Chapter 1

INTRODUCTION

1.1 Background

In 1990, capture fisheries in Indonesia accounted for 2,662,622 tonnes or 84.2 per cent of the national fish production (Directorate General of Fisheries (DGF) 1992). Most fish production is contributed by marine capture fisheries (74.9 per cent). Inland capture fisheries have contributed relatively little to national fish production (9.2 per cent). In terms of number of fishers (Table 1), inland open-water fisheries have accounted for less than a quarter of total fisheries' employment. The fishery is considered a small-scale fishery. However, fishing in inland water body resources, such as floodplains, rivers and lakes, has an important role for the rural people. The fishery generates significant income and provides employment opportunities. It also has an important role as a source of protein in the diets of many households, both in rural areas and urban centres.

Fishing is traditionally considered to be an important occupation for many rural people living in the floodplains of the Musi River and its major tributaries in South Sumatra, Indonesia. Fishing patterns in that particular area are significantly affected by fluctuations in water levels. In line with this, Welcomme (1985) observed that in most artisanal fishing communities, fishing patterns were influenced by local traditions, legends and even religious systems which enable communities to integrate culturally with the general ecology of fishery resources on which they live. In general, fishing patterns are indicated by fishing seasons, which can be distinguished as high water (December to February), receding water (March to May), low water (June to August) and rising water (September to November). The types of fishing unit used in each season may depend on fishing grounds.

Table 1.1 Number of fishers and fisheries production in Indonesia according to type of resource, 1983-1990

Year	Marine Capture		Inland Capture		T o t a l	
	Fishers (household)	Production (ton)	Fishers (household)	Production (ton)	Fishers (household)	Production[1] (ton)
1983	1,226,643	1,682,019	424,726	265,562	1,651,369	2,214,557
	(74.3)[2]	(76.0)	(25.7)	(12.0)	(100.0)	(100.0)
1984	1,294,472	1,712,804	438,953	269,321	1,733,425	2,261,065
	(74.7)	(75.8)	(25.3)	(11.9)	(100.0)	(100.0)
1985	1,286,448	1,821,725	434,290	269,266	1,720,738	2,395,638
	(74.8)	(76.0)	(25.2)	(11.2)	(100.0)	(100.0)
1986	1,357,279	1,922,781	450,382	273,012	1,807,661	2,529,966
	(75.1)	(76.0)	(24.9)	(10.8)	(100.0)	(100.0)
1987	1,372,430	2,017,350	457,553	276,291	1,829,983	2,670,489
	(75.0)	(75.5)	(25.0)	(10.4)	(100.0)	(100.0)
1988	1,417,424	2,169,557	461,619	281,264	1,879,043	2,881,244
	(75.4)	(75.3)	(24.6)	(9.8)	(100.0)	(100.0)
1989	1,463,875	2,272,179	437,504	296,385	1,901,379	3,035,343
	(77.0)	(74.9)	(23.0)	(9.8)	(100.0)	(100.0)
1990	1,524,348	2,370,107	470,942	292,537	1,995,290	3,162,544
	(76.4)	(74.9)	(23.6)	(9.2)	(100.0)	(100.0)

Source: DGF, 1992.

Note: 1) Total production includes the production from aquaculture.

2) Values in parentheses are percentages.

During the decade 1982-1991 fishery production from major fishing grounds, e.g., Lubuk Lampam, has shown a tendency to decrease (Table 2). The fisheries have deteriorated. On the other hand, fishing on that particular fisheries resources have significantly increased. This condition has led to a reduction in available fish stock. The fishery is likely to face a problem of over-fishing. In addition to this problem, local authority systems seem to be insufficient to maintain productivity and sustainability of the resource. This implies that the important task of maintaining the flow of benefits derived from the fishery may not be fulfilled. Hence. the community faces problems of lower and more unevenly distributed income.

The inland fishery in South Sumatra is generated from the system of freshwater bodies in Indonesia. The fishery resource consists of the main river itself, swamp areas (*rawang*), and small lakes (*lebung*). The river and small lakes contain water throughout the year, while the swamp areas tend to lose their water during the dry season.

A decline in stocks of certain commercial species has occurred in the inland fishery in South Sumatra. This is one indication that the fishery is being over-fished. The present rate of exploitation of such resources may be unsustainable, both from biological as well as economic points of view. Better fishery management needs to be imposed in order to maintain productivity of the fishery resource on a sustainable basis.

Unlike marine fisheries, inland capture fisheries have received relatively little attention from scientists. The problems, however, may be more complicated than those in the marine fisheries.

Table 1.2 Selected species of harvested fish from Lubuk Lampam fishing ground in South Sumatra, 1985-1993

Year	Species				
	Common Snakehead (tonnes)	Catfish (tonnes)	Giant Snakehead (tonnes)	Featherback (tonnes)	Freshwater Prawn (tonnes)
1985	6,896.50	4,179.80	986.50	36.00	2,063.40
1986	8,688.90	2,440.80	200.00	-	468.50
1987	6,090.80	1,869.10	2,023.30	50.00	409.90
1988	12,516.60	1,693.30	808.40	84.10	356.30
1989	643.00	4,052.50	500.00	152.00	639.50
1990	7,616.40	1,524.00	289.70	179.00	1,501.00
1991	9,565.50	4,683.70	52.00	133.50	736.20
1992	21,387.00	1,472.00	50.00	-	176.80
1993	15,043.00	2,771.90	890.70	2.20	497.20

Source: Research station of RIFF Mariana, South Sumatra *(Sub Balai Penelitian Perikanan Air Tawar, Mariana, Sumatra Selatan).* various years

1.2 Problem Statement

According to present practices, the inland fisheries resource allocation in South Sumatra may have assigned property rights. Some resources are managed by the community and based on traditional fishing rights. However, problems similar to those of an open-access fishery commonly occur. Under such management, each individual can maximise his or her individual benefits from the resource. The tendency is for the fishing community to deplete the resource. Consequently, the fishing community faces problems of lower and more unevenly distributed income. The productivity and sustainability of utilising resources cannot be maintained.

An open-access fishery may lead to over-fishing from both biological and economic points of view. Biological over-fishing occurs when growth of the stock is lower than the rate of harvest. Economic over-fishing occurs under open-access conditions because fishers are attracted by expected high rates of return from harvesting the fish stock. This tends to attract more investment long after the marginal rate of return from the fishery becomes negative. This was explained by Gordon (1954).

One possible solution to this kind of problem is to introduce a form of collective management of the fishery resource which changes the 'open-access' resource to a 'common property' resource. The concept of 'common property' resource means a redistribution of property rights so that a number of owners have rights. However, implementation of collective management becomes difficult when there are divergent interests in a 'common property' resource.

The formulation of appropriate management strategies for the use of publicly-owned natural resources, such as an inland fishery resource, has become one of the major problems for the society under study. For decision-makers, the question of to whom to assign property rights is difficult because it involves an assessment of who can use the resources in the best interests of society. Practically, a major problem confronting management policies is determination of the type and level of control which should be applied to fisheries in order to achieve objectives of maintaining the flow of benefits derived from the fishery and improving the productivity of the resources on a sustainable basis.

1.3 Objective of the Study

In general, the objective of the study is to identify an efficient level of fishery resource exploitation which will maximise social welfare. Specifically the objectives of this study are:

i. to evaluate existing fishery management;

ii. to formulate analytical tools to analyse fisheries resource allocation and property right systems, and

iii. to determine the type and level of management options which may be applied.

1.4 Hypothesis

It is hypothesised that under current fishery management the fishery resource is over-exploited from both biological and economic viewpoints and that better systems of management are not 'exist' but 'can be found'.

1.5 Organisation of the Thesis

The thesis will be arranged as follows. Chapter 2 describes the study area and its general characteristics, the fisheries production systems or fisheries resource allocation, the fishing community, demand relations in the market and fishing management that is currently practised. The methodology, in terms of conceptual framework and analytical tools, is described in Chapter 3. Relevant literature and previous studies on this topic are also reviewed. In this chapter, general bioeconomic approaches to fishery systems are examined. The selected bioeconomic model to represent the inland fishery in South Sumatra is selected. Chapter 4 consists of a description of the data, parameters of the model and estimation procedures. The appropriate bioeconomic model to represent the inland fishery in South Sumatra is selected. Chapter 5 is used to present empirical results for the study. These consist of development of the bioeconomic model, prediction of an optimal yield and an evaluation of current conditions in the fishery. The production function for the fishery is derived. This, in turn, is used to provide estimates of supply from the fishery for particular resources. Demand for the fish is also estimated in this chapter. Optimum yield is expressed in terms of the Maximum Sustainable Yield (MSY), the Maximum Economic Yield (MEY) and the Maximum Social Yield (MScY). Then, based on these results, current fishery management is evaluated. Chapter 6 is used to assess the nature of inland fishery resource allocation and property right systems. Management options, simulation and policy implications are presented in Chapter 7. Finally, Chapter 8 provides a summary and conclusions from the study. It also discusses the limitations of the study, possible solutions to the problems discussed in the thesis and offers suggestions for further research.

Chapter 2

THE STUDY AREA

2.1 Introduction

South Sumatra province, Indonesia (Figure 2.1), is located in the southern latitude range of 1^{O} to 4^{O} and the eastern longitude range of 102^{O} to 108^{O}. On the northern, western and southern parts of the region, it is bordered by the provinces of Jambi, Lampung and Bengkulu, respectively. On the eastern side, the region is adjacent to Karimata Straits and the Java Sea. The province covers an area of 109,254 km^2 and is divided into 10 regencies (BPS 1994).

According to Kaida (1980), South Sumatra is formed by a sharp slope rising from the west coast towards the Barisan mountain range, which includes many high peaks of 1,000 - 1,500 m and several steep volcanic cones. Towards the northeast the region is an upland area with an elevation ranging from 500 to 1,000 m. The upland area also covers hills of the Barisan mountain range with an elevation ranging from 100 to 500 m. Towards the Java Sea, the region gradually drops with a very small gradient (elevation 10 - 100 m) through the low terraces of the coastal plain.

The province of South Sumatra has important rivers, such as the Musi, Ogan and Komering. The rivers spring from the Barisan mountain and are squeezed by a low hill in the vicinity of the capital city Palembang. This hydrological condition creates an extensive, swampy and constricted river basin. Temperature is about 21.5 - 32.7 °C. Rain falls throughout the year with the exception of a short dry period of 2-4 dry months, with an average of 213 mm per month (1,500 to 3,200 mm per year) of rainfall. Humidity ranges from 82 to 9 per cent.

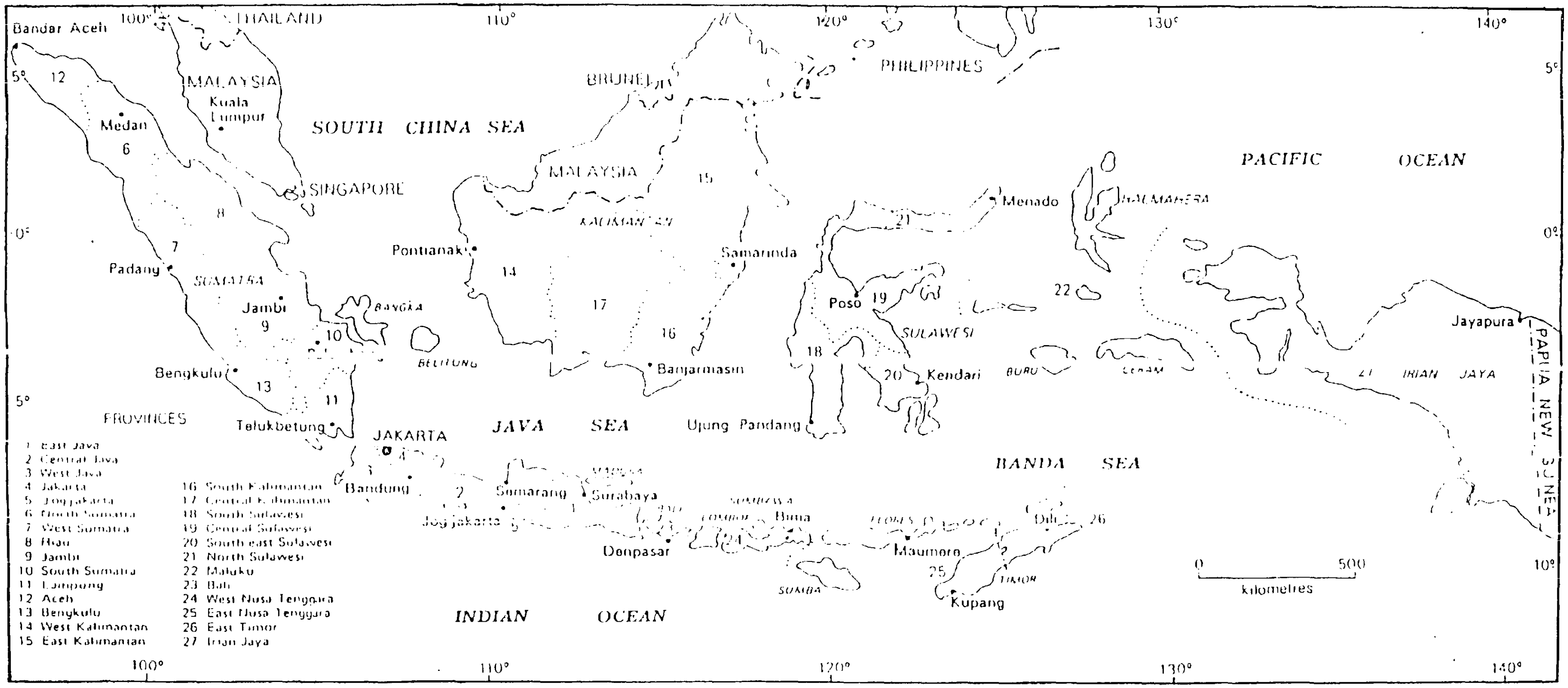

Figure 2.1 Geographical map of Indonesia (from Hill 1989)

In 1994, the total population of the province was recorded at 6.66 million (BPS 1995). The Gross Domestic Product (GDP) of South Sumatra at current market prices was 3,438 billion rupiah (1983) and 11,050 billion rupiah (1993). During 1983-1993, the region achieved a continuous increase in GDP with the agricultural sector contributing 18.4 per cent of total GDP in 1993 In 1993, only 2.0 per cent of total GDP was derived from fisheries. However, fisheries are an important sector for the region because of their contribution to rural people in terms of income, employment opportunities and relatively cheap animal protein.

The primary objective of this chapter is to provide some background knowledge on the inland fishery in the study site which is relevant to the rest of the study. Following that general background on South Sumatra, the characteristics of the inland fishery are reviewed in Section 2.2. Section 2.3 is devoted to a description of the production system of the fishery. Section 2.4 discusses the fishing community. Sections 2.5 and 2.6 are used to review the demand for fish in the region, the market and the fishing management practices, respectively. The last section of this chapter has a summary and concluding remarks.

2.2 Characteristics of Inland Fisheries in South Sumatra

Given the above brief physiographic characteristics, the inland fishery in South Sumatra may be termed a typical 'floodplain fishery resource'. The resource is basically formed by the main river, the Musi, and its major tributaries. The middle section of the rivers are characterised by extensive floodplains which are locally called *'lebak lebung'*. The river levees, which are locally called *'talang'*, are only slightly higher than the surrounding terrain. The floodplain of the river is considered a more general feature of the river basin and includes the tributaries flowing into the main channel along the entire length of the river. Often the rivers cut through their own embankment, creating direct connections with the extensive floodplains. Some parts of the extensive floodplains are shallow depressions with no links or permanent drainage to the surrounding river systems and are fed by their own minor tributaries. The vegetation in the extensive floodplains is variable, such as forest (*rawang*), sedge and grasslands (*lebak berkumpai*). Some extensive floodplains, which are close to settlements, are used for rice production (*sawah lebak*).

The floodplain and the river system are controlled by hydrological cycles which generally can be classified as tropical floodplain rivers. During the rainy season, the river basins flood and water levels in the rivers are high, whereas during the dry season, the river basins drain and water levels in the rivers fall. Water bodies on the floodplain lose water by evaporation and to a lesser degree by filtration during the dry season. In the cycle of the seasons, there are intermediate periods of rising and falling water levels. A typical hydrogeographic map of the inland fishery in South Sumatra is presented in Figure 2.2.

Tropical floodplain rivers, such as the Musi River, are representative of one of the large catchment basins in Indonesia. Jackson (1989) pointed out that such a resource could contribute dynamic and productive inland water fisheries. The nature of resource productivity is based primarily on energetic exchanges between terrestrial and aquatic components of the ecosystem. Substantial energy in the resource system is derived from organic materials which are broken down by continuous interactive physical and biological processes and enter into the aquatic environment. These processes enrich primary productivity of the resource. Hence, floods in this type of ecosystem provide the stimulus and appropriate environment for spawning and early life history stages for the majority of fish in tropical floodplain fisheries. This phenomenon was documented by Welcomme (1985).

The catchment area of the river basin comprises about 60,000 km^2 and has a cumulative length of over 2,000 km (Danielsen and Verheught, 1989). The fishery resource consists of the main river itself, swamp areas (*rawang*), and small lakes (*lebung*). Swamp and lake resources are usually distinct geological entities; however, ecologically they are integrated into the river and floodplain system. The river and small lakes contain water throughout the year while the swamp areas tend to lose water during the dry season (July to September).

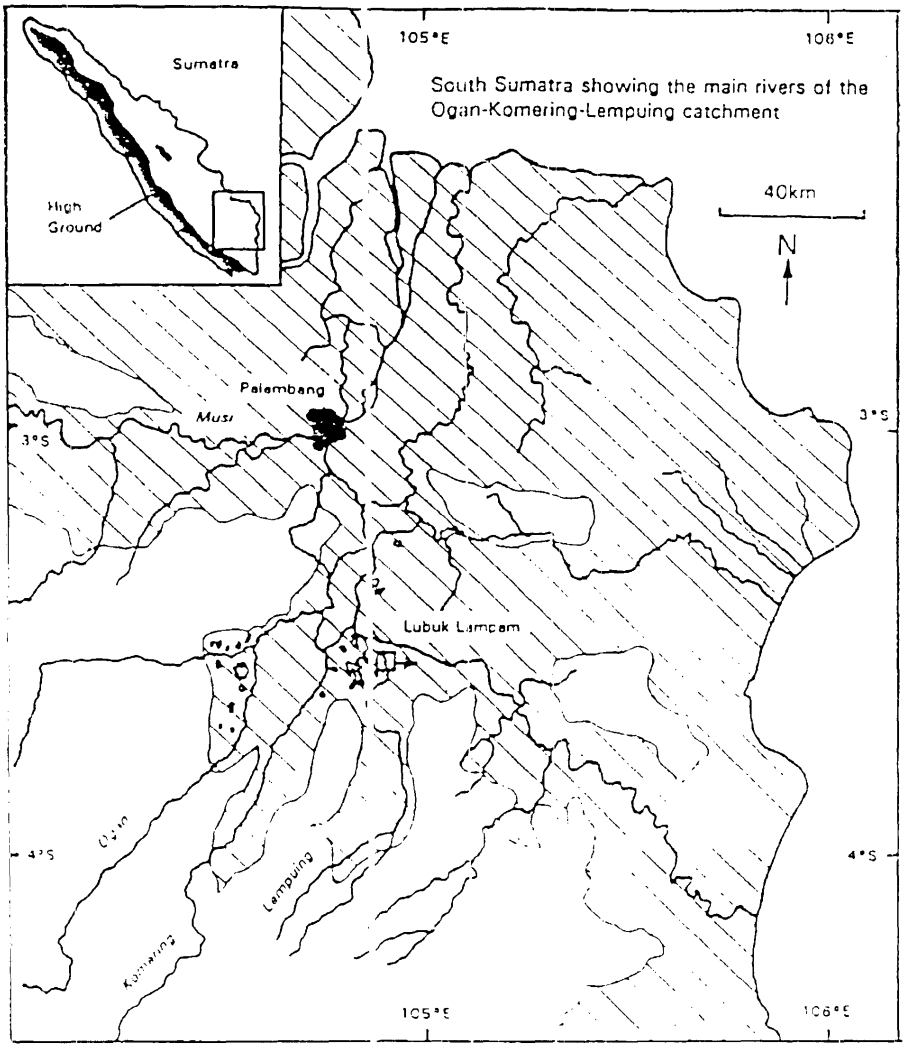

Figure 2.2 Typical hydrogeographic map for inland fishery in South Sumatra, Indonesia, represented by the Ogan-Komering-Lempuing catchment area (from anon. 1994)

Fishing is traditionally considered an important occupation for many rural people living in the area. Fishing patterns in the area are significantly affected by fluctuations in water levels. The fishing seasons can be distinguished as high water (December to February), receding water (March to May), low water (June to August) and rising water (September to November). The types of fishing gear operated depend on both area and season.

Previous studies indicate that environmental degradation occurs and has become a major public issue in the inland fishery resources of South Sumatra. This is because human interventions have both direct and indirect effects on particular fisheries. In other words, given intensive human activities that influence the system, the productivity of the fishery resource may decline. Specifically, with the overall impact of economic development in a region, the continued growth in the number of fishers and fishing units entering the fisheries is unlikely to be accompanied by increases in fishery resource productivity.

2.3 Production System of the Fishery

Most floodplain river fisheries experience increased fishing during periods of low flow with the greatest catch per unit of effort (CPUE) often associated with falling or rising water levels (Jackson 1989; Malvestuto 1989). Fish are more concentrated in low water and tend to become migrationally active during rising and falling water. Hence, they are more susceptible to capture during these times. In this regard, the structure and functional composition, as well as abundance of fish stock, are reflected in the types and intensities of fishing effort operated during this time of the year. Fish stock typically recover from intense low water exploitation during the high water season, when fishing efficiency is low due to dispersion of fish in newly inundated areas.

2.3.1 Fishing gear and techniques

Although Jackson (1989) and Malvestuto (1989) considered South Sumatra to have basically a floodplain river fishery, they observed that the province had various types of inland fishery resources. However, official records (Fishery Services of South Sumatra, various years) indicate that the inland fishery is classified into only three types of resources, namely: rivers, swamps and lakes. Many different types of fishing units are used by fishers; however, the South Sumatra Fishery Service divides those units into 10 categories. According to this classification, fishing units are recorded as shown in Table 2.1. As indicated in this table, gillnets, cast nets, hooks and lines and portable traps are employed by fishers. Lift nets are used in open-water such as riverines and swamps. The filtering barrier has been banned since 1991 and is only operated in the riverine fishery. However, fishers still operate this type of prohibited gear.

Almost all fishing units in the tropical floodplain fishery are artisanal, small-scale and labour-intensive. Many of the fishing units can only be operated for a short time, given water levels appropriate to use of particular gear. Consequently, fishers tend to operate a succession of fishing units as water levels change. Typical fishing units operated in the inland fishery of South Sumatra are presented in Figure 2.3

In general, static fishing units are operated when flood waters are rising or falling. This is because fish migrate around the water bodies for the purposes of feeding or breeding during that time. Active fishing units are operated during high and low water levels. This is because fish are relatively immobile at this time, and may be stranded in dry season pools.

Gillnets are used during high water for all types of the resource. This gear generally provides a relatively small catch per unit of effort but can be used over a long season or even throughout the year. These types of fishing units are relatively modern and have become common worldwide (Welcomme, 1985). Gillnets are selective fishing gear that is used for a limited size range of fish. However, they can be used to catch many different fish species.

Cast nets are operated in river channels or other fishing grounds where fish congregate naturally. This type of gear is considered secondary and is usually favoured by professional fishers.

Table 2.1 Fishing gear used on riverine, swamp and lake fishery resources in South Sumatra

Classes of fishing gear, local names and descriptions		**Type of resource**	**Mesh size (mm)**
Gillnets Drift gillnet Fixed gillnet	Fished in open-water or channels	Rivers, swamps and lakes	19 - 40
Cast nets *Anco*	Fished in open-water from canoes	Rivers, swamps and lakes	17
Lift nets *Serok*	Fished in open-water or channels by small portable bamboo frame. This fishing gear has different types of local name, such as *tangkul* and *langgian*.	Rivers and swamps	6
Hooks and lines *Rawai* *Pancing*	Longlines of 10 - 100 hooks Fishing rod, single hook	Rivers, swamps and lakes	7 - 12 (hook gape)
Filtering barriers *Jermal*	Fished in river by wide shallow barriers with net plumes to strand fish. This fishing gear has different types of local name which can be classified into two: static and active barriers. The static barrier has different types of local name, such as *kilung*, *tuguk*, *empang* and *corong*. The active barriers are *ngesek*, *ngesar* and *ngubek lubuk*.	Rivers	7 - 9
Portable traps *Sero* *Bubu*	Fished without bait in fish migration routes in open-water or channels. There are different types of local name, such as *pengilar rotan* (rattan fish trap), *bengkirai bilah* (bamboo fish trap), *bengkirai kawat* (chicken wire fish trap), *lapun* (wire predator trap), *menteban* (bamboo, baited trapdoor trap) and *sero* (bamboo bullet-shaped baitfish trap).	Rivers, swamps and lakes	12 -100
Other gear		Rivers, swamps and lakes	

Lift nets are operated in open-water or river channels. These fishing units are usually constructed of bamboo and nets. They usually catch small fish and shrimps. They are operated by drifting around with the current and lifted periodically by a single operator. In the study site these fishing units have different local names, such as *tangkul* and *langgian*. Even though lift nets are operated for subsistence purposes, the *langgian* scoop nets are important in the riverine fishery and used to catch valuable freshwater prawns at night. The prawns hide under weed beds and flow through the main river channels. The prawns can be detected by the reflection of their eyes in oil lamps of fishers.

Hooks and lines are operated throughout the year in all types fishing grounds. They are used both on an individual basis and on long lines. Various baits, such as earthworms and small fish, may be used to catch demersal or pelagic fish. With this type of gear, harvest is usually dominated by predatory fish.

Filtering barriers are used in the river alongside wide shallow barriers with net plumes to strand fish. These fishing units can be classified into two categories: static and active barriers. The static barrier has different types of local name, such as *kilung*, *tuguk*, *empang* and *corong*. The active barriers are *ngesek*, *ngesar* and *ngubek lubuk*. The *kilung* plume nets, for example, static barriers, are operated at a position between the river and the floodplain to capture migratory fish. In the study site, static filtering barriers are built with great care, so that few migrant fish escape. Active barriers are operated when the dry season approaches. This gear is operated by teams of up to 15 fishers taking up to 20 days per trip. When water levels are low enough for the nets or bamboo to be moved acrross the area to prevent the fish from escaping underneath, teams of fishers sweep the area using a combination of *kerakat* seine and bamboo *empang* fence. Then, the stranded fish are captured. This activity is locally called *ngesek*. Similar procedures are applied for *ngesar* activity. The difference is in terms of length of the part of the main river channels to be netted off and seined as single units. The *ngesar* operation can harvest a spectacular amount of fish. However, the efficiency of these fishing units is unknown.

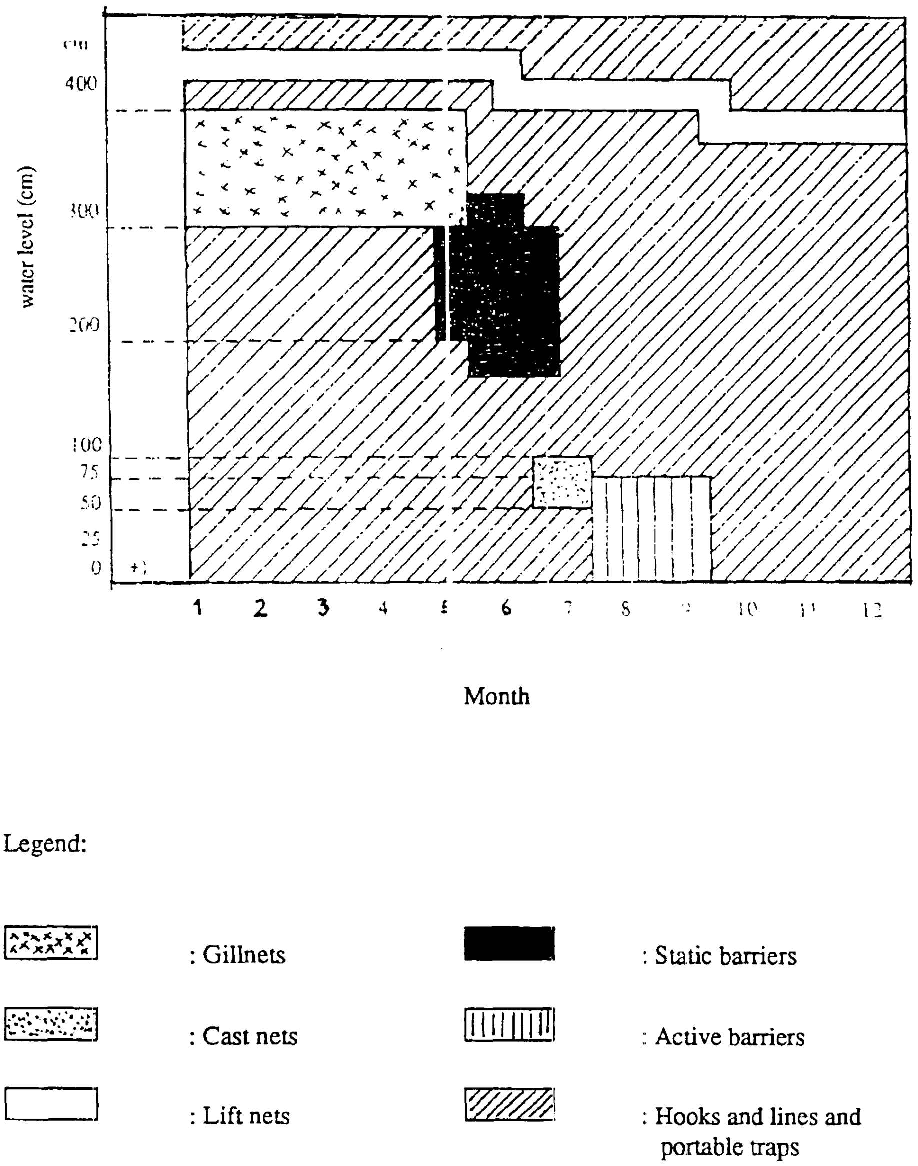

Figure 2.3. Typical fishing units operated in the inland fishery of South Sumatra (modified from Arifin and Ondara 1982)

Portable traps, which are commonly known as *bubu*, are constructed in many different shapes, sizes and materials according to location of fishing. These type of gear are widely used by fishers in all types of fishery resources. These fishing units are usually operated by placing them on a migration route facing the direction in which the fish are moving. There are a number of local variations, and these are described in many different types of local name, such as *pengilar rotan* (rattan fish trap), *bengkirai bilah* (bamboo fish trap), *bengkirai kawai* (chicken wire fish trap), *lapun* (wire predator trap), *menteban* (bamboo, baited trapdoor trap) and *sero* (bamboo bullet-shaped baitfish trap).

2.3.2 Fish populations

The composition of the fish stock may vary both spatially according to types of resource and temporally due to variation in spawning success (Gulland and Garcia 1984). Each species of the fish stock specialises to take advantage of a limited range of foods but is also able to switch its feeding preference as the season progresses to take advantage of food sources which become abundant for limited times. This indicates that many species of fish exist in response to the diversity of available foods. In terms of growth, the fish stock may be characterised as fast-growing and seasonal. Many large species grow particularly fast in their first season. This is possibly an adaptation to avoid intense predation on the floodplain by rapidly exceeding edible size before the shelter of the floating vegetation disappears in the dry season. Alternatively, they may remain vulnerable to predators all their lives but mature and breed as early as possible. Given the above, the effect of mortality due to fishing on such aggregated variable fish stock is very complicated and difficult to gauge. This is because the fishery is very complex, comprising many different fishing units, multi-species with different harvested sizes, seasonal factors and variation between fishing grounds.

Over one hundred species of fish are currently being harvested from the fishery. However, official records of the Fishery Service indicate that all harvested fish are combined into only 17 species. In contrast, Welcomme (1985) classified floodplain fish species into two broad categories, i.e., whitefish and blackfish. According to this classification, whitefish can be distinguished by their behaviour in terms of the pattern of migration. They migrate spatially and seasonally, from the river to the floodplain area every year to obtain nutritious foods and must return to the river due to intolerance of low oxygen in the dry season. Blackfish, on the other hand, may spend their whole lives in the standing waters of the floodplain. These migratory patterns may divide the community of tropical floodplain fish stock into different habitats. This may serve as an indication to fishers as to where and when most fish stock can be captured. Unfortunately, recorded data on such fish species groups are not available for the study site. This, in turn, creates difficulties in modeling the biology of the fishery according to particular species.

2.3.3 Spatial distribution and fish production

The structure of the inland capture fishery industry from 1979 to 1994 shows the existence of three different types of resources and ten types of fishing units (Appendix 2.1). According to resource category, the riverine and swamp fisheries contributed significantly to total inland capture fishery in South Sumatra. The lake fishery has contributed a relatively small proportion. From average historical data, the most important fishing gear in the study site is portable traps. These are followed by gillnets, then hooks and lines.

From Table 2.2, the regencies of Ogan Komering Ilir (OKI) and Musi Banyuasin (MUBA) contributed over 50 per cent of total fishing units, trips and production in South Sumatra during 1979 - 1994. In 1979, the inland fishery in OKI contributed 39.9, 35.3 and 23.5 per cent of total fishing units, number of trips and production in South Sumatra province, respectively The Muba regency contributed 11.2, 19.3 and 37.1 per cent of total fishing units, number of trips and production, respectively. In 1994, however, the contributions were not in the same direction. The OKI region showed decreases in its contribution to total fishing units and to number of trips based on South Sumatra figures, but increases in its contribution in terms of total production. The opposite was shown by the MUBA region.

Table 2.2 Units, number of trips and total production of inland fishery in South Sumatra for selected regions and years

Year	Fishing Unit (unit)	Trip (times/year)	Production (tonnes)
South Sumatra:			
1979	31,492	4,282,708	28,113.70
1984	32,854	4,695,344	36,206.87
1989	34,099	5,019,778	38,561.10
1994	35,311	5,051,110	41,979.20
Ogan Komering Ulu (OKI):			
1979	12,589	1,511,357	6,610.80
	(39.9)	(35.3)	(23.5)
1984	13,506	2,141,803	13,341.10
	(41.1)	(45.6)	(36.9)
1989	13,506	2,174,492	15,747.80
	(39.6)	(43.3)	(40.8)
1994	13,308	1,706,023	17,013.20
	(37.7)	(33.8)	(40.5)
Musi Banyuasin (MUBA):			
1979	3,538	827,299	10,431.40
	(11.2)	(19.3)	(37.1)
1984	3,542	945,553	11,668.60
	(10.8)	(20.1)	(32.2)
1989	6,797	1,029,198	11,994.40
	(19.9)	(20.5)	(31.1)
1994	7,428	1,296,491	13,406.80
	(21.0)	(25.7)	(31.9)

Source: Fisheries Services of South Sumatra (various years).

Note: Values in parentheses are percentage contributions of each region, i.e., OKI and MUBA, to South Sumatra.

Overall, the increase in total fishing units, number of trips and total production in the inland fishery between 1979 and 1994 were 12.1, 17.9 and 49.3 per cent, respectively. By region, a significant increase in total fishing units operating during that time was shown by the MUBA region. However, a significant increase in total production was shown by the OKI region. The growth in the number of fishing units was 0.4 and 6.9 per cent in OKI and MUBA regions, respectively. In contrast, growth in total fish production was 9.8 and 1.8 per cent in OKI and MUBA regions, respectively. This indicates that fishers in the OKI region were more responsive to the introduction of new technology than those of the MUBA region.

Theoretically, each fishing unit represents a particular level of technology. Fishing efficiency, which is usually expressed as a ratio of total catch to fishing effort, may be easily calculated from Table 2.2 by dividing total production by fishing units and number of trips. However, the figures may not represent the actual inland fishery in South Sumatra very well. This is because figures for total units and trips are aggregated from many types of fishing unit being operated in that particular area, instead of standardised ones.

The Reseach Institute for Freshwater Fisheries (RIFF Mariana) of South Sumatra, reported that during the last decade the fishery production in the major fishing ground, e.g., Lubuk Lampam, has shown a tendency to decrease (RIFF, various years). The inland fishery was likely to face a problem of over-fishing. Recently, the harvested fish in major areas of fishing have decreased 5 to 10 per cent (Pollnac and Malvestuto, 1992). The perception of fishers interviewed on the study sites indicated that their current fishing was less successful. They indicated that decreases in harvested fish were due to increases in the number of fishers and fishing units and possibly changes in the quality of environment. In line with this tendency, Jackson (1989) and Malvestuto (1989) reported that the fish harvest was represented by multi-species, and dominated by detrivorous fish with a significant portion of piscivorous species. However, large size fish were rare. Harvested fish have never been observed being discarded by fishers. This may indicate over-fishing in that particular fishing ground.

2.4 The Fishing Community

The structure of occupations in the fishing community can be classified into two categories, namely: activities essential to a fishery and occupational multiplicity (Pollnac and Malvestuto 1992). Activities essential to a fishery begin with the basic fishery. Fishing, distribution, processing and marketing of harvested fish are activities essential to a fishery. Occupational multiplicity may be defined as people in occupations other than fishing who are also involved in fishing activities on a part-time basis.

Another classification of the fishing community is made in terms of the fishers themselves (Welcomme 1985) who can be divided into three groups: occasional, part-time and full-time. Occasional fishers harvest fish for their own consumption. The time they spend fishing is relatively short and they use a comparatively unproductive fishing unit. Part-time and full-time fishers use more productive fishing units. However, they differ in the sense that part-time fishers tend to use a range of fishing gear rather than concentrating on a single item of gear. Full-time fishers operate their fishing as a main occupation, whereas part-time fishers usually operate their fishing as a consequence of lack of work in their main occupation.

There is a strong relationship amongst those engaged in fishing. Relationships between fishers and middlemen[1], for example, seem to be good. Fishers sometimes sell their harvested fish to the middlemen on credit and are paid when middlemen receive cash from other middlemen or retailers. In more remote fishing areas middlemen sometimes provide credit to fishers. This type of credit can be used to cover costs of fishing effort and sometimes for non-fishery purposes. In this case, the credit will be repaid by fishers on the basis of their daily fish harvest which is sold directly to the middlemen. Based on the reported experience of fishers, this system seems to be fair. Fishers are satisfied because they can receive cash easily. Middlemen are also satisfied because the fishers continue selling their product to them. Even though their relationship appears to

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[1] The economic relationship between fishers and middlemen in small-scale fishery was explained by Smith (1979, p. 16-19).

be harmonious at present, it may change in the future, given that access to other fish markets is improving.

However, middlemen or small-buyers have an important role in the small-scale fishery, particularly the role in maintaining fishing households during the poor-fishing season. Middlemen often provide 'gifts' which may not be considered as credit to fishers. This may reflect the existence of strong ties of mutual obligation in the community. With this, middlemen seem to provide security to fishers and have a guaranteed source of supply from them.

2.5 Demand Relations and Market

Market accessibility for harvested fish is reflected in the distance of the fishing grounds from consumers, where the fish are caught in the fishery and locations of most commonly used landing centers. This indicates the availability of inputs for fishing and also the accessibility to the market. Harvested fish are transported from fishing grounds to principal landing centers and wholesale markets through various market intermediaries and middlemen, e.g., assemblers and local traders. All harvested fish are consumed domestically. In general, small amounts of harvested fish are used for home consumption. This is typical for a subsistence fishery. Harvested fish for sale reach the domestic consumers in fresh form without processing. However, preservation techniques such as icing are commonly used to keep fish fresh for distant markets. Figure 2.4 shows the main marketing channels for harvested fish from the study sites.

As previously mentioned, pricing of harvested fish is decided by the middlemen when fishers have a debt to them. According to fishers, this system is satisfactory. However, fishers can sell their product directly to retailers or even consumers at market prices. Prices of harvested fish tend to be lower in the dry season than in the wet season. This is because fish stock in the dry season are relatively easy to capture. Bailey, Polnac and Malvestuto (1990) indicated that during that period most fish harvested were processed into salt-fish and dry-fish by fishing households. Middlemen

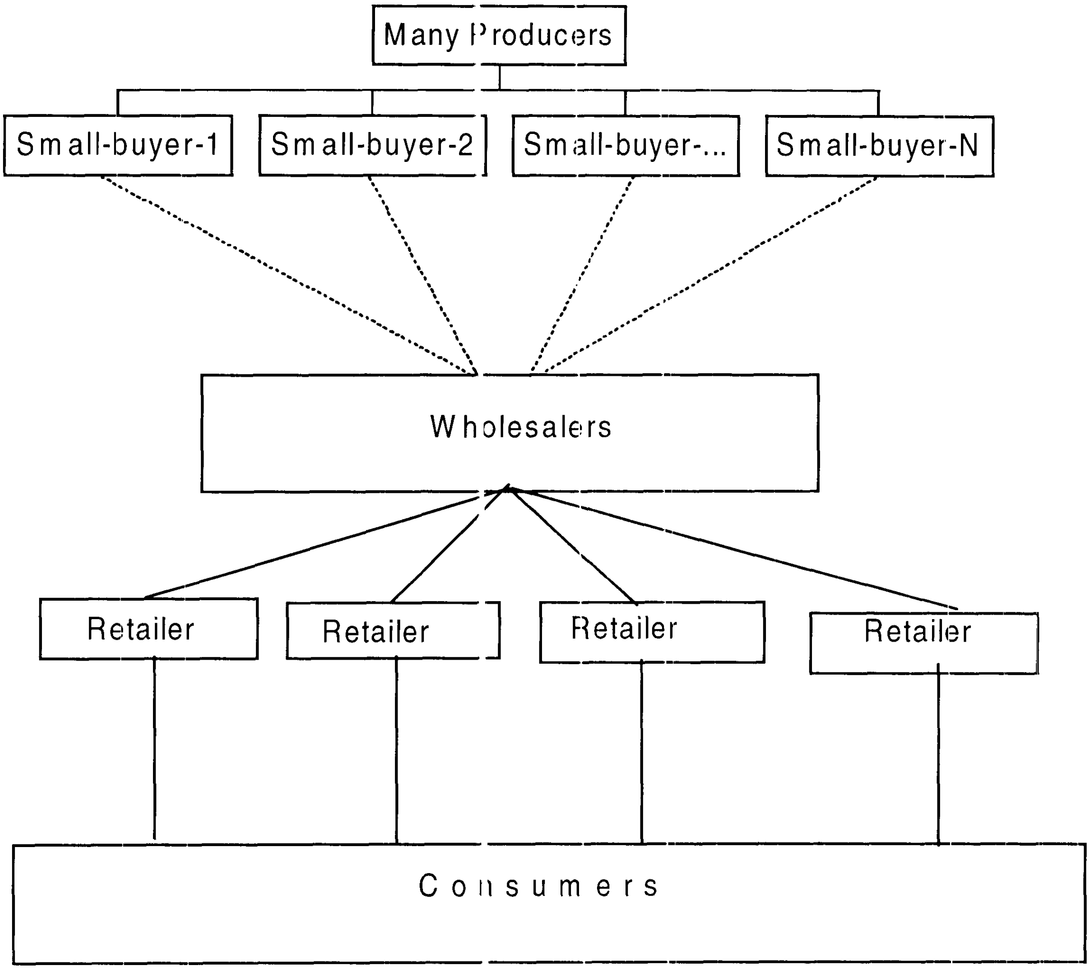


Figure 2.4 Typical marketing channel of freshwater fish from the inland fishery of South Sumatra

or small-buyers (*pengumpul*) collect this fish and sell it to wholesalers or retailers. Both individual fishers and small-buyers may hold live fish in cages prior to sale or further distribution.

2.6 Fishery Management Practice

A previous assessment of inland tropical fisheries in South and South-East Asia recommended that exploitation levels could be gauged by simple examination of fishing unit practices and catch rates (Anon 1994). These types of approaches have proven robust but may not be justified from a biological standpoint. However, these measurements may be useful for creating and identifying indicators in order to determine management action in relation to the resource.

Fisheries management is often assumed to be a government responsibility (Gordon 1954). However, previous experience indicates that the effective capacity of a government agency to manage a widely scattered fishing ground is limited (Bailey and Zerner 1992). This is true in the case of inland tropical fisheries in Indonesia. Government fisheries policy is based only on the assertion of total state management authority over the fishery resources. Indonesian fishery laws and regulations, moreover, do not explicitly recognise local community property rights or traditional law (customary law).

Instead of following traditional law (*hukum-hukum adat*), the government rents out access to inland fishery resources to the highest bidder. Annual rents are charged for sections of tributary rivers and floodplain areas in the basin. In addition to this, there are official government taxes on successful bidders.

The government sets different rates for different areas. These rates are costly and hence traditional fishers can rarely afford to pay them. Commonly, the highest bidders are concerned with distribution and marketing of fish from their rented areas. Most likely, the winner of the government auction will in turn rent a portion of the area to second parties such as middlemen or small-buyers who have previously covered that region. By this action, the winner can make a direct profit on his/her initial rental transaction. Then, small-buyers may split up the area into smaller parcels and rent these out to fishers. Traditional fishers may be allowed by the small-buyer to catch the fish in that area, but they must sell their product directly to them. It is typical for the government to ignore official rates and rent the areas to highest bidders.

The auction system was initiated by the Dutch colonial government as a means of generating revenue and over time has proliferated into a complex series of localised versions of the original plan. Recently, this system has dominated management practice in the inland fishery in South Sumatra

2.7 Summary and Concluding Remarks

This chapter has briefly reviewed the inland fishery of South Sumatra, Indonesia. The fishery resource is considered a tropical floodplain fishery and to be on a small-scale. The fishery is very complicated, comprising many different types of gear and harvested fish species. The relative importance of the fishing unit depends largely on hydrological conditions at each fishing ground. However, observation indicates that portable traps (*bubu*) are the most important fishing units in the study site.

Given the performance of the inland fishery, management of the fishery should consider two factors: firstly, the importance of the fishery to the fishing community and, secondly, the objectives for managing the fishery. Considering both these aspects, any theoretical framework developed to analyse the fishery should include biological, economic and social aspects of the inland fishery in the study site.

Chapter 3

METHODOLOGY

3.1 Introduction

The main objective of this chapter is to provide a theoretical basis for the bioeconomic analysis of fishery management which incorporates biological and economic characteristics of the fishery. The chapter is divided into six sections. Section 3.2 is devoted to an explanation of biological models of the fishery. Section 3.3 explains economic aspects of the fishery including supply of and demand for products from these fisheries. Section 3.4 discusses formulation of bioeconomic models and determination of optimal resource use. Section 3.5 discusses possible management options implemented for particular resources. In the last section, a summary of the chapter and concluding remarks are presented.

3.2 Biological Models

According to Sparre and Venema (1992), biological fisheries models can be either holistic or analytical. The holistic approach is characterised by consideration of a fish stock as a homogeneous biomass. This approach does not take account of growth parameters, such as age structure and rate of growth of individual fish. Included in this approach are 'surplus production models' which have been widely used by scientists because of their simple data requirements and applicability to solving long-run fisheries' problems.

The analytical approach provides a more detailed description of the fish stock. Models included in this category take account of detailed biological information on the fish stock or may provide a detailed scenario of adjustments due to fishing. In these biological models, parameters change in accordance with the density of the stock. These models are supposed to be more realistic (Gulland 1983). In practice, however, an ideal model representing the dynamic nature of the fishery may not exist. Caddy and Gulland (1983) reviewed various fisheries models and confirmed this statement. Any selected biological model usually holds certain parameters fixed in describing the behaviour of the stock. It is impossible to develop a single model which copes with all varieties of internal and external behavioural characteristics of the stock. One of the reason is because real biological systems change over time and vary according to available resources and the size of the fish stock (Hilborn and Walters 1992). Therefore, in most cases, the decision on the type of model to be used is limited by the quality and quantity of available data.

Modelling of biological aspects of a fishery can be approached as in Figure 3.1. According to this approach, the foundation for biological modelling assumes that fishery dynamics depends on biomass of the stock. These models, called biomass dynamics models, can be extended in four major ways by incorporating parameters on: (1) age structure of the fish; (2) fishing dynamics in terms of fleets, processing and marketing; (3) multiple species and their ecosystems interaction; and (4) spatial representation of stock structure. Amongst all of the possible extended models, explicit age structure of the fish is the parameter most commonly added to basic models (Beverton and Holt 1956, 1957; Ricker 1954, 1975; Walters 1969). In contrast, fishing dynamics incorporating fleets, processing and marketing have not been widely applied. A different perspective for classifying the basic biological model for fishery dynamics was given by Cushing (1983). This author outlined three types of biological models, namely: biomass dynamics models (Russell 1931; Graham 1935; and Schaefer 1954, 1957a, 1957b), discrete time stock growth models (Ricker, 1954) and age structure models (Beverton and Holt, 1956, 1957). Most extended models are developed along the lines of these basic models which are widely applied in analysis of the bioeconomics of the fishery (Hannesson 1993).

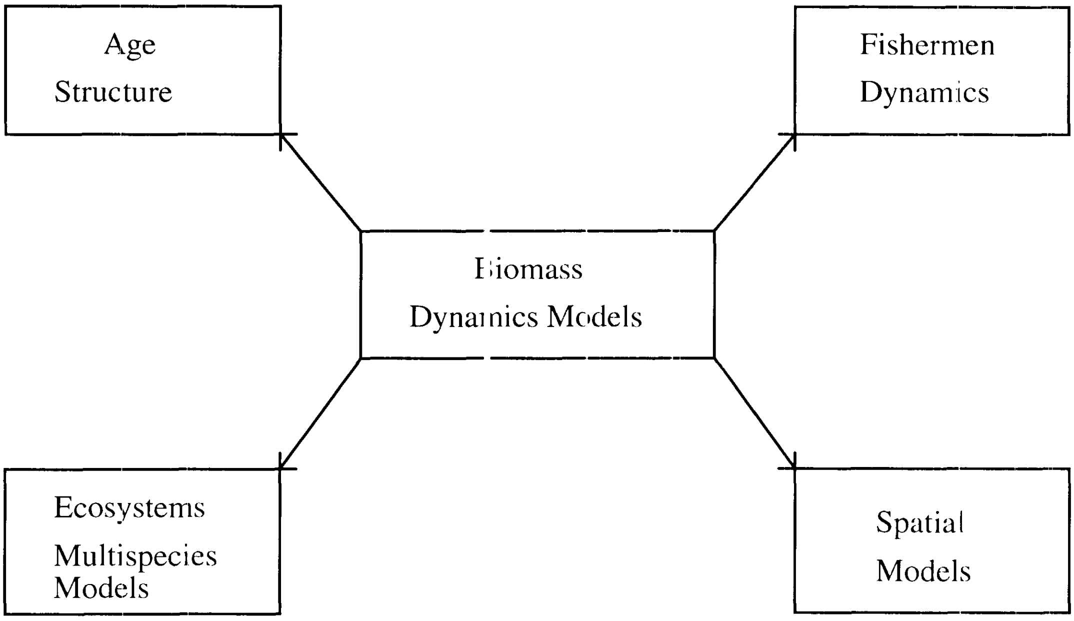


Figure 3.1 Basic biological model for the fisheries dynamics and four directions of possible elaboration (from Hilborn and Walters 1992, p. 70)

Russell's biological model described the change in biomass of fish stock as dependent on the difference between the summation of growth and recruitment of the stock and its mortality due to natural death and fishing (Russell 1931). The concept, however, was expressed as a qualitative model. Based on these ideas, Graham (1935) developed a relatively simple theory and converted the model into a mathematical expression. The expression showed how under equilibrium conditions the rate of increase in biomass over time is directly proportional to the difference between the weight of stock at any given time and carrying capacity. An attempt to describe a fundamental law of population growth due to fishing was formulated by Schaefer (1954). In his formulation, fishing is proportional to effort and stock while biomass is estimated as the ratio between catch per unit of effort and catchability. Schaefer's formulation is appropriate for situations in which the population tends to be stable, environmental factors are constant and food is limited. Whenever the rate of fishing equals the rate of natural growth, equilibrium will occur. The model is now commonly referred to as the 'Schaefer Surplus Production Model'. An extension of the Schaefer model was developed by Pella and Thomlinson 1969), who introduced a new parameter to the standard Schaefer model. Instead of a perfectly symmetric production curve relative to stock, their formulation generates a function which allows the stock production curve to be skewed. A similar model was developed by Fox (1970), in which a logarithmic relationship between catch per unit of effort and fishing effort was introduced.

Ricker's valuable contribution to the biological modelling of the fishery was to relate stock size and recruitment (Ricker 19[illegible]4). The model provides an empirical relationship between spawning stock size and the subsequent recruitment. The idea behind this model is that fish stock is limited in size and fluctuates according to natural controls. In this model, a distinction between immature and mature stages of the fish stock was introduced. One important assumption in this model is the simplified representation of the effect of fishing on the mature fish stock. The Ricker model is referred to as a 'discrete time stock growth model'.

As pointed out by Cushing (1983), the foundation given by Beverton and Holt (1956, 1957) in modelling the biological nature of fishery dynamics was in terms of their formulation of the effect of growth rate over time and mortality due to fishing. Their model relates recruitment and stock size and takes into account age groups of fish stock reflecting individual growth and mortality. Application of this model requires considerable information about the fish stock, usually obtained through analysis of catch and effort, age composition, and tagging data. The model is referred to as the 'age-structure model' or 'dynamic pool model'.

The Ricker and Beverton-Holt models are similar in the sense that they reflect stock-recruitment models describing a part of a complete age-structured analysis (Hilborn and Walters 1992). Apart from this similarity, the main difference between the Ricker and Beverton-Holt models is in the biological assumption on mortality. The Ricker model assumes that the mortality rate is proportional to the initial cohort size whereas the Beverton-Holt model assumes that mortality rate is proportional to cohort size at each stage in the life of the fish.

The problem of the relationship between recruitment and yield per recruit of the stock was discussed in analytical terms by Walters (1969). Walters' formulation treats the stock individually with respect to its fecundity, individual weight and mortality. Inclusion of the effects of biological interaction, technological interaction and/or environmental factors provide other extensions of the basic models. For a more detailed discussion of the various biological approaches to modelling fishery dynamics the reader is referred to Ricker (1975), Gulland (1983), Pauly (1984), Sparre and Venema (1992), and Hilborn and Walters (1992).

In order to describe the dynamics of a fishery in detail, an analytical approach needs to be employed. However, in the context of an inland tropical fishery, biological data such as fish growth, mortality, age class and stock recruitment, required to set up an advanced model, are not available. In this situation, simple biological models, such as surplus production models, are more useful to analyse fishery dynamics (Sparre and Venema 1992; Tai 1992).

Because of the lack of data, the present study employs a holistic biomass dynamic model. The framework of the model is explained in the following section, which starts with a review of the earliest work of Russell (1931).

Russell described the gains and losses of fish stock in a particular fishery as:

(3.1) $$\Delta X = R + I - M$$

where X is stock, R is recruitment, is individual growth and M is mortality. Under natural conditions the rate of change in stock or biomass tends to zero, resulting in the sum of recruitment and individual growth just balancing mortality. This implies that the amount of fish stock in a particular area is regulated by interactions between environmental factors and the fish themselves (Gulland 1978). The stock tends to stability and hence, for a particular set of environmental conditions, the stock has at each size a definite potential to increase which is dependent on the existing size of the stock. This phenomenon is called a 'density-dependent process'. Changes in environmental factors will affect the carrying capacity of the resource and the fish stock. Those changes will eventually affect the biological parameters, such as recruitment, individual growth and mortality rate. In this case, the rate of growth, natural mortality and recruitment are assumed to be constant (Russell 1931). The combination of recruitment and growth in the equation represents a single term called ‘production’. The above relationship means that whenever production is greater than mortality, the stock will grow, and whenever it is less than mortality, the stock will decline. In the absence of fishing, the difference between production and mortality is expressed in terms of surplus production. At the level of maximum fish stock size, the addition of recruitment and growth to the stock is just sufficient to compensate natural mortality and hence, surplus production will equal zero. This implies that fishing plans can be expressed in terms of surplus production.

The basis of this approach is the assumption that a natural population (or fish stock) will grow as a result of new fish entering the fishery and because of growth of individual fish. The growth will be kept in check only by natural mortality. The natural growth rate of fish biomass over time, F(X), can also be considered as a biological production function for the fishery. It indicates that for a given stock size, X, the net increase over a small period of time is determined by the size of the stock. Then, equation (3.1) can be written as a production function of a fishery:

$$(3.2) \quad \frac{dX}{dt} = F(X) = R + I - M \ .$$

Graham (1935) assumed that the relationship between growth rate of biomass (or fish stock) over time and the difference between the weight of stock and carrying capacity is parabolic, described by :

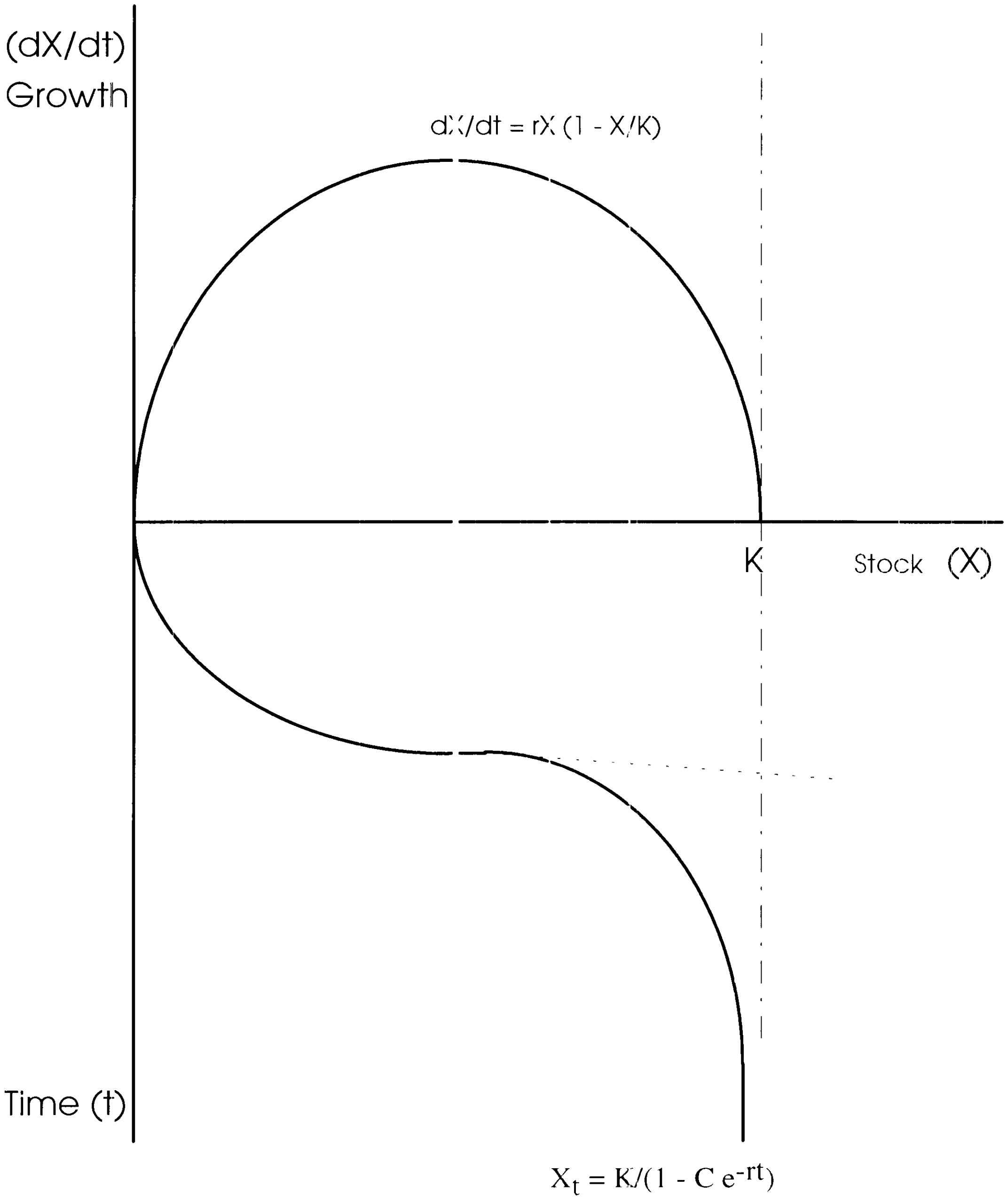
$$(3.3) \quad \frac{dX}{dt} = F(X) = rX\left(1 - \frac{X}{K}\right)$$

where K is carrying capacity, a parameter corresponding to the unfished equilibrium stock size, and r is intrinsic growth rate of the fish. In terms of the life-span of the fish, equation (3.3) may be determined by the logistic growth curve of Verhulst (Ricker 1975):

$$(3.4) \quad X(t) = \frac{K}{(1 + Ce^{-rt})}$$

where C = (K - Xo)/Xo , and Xo is stock size at initial year.

Graphically, the relationship between logistic growth and biotic potential is portrayed in Figure 3.2.



where, $C = (K - Xo)/Xo$

Figure 3.2 Biological relationship between growth, stock and time

Fishing has the effect of subtracting from that increase in stock which would occur at the existing level of stock and is viewed as a type of mortality. Fishing mortality can be expressed relative to the stock size and fishing effort. Therefore, at any given stock size, the higher the effort, the larger the catch and at any given level of effort, the larger the population the larger the catch will be.

The term *fishing effort* represents a simplified conversion of various biological variables of growth, mortality and recruitment into a single term 'catch'. Fishing effort was defined by Rothschild (1978) as the decision variable relevant to optimising the catch. In fisheries economics, fishing effort commonly represents a combination of the labour (fishers) and capital (vessels and gear). The term 'effort' is an abstract concept where an increase in effort may mean expanding fishing hours or increasing catching ability as a result of technological improvement. The fishing function is expressed as :

$$(3.5) \quad Y = y(E,X) = q\,X\,E$$

where Y is the catch measured in term of biomass, E is fishing effort, X is the stock, and q is a constant called *catchability coefficient*, a parameter that describes the effectiveness of each unit of fishing effort. The constant catchability coefficient implies that there is no change in technology over a certain period of time. Biologically, it implies that environmental conditions are constant. Even though the catchability coefficient may vary with time, it is common to assume it to be constant because of difficulties in measuring changes (Sparre and Venema 1992). The relationship in equation (3.5) also implies that catch per unit of effort is an index proportional to stock abundance :

$$(3.6) \quad \frac{Y}{E} = q\,X \,.$$

The growth of the stock inclusive of fishing can be written as follows (Schaefer 1954):

$$(3.7) \quad \frac{dX}{dt} = F(X) - y(E,X) \,.$$

This expression shows that the change in fish stock over time depends on its natural growth and the catch function. This relationship implicitly assumes that the natural growth rate responds immediately to changes in the fish stock density, which means that delayed effects of changes in stock on recruitment are ignored. Another variant of surplus production models with incorporating time delays may be developed as introduced by Walters (1973). However, these are not discussed in this study.

Equation (3.7) implies that whenever the rate of fishing is less than the natural rate of increase, the stock will increase. Conversely, stock will decrease if the fishing rate is greater than the natural rate of increase. The dynamic equilibrium of the stock will be hypothetically reached whenever the catch rate is exactly equal to natural growth rate. In accordance with this observation, Beverton and Holt (1956) defined the steady state condition, which illustrates the behaviour of stocks that maintain a relatively steady surplus production over reasonably long periods of time. Biologically, the steady state condition implicitly assumes that the age structure of the fish stock is uniquely determined by its biomass. Actual fisheries, however, are seldom in steady state. The dynamic equilibrium of the stock is sometimes called sustainable yield and written as :

$$(3.8) \quad \frac{dX}{dt} = F(X) - y(E,X) = 0 .$$

From equation (3.3) and equation (3.5), the above equation can be expressed as:

$$rX\left(1-\frac{X}{K}\right) - qEX = 0 .$$

Solving for X yields:

$$(3.9) \quad X = K\left(1-\frac{qE}{r}\right)$$

which is the equation for the stock equilibrium curve in the simplified model. This shows that when E equals zero, the equilibrium stock curve will be determined by the carrying capacity of the environment (K). As E increases, equilibrium will occur only at a smaller stock size depending on the catchability coefficient (q).

Substituting equation (3.9) into equation (3.5) describes the fishing function at a sustainable basis level:

$$Y = qEK\left(1-\frac{qE}{r}\right)$$

$$Y = (qK)E-\left(\frac{q^2K}{r}\right)E^2$$

$$(3.10)\quad Y = aE - bE^2$$

where $a = qK$ and $b = \frac{q^2K}{r}$.

Thus, the fishing function on a sustainable basis has a similar shape to the growth-stock curve. This model has been criticised because the stock production curve has a maximum point at exactly one-half of the theoretical maximum stock size (Pella and Thomlinson 1969). A convenient way of estimating this equation is to redefine the relationship in terms of catch per unit of effort as a function of fishing effort:

$$(3.11)\quad \frac{Y}{E} = a - bE\ .$$

Fox (1970) modified the model by assuming a 'Gompertz growth' stock production relationship. Recalling equation (3.7), the Schaefer model can be rewritten as:

$$(3.12)\quad \frac{dX}{dt} = rX - \frac{r}{K}X^2 - qXE\ .$$

In the continuous forms of the Schaefer model (as in the above equation) it is assumed that the relationship between growth rate and fish stock is logistic (parabolic). The Gompertz growth model is expressed as follows (Yoshimoto and Clarke 1993):

(3.13) $$\frac{dX}{dt} = rX\ln\left(\frac{K}{X}\right) - qXE \ .$$

This model represents an asymmetrical stock production curve. The model, in turn, describes an exponential relationship between fishing effort and stock size. The Schaefer model (1954) and Fox model (1970) are similar in the sense that they show a decline in catch per unit of effort (CPUE) with increasing fishing effort. Both the stock production curves imply that at a lower level of effort each additional unit of fishing effort will add a positive increment to the sustainable catch. However, additional catch declines as fishing effort increases. Beyond the maximum point of the sustainable yield curve, an additional unit of fishing effort will decrease sustainable catch. The two models differ in terms of their definition of the relationship between catch per unit effort and fishing effort. The former model assumes a declining linear relationship (equation 3.11) whereas the latter assumes a declining logarithmic relationship:

(3.14) $$\mathrm{Ln}\left(\frac{Y}{E}\right) = a - bE \ .$$

This implies that the stock can never be indirectly eliminated by fishing effort.

Pella and Thomlinson (1969) modified the Schaefer model by raising X to an arbritary power m to permit skewness of the curve and hence more flexibility. The Pella and Thomlinson model is:

(3.15) $$\frac{dX}{dt} = rX - \frac{r}{K}X^m - qXE \ .$$

Whenever $m \neq 2$, K is no longer the unfished equilibrium of the stock. Essentially, the applied arbritary power m allows the stock production curve to be skewed to the left ($m < 2$) or to the right ($m > 2$). This idea is based on their biological interpretations of the model. Laloe (1995) confirmed this specification and pointed out that the effectiveness of the generalised Schaefer model is due to the fact that biomass production has no reason to reach the highest level whenever biomass is one half of the virgin biomass. The catch per unit of effort and fishing effort relationship of the generalised Schaefer model can be written as

$$(3.16)\quad \frac{Y}{E} = (q^{m-1}K - \frac{q^{m}K}{r}E)^{1/(m-1)} .$$

This model appears to be superior because of its variable functional form. However, many studies, for example, Fox (1975) and Hongskul (1975), have confirmed that the optimal functional form closely approximates the fixed form Gompertz and Logistic models. The above generalised stock production function can also easily be viewed as the standard Schaefer model (Logistic form) and Fox model (Gompertz form) by setting the arbitrary power m equal to 2 or approaching one respectively.

3.3 Economic Models

Modelling economic aspects of the fishery resource can be viewed as a means of valuing the economic importance of its product. This may be approached through the relationships between supply and demand for the product. The framework of this approach begins with presentation of the process of determining supply and demand for the fishery. First, the description of supply from the fishery will be given so that the production function can be obtained. Second, an attempt will be made to describe demand for fish on the basis of economic factors such as prices, income per capita and population.

From an economic viewpoint, the fishery resource has a specific economic characteristic. Although for society the fishery resource is considered scarce, for individual fishers it is abundant. These characteristics derive from the fact that most fishery resources are common property. Thus, an individual fisher may still generate a profit in his fishing even though significant social losses have occurred as the fishing expands. The fishery resource is usually not private property and hence the resource rent that may result is not appropriated by any one individual.

A simple economic model has been introduced by Gordon (1954). In this model, the total cost and total revenue of the fishery are expressed in terms of fishing effort. In this approach, the total cost consists of two parts, i.e., fixed and variable costs of fishing effort. The fixed cost comprises all the costs required before any direct fishing effort is made. In other words, this kind of cost remains constant regardless of the level of fish caught. The variable cost consists of all the costs required directly to operate the fishing effort, such as fuel, bait, food and labour. In this approach, the amount of fishing effort is assumed to have no effect on factor prices[1]. With this assumption, cost per unit of fishing effort (c) is constant. Hence, the relationship between total cost and fishing effort would be linear. This means that the average and marginal costs of fishing effort are the same. The total cost of fishing (TC), marginal cost (MC) and average cost (AC) can be written as :

(3.17) $TC = c\,E$

(3.18) $AC = MC = c$.

Price in the fishery can be considered either as fixed or variable depending on supply and demand for the product in the market. Most likely, the former is commonly applied to formulate an economic model of the fishery. The assumption of a fixed price in the fishery is reasonable because it is determined by such uncontrolled factors as weather, environment and resource availability. The fixed price restriction implies that the share of this kind of product is very small in the overall market (Anderson 1977). This also implies that the dynamics of the fishery can be described in terms of supply adjustment in response to price levels. This, in turn, indicates that any regulations on the fishery will only affect producers.

Recalling the steady state condition of the Schaefer model, the sustainable catch curve is the long-run production function for the fishery from an economic point of view. This means that at any particular level of fishing effort the quantity of fish produced

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[1] A detailed explanation for this assumption can be found in Gordon (1953).

from such a resource is on a sustainable basis. Assuming fixed price of the fish caught, total revenue (TR), marginal revenue (MR) and average revenue (AR) functions can be expressed as:

(3.19) $TR = pY = p\left(aE - bE^2\right)$

(3.20) $MR = p\,(a - 2b\,E)$

(3.21) $AR = p\,(a - b\,E)$.

From an economic perspective, analysis of these relationships focuses on average and marginal sustainable catches. From this standpoint, the average and marginal sustainable catches are defined as the ratio between total sustainable catch and fishing effort and the change in sustainable catch due to a change in fishing effort, respectively.

By applying the Gordon-Schaefer model, the combination of biological and economic models for a fishery is described in terms of the relationship between fishing effort and total revenue. With those definitions, the relationships may be presented graphically as shown in Figure 3.3.

The first part of the graph (Figure 3.3 a) shows the long-run relationship between total revenue and fishing effort and total cost and fishing effort. The total revenue curve is similar to the sustainable catch curve because of the constant price of the fish. This implies that the total revenue curve varies directly with the catch. The linear cost curve indicates that increases in total costs vary proportionately with fishing effort.

The second part of the graph (Figure 3.3b) represents the marginal and average revenue and marginal and average cost associated with fishing effort. Both the marginal and average revenue curves have downward slopes and the curve for marginal revenue is steeper than that for average revenue. This indicates that as fishing effort increases, the decrease in marginal revenue is greater than that which occurs in average revenue. On the other hand, marginal and average cost curves are the same indicating that as fishing effort increases, marginal and average costs would be equal and constant.

The net economic benefit that can be derived from the fishery on a sustainable basis varies with the stock size. The net benefit which is commonly referred to as the resource rent is defined as the difference between TR and TC. At the level of fishing effort E_1, where the slope of TC is equal to the slope of the sustainable revenue curve (Figure 3.3), resource rent is at a maximum. It is theoretically the optimal resource rent from society's point of view. However, this point is never reached because of the nature of common property in the unregulated fishery. The level of fishing effort will tend to increase to the point where the resource rent is totally dissipated (E_3).

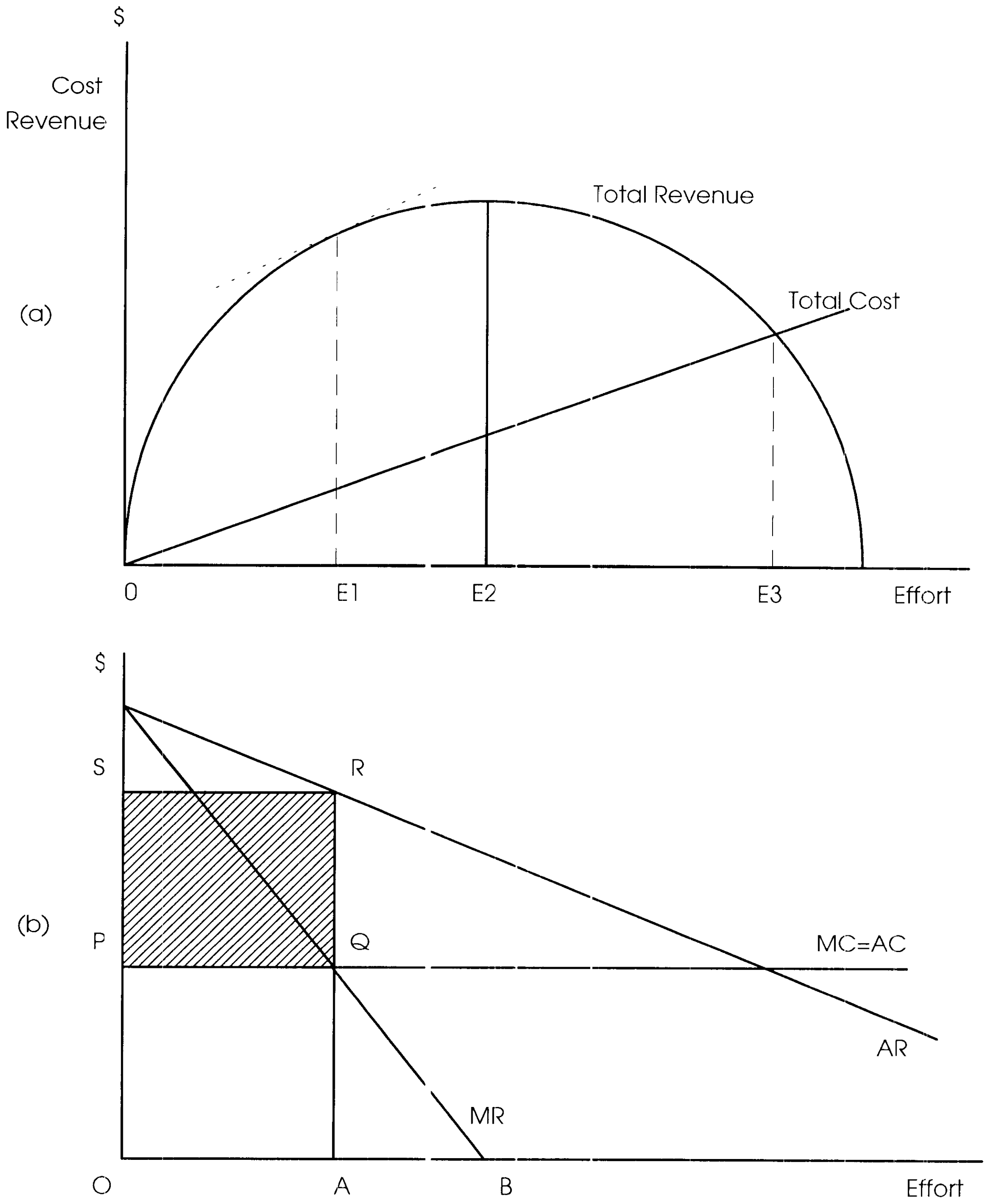

Figure 3.3 Sustainable rent generated by the fishery resource using the Gordon-Schaefer model

The curves of AR, MR, AC and MC in Figure 3.3b show a different view of the optimal resource rent indicated by the area PQRS. The fishery resource is common property hence any possible rent may be totally dissipated.

As the model suggests, the above analysis is considered a long-run phenomenon. It is obvious that over a longer period of time the dynamics of the fishery will change in response to the cost of fishing effort and because of stock levels. In this case, changes in stock levels may not be directly controlled by fishers who adjust to the changes indirectly by controlling their fishing effort. From this viewpoint, the fixed price assumption may not be appropriate. This, in turn, implies that the assumption about the price of fish can be relaxed using a variable price model. Variable prices in the fishery serve as an alternative to the conventional Gordon-Schaefer model. Variable prices indicate that prices are endogenously determined and that any changes in fishery regulation may affect both the producers and consumers.

3.3.1 Supply

From an economic perspective, the Gordon and Schaefer model can be criticised because it does not reflect a traditional supply relationship in the product market. For example, total revenue is a function of fishing effort. This means that total revenue is measured in terms of inputs instead of outputs. The other important feature of the model is the interpretation of the average revenue curve. As in traditional economic theory, the downward slope of the AR curve results from variability in the product price whereas the price in the above model is assumed constant. The demand slope occurs because of changes in biological productivity of the stock from changing in fishing effort[2].

To overcome confusion in interpreting the economic model of the fishery, a more general analysis has been formulated by including variable prices for fish and by considering cost and revenue in terms of fish caught. The conversion of cost of fishing effort (input) into cost of catch (output) provides a conventional supply curve for the

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[2] The reason behind this fact can be found in Cunningham, Dunn and Whitmarsh (1985, p. 42-44).

product. This relationship is likely to be more realistic than the Gordon-Schaefer model. This approach was first introduced by Copes (1970) by incorporating the sustainable yield curve into the cost of output relations. The Copes model is known as the 'backward bending supply' model. Here, the backward slope of the supply curve for the fishery has a specific interpretation[3]. In brief, the backward slope implies the nature of the common property resource and the biological dynamics of the fishery.

The mathematical derivation of the Copes model can be obtained by re-writing the relationship between catch and effort in terms of effort as a function of catch, instead of catch as a function of effort. The expression will yield:

$$Y = aE - bE^2$$

$$(3.22) \quad E = \frac{a \pm \sqrt{\left(a^2 - 4bY\right)}}{2b} \quad .$$

With the same assumptions of constant cost per unit of fishing effort, the total cost (TC), marginal cost (MC) and average cost (AC) can be obtained as:

$$TC = c\,E$$

$$(3.23) \quad TC = c\left\{\frac{a \pm \sqrt{\left(a^2 - 4bY\right)}}{2b}\right\}$$

$$(3.24) \quad MC = \frac{dTC}{dY} = \frac{c}{\pm\sqrt{\left(a^2 - 4bY\right)}}$$

$$(3.25) \quad AC = \frac{TC}{Y} = \frac{2c}{a \pm \sqrt{\left(a^2 - 4bY\right)}} \quad .$$

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[3] Copes (1970), pp. 74-75.

The long-run average cost for producing fish in the last equation constitutes the supply function for a fishery. Derivations of several important functional relationships in the fishery are undertaken graphically in Figure 3.4.

The curve in quadrant IV of Figure 3.4 describes long-run biological production for a fishery in terms of the sustainable yield curve. That is, the relationship between catch and effort from the Gordon-Schaefer model. It shows that successive unit yield per catch would require a higher amount of effort. The linear relationship between catch per unit of effort (Y/E) and effort (E) which is depicted in the quadrant III is calculated from the catch-effort relationship. Thus, fishing effort represents a combination of inputs, such as standard size of labour, gear and other production inputs for catching fish. The market price of inputs describes the cost of fishing effort. Under the assumption of constant cost per unit of effort, the long-run average cost curve slopes upward and bends backward beyond the maximum sustainable yield as shown in quadrant I. Hence, the curve is considered a backward bending supply curve.

Movements along the curve from the origin through the 'bend' and then toward the left-hand corner represent increases in fishing effort and decreases in the fish stock. This indicates that sustainable catch initially increases as fishing effort expands. However, beyond the maximum point the sustainable catch decreases as fishing effort continues to increase. On the other hand, as fishing effort increases, total cost increases at an increasing rate. This means that each successive unit of catch will be followed by a larger increase in total costs. Consequently, as fishing effort increases, average costs gradually increase. From Figure 3.4, as the maximum sustainable catch is approached, the average cost curve slopes upwards. Beyond that point total costs continue to increase but sustainable catch does not. This causes average costs to keep increasing and the curve to bend backward.

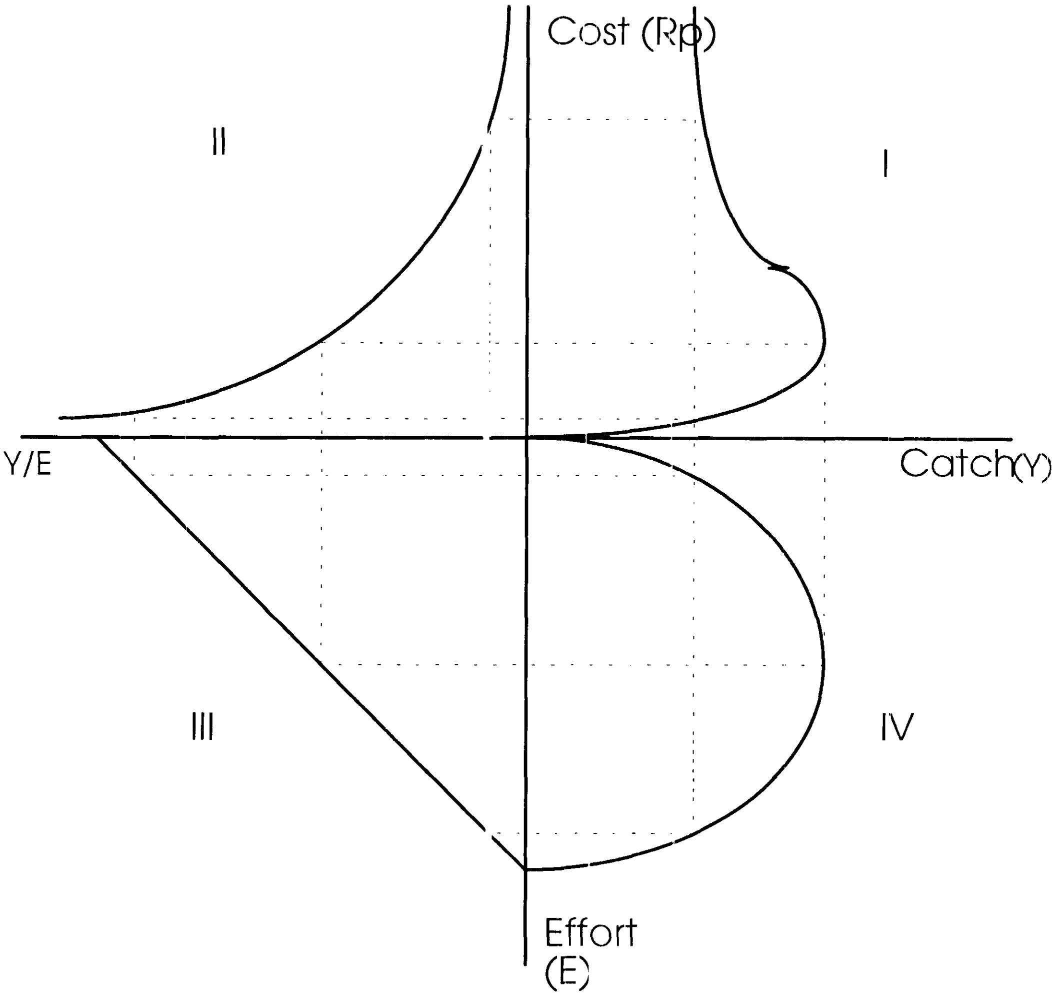

Figure 3.4 Relationship between catch, effort and cost in a fishery.

3.3.2 Demand

Assuming a derived demand for fish can be determined, this can be superimposed to investigate the optimal strategy for fishery resource exploitation. The demand function shows the marginal value that consumers place on fish at various levels of catch. The demand for agricultural products is usually downward sloping, since market price falls as output increases. However, demand for harvesting fish from South Sumatra may not follow this phenomenon. In the case of perfect substitution between freshwater fish and other fish, the demand may be a flat line indicating perfectly elastic demand.

It has been assumed that demand for fish is influenced by its own price, prices of related goods, disposable income and growth rate of the population. This can be expressed as:

(3.26) $Q_t = f(P_t, P_{st}, I_t, N_t)$

where Q_t : quantity demanded for fish at time t
P_t : price of the fish
P_{st} : price of substitute goods
I_t : disposable income
N_t : population.

In order to estimate parameters, the demand function is assumed to be either linear, semi-log or double-log in functional form. The linear version of the demand function is written as:

(3.27) $Q_t = A_o + B_o P_t + B_1 P_{st} + B_2 I_t + B_3 N_t$.

This equation becomes:

(3.28) $Q_t = A_1 + B_o P_t$

where $A_1 = A_o + B_1 P_{st} + B_2 I_t + B_3 N_t$.

Then, equation (3.28) can be converted to the common functional form of demand as

(3.29) $P_t = f(Q_t)$

or expressed as:

(3.30) $P_t = \alpha - \beta Q_t$.

3.4 Bioeconomic Models and Optimal Resource Use

As the name suggests, a bioeconomic model represents a combination of biological and economic models applied to the fishery. In this study, a biological surplus production or dynamics biomass model is used to represent the fishery. With the assumption of fixed prices for the product, the Gordon-Schaefer model (Gordon 1954; Schaefer 1954, 1957b) is applied. Alternatively, with the assumption of variable prices, the Copes model (Copes 1970) is applied. Optimal resource use is identified in terms of maximum sustainable yield (MSY), maximum economic yield (MEY) and maximum social yield (MScY).

The basic traditional bioeconomic model of Gordon and Schaefer covers only biological and economic factors in the fishery. With this model, it is implicitly assumed that the market price of fishing effort reflects the true sacrifices of society to obtain the fish. This means that fishers use all their available resources in fishing rather than in other possible occupations. Whenever the social aspect is taken into consideration, e.g., unemployment, fishing wages do not reflect the true opportunity cost of labour. Under such conditions, fishers have no alternative to fishing and society makes little sacrifice to keep them in the fishery since their opportunity cost is close to zero. Inclusion of this factor in the traditional bioeconomic model of Gordon-Schaefer provides an extension of the basic model. This has been undertaken by Panayotou

(1982) who showed that, with unemployment, the cost of labour should not be included in the variable cost of fishing effort.

3.4.1 Alternative sustainable equilibria

Optimal resource use in fisheries is often described by biologists in terms of maximising sustainable yield, or by economists in terms of maximising economic yield. Instead, optimal resource use can also be viewed as maximising social benefits. The analytical framework for defining optimal resource use in a fishery is as follows.

The level of effort which will generate the maximum sustainable yield (MSY) can be obtained from equation (3.10) by taking a partial derivative of Y with respect to E and setting it equal to zero as shown:

(3.31) $E_{MSY} = a/2b$.

The output at MSY can be obtained by substituting effort at MSY (equation 3.31) into equation (3.10).

(3.32) $Y_{MSY} = a^2/4b$.

Following the fixed price model, the long-run relationship between total revenue and effort, and total cost and effort, is illustrated in Figure 3.5.

The maximum sustainable yield (MSY), E_2, is the point about which biologists are most concerned in determining the optimal level of effort. As demonstrated, the sustainable catch-effort relationship is identical to the growth-effort relationship. More effort will bring about a more or less proportional increase in catch. At higher levels of effort, the growth in the size of catches will be smaller until the point of maximum sustainable yield is reached. Beyond this point, each additional effort reduces sustainable catch.

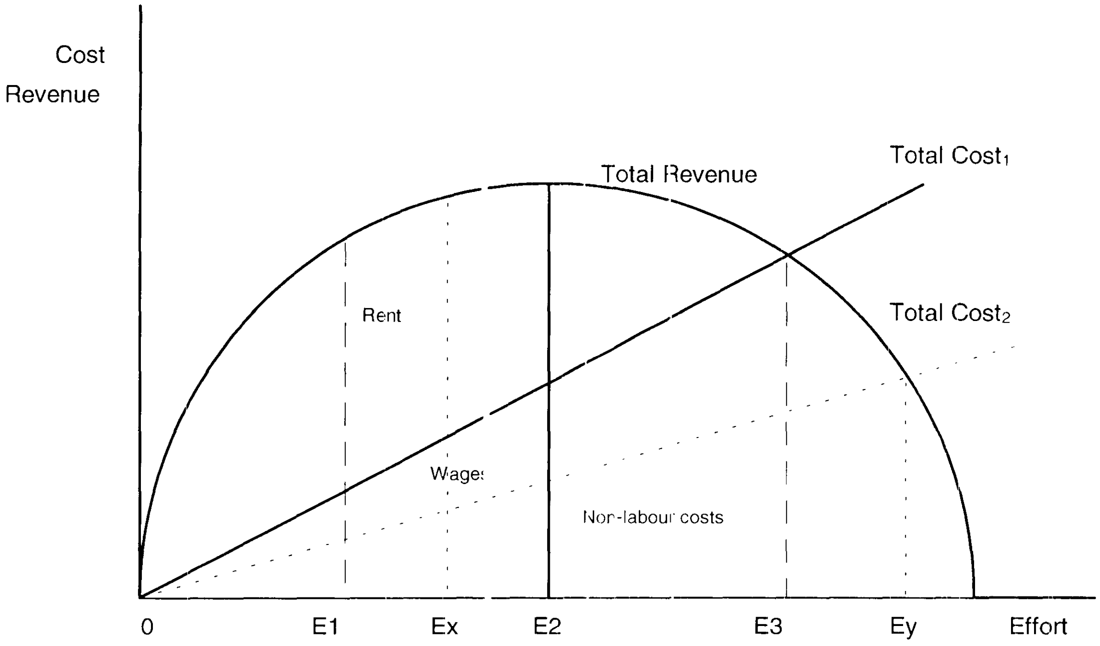

Figure 3.5 A fixed price mode of a fishery indicating five possible equilibria, i.e., the MEY (E1), MScY (Ex), MSY (E2), ZRR (E3) and ZScY (Ey)

The diminishing efficiency of effort as the level of exploitation increases can be shown by expressing catch per unit of effort (CPUE) as a function of effort (E). This is described mathematically in equation (3.11) (Schaefer model) and equation (3.14) (Fox model). The catch curve tends to decline as fishing effort increases reflecting the reduction in the stock which cannot reproduce at a high enough rate to sustain the stock.

Fishery economists prefer to reach the point of MEY (E_1) rather than MSY (E_2). The MEY generates the highest profits without threatening the fishery. The net benefit to the owner of the fishery is maximised when marginal revenue equals marginal cost where resource rents are maximised. Expanding the level of fishing effort from zero up to E_1 adds to profit. Beyond this point, profits decrease as additional fishing costs exceed additional revenues.

MEY is obtained by equating equations (3.20) and (3.18) as follows:

$$MR = MC$$

$$p(a - 2bE_{MEY}) = c$$

(3.33) $$E_{MEY} = (pa - c)/2bp = (a/2b) - (c/2bp) .$$

By solving equations (3.33) and (3.3) :

(3.34) $$E_{MEY} = E_{MSY} - c/2bp .$$

Since c, b, p >0, it is concluded that $E_{MEY} < E_{MSY}$. In other words, economic yield is maximised at a lower level of effort than physical yield. The MEY itself may be obtained from the difference between total revenue and total cost as follows :

(3.35) $MEY = TR_{MEY} - TC_{MEY}$

$= p(a E_{MEY} - bE_{MEY}^2) - c E_{MEY}$

$= [pa - c - b\{(pa - c)/2bp\}]/\{(pa - c)/2bp\}.$

Thus, excess profits or economic rents are lower at E_{MSY} than at E_{MEY}. This implies that the owner of the resource would prefer the level of effort at point E_1 to maximise profits.

Under an open-access or unregulated fishery individual fishers attempt to maximise their income by expanding effort as long as their average revenue (AR) is greater than the average cost (AC) of their effort. At the level of effort which generates zero resource rent (ZRR), the equilibrium is called a bioeconomic equilibrium (BE). At this point (E3), both the stock (bio) and the industry (economic) have stabilised. Thus, the fishery effort as a whole expands to point E_3 where:

$$AR = AC$$

$$p(a - bE) = c$$

(3.36) $E_{BE} = \{a - (c/p)\}/b$

When equations (3.19) and (3.24) are solved to obtain E_{BE}, profits are totally dissipated :

(3.37) $TR_{BE} - TC_{BE} = 0$

At this point, there is no economic rent from the resource. The reduction in effort from E_{BE} to E_{MEY} would generate profits to some of the fishers and at the same time, the size of the fish stock would increase.

Both the objectives of MSY and MEY are essentially considered single-objective options. MSY provides the maximum quantity of fish which could theoretically be caught from a given stock. MEY determines the quantity of fish which could produce the highest profit in the long term. Optimal sustainable yield (which would consider multiple-objectives for the fishery) may be defined as maximum social yield (MScY).

MScY may balance multiple-objectives in fishery management (Charles 1988). This optimal level ensures that the quantity of fish which would maximise welfare in terms of factors such as income distribution and employment is caught. Maximum social yield is defined by taking social aspects into consideration in determining fishery management. Crutchfield (1979) and Sinclair (1983) pointed out some previous studies on socioeconomic factors in fishery management. The results indicated that most studies have focused on the choice of fishery policy where fishers had low opportunity costs. In the small-scale fishery, for example, if other job opportunities are not available for poor fishers, at least they can earn a low but subsistence income. Referring to problems in the small-scale fishery, Panayotou (1982) noted that a variety of socioeconomic factors could be incorporated into the basic static bioeconomic model.

Compared to MEY, MScY includes the scarcity of alternative employment opportunities. This optimal level can be determined by dividing the cost of fishing into two components, private labour costs (wages) and other capital and operating costs. Given the high levels of unemployment in the economy, the opportunity cost of labour in the fishery is close to zero. This means that net social benefits will comprise the sum of surplus profits generated by the fishery and wages to fishers.

The bioeconomic model implicitly assumes that the market price of fishing inputs reflects the true sacrifices which society makes in using these inputs for fishing rather than in other occupations. Under this assumption, attaining the level of MEY from the fishery may require a large reduction in effort. This implies that a large number of fishers may be forced out of fishing.

However, because of unemployment problems, fishers may have no other alternative activity. Their opportunity cost is already close to zero. Society is making little or no sacrifice in keeping them in the fishery. Under these conditions, the cost of labour as well as labour paid in calculating the cost per unit effort is zero. Therefore, the new total cost (TC) will be lower than the previous one. This makes the level of effort in MScY (Ex) higher than in MEY (E1) as shown in Figure 3.5.

With respect to various fishery objectives, Figure 3.5 shows the existence of five possible equilibria. The first three equilibria, i.e., maximum economic yield (E1), maximum sustainable yield (E2) and open access equilibrium (E3) have been discussed earlier. A new equilibrium in this figure is maximum social yield (Ex) which incorporates the opportunity cost of fishers into the bioeconomic model. The other equilibrium is an optimal in terms of employment (Ey), that is, the point where social yield is zero (ZScY).

3.4.2 Measures of welfare change

As is indicated in the previous section, the variable price model is best described in terms of resources and costs per unit of catch rather than costs per unit of effort. The variable price model provides an economic description in terms of supply and demand. The supply curve, as indicated by Copes (1970), will bend backward. The supply is indicated by AC curve (equation 3.25) whereas the demand for the fish is illustrated by the AR curve (equation 3.30).

Common measures or economic welfare include producers' surplus defined as the area above the supply curve and below the price line and consumers' surplus defined as the area under the demand curve and above the price line. The consumers' surplus (CS) at each equilibrium point such as, MEY, MSY, Monopoly and Bioeconomic (BE) can be calculated by applying the following formulae

$$(3.38)\quad CS_i = \int_{Y_0}^{Y_i} P(Y_i)\,dY - TR(Y_i)$$

where 'i' denotes the state or condition specified in the objective of managing the fishery.

Producers' surplus (PS), can be expressed mathematically as:

(3.39) $PS_i = TR(Y_i) - \int_{Y_0}^{Y_i} MC(Y_i)\, dY$.

The maximum economic yield (MEY) and bioeconomic equilibrium (BE) levels of effort can be determined by setting, respectively, p = AR = MC and p = AR = AC, as shown in Figure 3.6.

The social benefits (resource rent + consumer benefits) are maximised at Y3. Profits, which include both resources and monopolistic rents, are maximised, at a lower level of effort, where MR = MC. These profits are completely dissipated at the point of Y1 (AR = AC).

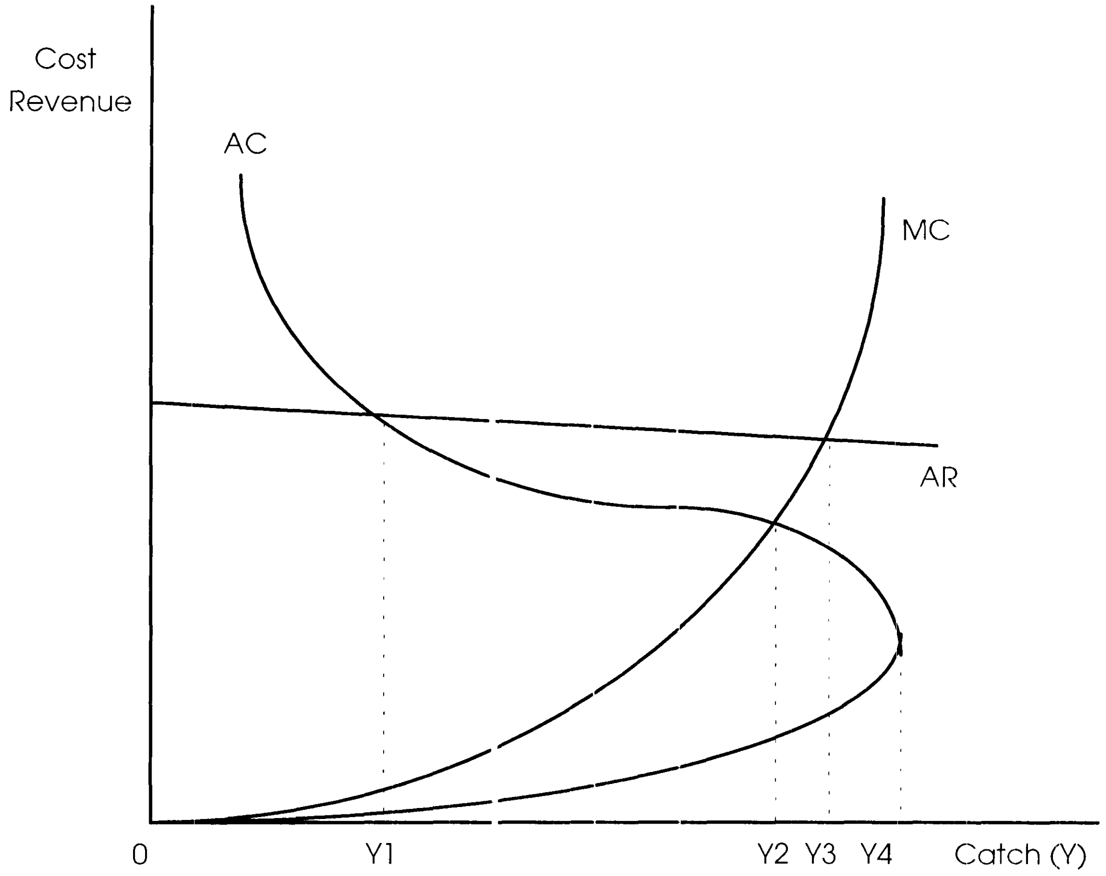

Figure 3.6 The Equilibrium Point of the maximum sustainable yield (Y4) maximum economic yield (Y3), monopoly condition (Y2) and bionomic condition (Y1) under the variable price model

3.5 Fishery Management

Renewable fishery resources face many problems, such as stock flow dynamics, externalities in production, the relationship between fishers and the natural environment, social control or regulations, public investment and the economic implications of property rights. All of the above problems are caused by the common nature of this fishery resource; that is, open-access fishery. Open access to the fishery leads to the problem of over-fishing, which can be interpreted (Cunningham *et al.* 1985; Walters 1986) as follows.

a. Biological over-fishing, defined as a level of effort which reduces the biomass below the MSY.
b. Recruitment over-fishing, defined as reducing the spawning stock to a level at which average recruitment is significantly diminished. This situation is usually indicated by continuous reduction in the size of fish being caught.
c. Economic over-fishing, defined as a level of effort beyond the level of MEY.

Given the above problems, most fishery management aims at avoiding over-fishing. Furthermore, fisheries management can be viewed as a means of achieving certain social goals or objectives through the use of appropriate regulatory instruments to avoid over-fishing. Such instruments provide an institutional and regulatory framework within which the desired level of fishing effort can be obtained. In this case, a biological reference point is first selected in fishery management as a measurement of the optimal level. This measurement aims at stabilising the stock at that biomass which provides the MSY which is available under average environmental conditions. From this viewpoint, effort levels exceeding MSY will cause a reduction in the stock population and thereby constitute biological over-fishing. On the other hand, effort levels below MSY will cause biological under-fishing. An economic reference point can be selected as an objective of fishery management in order to take into account various economic factors, such as price of output and cost per unit of fishing effort. This measurement aims at describing economic benefits obtainable from the fishery.

As is discussed in previous sections, optimising economic and/or socioeconomic benefits from the fishery will mean not exceeding maximum biological yield. Optimal resource use in terms of economic criteria is desirable since this level is more conservative than the biological optimal. Therefore, in this section, possible management options will be assessed mostly from the viewpoint of economic efficiency, that is, the ability of regulations to ensure the greatest net contribution to the economy.

The unregulated fishery may lead to expansion of the fishing effort to the level where the resource rent is completely dissipated (Gordon 1954; Ricker 1975; and Clark 1985). The dissipation of resource rent derivable from the fishery signifies economic over-fishing. In extreme cases, this could cause the destruction of the fish stock for a particular resource. Therefore, appropriate management of the fishery resource is desirable.

There are several alternatives for managing a fishery. In general, these alternatives can be classified into two categories, fishing effort and catch limitations. However, other classifications can be introduced without following those categories. In this section, the effects of possible management options for a fishery in terms of licensing, limited entry, Territorial Use Rights in Fisheries (TURFs) and mixed regulations are assessed from the viewpoint of economic efficiency. Then flexibility of the options in terms of the ease of implementation and enforcement is investigated.

3.5.1 Licensing

The main objective of a licensing scheme is to restrict inputs of labour and/or capital in the fishery (Crutchfield 1979; Scott 1979). In this scheme, the basic idea is to improve both the yield and economic performance of the fishery by reducing fishing pressure. This system is considered as a relatively flexible method and has been widely practised. Granting fishing licences, whether to one or several individuals, is similar to giving property rights to the fishery (Anderson 1977). However, this approach raises problems, such as what is to be licensed, how to issue licences, how many to issue and how the licences should be distributed.

In most small-scale fisheries licences are distributed on the basis of the number of total fishers. They may also be issued in terms of the fishing unit. Licensing in terms of fishers is usually difficult to relate to fishing effort. On the other hand, licensing in terms of fishing unit is impossible to impose in the particular case considered in this study. This is because the small-scale fishery is characterised by heterogeneous fishing units to target mixed species of fish. In this particular fishery, Meany (1977, p. 11) suggested having licences for the entire fishery and allowing fishers to catch all species according to a fee schedule.

The inland fishery is essentially multi-purpose in character since fishers use a combination of gear, switching from one kind to another depending on the seasons. Therefore, the issue of determining the optimal number of licences is complex and difficult to resolve. Theoretically, the optimal number of licences is calculated corresponding to the desired level of fishing effort, which, in turn, is determined by the objectives of management. In this sense, Campbell and Lindner (1990) argue that the most important determinant for the success of a licence limitation scheme is the structure of the production process for fishing effort in the fishery. In practice, because of the complexity of the fishery, this regulation device may diminish any derivable economic benefit from the fishery (Tai 1992). For example, studies by Fraser (1977) and Pearse and Wilen (1979) revealed that even though a licensing scheme successfully reduced the number of fishing units in the British Columbia salmon fishery, fishing effort actually increased. This was because fishers had adjusted their fishing units through technological improvement.

Licences can be distributed in several ways. The most common method is the 'grandfather' scheme whereby licences are granted to fishers who have been using the fishery previously. This scheme is widely applied in the case of the small-scale fisheries. Allocation of the licence is usually decided on equity considerations under a 'grandfather' system where individuals are granted licences by a nominated local authority. In this case, the initial actual fishing effort remains constant. This scheme keeps others from entering the fishery; however, it fails to reduce fishing effort. In order to maintain a possible reduction in fishing effort over time, an additional regulation is needed. This can be initiated through regulation with a non-transferable licence scheme in which licences expire when fishers retire.

In the case of available government funds, reduction of the current licences can be initiated by introducing a 'buy-back program'. Here, although total fishing effort is reduced, fishers may enjoy the improvement in net value of their catches and increased value in their licences. The increased returns from the fishery would be used to compensate fishers who decided to leave the fishery.

Another possibility for reducing the number of licences is to foster the rate of reduction in licences by introducing an auction, so that licenses are granted to the highest bidder. The purpose of this system is to allow the fishery management to be more flexible. Under this scheme, the licence could be either permanent or valid for only a specified time. Fewer fishers should be licensed, reducing the pressure on that particular resource, because only the most efficient fishers would be able to obtain the licences. However, a similar problem to that arising from the taxation system is likely to occur (Waugh 1984).Waugh pointed out that this procedure is politically difficult whenever an urgent need for control exists due to depletion of a particular species.

The controversial issue regarding the licensing scheme is the question of whether the licences should be transferable or not. Transferability of licences was indicated by Crutchfield (1979) as costless and relatively easy to be implemented. However, Copes (1988) argued against this type of regulation. He pointed out that in the long run, the transferable licence scheme will not increase fishing incomes. On the other hand, non-transferable licences may reduce the problem of 'capital stuffing'[4]. This is because any significant increase in fishing capacity through 'capital stuffing' could be reduced by fostering a reduction in the licence holders.

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[4] Capital stuffing is defined as a condition in which the fishery can provide profit but in a very short time. This is because in the early operation fish price and harvest are good and hence lead to an increased fishing effort in order to seek higher profits. However, an increase in the fishing effort

The economic implications of licences can be analysed in two ways: first, by examining effects on total costs and, second on total revenue. The former, as indicated by licensing based on fishers (or boat), is less effective than the latter, as indicated by licensing based on fishing effort. Assuming that the proper number of licences based on fishers (or boat) has been issued, whenever fishers operate at the least-cost point on their average cost curve, they tend to expand their amount of fishing effort, either in terms of lengthening their actual time for fishing or seeking more efficient fishing gear. In other words, fishers compensate for higher costs with more fishing effort to ensure that their return is greater than the marginal cost. This means that the resource may be excessively utilised. On the other hand, restrictions on the basis of total allowable fishing effort may ensure fishers use their fishing effort efficiently.

3.5.2 Limited entry

Limited entry to the fishery can be applied to overcome problems of over-fishing. Entry can be limited in terms of a licensing scheme, taxes, quotas, gear restrictions, mesh-size limitations, closed seasons and closed areas. As previously discussed, a limited-entry licensing scheme has the economic effect of restricting the number of fishers and/or fishing units. Other types of limited entry will be discussed below.

3.5.2.1 Taxes

Limited entry can be imposed by introducing taxes either on the basis of fish caught or on level of fishing effort. However, both of these regulations are likely to be unpopular, especially in case of the small-scale fisheries.

The economic effect of imposing taxes on the basis of total catch is to increase the cost of fishing and to reduce the amount of effort. It eliminates less efficient fishing units. This regulation looks very appealing in theory It allows fishers to act independently. It does not require monitoring of fishing effort, and it may lead to a social optimal. One of the advantages of this method, if it can be implemented, is that taxes can be levied

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is not accompanied by increases in the expected income.

on certain species, and differential treatment can be applied to conserve only the threatened species. However, an efficient and flexible administration is needed and costs may be high, especially if some measure of surveillance is required.

Taxation could probably be imposed if all the fish caught were landed at a port where the catches were recorded. However in the case of small-scale fishery, fishers usually sell their catches in dispersed areas which cannot be monitored. The fishers could counteract such a regulation if it was imposed. For the government, the difficulty exists especially in ensuring whether the tax was paid or not and also in collecting the tax.

As generally happens in a fishery, supply curve is relatively elastic. A small change in the price of fish will eventually lead to a large change in the quantity caught. If a tax is effective, aggregate effort will quickly decline. Those remaining in the fishery will not be worse off but some will have to leave. If finding alternative forms of employment proves costly then the final result for some will be a harder life than before. The authorities will eventually collect rent from the fishery and it may be possible to compensate displaced persons. However, this policy option is unlikely to appease them. Taxing the catch can create unemployment problems.

Whenever tax on fishing effort is to be considered, the most serious problem is how to define fishing effort. With such a tax, the long-run average costs will shift up and the amount of effort will eventually be reduced. This leads to reduction in the number of fishers and creates unemployment. Other disadvantages of this type of regulation are problems of acceptability and flexibility. The tax is paid by the fishers, not the larger society. Even without such a tax, small-scale fishers receive very little compared to the national per capita income. While the authority may wish to maintain the fish resources, they have also to improve the standard of living of the fishers. Another difficulty is that the tax must be revised each period. Hence, in most cases, this type of regulation is considered inflexible.

3.5.2.2 Quotas

A quota is a kind of regulation which prohibits further fishing once a specified catch has been taken. Regulation devices in terms of total allowable catch (TAC) and individual quota (IQ) control the level of catch directly. The total allowable catch may be considered as a highly flexible management tool. However, quota on the total catch could, in fact, worsen open-access problems. When harvest is reduced because of setting the quota, prices may increase. This may stimulate fishers to greater fishing effort since they would expect to benefit from higher prices in the regulated fishery. As a result, the fishing season will be shorter than before. Fewer fish may be harvested but more fishing effort than is needed. This, in turn, may lead to decreased efficiency of the fishing unit.

The potential profit will stimulate each fisher to greater fishing effort because he or she expects a large individual share of the catch before the overall quota is reached. In other words, the fisher will produce effort faster than without a quota policy. This situation may lead to an increase in average cost. As effort increases, the quota will shorten the fishing season in that area

Christy (1973) and Moloney and Pearse (1979) argue that the economic efficiency of the TACs can be improved if they can be divided into smaller units and allocated to individual fishers or fishing units. As individual fishers are guaranteed an entitlement to a specific share of the catch, they do not have to 'speed up' their operation to secure their share. In the case of an individual quota, it is believed that its economic efficiency can be improved by combining it with transferable licences. However, this may also create many problems, such as unstable stock, seasonal variations, 'flash fishery'[5] and industry acceptance (Copes 1986).

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[5] Flash fishery is defined as fishing which operates in a very short period of time.

3.5.2.3 Gear restrictions

Gear restrictions may be imposed in terms of either specific gear being banned outright or circumscribed in its use, such as by limitations on size of engine, boat and net. The main reason for this regulation is to reduce the catchability coefficient of the fishing unit. Economically, the impact of gear restrictions is similar to that of quotas in the sense of raising the average cost of fishing.

3.5.2.4 Mesh-size limitations

Economically, mesh-size restrictions will not improve fishing efficiency. However, increasing the mesh size may result in greater sustainable yield in the long run. This means that this regulation creates an economic rent, attracting more fishers, and hence over a long period of time the economic rent may be dissipated.

3.5.2.5 Closed seasons

Limited entry by means of a closed season is defined as a prohibition on fishing over a given period of time. The main purpose of this regulation is to reduce the total number of fish caught. Thus, in this respect, the regulation is also similar to quotas. Biologically, this regulation may produce such an improvement, but economically it will not. From an economic perspective, an important question is when the regulation will be imposed. This is because the decision of when fish should be caught is essentially an economic matter, involving a comparison of alternative costs and revenues at the different points in time when fishing is possible.

The effectiveness of closed season in reducing total fish caught or fishing mortality may vary widely, depending on specific characteristics of fish behaviour. Considering migratory fish, in which fish concentrate at different times in different areas, closed season may affect the fishery permanently. The effect of such a regulatory instrument would be to increase costs and possibly maintain sustainable yields of that particular fish.

3.5.2.6 Closed areas

Closing fishing areas for either part or all of the season is aimed at protecting either young or spawning fish. Like closed seasons, this regulation aims at improving the biological productivity of fish resources. With this regulation, the fundamental problem of open access can be resolved. However, long-run improvement in the economic performance of the fishery may not be expected. Limited entry by area closure causes an investment problem. For example, by taking less fish now, larger fish may be caught at a later time. The investment problem may happen whenever the weight increment yields a rate of return greater than the going rate of interest.

3.5.3 Territorial use rights in fisheries (TURFs)

Panayotou (1983) defines the term of territorial use rights in fisheries (TURFs) as an alternative management scheme which is designed to grant rights to a community over the fishery resource within a specific area and/or specific period of time. This regulation is potentially effective when applied to developing countries (Lawson 1984). This is because the local community has a role in controlling their resource. With respect to problems of multi-species, multi-gear tropical fisheries and wide spread of the fishing communities, this regulation is appropriate because government authorities do not have to spend money for monitoring and enforcement of regulations.

Even though the regulation has been used for a long time throughout the world, little effort has been made to encourage TURFs (Charles 1988) because of their limited applicability. Rettig (1989) argues that the application of TURFs depends on social and cultural traditions. Such social and cultural requirements may not exist in other fishery resources to be managed.

3.5.4 Mixed regulations

Instead of adopting single-management options for the fishery resource, mixed regulations may be appropriately applied to a particular resource such as the small-scale fishery. Mixed regulations give an opportunity to fulfil objectives of maximising biological, economic and social reference points. This can be built up by a combination of several possible management schemes as previously mentioned. For example, in the case of inland tropical fisheries, a combination of licensing, limited entry and TURFs may provide better management options for that particular resource.

3.6 Summary and Concluding Remarks

This chapter has reviewed the theoretical framework of bioeconomic analysis for fishery management. The framework was developed from biological and economic reference points of the fishery and then by combining them. Resource allocation of the fishery was analysed with this model. As was discussed in the fishery management section, quotas, gear restrictions, closed seasons and areas of fishing do not directly deal with the open-access problem None of these management schemes would significantly improve the economic performance of the fishery. However, they would significantly benefit the biological status of the fishery resource. On the other hand, licensing, taxation and individual quotas could significantly improve the economic efficiency of the fishery.

In general, the preceding review has shown that the literature deals mainly with biomass dynamic models with temperate marine fisheries in developed countries. There is limited literature on tropical inland fisheries in developing countries. Problems occurring in such fisheries may be more complex, comprising not only biological and economic aspects, but also social, institutional and political dimensions. Thus, the theoretical framework of bioeconomic analysis for fisheries should be applied to that particular resource taking into consideration all these possibly important considerations.

The nature of inland fisheries in South Sumatra can be characterised as mixed-species, multi-gear and small-scale fisheries. A limited-entry licensing scheme, with a combination of TURFs and biological reference points, appears to have some potential for success as a regulation scheme for managing those fisheries. Before analysing this question, a description of data, selection of parameters and estimation procedures for the selected model are presented in the next chapter