and one intermediate point adequately describe the set of efficient solutions, hence these constitute the menu. The characteristics of each menu item are described below.

However, a short digression with regard to the optimality conditions of each corner point of the efficiency frontier is

Figure 6.1. Feasible region in objective space: base case model



in order. Information on the relative importance (or weight) assigned by the decision maker to each objective, if available, leads to the identification of the optimal point. Assume w_1 as the weight assigned to the fishery profits objective and w_2 to the labor utilization objective. The following determines the optimal point:

w_1/w_2[1]	optimal point
$\geq$ 0.0123	A
0.0123	segment AB
$\leq$ 0.0123 to $\leq$ 0.0094	B
0.0094	segment BC
$\leq$ 0.0094	C

Moreover, prior specification of the decision makers' preferences, e.g., either the desired level of employment (labor utilization) or fishery profits enables the analyst to solve for the optimal fleet composition. The efficient point can be generated using the ϵ-constraint method described in section 4.3.2.

The decision menu consists of corner points on the efficiency frontier A and C and the intermediate point B, all of which are corner points. Point A corresponds to profit maximization (P_{max}) where total fishery profits amount to 416.9[2] million pesos (P 416.9 M) and incidental employment generated is 3.50 million crew-days (Table 6.1). At C, on the other hand, employment is at a maximum at 3.93 million crew-

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[1] The ratio w_1/w_2 is in units of crewdays/pesos.

[2] The estimated total fishery profits from the study area at P_{max} represents less than 10% of the rents at the point of maximum economic yield for the entire small pelagic fishery of the Philippines as estimated by Dalzell et al (1987). The results in this study therefore are not out of line with those of Dalzell et al.

Table 6.1. Standardized fishing effort values at each corner point on the efficiency frontier

Gear	Minimum effort level ('000)	Extreme points on the efficiency frontier ('000)			Percentage change from minimum effort values		
		Profit max.	Interm. point	Labor max.	Profit max.	Interm. point	Labor max.
Danish seine	23,300	23,300	23,300	41,003	nil	nil	76
Commercial	9,804	9,804	9,804	17,254	nil	nil	76
Municipal	13,496	13,496	13,496	23,749	nil	nil	76
Encircling gill net	410	12,206	10,026	10,866	2,877	2,345	2,550
Commercial	192	5,714	4,693	5,086	2,877	2,345	2,550
Municipal	218	6,493	5,333	5,780	2,877	2,345	2,550
Purse seine	2,464	26,947	28,680	19,674	994	1,064	698
Commercial	1,110	12,137	12,918	8,861	994	1,064	698
Municipal	1,354	14,810	15,763	10,813	994	1,064	698
Trawl	2,750	7,826	2,750	2,750	185	nil	nil
Commercial	533	1,517	533	533	185	nil	nil
Municipal	2,217	6,309	2,217	2,217	185	nil	nil
Drift net							
Municipal	228	2,801	5,257	5,205	1,128	2,206	2,183
Total (all gears)	29,152	73,080	70,013	79,498	151	140	173
Commercial	11,639	29,172	27,948	31,734	151	140	173
Municipal	17,513	43,907	42,065	47,764	151	140	173
Values of the objective functions							
Fishing profits ('000 pesos)		416,868	405,514	374,554			
Labor utilization ('000 crewdays)		3,498	3,638	3,927			

days and profits equal P 374.5 M. Point B is where the values of profits and employment are in between their respective minimum and maximum values. Between P_{max} and B and B and L_{max} respectively, profits decrease by 2.72% and 7.64% while labor utilization increases by 3.98% and 7.96%.

The total standardized units of fishing effort is more than twice the minimum total level set for the entire fleet at every corner point, which leaves that amount of effort over the prescribed minimum for free allocation across fleets during the optimization process. At P_{max}, no additional unit of effort goes to the Danish seine fleet (Table 6.1). However, as the employment objective is given more weight, i.e., the movement towards L_{max}, allocation to the Danish seine fleet increases by 76% while that for the trawl fleet is at the prescribed minimum[3]. At all corner points the most favored fleets in percentage and absolute terms are respectively, the encircling gill net and purse seine fleets. Moreover, it is interesting to note that the fleets given increased allocation at each corner point are those that catch mostly small pelagic species. The changing composition of the entire fleet at each corner point may be explained by the unit profit and the rate of labor utilization for each sector/fleet.

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[3] Refer to section 6.2.3 for discussion of the implications of relaxing these minimum fleet size constraints.

6.1.3 Volume and value of catch

The optimal fishing effort determines the total catch as well as the distribution of that catch across fleets. The catch of a particular sector *s* is equal to $\Sigma_i q_{ijs} f_{js}$ while total fishery catch is $\Sigma_s \Sigma_i q_{ijsj} f_{js}$ where *i* indicates species. L_{max} offers the highest catch at over 76.03 million tons although the difference in catch with the other corner points is only a few million tons (Table 6.2). The catch is valued at about 931.78 million pesos at P_{max} and 975.24 million pesos at L_{max}, hence, the value of a fishery is not necessarily maximized at the same point as fishery profits are.

Fishery resources allocated to the 9 sectors under study are not fully utilized at the various points of the efficiency frontier. The table below shows the percentage utilization by species group. At P_{max}, the limiting species are sardines, mackerels and anchovy while at L_{max} these are sardines, mackerels and crevalle. On the other hand, less than half of the target yields for round scads, round herring and big-eye scads are utilized at all corner points in the efficiency frontier. The level of catch (and the degree of underachievement of target yields) will certainly influence the choice of a specific item on the decision menu. However, that part of target yields not caught by the fleets included in the model does not represent waste to the extent that this is caught by the other fleets not included in the model.

Table 6.2. Distribution of catch at each corner point on the efficiency frontier

Gear	Profit maximization		Intermediate point		Labor maximization	
	Catch (kg)	Percent to total	Catch (kg)	Percent to total	Catch (kg)	Percent to total
Danish seine	16,326,350	22.11	16,326,350	22.56	28,730,469	37.79
Commercial	6,390,282	8.65	6,390,282	8.83	11,245,396	14.79
Municipal	9,936,068	13.45	9,936,068	13.73	17,485,073	23.00
Encircling gill net	18,944,214	25.65	15,559,760	21.50	16,864,619	22.18
Commercial	10,044,914	13.60	8,250,359	11.40	8,942,238	11.76
Municipal	8,899,300	12.05	7,309,402	10.10	7,922,380	10.42
Purse seine	29,826,601	40.39	31,745,227	43.87	21,776,682	28.64
Commercial	15,951,760	21.60	16,977,849	23.46	11,646,523	15.32
Municipal	13,874,841	18.79	14,767,378	20.41	10,130,158	13.32
Trawl	5,054,283	6.84	1,776,092	2.45	1,776,092	2.34
Commercial	928,223	1.26	326,180	0.45	326,180	0.43
Municipal	4,126,060	5.59	1,449,912	2.00	1,449,912	1.91
Drift gill net						
Municipal	3,701,246	5.01	6,947,790	9.60	6,879,068	9.05
Total	73,852,693	100.00	72,355,218	100.00	76,026,929	100.00
Commercial	33,315,178	45.11	31,944,669	44.15	32,160,338	42.30
Municipal	40,537,515	54.89	40,410,549	55.85	43,866,591	57.70

Table 6.3. Percent utilization of small pelagic species at each corner point on the efficiency frontier

Species group	P_{max}	Interm. pt.	L_{max}
Sardines	100.0	100.0	100.0
Mackerel	100.0	100.0	100.0
Crevalle	71.6	72.3	100.0
Anchovy	100.0	69.6	54.8
Round scad	44.7	47.1	49.9
Round herring	28.4	29.7	29.9
Big-eye scad	11.2	11.7	10.5
Total unused resources (tons)	16,290	17,788	14,116

The distribution of small pelagic catches across fleets does not mirror exactly the distribution of effort. This is because the quantity of small pelagic caught per unit of fishing effort varies across fleets, i.e., there are variations in catchability coefficients from one fleet to another. In fact, in some of the fleets the municipal sector catches less small pelagics than the commercial sector although more fishing effort is allocated to the former sector. However, if non-pelagic catches are included, catch distribution should replicate effort distribution. For the entire fishery L_{max} closely approximates, in terms of catch, the equity constraint specifying the 40-60 commercial-municipal sharing of total fishing effort.

6.1.3 Optimal number of vessels and level of investment

The output from the mathematical programming model is the optimal annual fishing effort that each fleet can exert on the small pelagics fishery. To translate these figures into a tangible fishing effort variable, e.g., number of vessels, annual fishing effort is factored by the average standardized effort exerted by the representative vessel in that sector or fleet for one year. The desirable fleet size is compared to the existing fleet size throughout this chapter.

When comparisons are made, the important assumption is that the optimal fleet is to operate only within Guimaras Strait and the Visayan Sea. This is in accordance with the regional approach to fisheries management as mentioned in chapter 5 whereby fishing vessels in the two provinces will be confined to the two fishing grounds within the area. Currently, however, the existing vessels do not actually limit their operations within the two fishing grounds. It was observed during the survey that most vessels exploit other fishing grounds at certain times of the year. Ideally, an equivalent number of vessels should be computed that would yield the fishing effort exerted by vessels in Guimaras Strait and the Visayan Sea only. The equivalent number of vessels should be the "existing number of vessels" with respect to the two fishing grounds. However, estimation of such number is not possible with the data that are available. It is important to note then that the existing number of vessels (and, hence, the number of fishermen in section 6.1.4) are overestimated.

The number of vessels and equivalent tonnage by sector at each corner point are tabulated in Table 6.4. There exist surplus vessels in the Danish seine and trawl fleets in both

Table 6.4. Optimal number of vessels and vessel tonnage at each corner point on the efficiency frontier

Gear	Existing number of vessels	Optimal number of vessels			Existing gross tonnage	Optimal tonnage			Difference (%) a		
		Profit max	Interm. point	Labor max		Profit max	Interm. point	Labor max	Profit max	Interm. point	Labor max
Danish seine	8,585	857	857	1,508	20,390	2,035	2,035	3,581			
Commercial	2,076	207	207	365	10,516	1,050	1,050	1,847	-90.0	-90.0	-82.4
Municipal	6,508	649	649	1,143	9,873	985	985	1,734			
Encircling gill net	279	825	677	734	745	2,198	1,805	1,957			
Commercial	117	346	285	308	428	1,263	1,037	1,124	195.2	142.5	162.8
Municipal	162	478	393	426	317	935	768	833			
Purse seine	299	327	348	239	3,333	3,644	3,878	2,661			
Commercial	171	187	199	136	3,083	3,371	3,587	2,461	9.3	16.4	-20.2
Municipal	128	140	149	102	250	273	291	200			
Trawl	2,182	620	218	218	4,827	1,371	482	482			
Commercial	311	88	31	31	1,584	450	158	158	-71.6	-90.0	-90.0
Municipal	1,872	532	187	187	3,244	921	324	324			
Drift net											
Municipal	1,768	2,167	4,068	4,027	1,043	1,278	2,400	2,376	22.5	130.0	127.7
Total (all gears)	13,114	4,795	6,168	6,726	30,338	10,527	10,600	11,056	-63.4	-53.0	-48.7
Commercial	2,675	829	722	841	15,611	6,133	5,832	5,590	-69.0	-73.0	-68.6
Municipal	10,439	3,967	5,446	5,885	14,727	4,394	4,768	5,466	-62.0	-47.8	-43.6

a = The percentage change is the same when comparing number of vessels and gross tonnage from existing number. Also the figures listed for each fleet are the same for the entire fleet or for a given sector (municipal or commercial).

commercial and municipal sectors while more vessels are required over their current levels for the rest of the fleet. Although transfer of the excess vessels from the Danish seine and trawl fleets to other fleets may be permitted, it can only be partial as a significant reduction in the number of vessels is called for at each corner point. Along this line, the results of this regional study on small pelagics support the findings of Dalzell et. al. (1987) nationwide study on the small pelagic fishery.

An important economic criterion in the management of the fishery is attaining the least capitalization from the fishery per unit of harvestable yield. Here, this occurs at P_{max}. P_{max} also gives the lowest absolute capitalization among the three corner points (Table 6.5). However, the average investment per fishing unit is also highest at this point, which implies that a more capital-intensive technology is called for at P_{max}. In fact, the capital-labor ratio (optimal fishery capitalization divided by the corresponding optimal number of fishermen) is also highest at P_{max}. While it may sound contradictory that P_{max} gives both the lowest capitalization and highest average investment, it is not. This is because the optimal fleet size and its composition changes at each corner point on the efficiency frontier. Moreover, the average investment requirement of a fishing unit varies considerably across fleets. Hence a smaller fleet size does not give the lowest overall capitalization, which occurs at L_{max}.

Table 6.5. Level of fishery capitalization at each corner point on the efficiency frontier

Gear	Average investment per vessel (pesos)	Current investment level ('000 pesos)	Total investment ('000 pesos)			Difference (%)		
			Profit max.	Interm. point	Labor max.	Profit max.	Interm. point	Labor max.
Danish seine		375,219	37,444	37,444	65,893			
Commercial	62,515	129,800	12,955	12,955	22,797	-90.02	-90.02	-82.44
Municipal	37,708	245,419	24,490	24,490	43,096			
Encircling gill net		13,296	39,249	32,237	34,941			
Commercial	53,017	6,222	18,368	15,087	16,352	195.22	142.47	162.81
Municipal	43,649	7,074	20,881	17,151	18,589			
Purse seine		104,309	114,045	121,381	83,265			
Commercial	439,967	75,211	82,229	87,518	60,036	9.33	16.36	-20.18
Municipal	226,958	29,098	31,816	33,863	23,229			
Trawl		88,934	25,262	8,877	8,877			
Commercial	41,124	12,774	3,629	1,275	1,275	-71.60	-90.02	-90.02
Municipal	40,688	76,159	21,634	7,602	7,602			
Drift net								
Municipal	18,492	32,703	40,070	75,218	74,474	22.53	130.00	127.73
Total (all gears)		614,460	256,071	275,158	267,450	-58.33	-55.22	-56.47
Commercial		224,007	117,180	116,835	100,460	-47.69	-47.84	-55.15
Municipal		390,453	138,891	158,323	166,990	-64.43	-59.45	-57.23

The preceding discussion shows that there are excess resources in the fishery. Such is not an aberration as economic theory predicts that an open-access fishery has a tendency to attract resources, especially capital, beyond what is optimal. The small pelagics fishery of Guimaras Strait at its present status is no exception. The estimated investment in fishing equipment for the 9 fleets under study is currently about 614 million pesos, more than half of which is accounted for by the Danish seine fleet. Indeed, the corner points of the efficiency frontier prescribe capital resource withdrawal from the fishery by as much as 52% of the present level.

The misallocation of resources is not only at the industry level but also at the fishery sector level. There is surplus investment in the Danish seine and trawl fleets. At the same time, there is a need to increase investment in the purse seine, drift net and encircling gill net fleets. This is one of the desirable features of the mathematical programming model; it is able to pinpoint where lies overcapitalization or undercapitalization. (The management implications of this are discussed in the section 6.3.)

The above changes in fleet composition are necessary in order to obtain the optimal values of fishery profits and labor utilization for the entire small pelagics fishery of Guimaras Strait and the Visayan Sea. An increase in the size of the purse seine, drift net and encircling gill net fleets would not come about under open access as investors would always opt for the gear that yields the highest returns on investment considering all catches of the vessel (pelagic and non-pelagic). As shown in section 2.3 the gears that registered the highest returns on investment are not those which are undercapitalized with respect to the small pelagics fishery.

6.1.4 Optimal employment levels

The standardized units of effort at the efficiency frontier need to be converted also into an important fishery variable -- the number of fishermen that can be accommodated. This is derived by multiplying the optimal number of vessels in each fleet by their respective crew requirement. It is important to emphasize that the resulting distribution of fishermen across fleets maximizes labor utilization (crewdays) as specified in the employment objective. Such specification not only aims to maximize the absolute number of fishermen that may be employed in the fishery but also the period of time in which they are gainfully employed in fishing. The inclusion of the temporal dimension of employment in the objective also considers the degree of underemployment of those in the fishery although this is not necessarily minimized.

The fishery currently provides part-time and full-time employment to about 76,000 fishermen from the provinces of Iloilo and Negros Occidental. (On top of this number are fishing operators, shore-based workers, fish traders and other allied workers who largely depend on the fishing industry for employment.) The optimal effort allocation points, however, call for a considerably smaller number of fishermen. Up to 50,375 (66%) of the current number of fishermen will be displaced from the fishery or conversely 34% (25,845) will remain in the fishery (Table 6.6)[4]. This occurs at P_{max}. The largest number of fishermen that can be optimally accommodated is 31,616 (41.5% of total) which corresponds to L_{max}. Dividing labor utilization at each corner point by the corresponding number of fishermen, average fishing days is 135.4 at P_{max}, 122.2 at the intermediate point and 124.1 at L_{max}. Hence, average effective fishing days is not necessarily at a maximum at L_{max}. This is because the more labor-intensive fishing gears are not the most frequently used.

The displacement of a large number of fishermen is the most difficult but the inevitable consequence of the process of rationalizing the fishery. Although employment-sharing arrangements have been observed in the study area, the employment effects of such would not be substantial. At most, such arrangements could only provide temporary employment to displaced fishermen but at the expense of reducing the length of participation of those left in the fishery. However, there are other possible adjustments, e.g., regulating other components of fishing effort, that may be implemented to reduce the negative employment effects of rationalization. These are discussed in section 6.3.

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[4] Actually, optimal employment is underestimated if the unutilized yields of some species are harvested by other fleets not included in this study. This additional employment, however, is not presented because it is difficult to calculate. This is the case for the succeeding discussions in this chapter.

Table 6.6. Optimal number of fishermen at each corner point on the efficiency frontier

Gear	Estimated number of existing fishermen	Optimal number of fishermen			Difference (%)		
		Profit max	Interm. point	Labor max	Profit max	Interm. point	Labor max
Danish seine	57,023	5,691	5,691	10,015			
Commercial	16,608	1,658	1,658	2,917	(90)	(90)	(82)
Municipal	40,415	4,033	4,033	7,097			
Encircling gill net	1,591	4,697	3,858	4,181			
Commercial	638	1,884	1,547	1,677	195	142	163
Municipal	953	2,813	2,311	2,505			
Purse seine	7,264	7,942	8,452	5,798			
Commercial	4,828	5,278	5,618	3,854	9	16	(20)
Municipal	2,436	2,663	2,835	1,945			
Trawl	5,479	1,556	547	547			
Commercial	857	244	86	86	(72)	(90)	(90)
Municipal	4,621	1,313	461	461			
Drift net							
Municipal	4,863	5,959	11,186	11,075	23	130	128
Total (all gears)	76,220	25,845	29,734	31,616	(66)	(61)	(59)
Commercial	22,931	9,063	8,908	8,533	(60)	(61)	(63)
Municipal	53,289	16,782	20,826	23,083	(69)	(61)	(57)

On a fishery-wide basis, the ratio of municipal fishermen to commercial fishermen is currently 2.32. This ratio is equal to 1.85 at P_{max}, 2.34 at the intermediate point and 2.77 at L_{max}. This ratio is of importance to the fishery participants and is another dimension of the equity objective which deserves a short discussion at this juncture. However, the ratio was not incorporated into the equity objective because of the difficulty of finding a specification that is devoid of any bias or value judgment. This is further discussed below.

Of special concern with regard to the proportion of municipal and commercial fishermen implied at the corner points of the efficiency frontier is the fact that there are differences in the compensation structure (ownership patterns included) adopted by the municipal and commercial sectors in all fleets. Municipal vessels are commonly owner-operated fishing units. On the other hand, most commercial fishing units are owned by capitalists who are usually non-fishermen. In the municipal sector, returns to capital are appropriated by a fisherman while in the commercial sector, a non-fisherman capitalist captures it. As noted earlier, the returns to capital from the small pelagics fishery are substantial.

A relevant concern is difference in the incomes of ordinary crew members in the commercial and municipal sectors. As given in Table 2.7 in chapter 2, however, there is not a clear trend in the incomes of the various crew members in the gears that are primarily municipal and in the gears that are primarily commercial. The primary reason is that fishing income is based on the skill of the crew member. For instance, the netman of a drift net (a municipal gear) receives much less than the netman of a Danish seine (a primarily commercial gear). This indicates that the netman of a Danish seine is more skilled than that of a drift net and hence, may be expected to obtain a higher producer surplus.

6.2 Sensitivity analysis

In this section the effects of fluctuations in the values of the model parameters to the allocation process are determined. Sensitivity analysis is performed on the following economic and technical parameters: prices of fish, the costs of fishing inputs and the catchability coefficients. On the other hand, changes in the biological parameters (i.e., the target yields) are considered in the analysis of management alternatives. We look into the resulting allocation of effort in terms of the values of the objective functions, the number of fishermen, the level and distribution of catch and the composition of the fleet. Of the above results, it is important to determine those parameter changes which alter the model variables, i.e., the composition of the fleet. There are changes in the values of the parameters that may not shift the efficiency frontier in decision space but may shift that in objective space. The former is of interest in the analysis as it indicates movement to a different optimal allocation of effort than that given by the base model. One of the objectives of this exercise is to investigate the robustness of the base case results to changes in non-technical parameters particularly costs and prices. The last part of this section is a discussion of shadow prices that are suggested by the binding constraints in the effort allocation process.

6.2.1 Changes in economic parameters: fish prices and costs of fishing

Sensitivity analysis with respect to prices of inputs and outputs is of particular relevance due to the volatility of the Philippine economy since the time of the survey. Fuel prices have increased significantly due to removal of government subsidies on this product, the depreciation of the peso and the increases in world oil prices. Fish prices must have also edged up in response to this increase in catching costs although the increase in fish prices should be proportionately lower.

In the formulation of the model, fish prices and fishing costs enter into the unit profitability of fishing effort. Upward pressure on the prices of fishery outputs and inputs, respectively increases and decreases unit profits. An important assumption that will be made is that a change in fish prices does not alter relative prices among species, in which case there is no redirection of fishing effort to species that in turn may change the matrix of catchability coefficients. Three levels of increases are considered. For fish prices, 25%, 50% and 75% increases in the ex-vessel prices of small pelagics are looked into. On the other hand, the increases in fuel prices considered are 100%, 150% and 200%. The percentage increases for fuel prices are higher than those for fish prices since the price of fuel has actually increased dramatically after the survey.

The unit profit figures were recomputed as any change in the prices of outputs and inputs affects the divisible earnings and hence the crew remuneration. The unit profit by fleet is listed in Table 6.7. Fleets which catch more small pelagics relative to their total fishing effort will benefit the most in absolute terms from any price increase. In percentage terms, however, those having small initial unit profits register the highest increase. The impact of fuel price increases on unit profitability (with respect to small pelagic catches) is generally lower than the assumed increases in fuel prices as fishing costs are allocated between small pelagic and non-small pelagic catches. The profit squeeze is greater for fleets where fuel expenses are larger relative to total fishing costs. For all fuel price increases considered, the unit profit of drift gill nets is negative. It is assumed that despite the negative profits, the drift gill net fleet will continue participating in the fishery due to the absence of employment opportunities of the fishing assets outside of the fishery.

The effects of a rise in fuel and fish prices are determined separately rather than assuming combinations of the two. This approach has an advantage although in reality the two are not mutually exclusive, e.g., an increase in fuel

Table 6.7. Profit levels and percent changes from base profits for specific changes in fish and fuel prices

Gear	Base unit profit (pesos)	Increase in fish prices					
		Profit level (pesos)			Percent change from base		
		25 %	50 %	75%	25 %	50 %	75%
Danish seine							
Commercial	1.83	2.49	3.19	3.90	36.07	74.32	113.11
Municipal	2.95	3.98	5.05	6.16	34.92	71.19	108.81
Encircling gill net							
Commercial	8.03	10.68	13.36	16.05	33.00	66.38	99.88
Municipal	6.51	8.98	11.46	13.96	37.94	76.04	114.44
Purse seine							
Commercial	9.11	12.11	15.16	18.24	32.93	66.41	100.22
Municipal	8.85	11.51	14.21	16.93	30.06	60.56	91.30
Trawl							
Commercial	3.48	4.52	5.60	6.71	29.89	60.92	92.82
Municipal	3	3.92	4.87	5.85	30.67	62.33	95.00
Drift net							
Municipal	1.85	4.32	6.79	9.27	133.51	267.03	401.08

	Base unit profit (pesos)	Increase in fuel prices					
		Profit level (pesos)			Percent change from base		
		100%	150%	200%	100%	150%	200%
Modified Danish seine							
Commercial	1.83	1.57	1.43	1.30	-14.21	-21.86	-28.96
Municipal	2.95	2.61	2.44	2.28	-11.53	-17.29	-22.71
Encircling gill net							
Commercial	8.03	7.69	7.51	7.34	-4.23	-6.48	-8.59
Municipal	6.51	5.83	5.5	5.16	-10.45	-15.51	-20.74
Purse seine							
Commercial	9.11	8.32	7.92	7.52	-8.67	-13.06	-17.45
Municipal	8.85	8.44	8.24	8.04	-4.63	-6.89	-9.15
Trawl							
Commercial	3.48	3.06	2.85	2.64	-12.07	-18.10	-24.14
Municipal	3	2.57	2.36	2.14	-14.33	-21.33	-28.67
Drift net							
Municipal	1.85	-0.71	-1.98	-3.26	-138.38	-207.03	-276.22

prices should trigger an increase in fish prices. The advantage is that it allows for assessing the effects of a wider range of unit profit fluctuations since the two factors have an opposite effect on unit profit. It should be noted that in the sensitivity analysis, changes occur only in the model objectives and none in the constraints. The plane that represents the objective functions may be pictured as shifting in the process. The optimal allocation of effort will change only if the point of tangency of the "objective function plane" to the feasible region in decision space moves to another point compared to the base model. The feasible region in objective space which is defined by the points of tangency mentioned above will certainly move due to changes in unit profit even with no changes in the optimal allocation of effort.

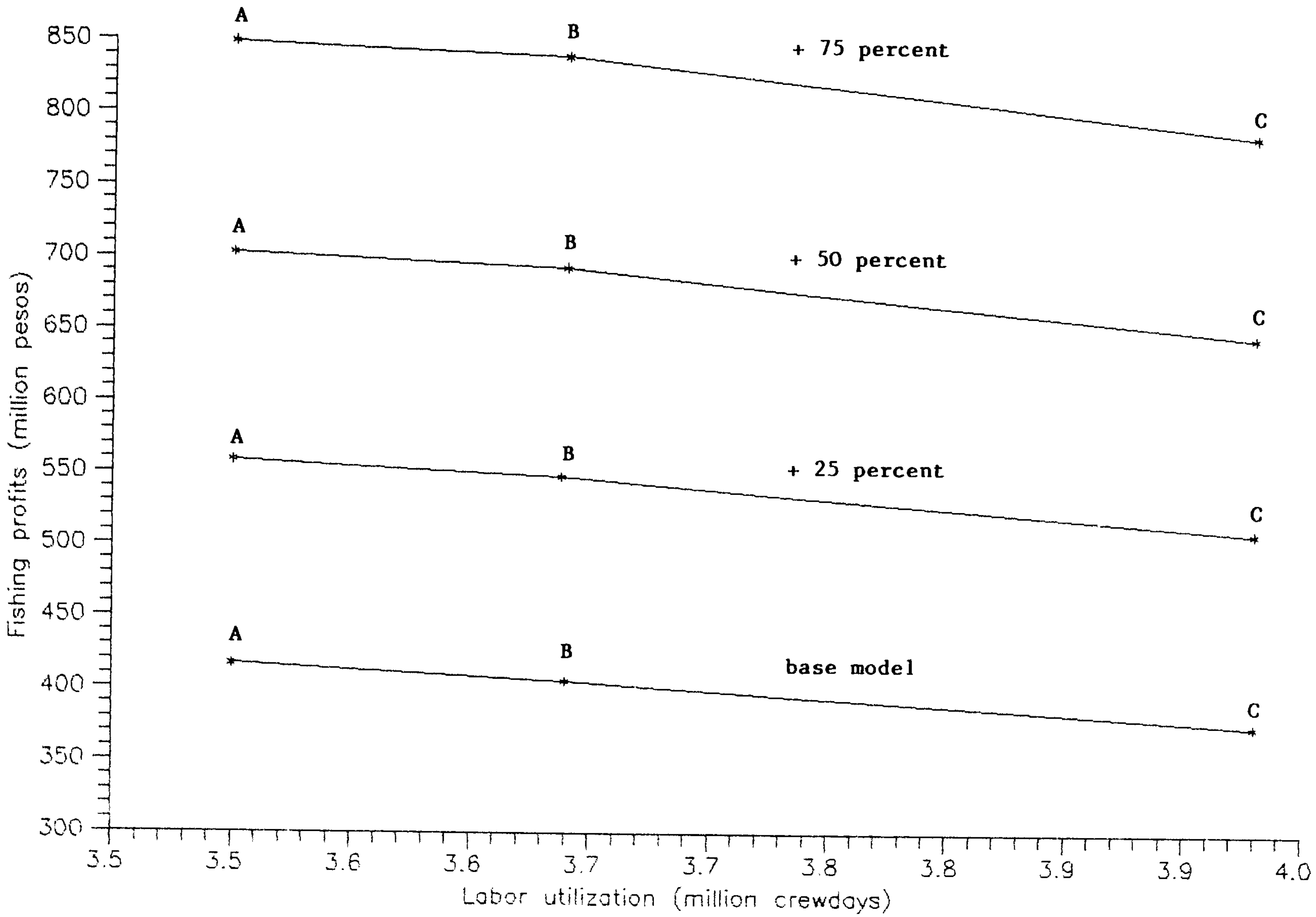
The impacts of fish price changes are calculated for 7 major indicators of fishery performance, namely: fishery profits, employment in terms of number of crewdays and number of fishermen, number of vessels, gross tonnage and level of fishery capitalization (Table 6.8). The base result is robust; the base-case optimal composition of the fleet does not change. The only change occurring is the amount of fishing profits which is expected due to the change in the unit profit of fishing effort. The shifting of the efficiency frontier is shown in Figure 6.2 which does not show the entire feasible region to emphasize the extent of the shift.

An increase in fuel prices squeezes unit profit although the decrease in fishery-wide profits is much smaller than the

Table 6.8. Major indicators of fishery performance for various changes in fish prices

Item	Base case model	Increase in prices			Percent change from base		
		25%	50%	75%	25%	50%	75%
Fishing profits (mil. pesos)							
Pmax	416.87	558.58	702.85	848.87	33.99	68.60	103.63
Intermediate point	405.51	547.81	692.54	838.90	35.09	70.78	106.87
Lmax	374.55	509.06	646.28	785.40	35.91	72.55	109.69
Employment (mil. crewdays)							
Pmax	3.498	No change from base figures					
Intermediate point	3.638						
Lmax	3.927						
Number of fishermen							
Pmax	25,845	No change from base figures					
Intermediate point	29,734						
Lmax	31,616						
Total catch (tons)							
Pmax	73,853	No change from base figures					
Intermediate point	72,355						
Lmax	76,027						
No. of vessels							
Pmax	4,795	No change from base figures					
Intermediate point	6,168						
Lmax	6,726						
Gross tonnage							
Pmax	10,527	No change from base figures					
Intermediate point	10,600						
Lmax	11,056						
Total capitalization (million pesos)							
Pmax	256.07	No change from base figures					
Intermediate point	275.16						
Lmax	267.45						

Figure 6.2. Efficiency frontiers in objective space for various changes in fish prices



percentage change in fuel prices. In absolute terms, however, the decrease is quite large (Table 6.9). The base case allocation of effort is also robust for downward pressure on profits; the optimal allocation of effort in the base model still applies for the entire range of fuel price increases considered even where the unit profit of the drift gill net is negative. This implies that the initial optimal fleet composition need not be altered in the face of declining profitability of the various fleets in the fishery. Hence, the sensitivity analyses for changes in fuel and fish prices indicate that there is no need for a recurrence of the painful adjustment in the fishery once the optimal fleet size is achieved.

One of the outputs from the post-optimality routine of IMPS are the ranges within which profit and labor utilization levels of each fleet can vary without affecting the optimal solution. It should, however, be interpreted in the context of comparative statics. For instance, any change in the prices of outputs or inputs that decrease (increase) the unit profitability of the purse seine fleet by no more than 3.38 pesos (23.65 pesos), *ceteris paribus*, does not affect the optimal solution. As shown in Table 6.11, the optimality range even permits negative profitability for some of the fleet and this was verified in the sensitivity analysis on fuel price increases. The optimality range for the labor utilization rates listed in the same table are interpreted similarly.

Table 6.9. Major indicators of fishery performance for various changes if fuel prices

Item	Base case model	Increase in prices			Percent change from base		
		25%	50%	75%	25%	50%	75%
Fishing profits (mil. pesos)							
Pmax	416.87	377.25	357.39	337.67	-9.50	-14.27	-19.00
Intermediate point	405.51	352.34	333.16	314.28	-13.11	-17.84	-22.50
Lmax	374.55	330.51	308.33	286.49	-11.76	-17.68	-23.51
Employment (mil. crewdays)							
Pmax	3.498	No change from base figures					
Intermediate point	3.638						
Lmax	3.927						
Number of fishermen							
Pmax	25,845	No change from base figures					
Intermediate point	29,734						
Lmax	31,616						
Total catch (tons)							
Pmax	73,853	No change from base figures					
Intermediate point	72,355						
Lmax	76,027						
No. of vessels							
Pmax	4,795	No change from base figures					
Intermediate point	6,168						
Lmax	6,726						
Gross tonnage							
Pmax	10,527	No change from base figures					
Intermediate point	10,600						
Lmax	11,056						
Total capitalization (million pesos)							
Pmax	256.07	No change from base figures					
Intermediate point	275.16						
Lmax	267.45						

Table 6.10. Optimality range for unit profitability and unit labor utilization at Pmax and Lmax

Gear	Unit profit		Unit labor utilization	
	Lower value	Upper value	Lower value	Upper value
Danish seine				
Commercial	-1 e 7	5.2408	-0.0075	0.2366
Municipal	-1 e 7	5.4261	0.0229	0.2002
Encircling gill net				
Commercial	-3.0938	36.5570	-0.0627	0.1534
Municipal	-3.2779	31.6147	-0.0418	0.1484
Purse seine				
Commercial	3.3792	23.6545	-0.0257	0.1291
Municipal	4.1563	20.7719	-0.1687	0.1100
Trawl				
Commercial	-8.0623	56.4643	-1 exp 8	0.1653
Municipal	0.2229	15.7416	-1 exp 8	0.0717
Drift Net				
Municipal	-18.4945	6.4705	0.0772	5.6929

6.2.2 Changes in technical parameters: catchability coefficients

The preceding discussion looked at the effects of changes in economic variables in the fishery while this section turns to technical changes, particularly its impact on the catchability coefficients. While sensitivity analysis on the coefficients may be interpreted as being in the realm of technological change in the fishery, it is also necessitated by difficulties encountered in the data gathering process. The field monitors were forced to visually estimate the proportion of small pelagic catches by species from mixed and unsorted fish landings (pelagic and demersal species) of Danish seine, trawl and purse seine fleets. Where possible, samples of the catch were taken to obtain more accurate estimates of the composition of catch by species group. Nevertheless, some estimation errors would have been committed.

Sensitivity analysis is performed on the catchability coefficients of the above-mentioned fleets. Since either the proportion of small pelagic catches is underestimated or overestimated, a 5% and a 10% figure were assumed in both directions. A negative (positive) change in catchability coefficient means that the three fleets (6 sectors) being looked into are less (more) effective in catching small pelagics per unit of standardized fishing effort. Hence a negative (positive) change results in bigger (smaller) total standardized fishing effort to harvest a given maximum catch of small pelagic species. In the effort allocation model, a negative (positive) change is equivalent to a relaxation (contraction) of the biological constraints. It should be expected then that sensitivity analyses will cause changes in the optimal allocation of effort from the base case model.

The implications of the assumed changes in catchability coefficients on the major indicators of fishery performance are listed in Table 6.11. An underestimation of small pelagic catches for the three fleets results in higher fishery profits, labor utilization and employment, catch, number of vessels and total capitalization in the fishery compared to the base case model. On the other hand, overestimation gives lower values for all major indicators of fishery performance. The percent changes in all indicators closely approximate the percent changes in the catchability coefficients.

The results may likewise be interpreted in the context of improvements in harvesting technology. Should the three fleets (6 sectors) become more effective in catching small pelagic fishes and hence increasingly more dependent on these species, a smaller fleet size needs to be employed in the fishery. It is reasonable to expect that such change is more likely to come from the purse seine, trawl and Danish seine fleets as the relative contribution of small pelagics to their catch is lower compared to the two other fleets. The base case optimal composition of the fleet does not vary by a wide degree as the diminution of the fleet is more or less distributed across fleets. Only the encircling gill net fleet is augmented in

Table 6.11. Major indicators of fishery performance for various changes in catchability coefficients of Danish seine, purse seine and trawl

Item	Base case model	Change in catchability coefficients				Percent change from base			
		-10%	-5%	+5%	+10%	-10%	-5%	+5%	+10%
Fishing profits (mil. pesos)									
Pmax	416.87	456.53	435.57	400.00	384.67	9.51	4.49	-4.05	-7.72
Intermediate point	405.51	444.47	423.92	388.93	373.87	9.61	4.54	-4.09	-7.80
Lmax	374.55	404.95	388.92	361.59	349.77	8.12	3.84	-3.46	-6.62
Employment (mil. crewdays)									
Pmax	3.498	3.781	3.632	3.378	3.268	8.09	3.83	-3.43	-6.58
Intermediate point	3.638	3.938	3.780	3.510	3.394	8.25	3.90	-3.52	-6.71
Lmax	3.927	4.296	4.102	3.770	3.626	9.40	4.46	-4.00	-7.66
Number of fishermen									
Pmax	25,845	27,685	26,713	25,069	24,363	7.12	3.36	-3.00	-5.73
Intermediate point	29,734	31,984	30,797	28,780	27,913	7.57	3.58	-3.21	-6.12
Lmax	31,616	34,277	32,876	30,484	29,447	8.42	3.99	-3.58	-6.86
Total catch (tons)									
Pmax	73,853	78,933	76,254	71,697	69,734	6.88	3.25	-2.92	-5.58
Intermediate point	72,355	77,367	74,722	70,232	68,302	6.93	3.27	-2.93	-5.60
Lmax	76,027	81,812	78,766	73,566	71,312	7.61	3.60	-3.24	-6.20
No. of vessels									
Pmax	4,795	5,059	4,924	4,682	4,579	5.51	2.69	-2.36	-4.50
Intermediate point	6,168	6,581	6,363	5,994	5,835	6.70	3.16	-2.82	-5.40
Lmax	6,726	7,263	6,980	6,498	6,288	7.98	3.78	-3.39	-6.51
Gross tonnage									
Pmax	10,527	11,275	10,880	10,209	9,920	7.11	3.35	-3.02	-5.77
Intermediate point	10,600	11,367	10,963	10,275	9,980	7.24	3.42	-3.07	-5.85
Lmax	11,056	11,916	11,463	10,690	10,356	7.78	3.68	-3.31	-6.33
Total capitalization (million pesos)									
Pmax	256.07	279.20	267.19	246.33	237.46	9.03	4.34	-3.80	-7.27
Intermediate point	275.16	300.17	292.03	264.35	254.28	9.09	6.13	-3.93	-7.59
Lmax	267.45	290.40	278.09	257.59	248.77	8.58	3.98	-3.69	-6.98

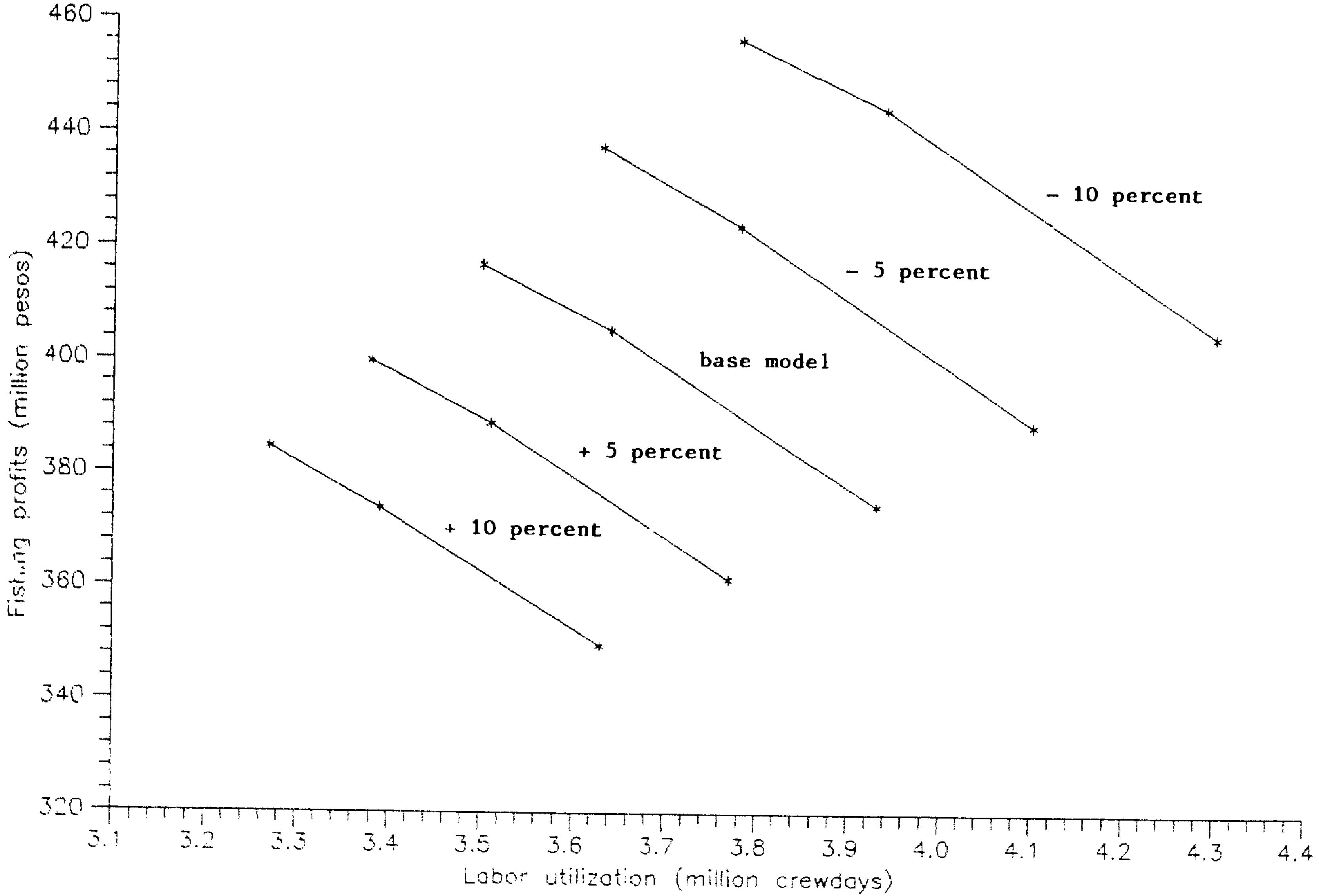
size while the number of vessels for the rest of the fleets is reduced at all corner points on the efficiency frontier.

In objective space, the efficiency frontier is shifting as shown in Figure 6.3. For all cases, there are still three corner points on the efficiency frontier. The degree of shift of the frontier from its original position is proportional to the change in catchability coefficient in the opposite direction. The outward shifts represent decreases in catchability coefficients while the inward shifts correspond to increases in catchability coefficients.

6.2.3 Shadow prices

The effort allocation process is a constrained optimization problem. The constraints are in the form of target yields for each species and the equity considerations (the proportionality between municipal and commercial sectors in each fleet and for the entire fleet and the minimum fleet size requirement). These constraints are all incorporated in all runs of the effort allocation process. However, not all of the constraints are binding. Of interest then is the determination of the effects of relaxing those binding constraints on the value of the objective function. The shadow price, which is the amount of change in the objective function per unit change in the binding constraint, measures this effect.

Figure 6.3. Efficiency frontiers in objective space for various changes in catchability coefficients of selected fishing gears



The shadow prices are given in Table 6.12. These figures are applicable for the base case model and are for two points on the efficiency frontier, which are P_{max} and L_{max}. The number of binding constraints at P_{max} and L_{max} is the same but the specific constraints are not the same. This can be verified in the table where only the binding constraints have shadow price entries. It is expected that all the proportionality constraints are binding since these are all in the form of equality (refer to appendix A).

The shadow prices of the binding biological constraints are all positive which means that increasing target yields will increase total fishery profits and/or total labor utilization. For instance, increasing the target yield for mackerels by 1 kg will increase profits by 13.34 pesos at P_{max} and will increase labor utilization by 0.09564 at L_{max}. Of course, there are incidental labor benefits at P_{max} and incidental profits at L_{max}.

The interpretation of the shadow prices for the proportionality constraints needs clarification. These constraints given in numerical form in Appendix A are transformed by simplifying the equations making the right side of each constraint equal to zero for input to IMPS. For example, in the Danish seine fleet, the proportionality constraint becomes: $f_1 - 0.7265f_2 = 0$ for input into the linear programming package. The same follows for the other proportionality constraints. Relaxing the Danish seine fleet constraint by one point transforms the above equation to f_1 -

$0.7265f_2 = 1$. This implies that allocation to the commercial sector for the Danish seine fleet (f_1) is increased by one unit of standardized fishing effort. The ratio between f_1 and f_2 thereby increases, although marginally, since the minimum values of f_1 and f_2 are large numbers. Thus, the shadow prices of the proportionality constraints give vital information to the decision maker of the consequences of altering the ratio of standardized fishing effort between the commercial and municipal sectors in each fleet.

The negative shadow prices for the 4 fleets at P_{max} indicate that relaxing the constraint for either one of the fleets, i.e., increasing the minimum fleet size for the commercial sector relative to the municipal sector for any of the 4 fleets, would reduce total fishery profits. However, for the entire fleet (which is the fishery-wide constraint specifying the ratio of commercial to municipal fishing effort for all fleets in the model) it would actually increase profits by 4.1754 pesos. The reason is that this constraint includes the drift gill net fleet which is the least profitable of all fleets. Relaxing such constraint therefore implies a reallocation away from the less profitable drift gill net fleet. The shadow prices for the proportionality constraints at L_{max} may be interpreted in the same manner. It should be noted, however, that the signs of the shadow prices at L_{max} are the opposite of those at P_{max}. This means that the direction of change in the value of the objective function would be the opposite compared to the above when the proportionality constraints are relaxed.

Only one minimum fleet size constraint is binding at P_{max} and at L_{max} but the fleets concerned are different. The negative shadow price indicates that reducing the Danish seine (trawl) fleet by one unit of standardized fishing effort at P_{max} (L_{max}) would increase the amount of profits (labor utilization) in the fishery by 1.4365 pesos (0.25859 crewdays). Also given in Table 6.12 is the range which the right side of the constraints may be allowed to change without any effect on the optimal solution. In the biological constraint for instance, the optimal solution will not change for target yields for sardine varying from 18,486 to 38,486 tons. An additional condition though is that the change in the target yield for sardine must not be accompanied by any change in the values of the other constraints.

6.3 Analysis of alternative management schemes

In this section specific fishery regulations are examined. These fishery regulations may be considered complementary to a licensing scheme as these regulations may cushion the restrictive fleet composition called for by the optimal solution. A limited entry regime which is first discussed below may also be viewed as the primary regulatory scheme for the fishery while the other regulations are instruments that may be implemented to "fine tune" the fishery to the desired

Table 6.12. Shadow prices and optimality limits for the various constraints

	Profit maximization			Labor maximization		
Constraint	Shadow price	Upper limit ('000)	Lower limit ('000)	Shadow price	Upper limit ('000)	Lower limit ('000)
A. Biological constraints						
Sardines	3.8700	18,486	38,486	0.02746	18,486	38,486
Mackerels	13.3402	16,889	31,713	0.09564	15,931	32,693
Crevalle	n.a.	11,507	26,079	0.06508	11,630	24,581
Anchovy	6.0540	4,295	8,135	n.a.	3,381	16,171
Round scad	n.a.	31,010	16,931	n.a.	3,460	16,931
Round herring	n.a.	1,325	14,660	n.a.	1,395	14,660
Big-eye scad	n.a.	572	15,127	n.a.	536	15,127
B. Proportionality constraints						
Danish seine	-3.5901	(1,805)	9,713	0.13144	(3,810)	9,312
Encircling gill net	-2.8597	(1,994)	5,210	0.12068	(4,247)	4,834
Purse seine	-4.5927	(1,884)	9,999	0.12758	(4,097)	9,923
Trawl	-4.8551	(1,309)	5,832	0.18904	(661)	2,750
All fleets	4.1754	(9,795)	1,784	-0.14207	(9,341)	3,715
C. Minimum constraints						
Danish seine	-1.4365	13,300	33,300	n.a.	13,300	33,300
Encircling gill net	n.a.	(9,590)	10,410	n.a.	(9,590)	10,410
Purse seine	n.a.	(7,536)	12,464	n.a.	(7,536)	12,464
Trawl	n.a.	(7,250)	7,826	-0.25859	.232 E -9	10,404
Drift gill net	n.a.	(9,772)	2,801	n.a.	(9,772)	5,205

n.a. = not applicable, i.e., constraint is not binding status. The impacts of these additional regulations on the economic, social and biological status of the fishery are ascertained.

As discussed in section 4.4, the analysis of alternative management schemes may proceed in two ways with reference to the effort allocation process. The effects of a specific fishery regulation may be evaluated after running the allocation problem (*ex post*) or before running the allocation problem (*ex ante*). In the first case, the optimal allocation of effort is given by the base case results. What changes is the conversion factor in determining the equivalent number of vessels from the optimal level of standardized fishing effort for each sector. (Such conversion was done in section 6.1.3.) In the *ex ante* analysis, the optimal solution may likely vary from the results of the base case model as the target yields for each species are changed. These approaches to the analysis of management alternatives will become clearer in sections 6.3.2, 6.3.3. and 6.3.4.

The management schemes that can be included in the analysis are limited by what is practically applicable to the fishery. As mentioned in the description of the fishery in chapter 2, the social, economic and institutional aspects of the fishery dictate what can be reasonably done to manage the resources and those dependent on these resources. The alternatives included in this section are formulated in such a way that they are potentially enforceable in the fishery although the enforcement problems that may still arise are discussed.

6.3.1 Limited entry licensing

The determination of the optimal fleet composition for the base case model in section 6.1 did not incorporate a specific management scheme for the fishery. The allocation process proceeded assuming no change in the current configuration of the fishing units and the exploitation patterns which determine to a certain degree the values of the biological parameters. However, it only preserves the *status quo* in the fishery in the biological and technical spheres. The points on the efficiency frontier suggest a number of vessels and associated crew much smaller than those presently in the fishery. The assumption made in section 6.1 and 6.2 is that a mechanism to move the fishery from its present overcapacity to a desired point on the frontier can be effected. A limited entry regime is often instituted to directly control fleet size to the desired level. The following analysis of limited entry licensing does not entail any modification of the effort allocation problem.

The potential problems in the implementation of a limited entry scheme to the extent suggested by the model may be classified into the following areas. First is the political unpalatability of limiting entry to a common property resource. In addition, such a scheme will likely be met with resistance from those in the industry and hence enforcement will be difficult. A licensing scheme should also resolve the thorny issue of determining who or which should be licensed. Finally, even where a licensing scheme is successfully implemented, fishing intensity may not be successfully regulated due to capital stuffing. These problems are not mutually exclusive but are likely to occur in the small pelagics fishery of Guimaras Strait and the Visayan Sea with the implementation of limited entry licensing.

While the efficiency frontier gives the maximum possible combinations of fishery profits and labor utilization in the fishery, any point on the frontier may still not be politically acceptable to the decision maker. It calls for a very considerable reduction in the number of existing vessels and in the number of fishermen. The displacement of fishermen in an economy characterized by high unemployment and underemployment is unattractive. In addition, the withdrawal of vessels which do not have alternative employment outside of the fishery is rather unsatisfactory. Hence, there are huge obstacles to instituting a limited entry regime in Philippine fisheries. The same problems are experienced even in developed country fisheries (Commission of Pacific Fisheries Policy 1982; Rettig and Ginter 1978).

These problems, notwithstanding, there is a great need to limit entry in the fishery. Often, limited entry regimes are watered down and/or compromised to be acceptable to those affected. This should be the case in the small pelagics fishery of Guimaras Strait and the Visayan Sea as the size of some fleets need to be increased while massive reductions should be carried out for the majority of the fleets. A corollary problem then is that of enforcement of a regulatory scheme that is not widely accepted by the fishermen. Enforceability is even more difficult due to the region's geography. The long coastline and the widely dispersed fish landing areas makes monitoring of vessels next to impossible.

The objective of limited entry regimes in fisheries is to bring effort down to the desired level. This is effected through licensing which seeks to regulate directly who may and may not participate in the fishery. Licensing must resolve the thorny issue of who should be given a license and the distribution of such licenses. However, this is not a subject of discussion here as it is an implementation problem. Another issue of equal importance is who or what should carry the license. Fishery laws in the Philippines require that both vessels and fishermen should obtain a license although the objective of licensing is simply to keep track of the extent of fishery participation. Nevertheless, it is not strictly enforced. In the formulation of the model, the optimal fleet is defined in terms of the number of vessels in each gear category (fleet) and sector (municipal and commercial). Hence, the license should be for the vessel specifying the tonnage and the gear it can use. The upper limits on the number of vessels to be licensed are given by the optimal fleet size implied by the point chosen on the efficiency frontier.

Licensing *per se* does not effectively control fishing effort in the sense that vessel tonnage is not the only indicator of fishing power. Other attributes of the vessel affect fishing power. The use of fish finding devices and more powerful engines shortens the search time and travel between port and fishing ground thus increasing effective fishing time. Hence, a licensing scheme as described above may not effectively bring fishing effort down. As experiences in fishery rationalization schemes around the world have shown (e.g. Fraser 1979) fishermen have increased fishing power substantially by manipulating unconstrained components of the fishing unit. The phenomenon called "capital stuffing" should be anticipated in the small pelagics fishery of Guimaras Strait in case limited entry licensing is initiated. The implications of "capital stuffing" and other relevant issues associated with limited entry licensing were discussed in section 3.3.3. In addition to limited entry licensing, further rationalization of the fishery may be necessary to deal with this prospective problem.

6.3.2 Resource sharing through seasonal closures

The optimal standardized fishing efforts derived in the allocation process in sections 6.1 and 6.2 are converted into actual numbers of vessels by dividing them by the average annual standardized effort exerted by a representative vessel in each sector. In the annual effort estimation an important determinant is the temporal dimension as measured by the frequency of trips per unit time and the number of crewdays. The assumption for the licensed vessels is that the length of time of their participation in the fishery corresponds to the average time they actually fished during the monitoring period. These figures are listed in Table 5.6.

In the face of possible massive displacement[5] of capital and labor from the fishery, it is important to find means to minimize displacement. A concept which may be termed as "resource sharing" may be introduced. The mechanism is similar to the voluntary reduction in the length of shifts in manufacturing concerns to avoid or reduce layoffs during recession. In the fishery, operators may be called on to shorten the length of fishing trips or to reduce the frequency of fishing trips so as to accommodate more participants without exceeding the annual target yields for each small pelagic species. This may be done through seasonal closures of the fishery. Seasonal closures are regulations commonly used to protect the stocks from overexploitation but may also be looked at as a means of bringing about resource sharing. While such a scheme reduces displacement from the fishery, it is at the expense of lower average catch per vessel per year and shorter average employment in the fishery. A basic assumption is that

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[5] As mentioned earlier, the optimal solution in the base case model and in the succeeding analysis of alternative management schemes involves underutilization of some species. To the extent that these are caught by other fleets not considered in the model, the employment effects are underestimated. However, estimation of such is difficult and hence, is not included in the computations.

fishing units do not increase fishing intensity during the open season which may offset the loss of fishing time.

The timing of closures may coincide with the spawning season to ensure good recruitment into the fishery. It may also take into account the negative social effects especially for those almost entirely dependent on the fishery. Closures may be also timed to coincide with periods when off-fishery jobs are available, e.g., during the rice planting and rice harvesting months. Seasonal closures may also be based on some economic criteria, i.e., fleets may be allowed to fish until reasonable returns from investments, taking into account the risks of fishing, are obtained. This results in different length of fishing season for each of the fleet. There are, of course, attendant enforcement problems in any system followed.

The effects of seasonal closures on the optimal fleet size, the average catch of vessels and of fishermen and the returns from fishing are analyzed. In the context of the effort allocation model, the effects are determined *ex post*. The total standardized fishing effort for each sector remains the same; only the number of vessels, the number of fishermen and the other related fishery variables vary. Up to three months of closure in one month increments are considered. For simplicity, the average trip frequency for one month is assumed to be constant although such would actually vary depending on the month. The results are compared to the current status of the fishery and to those implied at L_{max} since this point gives the maximum number of vessels and crew component on the efficiency frontier.

Resource sharing through seasonal closures does not have much impact in reducing the displacement of vessels and fishermen. The longest closure of 3 months may still entail withdrawal from the fishery of at most, about 31% of vessels and 45% of fishermen (Table 6.13), considering that the estimated number of vessels and fishermen is overestimated as noted earlier. Although these represent significant increases from those implied at L_{max}, the situation may still be unacceptable politically. The average catch per vessel and per fisherman compared to L_{max} is reduced by as much as 25% for a three-month closure. The implication of this is that the fixed costs of fishing is spread over a smaller catch level thus increasing fishing costs. However, at the current unit profits of fishing, fishing units should still be earning reasonable profits from the small pelagics fishery. The figures, however, indicate the extent of overcapacity in the fishery.

6.3.3 Fishing mortality regulations

The analyses have so far maintained, on the biological aspect, the historical trend in landings without regard to the biological potentials of the resource. In the remaining sections, the biological characteristics of the resource are taken into account in examining alternative management schemes for the fishery. The following analysis seeks to determine

Table 6.13. Effects of different lengths of seasonal closure on selected fishery variables

Item	Current number	Lmax	No. of months closure		
			1 month	2 month	3 month
No. of vessels	13,114	6,726	7,337	8,071	8,968
% change from current number		-48.71	-44.05	-38.46	-31.62
No. of fishermen	76,220	31,616	34,503	37,949	42,146
% change from current number		-58.52	-54.73	-50.21	-44.70
Ave. catch per vessel per yr (kg)		11,303	10,362	9,420	8,478
% change from Lmax			-8.33	-16.66	-24.99
Ave. catch per fisherman per yr		2,405	2,203	2,003	1,804
% change from Lmax			-8.40	-16.72	-24.99

whether there is still room for increasing employment in the fishery compared to the results of the base case model by exploiting the full biological potential of the small pelagics.

The yield-per-recruit curves as a function of fishing mortality for the various small pelagic species are drawn in Figure 6.4. The biological parameters are those presented in chapter 5. The largest fish in the group are the round scads while the smallest are anchovy with a yield per recruit of about 1 gram. The current points of exploitation are marked which indicate that all species are harvested to the left of their maximum yields.

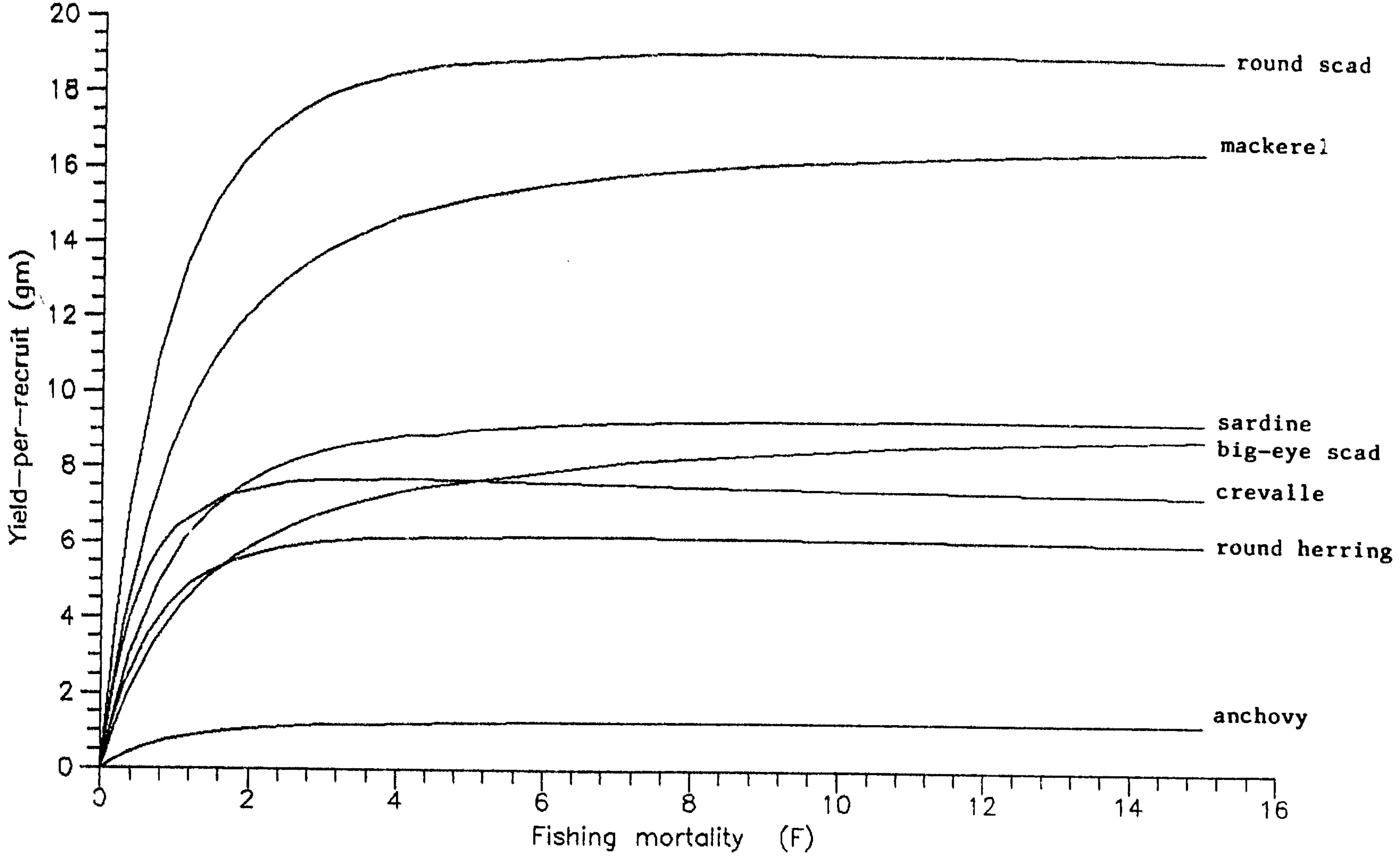
Regulations involving two levels of fishing mortality are examined. First is the concept of $F_{0.1}$ (Gulland and Boerema 1973) which corresponds to the point at which the marginal yield-per-recruit from an additional level of effort is 0.1 the marginal yield-per-recruit at very low levels of fishing. Algebraically F0.1 implies the following

$$\left.\frac{d(Y/R)}{dF}\right|_{F_{0.1}} = 0.1 \times \left.\frac{d(Y/R)}{dF}\right|_{F=0}$$

assuming the very low level of fishing is F=0. Although the basis of $F_{0.1}$ is arbitrary, its main advantage is that it ensures the conservation of fishery stocks.

Another fishing mortality regulation is F_{max} which corresponds to the fishing intensity that gives the maximum yield-per recruit for each species. It should be noted at this point, however, that maximizing yield-per-recruit may not be

Figure 6.4. Yield-per-recruit curves as a function of fishing mortality (F) for current levels of age-at-first-capture (tp) for the various small pelagic species of Guimaras Strait and the Visayan Sea, Philippines



applicable to the small pelagic stocks. Given the high M/K ratios, the maximum point in the yield-per-recruit diagrams in Figure 6.4 is not distinct or pronounced[6]. Rather, the yield-per-recruit for each species increases over a wide range of F and the maximum occurs at a very high level of F for each stock. Hence, targeting yields corresponding to F_{max} leads to extremely low stock biomass and to recruitment failures if recruitment is dependent on the level of stocks. Nevertheless, this is considered as an alternative management strategy to satisfy intellectual curiosity.

The specific values of $F_{0.1}$ and F_{max} are computed numerically using a program called Calculus Calculator (Meredith 1990). Total yield for each species is estimated by the relationship $Y = (Y/R)xR$ which is equation 5.1. Recruitment is the mean annual recruitment given in Table 5.1. Fishing mortality, yield-per-recruit and total yields are listed in Table 6.14. Total fishery yield corresponding to $F_{0.1}$ is 93,475 tons while at F_{max} it is 113,667 tons. While these are greater than the current fishery yield of about 90,146 tons, the yields of species (sardines and mackerels) which are binding biological constraints in the allocation model have actually declined, but only at $F_{0.1}$. The largest increase in yield is for anchovy since current exploitation gives a very low yield-per-recruit which is less than half of that at $F_{0.1}$ and at F_{max}.

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[6] This is not the case for temperate stocks (which have low M/K ratios) where the maximum yield-per-recruit occurs at lower levels of fishing mortality.

Table 6.14. Yield-per-recruit and total fishery yields by species at two levels of fishing mortality for current age-at-first-capture

	F0.1		Fmax	
	Y/R (g)	Total yield (tons)	Y/R (g)	Total yield (tons)
Sardine	7.76	25,342	9.28	28,617
Mackerel	13.07	21,513	16.98	25,722
Crevalle	6.70	17,979	7.68	16,240
Anchovy	1.08	13,543	1.28	7,017
Round scad	16.15	6,089	19.07	6,931
Round herring	5.34	4,142	6.18	4,673
Big-eye scad	6.76	4,868	9.46	9,931
Total yield		93,475		113,667

In the context of the multi-objective programming model, the yields can represent changes in the biological constraints -- the target yield for each species. The effort allocation problem is run again to determine the "new" optimal fleet composition. The effects on key indicators of fishery performance of the two regulations on fishing mortality are given in Table 6.15. The values of the key indicators have actually declined for $F_{0.1}$ because of the reduction in yields of the constraining species. For F_{max} the values have generally increased compared to the base case figures. Hence, the two regulations of fishing mortality cause changes in the optimal composition of the fleet. Moreover, a more important result is that in the process of maximizing fishery profits or labor utilization in the fishery, neither of the yields corresponding to the two target mortality rates can be obtained

Table 6.15. Major indicators of fishery performance for various regulations on fishing mortality (F)

Item	Base case model	Fishing mortality		Percent change from base	
		F0.1	Fmax	F0.1	Fmax
Fishing profits (mil. pesos)					
Pmax	416.87	397.17	517.37	-4.73	24.11
Intermediate point	405.51	376.27	489.15	-7.21	20.63
Lmax	374.55	330.17	436.82	-11.85	16.63
Employment (mil. crewdays)					
Pmax	3.498	3.164	3.937	-9.55	12.55
Intermediate point	3.638	3.421	4.283	-5.98	17.73
Lmax	3.927	3.852	4.773	-1.92	21.53
Number of fishermen					
Pmax	25,845	20,345	24,844	-21.28	-3.87
Intermediate point	29,734	27,502	34,510	-7.51	16.06
Lmax	31,616	30,305	37,691	-4.15	19.21
Total catch (tons)					
Pmax	73,853	69,960	86,696	-5.27	17.39
Intermediate point	72,335	67,204	82,974	-7.09	14.71
Lmax	76,027	72,671	89,180	-4.41	17.30
No. of vessels					
Pmax	4,795	3,124	3,623	-34.85	-24.44
Intermediate point	6,168	5,650	7,034	-8.40	14.04
Lmax	6,726	6,481	7,977	-3.64	18.60
Gross tonnage					
Pmax	10,527	9,700	12,045	-7.86	14.42
Intermediate point	10,600	9,835	12,228	-7.22	15.36
Lmax	11,056	10,514	12,998	-4.90	17.57
Total capitalization (million pesos)					
Pmax	256.07	219.45	282.13	-14.30	10.18
Intermediate point	275.16	254.59	329.52	-7.48	19.76
Lmax	267.45	243.13	316.30	-9.09	18.26

Appendix E (Tables 1-10) show the breakdown of the indicators by fleet.

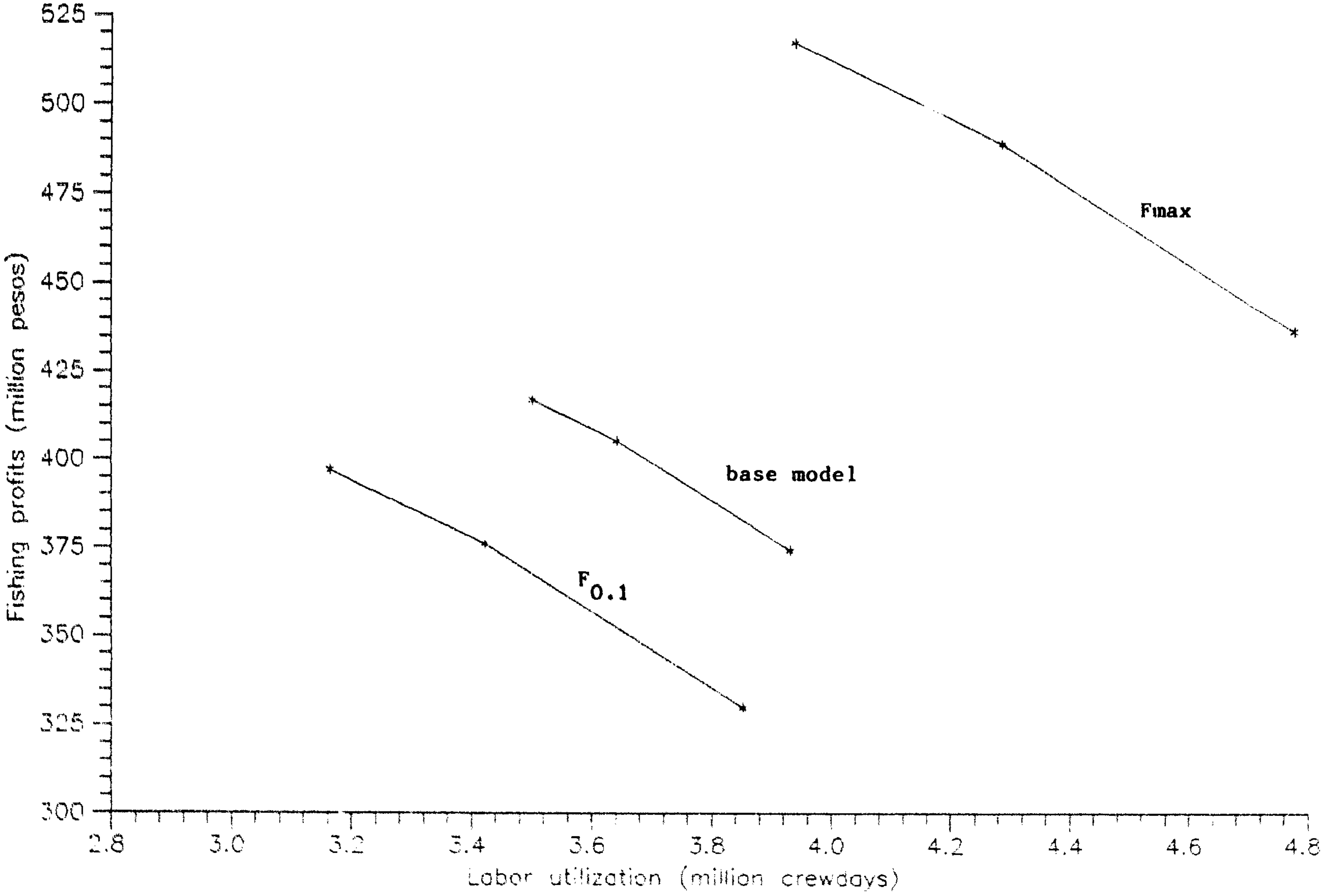
simultaneously across species. As in the base model, two or more species are fully exploited while there are slacks in some species.

The efficiency frontiers are plotted in Figure 6.5. The two regulations increase the number of efficient points although the number of corner points is not changed. This means that the decision makers have a wider range of choice particularly at F_{max} which represents a substantial increase in profits and labor utilization in the fishery. This also increases by about 19% the number of vessels and the number of fishermen at L_{max}. The employment effect would be greater if the unharvested yields by the fleets under study can be captured by the other fleets. However, the levels of displacement of vessels and fishermen remain large at about 39% and 51%, respectively. To further decrease displacement an adoption of F_{max} (although at the risk of the collapse of the small pelagic stocks) may be coupled with seasonal closures as the appropriate management schemes.

6.3.4 Mesh size regulations

Regulations restricting mesh size of fishing gears can be analyzed in the model. These involve changes in the biological constraints following the concept of eumetric yield. A given yield for each species would be the maximum yield for a specific mesh size. However, the estimation of these yields requires selection data for each mesh size by species and by

Figure 6.5. Efficiency frontiers in objective space for various regulations of fishing mortality (F)



gear, which is not available. To examine the effects of mesh size regulations, a simplifying assumption is made in this regard, which is described below. It should be noted then that the results in this section, due to the simplifying assumption made, are illustrative in nature.

Figure 6.6 graphs the yield-per-recruit curve for each species as a function of length at first capture at current levels of fishing mortality. Fishery yields are estimated by looking at a uniform fish length across species where each length may correspond to a specific mesh size. Three arbitrary lengths are considered and target fishery yields are computed given the yield per recruit curves and recruitment. The number of recruits for each species are as given in Table 5.1. The yields are listed in Table 6.16. The small pelagic species reach their respective maximum yield per recruit at a short length (age) although some species are faster growing than others. Combined fishery yield is at a maximum at 10-cm length and decreases with time (or length). This is because for most species, the gain from individual growth is outweighed by loss in natural mortality beyond the 10 cm length. The lengths (10 and 12 cm) considered give a larger yield per recruit for the two constraining species, sardine and mackerel. The inclusion of 14 cm length in the analysis is to show that there are limits of increasing the target length for the small pelagic fishes. For all lengths considered the yield per recruit for anchovy is maintained at a maximum (at 11 cm) as this species

Figure 6.6. Yield-per-recruit curves as a function of length-at-first-capture (tp) for current values of fishing mortality (F) for the small pelagic species of Guimaras Strait and the Visayan Sea, Philippines

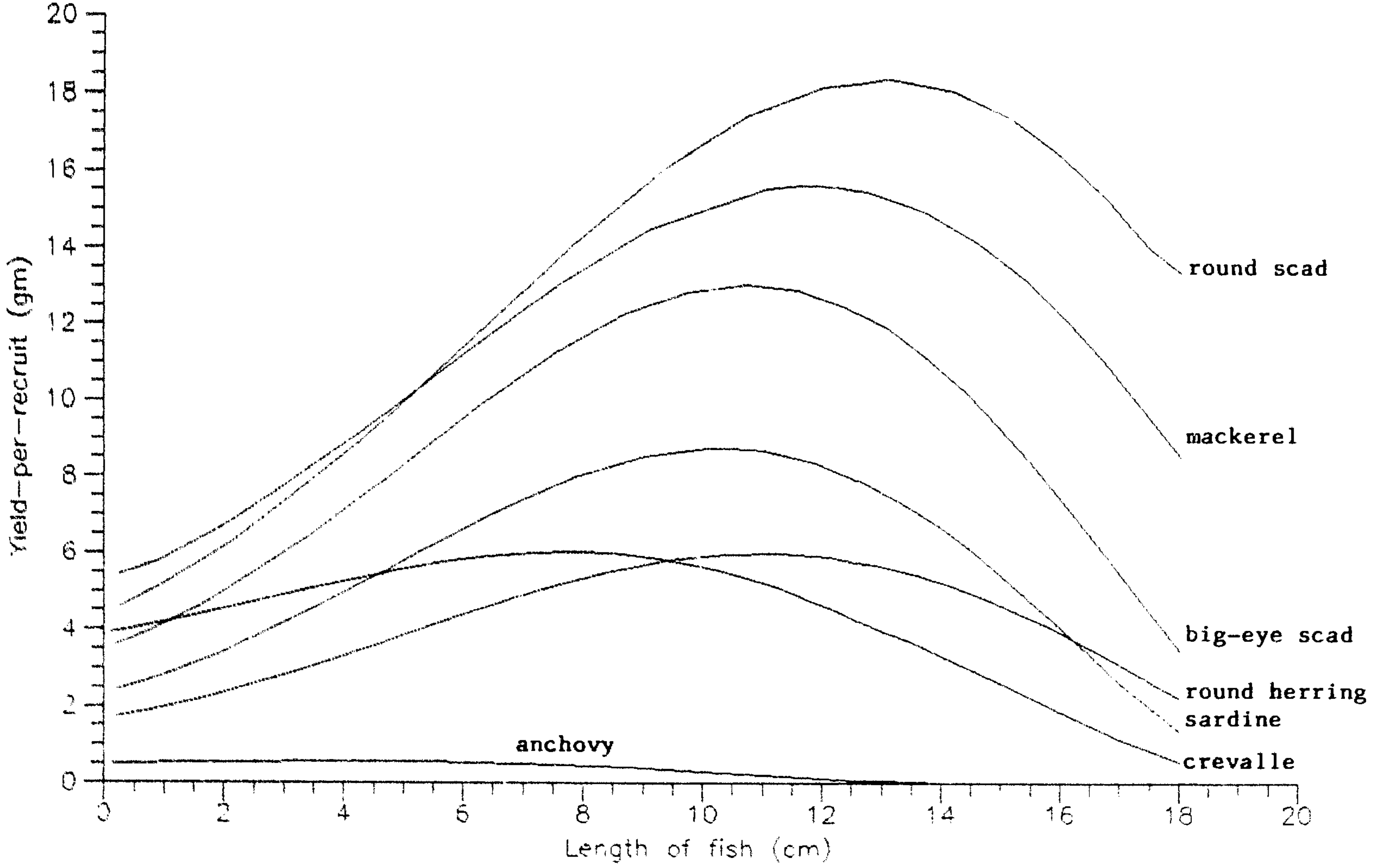


Table 6.16. Yield-per-recruit and total fishery yields by species for various lengths at first capture

Species	10 cm		12 cm		14 cm	
	Y/R (gm)	Yield (ton)	Y/R (gm)	Yield (ton)	Y/R (gm)	Yield (ton)
Sardine	8.75	28,591	8.32	27,183	6.67	21,789
Mackerel	15.09	24,833	15.62	25,708	14.72	24,224
Crevalle	5.74	15,392	4.82	12,931	3.43	9,209
Anchovy	0.56	7,071	0.56	7,071	0.56	7,071
Round scad	16.76	6,319	18.20	6,861	18.16	6,846
Round herring	5.95	4,608	5.95	4,610	5.27	4,084
Big-eye scad	12.94	9,319	12.71	9,153	10.80	7,778
Total yields		96,133		93,517		81,001

does not grow beyond 14 cm. It is assumed that adjustments can be made in some gears to not catch anchovy at shorter lengths.

The resulting allocation and the values of the important indicators of fishery performance are given in Table 6.17. The optimal allocation of fishing effort differs from the base results as the regulation of mesh sizes involves changes in the biological constraints. The values of the two objective functions increase for the 10 and 12 cm lengths. The trade-off between the two objectives is illustrated in Figure 6.7. For the 10 and 12 cm lengths, the number of corner points remain at three while for the 14 cm fish length the number of corner points is two, thus the number of efficient points is smaller.

Only two of the mesh size regulations considered are an improvement over the base case results in terms of employment. The number of fishermen increased although the results are mixed in the number of vessels. However, the increase in the number of fishermen is rather insignificant and there would still be a large displacement of labor from the fishery. Optimizing yields with mesh size regulations alone does not reduce significantly the capital and labor displacement from the fishery.

In view of the considerable profits that the small pelagics fishery is capable of generating, the discussion of management alternatives has focused mainly on the social objective of maximizing employment. The effects of the four general types of fishery regulations were analyzed independently from each other. The conclusion is the same; the

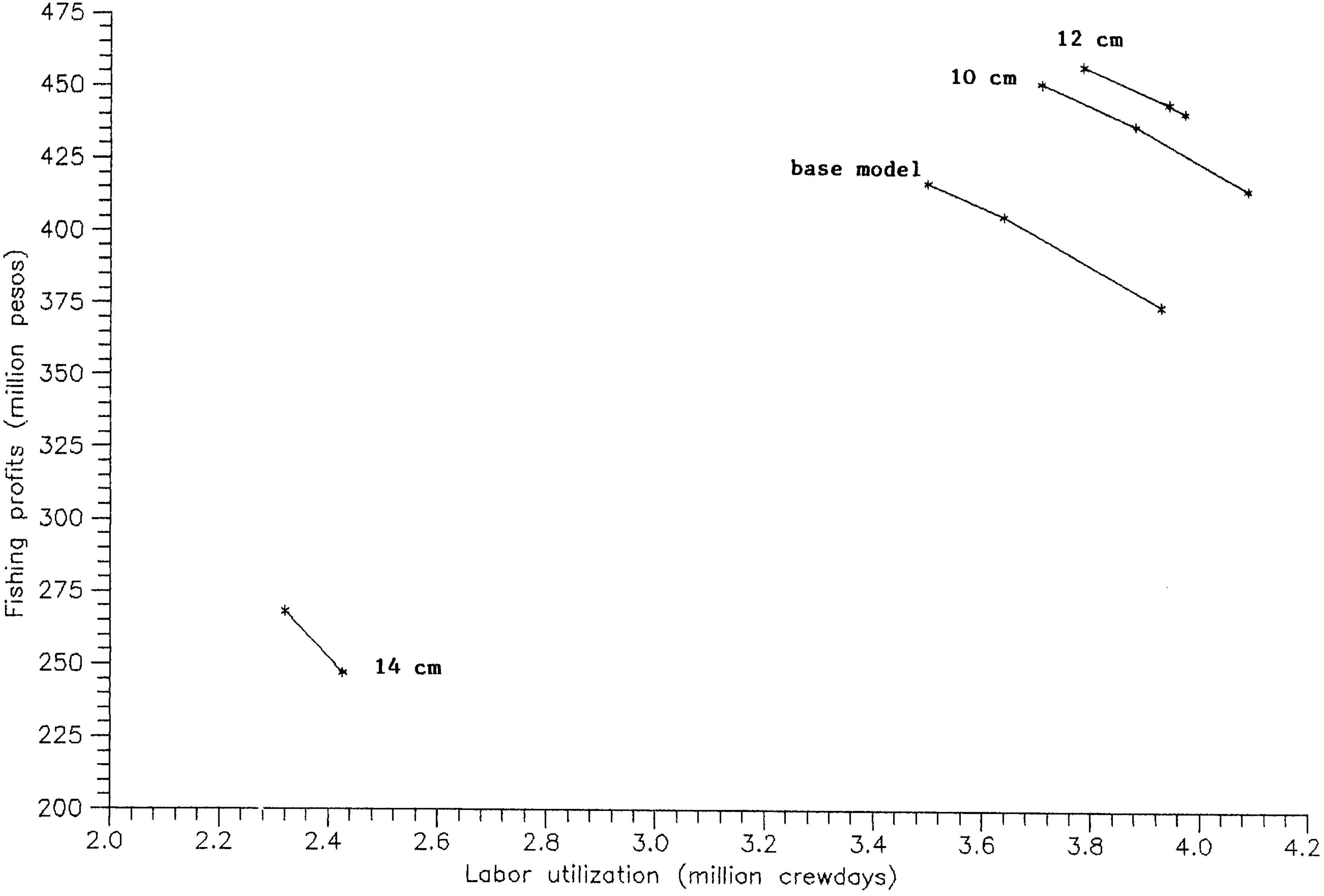
Table 6.17. Major indicators of fishery performance for various regulations on mesh sizes (indicated by length at first capture)

Item	Base case model	Length at first capture			Percent change from base		
		10 cm	12 cm	14 cm	10 cm	12 cm	14 cm
Fishing profits (mil. pesos)							
Pmax	416.87	451.27	457.50	268.17	8.25	9.75	-35.67
Intermediate point	405.51	437.16	444.56	n.a.	7.80	9.63	
Lmax	374.55	415.11	441.50	247.09	10.83	17.87	-34.03
Employment (mil. crewdays)							
Pmax	3.498	3.711	3.788	2.321	6.08	8.28	-33.66
Intermediate point	3.638	3.884	3.946	n.a.	6.77	8.48	
Lmax	3.927	4.090	3.975	2.426	4.15	1.22	-38.22
Number of fishermen							
Pmax	25,845	26,574	27,046	15,753	2.82	4.65	-39.05
Intermediate point	29,734	31,415	31,479	n.a.	5.65	5.87	
Lmax	31,616	32,749	31,665	19,962	3.58	0.15	-36.86
Total catch (tons)							
Pmax	73,853	77,896	77,780	53,032	5.47	5.32	-28.19
Intermediate point	72,335	76,039	76,073	n.a.	5.12	5.17	
Lmax	76,027	78,650	76,436	50,385	3.45	0.54	-33.73
No. of vessels							
Pmax	4,795	4,739	4,822	2,689	-1.17	0.56	-43.92
Intermediate point	6,168	6,447	4,364	n.a.	4.52	-29.25	
Lmax	6,726	6,842	6,442	4,250	1.72	-4.22	-36.81
Gross tonnage							
Pmax	10,527	11,078	11,107	7,313	5.23	5.51	-30.53
Intermediate point	10,600	11,171	11,191	n.a.	5.39	5.58	
Lmax	11,056	11,495	11,236	7,265	3.97	1.63	-34.29
Total capitalization (million pesos)							
Pmax	256.07	271.47	277.67	153.09	6.01	8.43	-40.22
Intermediate point	275.16	295.18	298.97	n.a.	7.28	8.65	
Lmax	267.45	289.99	298.25	170.95	8.43	11.52	-36.08

n.a. = not applicable, i.e., no intermediate point

Appendix E (Tables 11-25) show the breakdown of the indicators by fleet.

Figure 6.7. Efficiency frontiers in objective space for target yields corresponding to various lengths-at-first capture



extent of labor and capital displacement from the fishery is rather large. However, a combination of management alternatives may be considered to mitigate the negative employment effects. For instance, mesh size or fishing mortality targets may be accompanied by seasonal closures. Nevertheless, it is expected that there would not be a significant increase in optimal employment levels and hence the number of vessels and fishermen that will be displaced from the small pelagics fishery remains large. The results thus indicate the extent of overcapacity and overemployment in the small pelagics fishery of Guimaras Strait and the Visayan Sea.

Chapter 7

Summary and Conclusions

The analysis of the fishery in the thesis proceeded in several steps. First, fishery yields were determined using the yield per recruit model, one of the work-horses in fishery stock assessment. The yields were then allocated to competing fleets in such a way as to obtain the maximum possible profits from the fishery and the highest degree of labor utilization. Fishery management alternatives were analyzed in the context of this model and their effects on several indicators of fishery performance were ascertained.

The model that was developed assumed a steady state situation, *i.e.*, it is static and deterministic. However, it was able to tackle the important characteristics of tropical fisheries in a developing country scenario, namely: multispecies, multigear and the pursuit of conflicting objectives in exploitation. More specifically, the analysis has the following dimensions in terms of the above characteristics: seven species groups of small pelagic fishes, 5 gears involving 2 sectors (commercial and municipal sectors) and 2 explicit objectives. The interesting results derived from the empirical application of the model have shown that the above modeling approach is satisfactory considering the complexity of the small pelagics fishery resource system of Guimaras Strait and Visayan Sea in the Philippines.

The biological and economic sub-models involved a large number of parameters. The estimation of these parameters would have been a daunting task had it not been for an extensive survey and monitoring of catch and fishing operations in the study area. Considerable primary data for the thesis was collected in that activity which lasted for one year. The biological parameters were estimated using a computer package called ELEFAN, which requires length frequency distributions as an input. Since a number of gears which differ in the manner of catching fish were included in the analysis, one of the primary tasks is the standardization of fishing effort. A fishing effort function was constructed and this showed that the amount of effort varies considerably across fleets or gears. With reference to the small pelagics fishery, the biological impacts of fishing vessels having the same gross tonnage but employing different fishing gear are not equal. This is because some gears are more effective in catching small pelagics than others.

The base case model was the allocation of effort to the various fishing fleets with target yields set equal to the historical level of annual landings. With multiobjective programming an efficiency frontier was derived. The extreme points on the frontier were identified and, in addition, an intermediate corner point, where applicable. The character-istics of these points were described. The efficient or op-timal fleet composition implied at any corner point could generate sizable profits but called for considerable reduction in the number of vessels and fishermen. The historical level of catch can be harvested with just a fraction of the existing fleet size although the extent of fleet reduction may be overestimated for reasons mentioned earlier. Nevertheless, there are serious social implications if the goals of fisheries management include the optimization of fishery profits and employment.

The analysis of several alternative management schemes for the fishery was handled conveniently by the model. The objective of the analysis was to determine the impact of various regulatory schemes applied to the fishery particularly on employment, or conversely, on the degree of displacement of vessels and fishermen. Resource sharing through seasonal closures could increase the efficient or optimal number of vessels and fishermen, however, even a three months closure of the fishery does not reduce displacement by a significant amount. The results emphasized the overemployment of capital and labor in the fishery.

Alternative target yields for the various species groups were computed by regulating fishing mortality and age at first capture. The latter is related to the mesh size of gears. The alternative target yields do not represent a significant increase from the historical level of landings since the present level of exploitation of the small pelagics are close to that yielding the maximum yield per recruit. In fact, if a conservative level of exploitation is to be targeted, say at $F_{0.1}$, the target yields are much lower and hence so is the level of optimal employment compared to the base results.

The model that is developed is a partial equilibrium analysis with respect to the fishery resources. Ideally, both pelagic and non-pelagic catches should have been included since there are technological interactions between these two groups of fishes. An implicit assumption then throughout the analysis is that the quantity of demersal fishes caught by the optimal fleet composition (optimal for the small pelagic fishery) is within the acceptable catch levels for these species. Modeling may be extended to include non-small pelagic catches and the inclusion of more gears into the analysis. Moreover, a bigger area of coverage may be considered, e.g., other significant fishing grounds in the Visayan region which most fishing vessels jointly exploit. Further extension may be in the form of determining the optimal configuration of the fishing vessels. However, the data requirement of any extension of the fishery model that was employed in this thesis would be significant.

The multiobjective programming model considered only two explicit management objectives although the constraints embody other objectives implicitly. The present formulation, however, is satisfactory with respect to the small pelagics fishery. Moreover, the bicriteria model that was employed is also a convenient starting point in obtaining numerical results and in illustrating the tradeoffs between objectives. It may be of interest then to extend the model to incorporate other possible management objectives explicitly to determine the robustness of the present results.

Another worthwhile extension is in the area of dynamics. There are two levels of dynamic analysis with respect to the small pelagics fishery of Guimaras Strait and the Visayan Sea. First is the determination of the optimal effort allocation within the year if the pronounced seasonality of landings may be interpreted as a biological phenomenon. That is, seasonality in landings indicates the seasonal fluctuations in the availability of the small pelagics. Dynamic analysis may also look at the entire lifespan of the small pelagic fishes to determine the optimal time of harvest. Both analyses may be approached with dynamic programming.

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APPENDICES

Appendix A

Multi-objective Program
in Numerical Form
(Base case model)

Maximize:

$$\begin{aligned} h_1(f) = {} & 1.8278f_1 + 2.9466f_2 + 8.0307f_3 + 6.5116f_4 + 9.1091f_5 + \\ & 8.8520f_6 + 3.4769f_7 + 2.9981f_8 + 1.8481f_9 \end{aligned}$$

$$\begin{aligned} h_2(f) = {} & 0.0314f1 + 0.0511f_2 + 0.0262f_3 + 0.0365f_4 + 0.0577f_5 + \\ & 0.0515f_6 + 0.0320f_7 + 0.0397f_8 + 0.1253f_9 \end{aligned}$$

subject to:

Biological constraints

Sardines

$$\begin{aligned} & 0.0548f_1 + 0.0654f_2 + 1.7162f_3 + 1.1259f_4 + 0.3060f_5 + \\ & 0.1935f_6 + 0.0876f_7 + 0.0124f_8 + 1.1282f_9 \leq 28{,}486{,}000 \end{aligned}$$

Mackerels

$$\begin{aligned} & 0.1849f_1 + 0.3220f_2 + 0.0055f_3 + 0.1808f_4 + 0.5570f_5 + \\ & 0.5056f_6 + 0.0884f_7 + 0.1501f_8 + 0.0\ f_9 \leq 16{,}079{,}000 \end{aligned}$$

Crevalle

$$\begin{aligned} & 0.3512f_1 + 0.3023f_2 + 0.0\ f_3 + 0.0013f_4 + 0.1624f_5 + \\ & 0.1229f_6 + 0.0\ f_7 + 0.0292f_8 + 0.0\ f_9 \leq 6{,}931{,}000 \end{aligned}$$

Anchovy

$$\begin{aligned} & 0.0\ f_1 + 0.0\ f_2 + 0.0\ f_3 + 0.0\ f_4 + 0.1506f_5 + \\ & 0.0609f_6 + 0.4358f_7 + 0.4219f_8 + 0.0423f_9 \leq 6{,}171{,}000 \end{aligned}$$

Round scad

$$\begin{aligned} & 0.0585f_1 + 0.0398f_2 + 0.0\ f_3 + 0.0\ f_4 + 0.0988f_5 + \\ & 0.0503f_6 + 0.0\ f_7 + 0.0\ f_8 + 0.0165f_9 \leq 22{,}693{,}000 \end{aligned}$$

Round herring

$$\begin{aligned} & 0.0\ f_1 + 0.0\ f_2 + 0.0364f_3 + 0.0627f_4 + 0.0019f_5 + \\ & 0.0037f_6 + 0.0\ f_7 + 0.0405f_8 + 0.1346f_9 \leq 4{,}660{,}000 \end{aligned}$$

Big-eye scad

$$\begin{aligned} & 0.0024f_1 + 0.0068f_2 + 0.0\ f_3 + 0.0\ f_4 + 0.0376f_5 + \\ & 0.0\ f_6 + 0.0\ f_7 + 0.0\ f_8 + 0.0\ f_9 \leq 5{,}127{,}000 \end{aligned}$$

Proportionality constraints

Danish seine	f_1/f_2	$= 0.7265$
Encircling gill net	f_3/f_4	$= 0.8800$
Purse seine	f_5/f_6	$= 0.8195$
Trawl	f_7/f_8	$= 0.2405$
All fleets		
	$(f_1 + f_3 + f_5 + f_7)/(f_2 + f_4 + f_6 + f_8 + f_9)$	$= 0.6644$

Minimum constraints

Danish seine	$f_1 + f_2$	$\geq$ 23,300,000
Encircling gill net	$f_3 + f_4$	$\geq$ 410,000
Purse seine	$f_5 + f_6$	$\geq$ 2,464,000
Trawl	$f_7 + f_8$	$\geq$ 2,750,000
Drift net	f_9	$\geq$ 228,000

Appendix B

A Brief Description of the ELEFAN package[1]

The ELEFAN system (Electronic LEngth Frequency ANalysis) was developed at ICLARM in response to (1) the need for robust analysis of length-frequency data; (2) the availability of cheap microcomputers. These two points provide the reasons why the system has found wide acceptance in developing countries.

The system, as it now stands, consists of five programs, ELEFAN O, I, II, III, and IV. ELEFAN O is used to create and modify length-frequency data files for use with the other four ELEFAN programs as the other four programs have length-frequency data created by ELEFAN O as their main input.

ELEFAN I is used to estimate the growth parameters of fish or invertebrates. The growth equation of which these parameters are estimated is a seasonally oscillating version of the von Bertallanfy Growth Formula (VBGF). ELEFAN I can thus be used to provide quantitative information on growth oscillations of fish and invertebrates, which can be correlated with oscillation of selected environmental parameters. The ELEFAN I program has been rather widely disseminated since 1980 and a relatively large number of papers and reports have been published which relied predominantly or least partly on this program.

ELEFAN II performs a variety of computations, of which the following are the main ones. The first is the estimation of total mortality (Z) and derived quantities from the strait descending arm of a length-converted catch curve. Second is the estimation of probabilities of capture by length and mean length at first capture from the ascending, left arm of a length converted catch curve. ELEFAN II also provides an expression of the seasonal changes on recruitment intensity in the form of a graphical "recruitment pattern". Such can be further subdivided into normally distributed recruitment pulses, suggestive of the number of spawning and/or recruitment seasons per year. This routine requires the length-frequency data from ELEFAN O and the growth parameters.

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[1] This appendix is summarized from Pauly (1987) to which the reader is referred to for further information. In the thesis, only ELEFAN O, I, and II were employed.

ELEFAN III incorporates three types of virtual population analysis (VPA). VPA I estimates standing stock (in numbers) and fishing mortalities by time intervals (month, quarter, year, etc.). VPA II is used to estimate standing stock (in numbers) and fishing mortality by length class in a stock with stable age distribution, as can be simulated by combining data for several years. VPA III provides estimates of standing stock and fishing mortality by month and by length, which is achieved by "slicing" (pseudo-) cohorts through the catch-at-length data by means of a set of growth parameters. This approach assumes that little exchange occurs between the monthly "cohorts", which applies mainly in short-lived animals, such as anchovies and penaeid shrimps, for which the VPA III routine has been specifically designed. The inputs in ELEFAN III include length-frequency distributions, monthly bulk catch, M, growth parameters and length-weight relationship.

ELEFAN IV is a program which, provided that gear selection is known (i.e., that probabilities of capture by length class are available), can be used to estimate M and probabilities of recruitment by length class from catch samples representative of an exploited population.

Appendix C

Illustration and Description of the Sample Fishing Gears

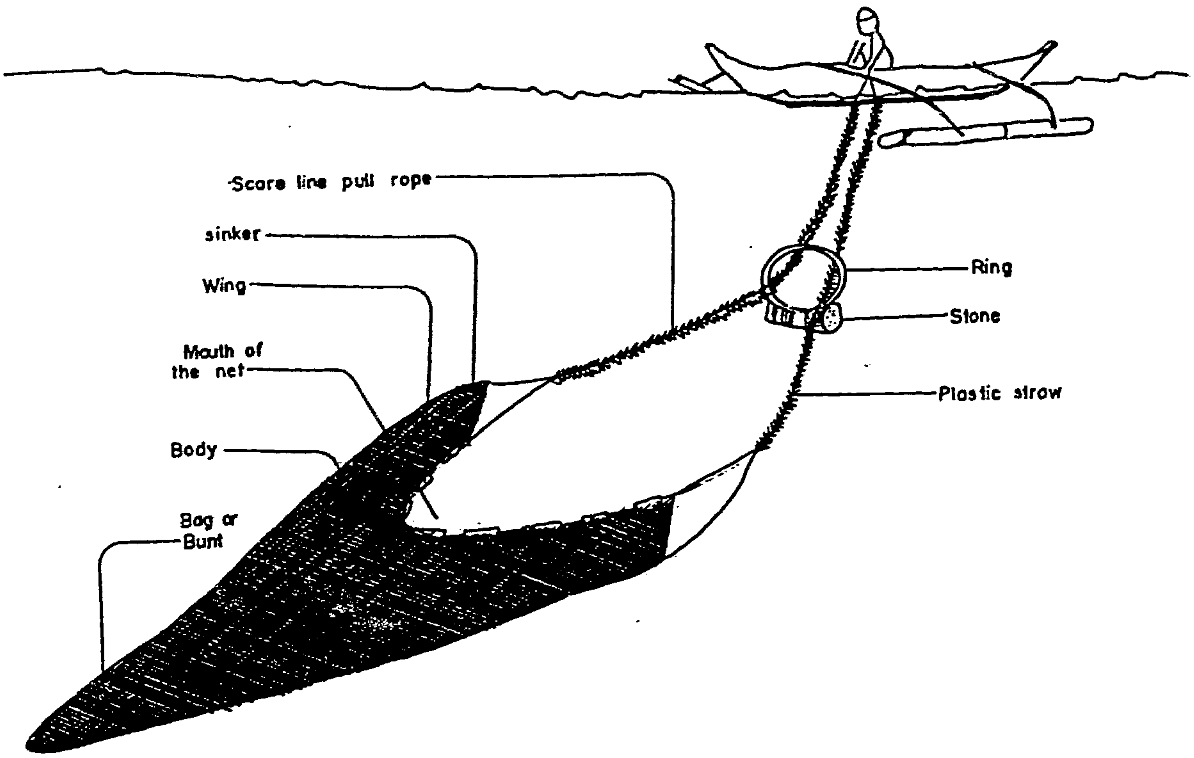

Figure 1. **Modified Danish seine**

Local names : bira-bira, basketbol
Description : It consists of a conical shaped net with a pair of wings, the ends of which are connected to two ropes with buri, plastic strips or any similar materials to serve as scaring/harding device with hauling ropes passing through a metallic ring permanently attached to a tom weight when hauled to a fishing boat.
Specifications: (average)
Length of scareline - 601.93 m
Length of net - 45.73 m
Mesh size - 3.25 cm
Capacity of catcher boat - 4.95 gt
Crew size - 8

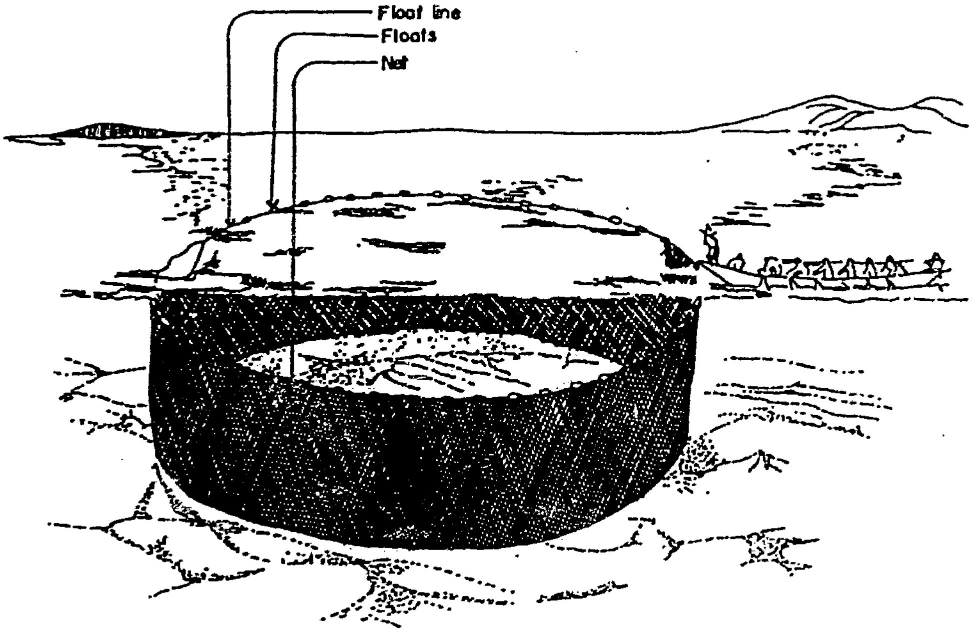

Figure 2. Encircling gill net

Local names : pukot, likos, likop

Description : It is made out in a circle or an arc of a circle, and the gilling process hastened by frightening the fish with various devices.

Specifications : (average)

Length - 591.87 m
Width - 19.53 m
Mesh size - 2.98 cm
Catcher boat - 2.57 gt
Crew size - 5

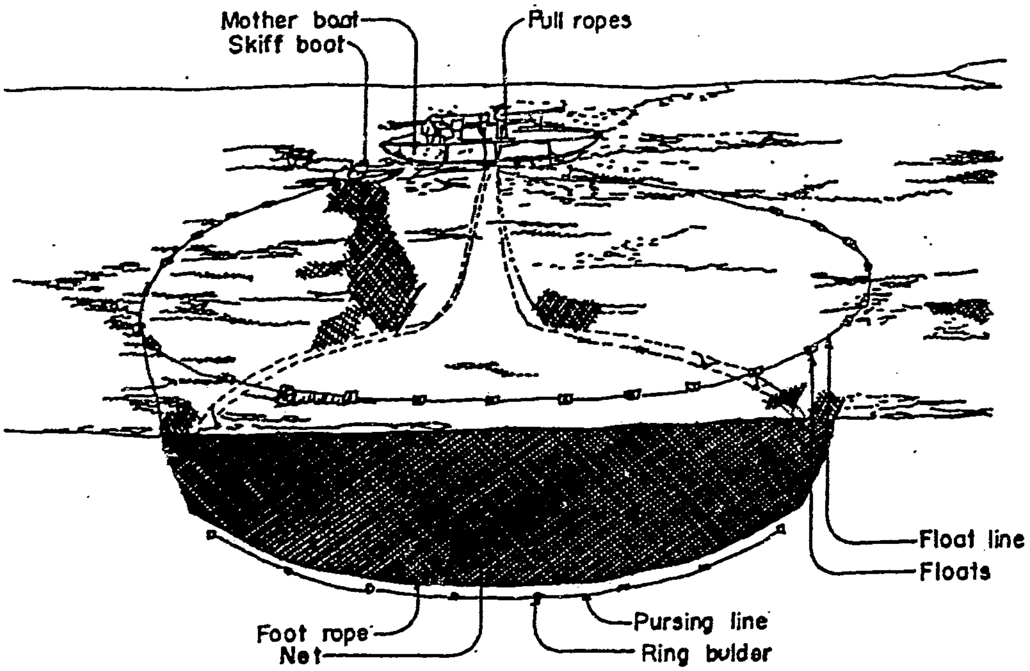

Figure 3. Purse seine

Local names : parsen, pursyan, licom-licom, kubkuban

Description : It consists of a net with the bunt or landing piece located in any side of the net and the whole net is provided with a pursing device which consists of a series of purse rings attached to the footrope by straps or ring bridles, a pursing line through the rings that closes the bottom of the seine when pulled thereby forming a trap or purse. The net is hauled by means of a power block.

Specifications : (average for commercial purse seine)

Length - 254.56 m
Width - 35.03 m
Mesh size - 2.33 cm
Capacity of catcher boat - 33.16 gt
Crew size - 32

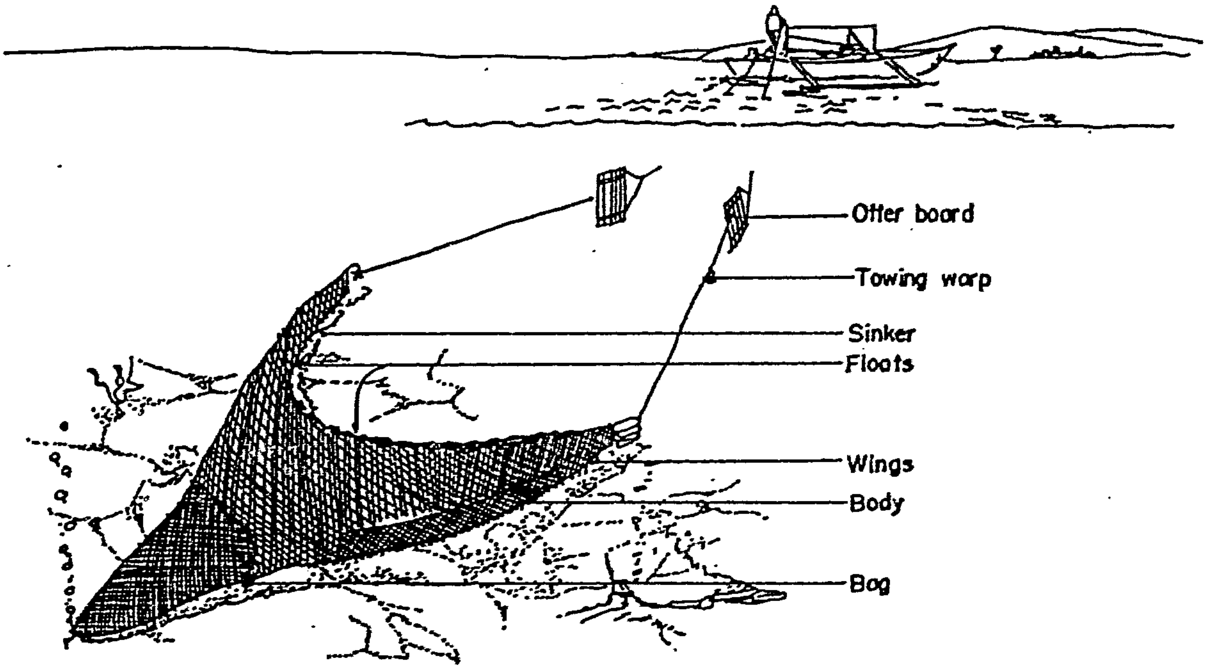

Figure 4. Trawl

Local names : Trawl, manchuria
Description : It is made in the form of conical bag with the mouth kept open by various devices and the entired gear towed or trailed, usually on the bottom of the sea to capture species that naturally thrive at or live near the bottom. It is usually classified into large, medium and baby trawls.
Specifications : (average)

Length	- 20.3 m
Width of mouth	- 7.3 m
Mesh size	- 2.6 cm
Catcher boat	- 2.4 gt
Crew size	- 2

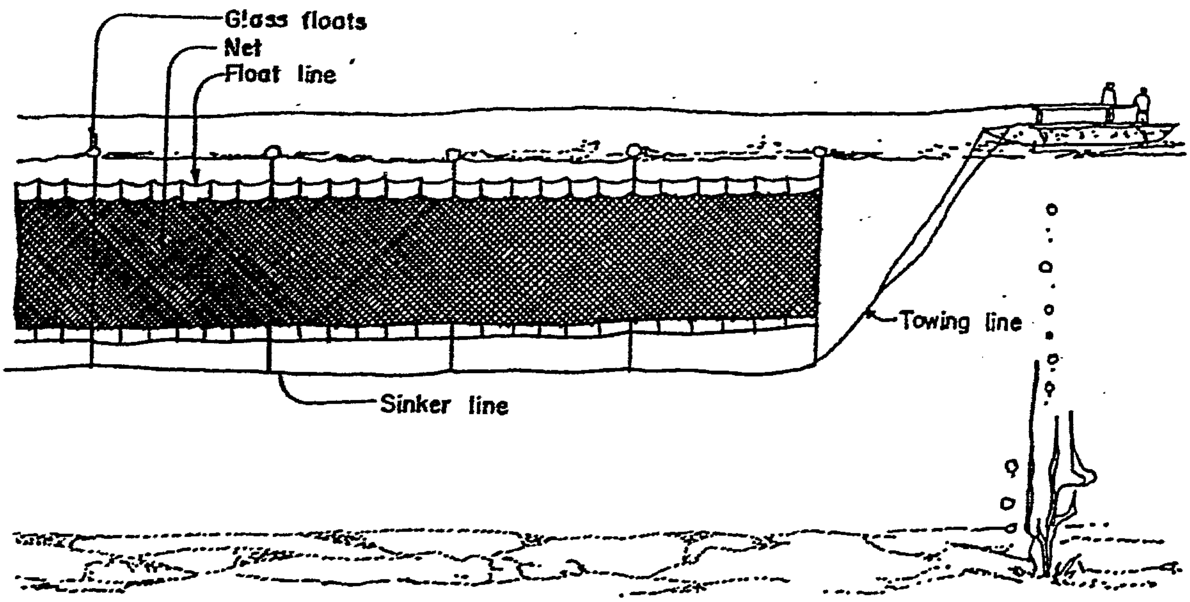

Figure 5. Drift gill net

Local names : pukot, palutaw, patuloy
Description : Usually fixed to boats or other craft and are free to move with the wind or tide.
Specifications : (average)
Length - 871.2 m
Width - 7.9 m
Mesh size - 2.9 cm
Catcher boa - 1.4 gt
Crew size - 2

Appendix D. Detailed costs and earnings per fishing trip per vessel for the sample fishing gears (amounts in pesos)

Item	Danish seine Mun	Danish seine Com	Enc'cling net Mun	Enc'cling net Com	Trawl Mun	Trawl Com	Purse seine Mun	Purse seine Com	Drift net
EARNINGS									
A. Small pelagics	702.67	2055.84	535.22	587.60	263.30	255.92	2191.43	3003.07	63.69
Sardines	34.93	65.86	426.25	534.73	2.69	0.00	242.60	315.72	49.50
Mackerels	298.97	693.82	95.92	1.57	65.54	74.89	1040.92	1534.00	0.00
Anchovy	0.00	0.00	0.00	0.00	71.57	139.11	228.74	274.26	1.62
Big-eye scad	4.19	10.00	0.00	0.00	0.00	0.00	10.00	19.17	0.00
Round scad	15.52	84.18	0.00	0.00	0.00	0.00	90.49	192.75	0.98
Round herring	0.00	0.00	6.69	3.12	5.39	0.00	1.24	1.62	3.52
Crevalle	239.70	991.73	0.15	0.00	10.93	0.00	422.27	358.01	0.00
Fusilier	0.04	0.00	0.00	6.00	0.00	0.00	0.00	0.00	0.00
Mixed small pelagics	109.32	210.25	6.21	42.18	107.18	41.92	155.17	307.54	8.07
B. Big pelagics	1.72	3.03	6.95	49.50	11.65	2.17	161.88	311.52	0.00
C. Non pelagics	569.38	1596.14	44.89	36.13	439.44	357.42	611.34	643.60	34.04
Total sold	1273.77	3655.01	587.06	673.23	714.39	615.51	2964.65	3958.19	97.74
D. Consumed	41.21	95.95	30.59	20.63	14.00	15.88	90.25	77.93	1.34
E. Employees share	38.85	31.56	8.31	10.12	6.40	6.40	503.52	266.40	1.19
F. Given away	8.48	29.89	13.77	21.77	6.28	19.55	10.17	14.39	0.12
G. Wasted	0.00	0.89	0.26	0.04	0.00	0.00	0.00	0.00	0.00
Imputed value	88.54	158.29	52.93	52.56	26.68	41.83	603.94	358.72	2.66
Total catch value	1362.31	3813.30	639.99	725.79	741.07	657.34	3568.59	4316.91	100.39
COSTS									
A. Operating expenses	314.79	710.28	189.00	159.69	236.35	250.83	759.84	996.00	31.82
Fuel	105.18	211.84	64.66	37.68	108.10	117.81	305.44	474.89	6.56
Oil	5.52	16.30	4.42	1.80	10.46	12.59	42.49	50.30	18.12
Kerosene	0.10	0.76	0.04	0.11	0.03	0.00	28.25	0.98	0.43
Ice	44.19	124.96	3.31	0.78	17.19	13.99	63.80	127.28	0.46
Food	90.49	145.23	79.87	69.91	63.28	65.16	139.53	127.21	3.35
Broker's comm.	48.58	154.99	15.56	18.20	27.27	19.95	91.42	93.76	0.00
Landing fees	6.03	19.11	0.22	1.71	1.01	0.92	7.56	10.27	0.00
Permits & licenses	0.58	0.73	0.29	0.43	0.36	0.39	0.36	0.34	0.01
Other expenses	14.12	36.36	20.63	29.07	8.65	20.02	80.99	110.97	2.88

Continuation: Appendix D

Item	Danish seine Mun	Danish seine Com	Enc'cling net Mun	Enc'cling net Com	Trawl Mun	Trawl Com	Purse seine Mun	Purse seine Com	Drift net
B. Repairs & maintenance	34.04	24.84	45.84	27.10	26.08	48.66	57.60	135.20	6.24
Boat	13.04	0.94	7.60	1.95	3.70	2.81	28.40	66.16	1.15
Net	9.44	9.98	16.38	10.53	6.33	22.03	15.40	27.32	2.40
Engine	10.88	13.83	21.39	14.62	15.91	23.82	12.99	39.17	2.70
Other assets	0.68	0.09	0.47	0.00	0.13	0.00	0.81	2.55	0.00
C. Crew share	648.47	1859.72	188.47	277.42	287.07	200.69	1333.50	1610.28	25.41
In-kind	38.85	31.56	8.31	10.12	6.40	6.40	503.52	266.40	1.19
Percent share	609.47	1827.89	180.16	267.30	280.67	194.29	826.35	1337.80	24.22
Fixed salary/others	0.15	0.27	0.00	0.00	0.00	0.00	3.63	6.08	0.00
Total variable expenses	997.30	2594.84	423.31	464.21	549.49	500.17	2150.94	2741.48	63.47
D. Depreciation	31.50	68.51	36.87	37.13	46.96	43.81	171.32	345.10	23.64
Boat	11.74	25.71	7.92	8.36	7.27	8.09	37.95	154.76	6.38
Engine	14.38	36.77	14.98	17.33	36.45	30.62	53.67	57.60	10.16
Motor	0.50	1.75	0.06	0.00	0.00	0.00	0.13	21.89	0.00
Net	3.52	3.38	11.24	11.15	2.83	4.62	71.18	105.45	6.91
Container	1.26	0.68	0.41	0.22	0.29	0.35	6.53	4.17	0.06
Other assets	0.10	0.22	2.26	0.09	0.12	0.13	1.86	1.23	0.12
Gross profit	365.01	1218.46	216.68	261.58	191.58	157.16	1417.65	1575.43	36.92
Net profit	333.51	1149.95	179.81	224.44	144.62	113.35	1246.33	1230.33	13.28

Guidelines in computations:
Total sold = sum of small pelagics, big pelagics and non-pelagic species
Imputed value = price assumed is the average price for all species caught
Total catch value = sum of catch sold and imputed value of catch
Crew share (percent share) = share from divisible earnings
Gross profit = total catch value minus total variable expenses
Net profit = gross profit minus depreciation allowances

Appendix E

Appendix Tables 1-25

Appendix Table 1. Standardized fishing effort at extreme points on the efficiency frontier for yield targets corresponding to F0.1 fishing mortality for all species groups

Gear	Minimum effort level ('000)	Extreme points on the efficiency frontier			Percentage change from minimum effort values		
		Profit max.	Interm. point	Labor max.	Profit max.	Interm. point	Labor max.
Danish seine	23,300	23,300	23,300	49,658			
Commercial	9,804	9,804	9,804	20,896	nil	nil	113
Municipal	13,496	13,496	13,496	28,763			
Encircling gill net	410	12,545	8,532	9,784			
Commercial	192	5,872	3,994	4,580	2,960	1,981	2,286
Municipal	218	6,673	4,538	5,204			
Purse seine	2,464	23,537	26,727	13,317			
Commercial	1,110	10,601	12,038	5,998	855	985	440
Municipal	1,354	12,936	14,689	7,319			
Trawl	2,750	12,091	2,750	2,750			
Commercial	533	2,344	533	533	340	nil	nil
Municipal	2,217	9,747	2,217	2,217			
Drift net							
Municipal	228	228	4,749	4,671	0	1,983	1,949
Total (all gears)	29,152	71,702	66,058	80,181			
Commercial	11,639	28,622	26,369	32,007	146	127	175
Municipal	17,513	43,080	39,689	48,174			
Values of the objective functions							
Fishing profits ('000 pesos)		397,169	376,271	330,173			
Labor utilization ('000 crewdays)		3,164	3,421	3,852			

Appendix Table 2. Distribution of catch at each extreme point on the efficiency frontier for target yields corresponding to F0.1 fishing mortality for all species groups

Fleet	Profit maximization		Intermediate point		Labor maximization	
	Catch (kg)	Percent to total	Catch (kg)	Percent to total	Catch (kg)	Percent to total
Danish seine	16,326,350	23.34	16,326,350	24.29	34,795,666	47.88
Commercial	6,390,282	9.13	6,390,282	9.51	13,619,341	18.74
Municipal	9,936,068	14.20	9,936,068	14.78	21,176,324	29.14
Encircling gill net	19,470,737	27.83	13,242,253	19.70	15,185,119	20.90
Commercial	10,324,099	14.76	7,021,522	10.45	8,051,712	11.08
Municipal	9,146,638	13.07	6,220,731	9.26	7,133,407	9.82
Purse seine	26,052,413	37.24	29,583,086	44.02	14,740,460	20.28
Commercial	13,933,228	19.92	15,821,511	23.54	7,883,431	10.85
Municipal	12,119,184	17.32	13,761,576	20.48	6,857,029	9.44
Trawl	7,808,974	11.16	1,776,092	2.64	1,776,092	2.44
Commercial	1,434,123	2.05	326,180	0.49	326,180	0.45
Municipal	6,374,851	9.11	1,449,912	2.16	1,449,912	2.00
Drift gill net						
Municipal	301,319	0.43	6,275,967	9.34	6,173,637	8.50
Total	69,959,793	100.00	67,203,748	100.00	72,670,974	100.00
Commercial	32,081,732	45.86	29,559,495	43.98	29,880,664	41.12
Municipal	37,878,061	54.14	37,644,253	56.02	42,790,310	58.88

Appendix Table 3. Optimal number of vessels and vessel tonnage at each corner point on the efficiency frontier for target yields corresponding to F0.1 fishing mortality for all species gro

Gear	Existing number of vessels	Optimal number of vessels			Existing gross tonnage	Optimal tonnage			Difference (%) a		
		Profit max	Interm. point	Labor max		Profit max	Interm. point	Labor max	Profit max	Interm. point	Labor max
Danish seine	8,585	857	857	1,826	20,390	2,035	2,035	4,337			
Commercial	2,076	207	207	442	10,516	1,050	1,050	2,237	-90.0	-90.0	-78.7
Municipal	6,508	649	649	1,384	9,873	985	985	2,100			
Encircling gill net	279	848	577	661	745	2,259	1,536	1,762			
Commercial	117	356	242	278	428	1,298	883	1,012	203.4	106.4	136.6
Municipal	162	492	334	383	317	961	654	750			
Purse seine	299	286	324	162	3,333	3,183	3,614	1,801			
Commercial	171	163	185	92	3,083	2,944	3,343	1,666	-4.5	8.4	-46.0
Municipal	128	122	139	69	250	239	271	135			
Trawl	2,182	958	218	218	4,827	2,119	482	482			
Commercial	311	136	31	31	1,584	695	158	158	-56.1	-90.0	-90.0
Municipal	1,872	821	187	187	3,244	1,424	324	324			
Drift net											
Municipal	1,768	176	3,674	3,614	1,043	104	2,168	2,132	-90.0	107.8	104.4
Total (all gears)	******	3,124	5,650	6,481	30,338	9,700	9,835	10,514	-76.2	-56.9	-50.6
Commercial	2,675	863	666	843	15,611	5,987	5,433	5,073	-67.7	-75.1	-68.5
Municipal	******	2,261	4,984	5,638	14,727	3,713	4,402	5,441	-78.3	-52.3	-46.0

a = The percentage change is the same when comparing number of vessels and gross tonnage from existing number. Also the figures listed for each fleet are the same for the entire fleet or for a given sector (municipal or commercial).

Appendix Table 4. Level of fishery capitalization at each extreme point on the efficiency frontier for target yields corresponding to F0.1 fishing mortality for all species groups

Gear	Average investment per vessel (pesos)	Current investment level ('000 pesos)	Total investment ('000 pesos)			Difference (%)		
			Profit max.	Interm. point	Labor max.	Profit max.	Interm. point	Labor max.
Danish seine		375,219	37,444	37,413	79,820			
Commercial	62,515	129,800	12,955	12,941	27,632	-90.02	-90.03	-78.71
Municipal	37,708	245,419	24,490	24,473	52,188			
Encircling gill net		13,296	40,349	27,409	31,456			
Commercial	53,017	6,222	18,874	12,830	14,739	203.35	106.21	136.89
Municipal	43,649	7,074	21,475	14,579	16,718			
Purse seine		104,309	99,404	112,941	56,137			
Commercial	439,967	75,211	71,715	81,394	40,477	-4.65	8.22	-46.18
Municipal	226,958	29,098	27,689	31,547	15,660			
Trawl		88,934	38,997	8,883	8,883			
Commercial	41,124	12,774	5,593	1,275	1,275	-56.22	-90.02	-90.02
Municipal	40,688	76,159	33,405	7,609	7,609			
Drift net								
Municipal	18,492	32,703	3,255	67,940	66,830	-90.05	107.75	104.36
Total (all gears)		614,460	219,449	254,586	243,127	-64.29	-58.57	-60.43
Commercial		224,007	109,136	108,440	84,122	-51.28	-51.59	-62.45
Municipal		390,453	110,313	146,147	159,005	-71.75	-62.57	-59.28

Appendix Table 5. Optimal number of fishermen at each extreme point on the efficiency frontier for target yields corresponding to F0.1 fishing mortality for all species groups

Gear	Estimated number of existing fishermen	Optimal number of fishermen			Difference (%)		
		Profit max	Interm. point	Labor max	Profit max	Interm. point	Labor max
Danish seine	57,023	5,691	5,691	12,129			
Commercial	16,608	1,658	1,658	3,533	-90.0	-90.0	-78.7
Municipal	40,415	4,033	4,033	8,596			
Encircling gill net	1,591	4,828	3,283	3,765			
Commercial	638	1,936	1,317	1,510	203.4	106.4	136.6
Municipal	953	2,892	1,967	2,255			
Purse seine	7,264	6,937	7,877	3,925			
Commercial	4,828	4,610	5,235	2,608	-4.5	8.4	-46.0
Municipal	2,436	2,326	2,642	1,316			
Trawl	5,479	2,405	547	547			
Commercial	857	376	86	86	-56.1	-90.0	-90.0
Municipal	4,621	2,028	461	461			
Drift net							
Municipal	4,863	485	10,104	9,940	-90.0	107.8	104.4
Total (all gears)	76,220	20,345	27,502	30,305	-73.3	-63.9	-60.2
Commercial	22,931	8,580	8,295	7,737	-62.6	-63.8	-66.3
Municipal	53,289	11,765	19,207	22,568	-77.9	-64.0	-57.6

Appendix Table 6. Standardized fishing effort at extreme points on the efficiency frontier for yield targets corresponding to maximum fishing mortality for all species groups

Gear	Minimum effort level ('000)	Extreme points on the efficiency frontier			Percentage change from minimum effort values		
		Profit max.	Interm. point	Labor max.	Profit max.	Interm. point	Labor max.
Danish seine	23,300	23,300	23,300	53,222			
Commercial	9,804	9,804	9,804	22,395	nil	nil	128
Municipal	13,496	13,496	13,496	30,826			
Encircling gill net	410	14,112	8,692	10,113			
Commercial	192	6,605	4,069	4,734	3,342	2,020	2,367
Municipal	218	7,506	4,623	5,379			
Purse seine	2,464	34,551	38,859	23,636			
Commercial	1,110	15,562	17,502	10,646	1,302	1,477	859
Municipal	1,354	18,990	21,357	12,991			
Trawl	2,750	15,364	2,750	2,750			
Commercial	533	2,979	533	533	459	nil	nil
Municipal	2,217	12,385	2,217	2,217			
Drift net							
Municipal	228	228	6,333	6,245	0	2,678	2,639
Total (all gears)	29,152	87,555	79,934	95,967			
Commercial	11,639	34,950	31,908	38,308	200	174	229
Municipal	17,513	52,605	48,026	57,658			
Values of the objective functions							
Fishing profits ('000 pesos)		517,370	489,150	436,820			
Labor utilization ('000 crewdays)		3,937	4,283	4,773			

Appendix Table 7. Distribution of catch at each extreme point on the efficiency frontier for target yields corresponding to maximum fishing mortality for all species grou

Fleet	Profit maximization		Intermediate point		Labor maximization	
	Catch (kg)	Percent to total	Catch (kg)	Percent to total	Catch (kg)	Percent to total
Danish seine	16,326,350	18.83	16,326,350	19.68	37,292,538	41.82
Commercial	6,390,282	7.37	6,390,282	7.70	14,596,672	16.37
Municipal	9,936,068	11.46	9,936,068	11.97	22,695,866	25.45
Encircling gill net	21,901,354	25.26	13,490,391	16.26	15,695,903	17.60
Commercial	11,612,904	13.40	7,153,098	8.62	8,322,546	9.33
Municipal	10,288,450	11.87	6,337,293	7.64	7,373,357	8.27
Purse seine	38,243,614	44.11	43,011,423	51.84	26,162,221	29.34
Commercial	20,453,303	23.59	23,003,213	27.72	13,991,978	15.69
Municipal	17,790,312	20.52	20,008,210	24.11	12,170,243	13.65
Trawl	9,922,916	11.45	1,776,092	2.14	1,776,092	1.99
Commercial	1,822,350	2.10	326,180	0.39	326,180	0.37
Municipal	8,100,566	9.34	1,449,912	1.75	1,449,912	1.63
Drift gill net						
Municipal	301,319	0.35	8,369,515	10.09	8,253,348	9.25
Total (all gears)	86,695,553	100.00	82,973,771	100.00	89,180,103	100.00
Commercial	40,278,839	46.46	36,872,773	44.44	37,237,376	41.76
Municipal	46,416,714	53.54	46,100,998	55.56	51,942,726	58.24

Appendix Table 8. Optimal number of vessels and vessel tonnage at each corner point on the efficiency frontier for target yields corresponding to maximum fishing mortality for all species groups

Gear	Existing number of vessels	Optimal number of vessels			Existing gross tonnage	Optimal tonnage			Difference (%) a		
		Profit max	Interm. point	Labor max		Profit max	Interm. point	Labor max	Profit max	Interm. point	Labor max
Danish seine	8,585	857	857	1,957	20,390	2,035	2,035	4,648			
Commercial	2,076	207	207	473	10,516	1,050	1,050	2,397	-90.0	-90.0	-77.2
Municipal	6,508	649	649	1,483	9,873	985	985	2,250			
Encircling gill net	279	954	587	683	745	2,541	1,565	1,821			
Commercial	117	401	247	287	428	1,460	899	1,046	241.3	110.2	144.6
Municipal	162	553	341	396	317	1,081	666	775			
Purse seine	299	419	472	287	3,333	4,672	5,255	3,196			
Commercial	171	240	270	164	3,083	4,322	4,860	2,956	40.2	57.7	-4.1
Municipal	128	180	202	123	250	351	394	240			
Trawl	2,182	1,217	218	218	4,827	2,692	482	482			
Commercial	311	173	31	31	1,584	883	158	158	-44.2	-90.0	-90.0
Municipal	1,872	1,044	187	187	3,244	1,809	324	324			
Drift net											
Municipal	1,768	176	4,900	4,832	1,043	104	2,891	2,851	-90.0	177.1	173.2
Total (all gears)	13,114	3,623	7,034	7,977	30,338	12,045	12,228	12,998	-72.4	-46.4	-39.2
Commercial	2,675	1,021	754	955	15,611	7,714	6,967	6,558	-61.8	-71.8	-64.3
Municipal	10,439	2,603	6,279	7,022	14,727	4,330	5,260	6,440	-75.1	-39.8	-32.7

a = The percentage change is the same when comparing number of vessels and gross tonnage from existing number. Also the figures listed for each fleet are the same for the entire fleet or for a given sector (municipal or commercial).

Appendix Table 9. Level of fishery capitalization at each extreme point on the efficiency frontier for target yields corresponding to maximum fishing mortality for all species groups

Gear	Average investment per vessel (pesos)	Current investment level ('000 pesos)	Total investment ('000 pesos)			Difference (%)		
			Profit max.	Interm. point	Labor max.	Profit max.	Interm. point	Labor max.
Danish seine		375,219	37,444	37,413	85,491			
Commercial	62,515	129,800	12,955	12,941	29,570	-90.02	-90.03	-77.22
Municipal	37,708	245,419	24,490	24,473	55,921			
Encircling gill net		13,296	45,398	27,980	32,501			
Commercial	53,017	6,222	21,260	13,095	15,216	241.69	110.47	144.55
Municipal	43,649	7,074	24,138	14,884	17,285			
Purse seine		104,309	146,445	164,637	100,070			
Commercial	439,967	75,211	105,592	118,791	72,155	40.40	57.94	-4.06
Municipal	226,958	29,098	40,852	45,846	27,916			
Trawl		88,934	49,592	8,883	8,883			
Commercial	41,124	12,774	7,114	1,275	1,275	-44.31	-90.02	-90.02
Municipal	40,688	76,159	42,478	7,609	7,609			
Drift net								
Municipal	18,492	32,703	3,255	90,611	89,353	-90.05	177.07	173.23
Total (all gears)		614,460	282,134	329,524	316,299	-54.08	-46.37	-48.52
Commercial		224,007	146,921	146,102	118,215	-34.41	-34.78	-47.23
Municipal		390,453	135,213	183,422	198,084	-65.37	-53.02	-49.27

Appendix Table 10. Optimal number of fishermen at each extreme point on the efficiency frontier for target yields corresponding to maximum fishing mortality for all species groups

Gear	Estimated number of existing fishermen	Optimal number of fishermen			Difference (%)		
		Profit max	Interm. point	Labor max	Profit max	Interm. point	Labor max
Danish seine	57,023	5,691	5,691	12,999			
Commercial	16,608	1,658	1,658	3,787	-90.0	-90.0	-77.2
Municipal	40,415	4,033	4,033	9,212			
Encircling gill net	1,591	5,430	3,345	3,892			
Commercial	638	2,178	1,341	1,561	241.3	110.2	144.6
Municipal	953	3,253	2,003	2,331			
Purse seine	7,264	10,183	11,452	6,966			
Commercial	4,828	6,767	7,611	4,630	40.2	57.7	-4.1
Municipal	2,436	3,415	3,841	2,336			
Trawl	5,479	3,055	547	547			
Commercial	857	478	86	86	-44.2	-90.0	-90.0
Municipal	4,621	2,577	461	461			
Drift net							
Municipal	4,863	485	13,475	13,288	-90.0	177.1	173.2
Total (all gears)	76,220	24,844	34,510	37,691	-67.4	-54.7	-50.5
Commercial	22,931	11,081	10,696	10,063	-51.7	-53.4	-56.1
Municipal	53,289	13,763	23,814	27,629	-74.2	-55.3	-48.2

Appendix Table 11. Standardized fishing effort at extreme points on the efficiency frontier for yield targets corresponding to fish length of 10 cm. for all species groups

Gear	Minimum effort level ('000)	Extreme points on the efficiency frontier			Percentage change from minimum effort values		
		Profit max.	Interm. point	Labor max.	Profit max.	Interm. point	Labor max.
Danish seine	23,300	23,300	23,300	35,907			
Commercial	9,804	9,804	9,804	15,109	nil	nil	54
Municipal	13,496	13,496	13,496	20,797			
Encircling gill net	410	11,772	9,061	9,660			
Commercial	192	5,510	4,242	4,522	2,771	2,110	2,256
Municipal	218	6,262	4,820	5,138			
Purse seine	2,464	30,753	32,908	26,494			
Commercial	1,110	13,851	14,822	11,933	1,148	1,236	975
Municipal	1,354	16,902	18,086	14,561			
Trawl	2,750	9,060	2,750	2,750			
Commercial	533	1,756	533	533	229	nil	nil
Municipal	2,217	7,303	2,217	2,217			
Drift net							
Municipal	228	2,579	5,636	5,596	1,031	2,372	2,354
Total (all gears)	29,152	77,464	73,655	80,407	166	153	176
Commercial	11,639	30,922	29,401	32,097	166	153	176
Municipal	17,513	46,542	44,255	48,310	166	153	176
Values of the objective functions							
Fishing profits ('000 pesos)		451,270	437,159	415,106			
Labor utilization ('000 crewdays)		3,711	3,884	4,090			

Appendix Table 12. Distribution of catch at each extreme point on the efficiency frontier for target yields corresponding to fish length of 10 cm for all species groups

Fleet	Profit maximization		Intermediate point		Labor maximization	
	Catch (kg)	Percent to total	Catch (kg)	Percent to total	Catch (kg)	Percent to total
Danish seine	16,326,350	20.96	16,326,350	21.47	25,159,841	31.99
Commercial	6,390,282	8.20	6,390,282	8.40	9,847,803	12.52
Municipal	9,936,068	12.76	9,936,068	13.07	15,312,038	19.47
Encircling gill net	18,270,687	23.46	14,063,536	18.50	14,992,791	19.06
Commercial	9,687,792	12.44	7,457,002	9.81	7,949,725	10.11
Municipal	8,582,894	11.02	6,606,534	8.69	7,043,066	8.95
Purse seine	34,039,309	43.70	36,424,142	47.90	29,325,204	37.29
Commercial	18,204,766	23.37	19,480,181	25.62	15,683,639	19.94
Municipal	15,834,544	20.33	16,943,961	22.28	13,641,565	17.34
Trawl	5,851,121	7.51	1,776,092	2.34	1,776,092	2.26
Commercial	1,074,564	1.38	326,180	0.43	326,180	0.41
Municipal	4,776,557	6.13	1,449,912	1.91	1,449,912	1.84
Drift gill net						
Municipal	3,408,966	4.38	7,448,614	9.80	7,395,712	9.40
Total (all gears)	77,896,432	100.00	76,038,734	100.00	78,649,640	100.00
Commercial	35,357,404	45.39	33,653,645	44.26	33,807,347	42.98
Municipal	42,539,028	54.61	42,385,090	55.74	44,842,293	57.02

Appendix Table 13. Optimal number of vessels and vessel tonnage at each corner point on the efficiency frontier for target yields corresponding to fish length of 10 cm for all species group

Gear	Existing number of vessels	Optimal number of vessels			Existing gross tonnage	Optimal tonnage			Difference (%) a		
		Profit max	Interm. point	Labor max		Profit max	Interm. point	Labor max	Profit max	Interm. point	Labor max
Danish seine	8,585	857	857	1,320	20,390	2,035	2,035	3,136			
Commercial	2,076	207	207	319	10,516	1,050	1,050	1,617	-90.0	-90.0	-84.6
Municipal	6,508	649	649	1,001	9,873	985	985	1,518			
Encircling gill net	279	796	612	653	745	2,120	1,632	1,740			
Commercial	117	334	257	274	428	1,218	937	999	184.7	119.2	133.6
Municipal	162	461	355	379	317	902	694	740			
Purse seine	299	373	399	322	3,333	4,159	4,450	3,583			
Commercial	171	213	228	184	3,083	3,847	4,116	3,314	24.8	33.5	7.5
Municipal	128	160	171	138	250	312	334	269			
Trawl	2,182	718	218	218	4,827	1,587	482	482			
Commercial	311	102	31	31	1,584	521	158	158	-67.1	-90.0	-90.0
Municipal	1,872	616	187	187	3,244	1,067	324	324			
Drift net											
Municipal	1,768	1,996	4,361	4,330	1,043	1,178	2,573	2,555	12.9	146.6	144.8
Total (all gears)	13,114	4,739	6,447	6,842	30,338	11,078	11,171	11,495	-63.9	-50.8	-47.8
Commercial	2,675	857	724	808	15,611	6,635	6,261	6,089	-68.0	-72.9	-69.8
Municipal	10,439	3,882	5,723	6,034	14,727	4,444	4,910	5,406	-62.8	-45.2	-42.2

a = The percentage change is the same when comparing number of vessels and gross tonnage from existing number. Also the figures listed for each fleet are the same for the entire fleet or for a given sector (municipal or commercial).

Appendix Table 14. Level of fishery capitalization at each extreme point on the efficiency frontier for target yields corresponding to fish length of 10 cm for all species groups

Gear	Average investment per vessel (pesos)	Current investment level ('000 pesos)	Total investment ('000 pesos)			Difference (%)		
			Profit max.	Interm. point	Labor max.	Profit max.	Interm. point	Labor max.
Danish seine		375,219	37,444	37,413	57,688			
Commercial	62,515	129,800	12,955	12,941	19,942	-90.02	-90.03	-84.64
Municipal	37,708	245,419	24,490	24,473	37,746			
Encircling gill net		13,296	37,830	29,121	31,070			
Commercial	53,017	6,222	17,708	13,625	14,527	184.60	118.99	133.48
Municipal	43,649	7,074	20,122	15,495	16,543			
Purse seine		104,309	130,026	139,122	112,274			
Commercial	439,967	75,211	93,713	100,313	80,954	24.60	33.38	7.64
Municipal	226,958	29,098	36,313	38,810	31,320			
Trawl		88,934	29,258	8,883	8,883			
Commercial	41,124	12,774	4,195	1,275	1,275	-67.16	-90.02	-90.02
Municipal	40,688	76,159	25,064	7,609	7,609			
Drift net								
Municipal	18,492	32,703	36,910	80,644	80,070	12.86	146.59	144.84
Total (all gears)		614,460	271,469	295,184	289,986	-55.82	-51.96	-52.81
Commercial		224,007	128,570	128,154	116,698	-42.60	-42.79	-47.90
Municipal		390,453	142,899	167,030	173,288	-63.40	-57.22	-55.62

Appendix Table 15. Optimal number of fishermen at each extreme point on the efficiency frontier for target yields corresponding to fish length of 10 cm for all species groups

Gear	Estimated number of existing fishermen	Optimal number of fishermen			Difference (%)		
		Profit max	Interm. point	Labor max	Profit max	Interm. point	Labor max
Danish seine	57,023	5,691	5,691	8,770			
Commercial	16,608	1,658	1,658	2,555	-90.0	-90.0	-84.6
Municipal	40,415	4,033	4,033	6,215			
Encircling gill net	1,591	4,530	3,487	3,717			
Commercial	638	1,817	1,398	1,491	184.7	119.2	133.6
Municipal	953	2,713	2,089	2,227			
Purse seine	7,264	9,063	9,698	7,808			
Commercial	4,828	6,023	6,445	5,189	24.8	33.5	7.5
Municipal	2,436	3,040	3,253	2,619			
Trawl	5,479	1,802	547	547			
Commercial	857	282	86	86	-67.1	-90.0	-90.0
Municipal	4,621	1,520	461	461			
Drift net							
Municipal	4,863	5,488	11,992	11,907	12.9	146.6	144.8
Total (all gears)	76,220	26,574	31,415	32,749	-65.1	-58.8	-57.0
Commercial	22,931	9,780	9,587	9,320	-57.4	-58.2	-59.4
Municipal	53,289	16,794	21,828	23,429	-68.5	-59.0	-56.0

Appendix Table 16. Standardized fishing effort at extreme points on the efficiency frontier for yield targets corresponding to fish length of 12 cm. for all species groups

Gear	Minimum effort level ('000)	Extreme points on the efficiency frontier			Percentage change from minimum effort values		
		Profit max.	Interm. point	Labor max.	Profit max.	Interm. point	Labor max.
Danish seine	23,300	23,300	23,300	25,048			
Commercial	9,804	9,804	9,804	10,540	nil	nil	8
Municipal	13,496	13,496	13,496	14,508			
Encircling gill net	410	10,201	7,715	7,798			
Commercial	192	4,775	3,611	3,650	2,388	1,782	1,802
Municipal	218	5,426	4,104	4,148			
Purse seine	2,464	32,839	34,815	33,925			
Commercial	1,110	14,791	15,681	15,280	1,233	1,313	1,277
Municipal	1,354	18,048	19,134	18,645			
Trawl	2,750	8,535	2,750	2,750			
Commercial	533	1,655	533	533	210	nil	nil
Municipal	2,217	6,881	2,217	2,217			
Drift net							
Municipal	228	2,846	5,646	5,640	1,148	2,376	2,374
Total (all gears)	29,152	77,721	74,226	75,162			
Commercial	11,639	31,025	29,630	30,004	167	155	158
Municipal	17,513	46,696	44,596	45,159			
Values of the objective functions							
Fishing profits ('000 pesos)		457,499	444,557	441,499			
Labor utilization ('000 crewdays)		3,788	3,946	3,975			

Appendix Table 16. Distribution of catch at each extreme point on the efficiency frontier for target yields corresponding to fish length of 12 cm for all species groups

Fleet	Profit maximization		Intermediate point		Labor maximization	
	Catch (kg)	Percent to total	Catch (kg)	Percent to total	Catch (kg)	Percent to total
Danish seine	16,326,350	20.99	16,326,350	21.46	17,551,425	22.96
Commercial	6,390,282	8.22	6,390,282	8.40	6,869,796	8.99
Municipal	9,936,068	12.77	9,936,068	13.06	10,681,629	13.97
Encircling gill net	15,831,921	20.35	11,974,333	15.74	12,103,199	15.83
Commercial	8,394,663	10.79	6,349,228	8.35	6,417,565	8.40
Municipal	7,437,258	9.56	5,625,105	7.39	5,685,634	7.44
Purse seine	36,348,342	46.73	38,535,055	50.66	37,550,606	49.13
Commercial	19,439,700	24.99	20,609,181	27.09	20,082,665	26.27
Municipal	16,908,642	21.74	17,925,874	23.56	17,467,941	22.85
Trawl	5,512,547	7.09	1,776,092	2.33	1,776,092	2.32
Commercial	1,012,381	1.30	326,180	0.43	326,180	0.43
Municipal	4,500,165	5.79	1,449,912	1.91	1,449,912	1.90
Drift gill net						
Municipal	3,760,571	4.83	7,460,958	9.81	7,454,178	9.75
Total	77,779,730	100.00	76,072,787	100.00	76,435,501	100.00
Commercial	35,237,026	45.30	33,674,871	44.27	33,696,206	44.08
Municipal	42,542,704	54.70	42,397,916	55.73	42,739,294	55.92

Appendix Table 18. Optimal number of vessels and vessel tonnage at each corner point on the efficiency frontier for target yields corresponding to fish length of 12 cm for all species group

Gear	Existing number of vessels	Optimal number of vessels			Existing gross tonnage	Optimal tonnage			Difference (%) a		
		Profit max	Interm. point	Labor max		Profit max	Interm. point	Labor max	Profit max	Interm. point	Labor max
Danish seine	8,585	857	857	921	20,390	2,035	2,035	2,187			
Commercial	2,076	207	207	223	10,516	1,050	1,050	1,128	-90.0	-90.0	-89.3
Municipal	6,508	649	649	698	9,873	985	985	1,059			
Encircling gill net	279	689	521	527	745	1,837	1,389	1,404			
Commercial	117	290	219	221	428	1,055	798	807	146.7	86.6	88.6
Municipal	162	400	302	306	317	782	591	598			
Purse seine	299	399	423	412	3,333	4,441	4,708	4,588			
Commercial	171	228	241	235	3,083	4,108	4,355	4,243	33.2	41.3	37.6
Municipal	128	171	181	176	250	333	353	344			
Trawl	2,182	676	218	218	4,827	1,496	482	482			
Commercial	311	96	31	31	1,584	491	158	158	-69.0	-90.0	-90.0
Municipal	1,872	580	187	187	3,244	1,005	324	324			
Drift net											
Municipal	1,768	2,202	4,368	4,364	1,043	1,299	2,577	2,575	24.5	147.0	146.8
Total (all gears)	13,114	4,822	6,387	6,442	30,338	11,107	11,191	11,236	-63.2	-51.3	-50.9
Commercial	2,675	821	699	710	15,611	6,703	6,360	6,337	-69.3	-73.9	-73.4
Municipal	10,439	4,002	5,688	5,731	14,727	4,404	4,831	4,900	-61.7	-45.5	-45.1

a = The percentage change is the same when comparing number of vessels and gross tonnage from existing number. Also the figures listed for each fleet are the same for the entire fleet or for a given sector (municipal or commercial).

Appendix Table 19. Level of fishery capitalization at each extreme point on the efficiency frontier for target yields corresponding to fish length of 12 cm for all species groups

Gear	Average investment per vessel (pesos)	Current investment level ('000 pesos)	Total investment ('000 pesos)			Difference (%)		
			Profit max.	Interm. point	Labor max.	Profit max.	Interm. point	Labor max.
Danish seine		375,219	37,444	37,413	40,261			
Commercial	62,515	129,800	12,955	12,941	13,941	-90.02	-90.03	-89.26
Municipal	37,708	245,419	24,490	24,473	26,320			
Encircling gill net		13,296	32,835	24,793	25,073			
Commercial	53,017	6,222	15,375	11,611	11,717	147.11	86.61	88.32
Municipal	43,649	7,074	17,460	13,182	13,357			
Purse seine		104,309	139,122	147,112	143,337			
Commercial	439,967	75,211	100,313	106,032	103,392	33.38	40.98	37.47
Municipal	226,958	29,098	38,810	41,079	39,945			
Trawl		88,934	27,547	8,883	8,883			
Commercial	41,124	12,774	3,948	1,275	1,275	-69.10	-90.02	-90.02
Municipal	40,688	76,159	23,599	7,609	7,609			
Drift net								
Municipal	18,492	32,703	40,719	80,773	80,699	24.51	146.99	146.76
Total (all gears)		614,460	277,667	298,974	298,254	-54.81	-51.34	-51.46
Commercial		224,007	132,590	131,858	130,325	-40.81	-41.14	-41.82
Municipal		390,453	145,077	167,116	167,929	-62.84	-57.20	-56.99

Appendix Table 20. Optimal number of fishermen at each extreme point on the efficiency frontier for target yields corresponding to fish length of 12 cm for all species groups

Gear	Estimated number of existing fishermen	Optimal number of fishermen			Difference (%)		
		Profit max	Interm. point	Labor max	Profit max	Interm. point	Labor max
Danish seine	57,023	5,691	5,691	6,118			
Commercial	16,608	1,658	1,658	1,782	-90.0	-90.0	-89.3
Municipal	40,415	4,033	4,033	4,336			
Encircling gill net	1,591	3,925	2,969	3,001			
Commercial	638	1,574	1,191	1,203	146.7	86.6	88.6
Municipal	953	2,351	1,778	1,797			
Purse seine	7,264	9,678	10,260	9,998			
Commercial	4,828	6,432	6,819	6,645	33.2	41.3	37.6
Municipal	2,436	3,246	3,441	3,353			
Trawl	5,479	1,697	547	547			
Commercial	857	266	86	86	-69.0	-90.0	-90.0
Municipal	4,621	1,432	461	461			
Drift net							
Municipal	4,863	6,054	12,012	12,001	24.5	147.0	146.8
Total (all gears)	76,220	27,046	31,479	31,665	-64.5	-58.7	-58.5
Commercial	22,931	9,930	9,753	9,716	-56.7	-57.5	-57.6
Municipal	53,289	17,116	21,726	21,949	-67.9	-59.2	-58.8

Appendix Table 21. Standardized fishing effort at extreme points on the efficiency frontier for yield targets corresponding to fish length of 14 cm. for all species groups

Gear	Minimum effort level ('000)	Extreme points on the efficiency frontier			Percentage change from minimum effort values		
		Profit max.	Interm. point	Labor max.	Profit max.	Interm. point	Labor max.
Danish seine	23,300	23,300	n.a.	23,300			
Commercial	9,804	9,804	n.a.	9,804	nil	n.a.	0
Municipal	13,496	13,496	n.a.	13,496			
Encircling gill net	410	12,354	n.a.	10,023			
Commercial	192	5,783	n.a.	4,692	2,913	n.a.	2,345
Municipal	218	6,571	n.a.	5,331			
Purse seine	2,464	10,454	n.a.	11,471			
Commercial	1,110	4,708	n.a.	5,167	324	n.a.	366
Municipal	1,354	5,745	n.a.	6,305			
Trawl	2,750	8,763	n.a.	2,750			
Commercial	533	1,699	n.a.	533	219	n.a.	nil
Municipal	2,217	7,064	n.a.	2,217			
Drift net							
Municipal	228	228,000	n.a.	3,049	99,900	n.a.	1,237
Total (all gears)	29,152	282,871	n.a.	50,593	870	n.a.	74
Commercial	11,639	21,995	n.a.	20,196	89	n.a.	74
Municipal	17,513	260,876	n.a.	30,397	1,390	n.a.	74
Values of the objective functions							
Fishing profits ('000 pesos)		689,116	n.a.	247,086			
Labor utilization ('000 crewdays)		30,871	n.a.	2,426			

n.a. = not applicable, no intermediate point

Appendix Table 22. Distribution of catch at each extreme point on the efficiency frontier for target yields corresponding to fish length of 14 cm for all species groups

Fleet	Profit maximization		Intermediate point		Labor maximization	
	Catch (kg)	Percent to total	Catch (kg)	Percent to total	Catch (kg)	Percent to total
Danish seine	16,326,350	30.79	n.a.	n.a.	16,326,350	32.40
Commercial	6,390,282	12.05	n.a.	n.a.	6,390,282	12.68
Municipal	9,936,068	18.74	n.a.	n.a.	9,936,068	19.72
Encircling gill net	19,173,914	36.16	n.a.	n.a.	15,556,019	30.87
Commercial	10,166,714	19.17	n.a.	n.a.	8,248,372	16.37
Municipal	9,007,200	16.98	n.a.	n.a.	7,307,647	14.50
Purse seine	11,570,775	21.82	n.a.	n.a.	12,696,997	25.20
Commercial	6,188,235	11.67	n.a.	n.a.	6,790,561	13.48
Municipal	5,382,540	10.15	n.a.	n.a.	5,906,436	11.72
Trawl	5,659,620	10.67	n.a.	n.a.	1,776,092	3.53
Commercial	1,039,392	1.96	n.a.	n.a.	326,180	0.65
Municipal	4,620,228	8.71	n.a.	n.a.	1,449,912	2.88
Drift gill net						
Municipal	301,319	0.57	n.a.	n.a.	4,029,261	8.00
Total (all gears)	53,031,978	100.00	n.a.	n.a.	50,384,719	100.00
Commercial	23,784,624	44.85	n.a.	n.a.	21,755,395	43.18
Municipal	29,247,354	55.15	n.a.	n.a.	28,629,324	56.82

n.a. = not applicable, no intermediate point

Appendix Table 23. Optimal number of vessels and vessel tonnage at each corner point on the efficiency frontier for target yields corresponding to fish length of 14 cm for all species group

Gear	Existing number of vessels	Optimal number of vessels			Existing gross tonnage	Optimal tonnage			Difference (%) a		
		Profit max	Interm. point	Labor max		Profit max	Interm. point	Labor max	Profit max	Interm. point	Labor max
Danish seine	8,585	857	n.a.	857	20,390	2,035	n.a.	2,035			
Commercial	2,076	207	n.a.	207	10,516	1,050	n.a.	1,050	-90.0	n.a.	-90.0
Municipal	6,508	649	n.a.	649	9,873	985	n.a.	985			
Encircling gill net	279	835	n.a.	677	745	2,225	n.a.	1,805			
Commercial	117	351	n.a.	284	428	1,278	n.a.	1,037	198.8	n.a.	142.4
Municipal	162	484	n.a.	393	317	947	n.a.	768			
Purse seine	299	127	n.a.	139	3,333	1,414	n.a.	1,551			
Commercial	171	73	n.a.	80	3,083	1,308	n.a.	1,435	-57.6	n.a.	-53.5
Municipal	128	54	n.a.	60	250	106	n.a.	116			
Trawl	2,182	694	n.a.	218	4,827	1,535	n.a.	482			
Commercial	311	99	n.a.	31	1,584	504	n.a.	158	-68.2	n.a.	-90.0
Municipal	1,872	595	n.a.	187	3,244	1,032	n.a.	324			
Drift net											
Municipal	1,768	176	n.a.	2,359	1,043	104	n.a.	1,392	-90.0	n.a.	33.4
Total (all gears)	13,114	2,689	n.a.	4,250	30,338	7,313	n.a.	7,265	-79.5	n.a.	-67.6
Commercial	2,675	729	n.a.	602	15,611	4,139	n.a.	3,679	-72.7	n.a.	-77.5
Municipal	10,439	1,960	n.a.	3,648	14,727	3,174	n.a.	3,585	-81.2	n.a.	-65.1

a = The percentage change is the same when comparing number of vessels and gross tonnage from existing number. Also the figures listed for each fleet are the same for the entire fleet or for a given sector (municipal or commercial).

n.a.= not applicable, no intermediate point

Appendix Table 24. Level of fishery capitalization at each extreme point on the efficiency frontier for target yields corresponding to fish length of 14 cm for all species groups

Gear	Average investment per vessel (pesos)	Current investment level ('000 pesos)	Total investment ('000 pesos)			Difference (%)		
			Profit max.	Interm. point	Labor max.	Profit max.	Interm. point	Labor max.
Danish seine		375,219	37,444	n.a.	37,413			
Commercial	62,515	129,800	12,955	n.a.	12,941	-90.0	n.a.	-90.0
Municipal	37,708	245,419	24,490	n.a.	24,473			
Encircling gill net		13,296	39,735	n.a.	32,211			
Commercial	53,017	6,222	18,609	n.a.	15,057	199.1	n.a.	142.0
Municipal	43,649	7,074	21,126	n.a.	17,154			
Purse seine		104,309	44,373	n.a.	48,815			
Commercial	439,967	75,211	32,118	n.a.	35,197	-57.3	n.a.	-53.2
Municipal	226,958	29,098	12,256	n.a.	13,617			
Trawl		88,934	28,280	n.a.	8,883			
Commercial	41,124	12,774	4,071	n.a.	1,275	-68.1	n.a.	-90.0
Municipal	40,688	76,159	24,209	n.a.	7,609			
Drift net								
Municipal	18,492	32,703	3,255	n.a.	43,623	-90.0	n.a.	33.4
Total (all gears)		614,460	153,088	n.a.	170,945	-75.1	n.a.	-72.2
Commercial		224,007	67,753	n.a.	64,470	-69.8	n.a.	-71.2
Municipal		390,453	85,335	n.a.	106,475	-78.1	n.a.	-72.7

n.a. = not applicable, no intermediate point

Appendix Table 25. Optimal number of fishermen at each extreme point on the efficiency frontier for target yields corresponding to fish length of 14 cm for all species groups

Gear	Estimated number of existing fishermen	Optimal number of fishermen			Difference (%)		
		Profit max	Interm. point	Labor max	Profit max	Interm. point	Labor max
Danish seine	57,023	5,691	n.a.	5,691			
Commercial	16,608	1,658	n.a.	1,658	-90.0	n.a.	-90.0
Municipal	40,415	4,033	n.a.	4,033			
Encircling gill net	1,591	4,754	n.a.	3,857			
Commercial	638	1,907	n.a.	1,547	198.8	n.a.	142.4
Municipal	953	2,847	n.a.	2,310			
Purse seine	7,264	3,081	n.a.	3,381			
Commercial	4,828	2,048	n.a.	2,247	-57.6	n.a.	-53.5
Municipal	2,436	1,033	n.a.	1,134			
Trawl	5,479	1,743	n.a.	547			
Commercial	857	273	n.a.	86	-68.2	n.a.	-90.0
Municipal	4,621	1,470	n.a.	461			
Drift net							
Municipal	4,863	485	n.a.	6,487	-90.0	n.a.	33.4
Total (all gears)	76,220	15,753	n.a.	19,962	-79.3	n.a.	-73.8
Commercial	22,931	5,885	n.a.	5,537	-74.3	n.a.	-75.9
Municipal	53,289	9,869	n.a.	14,426	-81.5	n.a.	-72.9

n.a. = not applicable, no intermediate point