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MANAGEMENT OF SMALL PELAGIC FISHERIES ON THE NORTHWEST COAST OF PENINSULAR MALAYSIA: A BIO-SOCIOECONOMIC SIMULATION ANALYSIS

by

Tai Shzee-Yew

B.S., Universiti Pertanian Malaysia, 1980
M.Ec., University of New England, 1984

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

SIMON FRASER UNIVERSITY
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ABSTRACT

A number of studies have indicated that three major problems exist in the fishery sector of Malaysia. They are: (1) biological and economic overexploitation of the resource; (2) persistent poverty among fishing households; and (3) ensuing conflicts among various gear types. These problems indicate a need to better manage the resource. A major problem confronting management authority is the determination of the type and level of control to be applied to the fishery in order to best achieve some predetermined objectives. The main objective of this study is to develop a bio-socioeconomic simulation model to analyze the performance of management regulations for the small pelagic fishery on the Northwestern Coast of Peninsular Malaysia. The small pelagic fishery is judged as one of the most important fisheries in terms of landings, as a source of protein for domestic consumers, and as a major source of revenue for the purse seine, trawl and drift net fleets.

Simulation is the principal analytical tool used in this study. A model is developed which describes the biological, socioeconomic and management components of the fishery and their interrelationships, and which tracks the performance of the fishery over time. The model incorporates four major small pelagic species or species groups and three gear types. Several types of regulations for the fishery have been considered and analysed. They include: present management, pure limited entry; limited entry coupled with a license fee; increases in the opportunity cost of fishing effort; and a combination of the latter two. These regulations are evaluated using several performance measures such as landings, level of effort, consumer's surplus, social profits, employment and crew member's income.

The results confirm that the small pelagic resource in the study area has been biologically and economically overfished, but there are some rents being generated under the present management regime. Sensitivity analysis indicates that the model is not very sensitive to small changes in the values of most parameters. A reduction of fishing effort by about 50% results in the biological optimum while a 60% effort reduction gives the socio-economic optimum for the small pelagic fishery.

The most effective way of reducing fishing effort to the desired level is a combination of policies involving a reduction in fishing effort by 60% , levying licence fees, and increasing the opportunity costs of effort by 50%. This method appears to be socially acceptable and biologically and economically viable.

Acknowledgements

I would like to express my gratitute to Professor Parzival Copes and Professor Terry Heaps for their time, guidance and support throughout the preparation of this thesis and my graduate studies. Professor Copes' experience and knowledge in fishery management and Professor Heaps' skills in mathematical modelling have helped to improve this thesis immensely.

The financial support provided by the International Development and Research Center and the Universiti Pertanian Malaysia during my doctoral studies is greatly appreciated.

Many friends have made our stay in Vancouver memorable. Many thanks to Peter and Sarah Heindrichs and the family of James and Soi-Ping Hong for their friendship and hospitality. Special thanks to my wife Kwee-Peng and my children Ling-Ling, Liang-Kwang and Jie-Chuin for their patience, encouragement, and inspiration throughout the duration of my graduate study. To them, I dedicate this work.

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Chapter 1

Introduction

1.1 The Problem

Fisheries resources in many parts of the world can be characterised as being open-access. This nature of fisheries results in a pervasive tendency for fishing effort to expand to a point where resource rent is dissipated (Gordon, 1954). In many fisheries, the problem of economic overexploitation may also lead to stock depletion beyond the level which permits maximum sustainable yield. In the context of the fishery sector in Malaysia, there are also issues of poverty among fishermen's households and intense competition between users of various types of gear, resulting in crowding externalities and gear conflicts.

Due to the undesirable consequences of open-access fisheries, various management regulations have been proposed in the literature which aim at increasing yields, restricting allowable catches, and/or at increasing social and economic benefits (Pearse, 1980). Moreover, the extension of fisheries jurisdictions throughout the world in recent years also offers a unique opportunity for authorities to initiate management programs. In practice, fisheries management should be addressed in the context of programs which aim at improving social and economic benefits, as well as meeting the prevailing resource conservation goals. However, despite the growing recognition of the need to consider social and economic factors, most fishery regulation programs such as catch limitations, seasonal closure or mesh size limitations are still designed only to achieve conservation objectives.

A major problem confronting practical management of the fishery is the determination of the type and level of control appropriate to be applied to a fishery in order to best attain some predetermined objectives. Clearly, the more complex the fishery, the more difficult it is to estimate the optimal level of intervention (Clark, 1976).

1.2 The Objectives

The general objective of this study is to develop a bio-socioeconomic simulation model to analyze the performance of several management regulations or rules for the small pelagic fishery on the Northwestern Coast of Peninsular Malaysia. The specific objectives are:

(1) To estimate the parameters of the population dynamics of small pelagic species in the study area.

(2) To estimate the parameters of the dynamics of effort for major small pelagic fishing gears in the study area.

(3) To estimate demand equations and to determine market interactions for small pelagic species.

(4) To determine the extent of overexploitation of the small pelagic species in the study area.

(5) To analyze the performance of some management regulations for the small pelagic fishery in the study area.

The small pelagic fishery is chosen because its landings constitute a major proportion of the total harvest in the study area. These landings are mainly destined for domestic markets, thereby constituting an important source of protein to domestic consumers. In addition, the purse seine fleet in the study area derived a large proportion of its revenue from the small pelagic fishery. The small pelagic fishery also provides an important source of revenue for the trawl and drift net fleets.

1.3 The Approach

Fisheries management can be seen as a dynamic optimal control problem. While the solutions may be derived through optimization techniques such as dynamic programming or optimal control algorithms, these methods appear to be constrained by the problems of "curse of dimensionality" and convergence, especially in the context of complex real world fisheries. The complexity of most real world fisheries stems from, for example, the joint exploitation of several species, the heterogeneity of the fleet and the presence of market interactions. The complexity may preclude the derivation of optimal levels of regulation. Moreover, numerous social, economic and political constraints imposed on the management authority and the type and quality of information required to properly adjust in a timely fashion the levels of regulation to changing environment, further limit the applicability of the optimization approach (Anderson, 1982).

A less elegant but more tractable approach would be in practice more relevant in determining appropriate management regulations. One such approach is the use of a simulation model to portray the behaviour of a fishery under various management alternatives. This approach has the major advantage of allowing for considerable detail in specification of the model, therefore allowing for relative realism in modelling of a complex fishery system.

1.4 The Organisation

The characteristics of the fishery sector in Malaysia, with particular refrence to the small pelagic fishery in the study area are described in Chapter 2. In addition, a brief description of the various management regulations that have been implemented in Malaysia thus far are also presented.

A review of theories of fisheries management is given in Chapter 3. This review of the literature focuses on resource externalities and other inefficiencies arising from unregulated fisheries; the objectives and goals of fisheries management; and a discussion of major management regulations being practised in fisheries throughout the world.

A detailed description of the specification of the mathematical model is presented in Chapter 4. The model reflects the fundamental structure of the dynamics of the fishery as well as the interactions between its various components. The mathematical model consists of three interrelated sub-models: (1) biological and harvest, (2) demand and economic, and (3) effort dynamics and management.

The estimation of the parameters of the mathematical model and the specification of the empirical model for the small pelagic fishery on the Northwest Coast of Peninsular Malaysia is discussed in Chapter 5. In addition, the determination of the initial conditions, the setting up of the simulation runs and the adaptation of the general model to the specifics of the fishery are also discussed.

The simulation model is used to analyze the behaviour of the fishery under various management alternatives. The results of the analyses are presented in Chapter 6. The model is first validated by conducting sensitivity analyses around the results derived under the current conditions of the fishery (the base-case). The model is then adapted and used to determine the type and level of controls for the fishery which would achieve some predetermined bio-socioeconomic objectives.

Finally, a summary of this study, together with the conclusions and implications for small pelagic fishery management in the study area are presented and discussed in Chapter 7.

CHAPTER 2

The Marine Fishery Sector

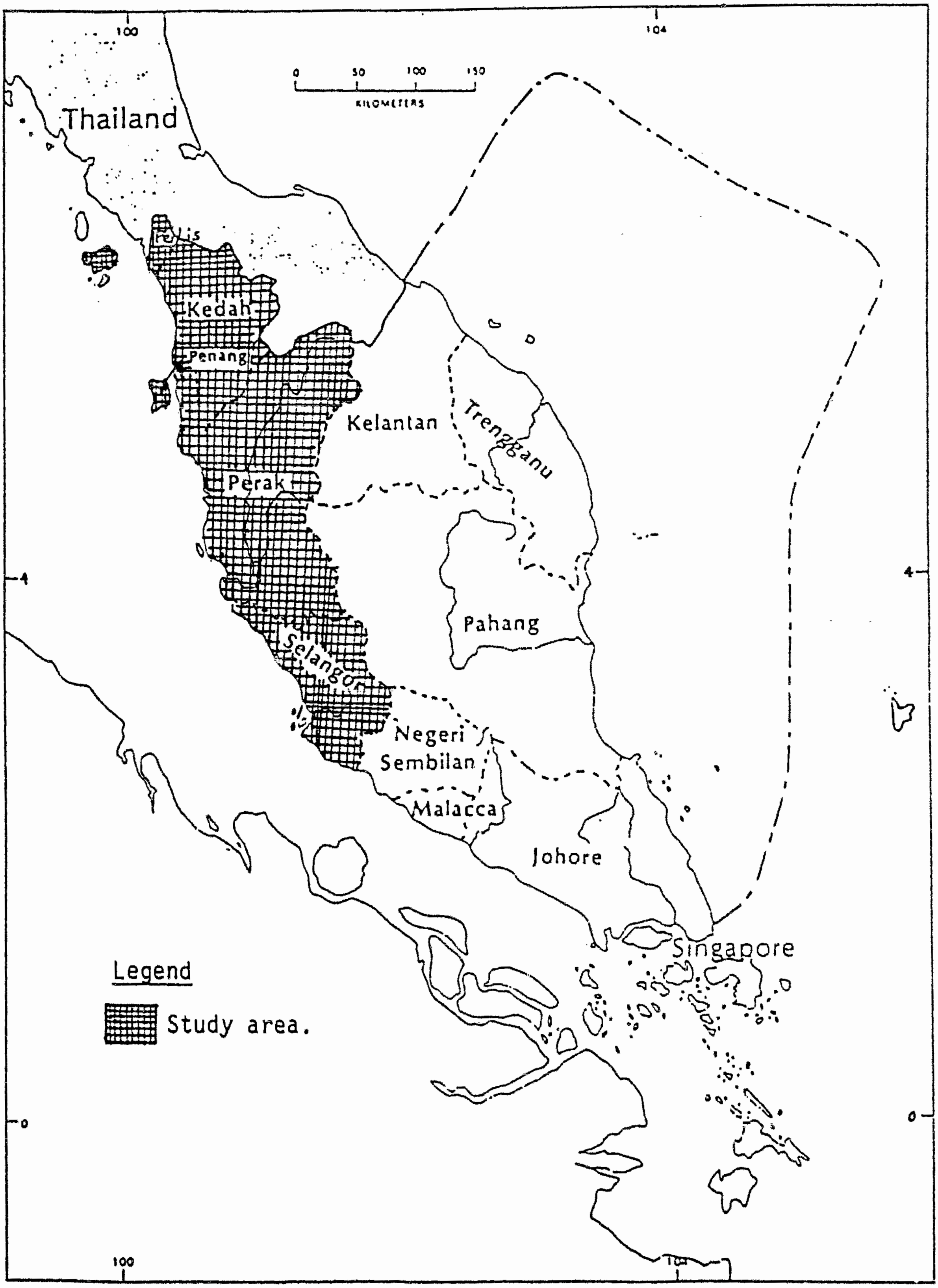
2.1 Introduction

Malaysia is a small country with a total land area of 329,758 square km. It consists of thirteen states, eleven of which are located in Peninsular Malaysia while the states of Sabah and Sarawak on the island of Borneo constitute East Malaysia. The study area in northwestern Peninsular Malaysia is made up of five states, namely, Perlis, Kedah, Pulau Pinang , Perak, and Selangor (see Figure 2.1).

Malaysia has a coastline of 4,055 km, of which 1,640 km is in Peninsular Malaysia and 2,415 km in the states of Sabah and Sarawak. The East and West Coasts of Peninsular Malaysia have coastlines of 915 km and 725 km respectively (Lembaga Kemajuan Ikan Malaysia, 1982). With the declaration of the 200-mile Exclusive Economic Zone, the total sea area of Malaysia has expanded to 160,000 square nautical miles.

Peninsular Malaysia has a humid equatorial climate. However regional and seasonal climatic differences exist between the East and West Coast due to the influence of the dual monsoonal pattern of Southeast Asia. The mean annual

Figure 2.1 Map of Peninsular Malaysia Showing Study Area.



temperature for the coastal areas of the peninsula varies between 26 and 28 °C while humidity fluctuates between 82% and 86%. The Northeast Monsoon that occurs between November and March affects the climate on the East Coast of Peninsular Malaysia. The mean annual rainfall in the region is around 254 to 305 cm, of which about 178 to 203 cm falls during the monsoon months. The severe weather associated with the Northeast Monsoon is not as extreme as the weather experienced in many other parts of Asia, but three-meter seas and gale-force winds are frequent. Consequently, fishing operations on the East Coast are mostly halted during the Northeast Monsoon season. The weather patterns on the West Coast of Peninsular Malaysia , however, are distinctly different as it is sheltered from the direct effect of both of the monsoonal systems. The central dividing mountain range provides protection from the Northeast Monsoon, while the Sumatran landmass attenuates the Southwest Monsoon system. Correspondingly, the median rainfall is lower than that on the East Coast with a range of 178 to 305 cm. The average wind and sea conditions are more placid than those found on the East Coast. As a result of the milder sea and weather conditions, fishing operations can be conducted throughout the year on the West Coast.

The topography varies between the East and West Coasts of Peninsular Malaysia. The northeast coastline is composed of long sandy beaches intermittent with rocky patches due to the effect of the Northeast Monsoon. The offshore bottom is sandy and becomes muddy beyond the ten fathom line with numerous rocky or coral patches. The continental shelf in the South China Sea has a gradual slope and the 20 fathom line is more than 15 nautical miles off shore. There are numerous fertile mangrove swamps along the shoreline and the littoral and sublittoral sea floors are very muddy with a few rocky islands. On the West Coast, the Strait of Malacca is very shallow with a depth of 15 fathoms in the south to a maximum depth of 40 fathoms in the north. A northwest current prevails up the Strait throughout the year, except during June through August when the current abates, and sometimes reverses in the southern reaches. Numerous heavily silted rivers are found along both coasts and the major fishing centres are located in the river mouths or "kuala". The East Coast does not have many natural harbours, whereas the nearshore islands off the West Coast such as Pangkor, Pulau Pinang, Langkawi and numerous other smaller islands provide unhampered access and shelter during inclement weather.

2.2 Contributions of the Fishery Sector

The fishery sector in Malaysia is small. The value of landings contributed on average only about 2 percent to the country's GDP in the last decade (Department of Fishery, 1990). This contribution is much less significant than those from other sectors such as manufacturing, petroleum, rubber and oil palm.

The fishery sector plays, however, an important role as a source of animal protein for the country's populace. Fish constitutes about 60 percent of total animal protein consumed in the country, mainly due to the fact that it is a cheap and easily accessible form of protein food acceptable to all ethnic and religious groups. The average annual per capita consumption of fish between 1960 and 1984 was approximately 21 kg which is three times higher than any other source of protein food.

Another important contribution of the fishery sector is in the form of employment. In 1989, direct employment in the fishery sector amounted to 103,995 fishermen or 1.7 percent of the total labour force in the country (Department of Fishery, 1990). If indirect employment in fishery-related activities such as handling, processing, distribution as well as ancilliary industries is considered, the employment rate of the fishery sector is around 4.4 percent of the economically active population (Clad, 1984).

The fishery sector also contributes foreign exchange earnings to the country. Malaysia is a net exporter of fish and fishery products, deriving about \$168.56[1] million as net foreign earnings in 1989 (Department of Statistics 1990). Although small, it represents a positive contribution to the trade balance of the country.

2.3 The Marine Fishery Industry in Peninsular Malaysia

Peninsular Malaysia is the most important region in the country in terms of marine fishery production, employment and number of active fishing vessels. The marine fishery industry in Peninsular Malaysia will be described in this section.

On the average, there were 25,281 licensed fishing vessels in Peninsular Malaysia for the period between 1980 and 1989 (Table 2.1). The majority of these vessels (72%) were found on the West Coast as compared to about 7,179 on the East Coast. These vessels can be categorised into three main groups, namely non-powered vessels, those powered with outboard engines and those with inboard engines. The inboard-powered vessels can be sub-divided further, based on their tonnage. As shown in Table 2.1, inboard powered vessels of size less than 25 Gross Registered Tonnage (GRT) are the most numerous both on the West and East Coasts of

---

[1] *The \$ sign used here and in subsequent chapters refers to Ringgit which is the Malaysian currency unit. In 1990, the average exchange rate was \$2.71 = U.S. \$1.*

Table 2.1 Average Annual Fleet Size, by Power Source and Tonnage Class, in Peninsular Malaysia, 1980-89

	West Coast		East Coast	
Tonnage class	Number	Percent	Number	Percent
Non-powered	1,441	8	676	9
Outboard-powered	5,914	33	974	14
Inboard-powered:				
Below 10 GRT	6,887	38	3,089	43
10 - 24.9 GRT	2,238	12	1,809	25
25 - 39.9 GRT	848	4	321	4
40 - 69.9 GRT	678	4	257	4
70 GRT & above	96	1	58	1
Total	18,102	72[1]	7,179	28[1]

[1] Denotes percent out of average annual number of licensed vessels in Peninsular Malaysia during 1980-1989.

Source : Annual Fisheries Statistics, various years.

Peninsular Malaysia. There was also quite a substantial number of outboard-powered vessels on the East Coast. Inboard-powered vessels of larger size, for instance, those with 70 GRT and above, were the least in number because the capital investment and operating costs of these vessels are substantial, beyond the capabilities of most small artisanal fishermen.

It has often been stated that technological dualism exists in the marine fishery industry in Malaysia, whereby traditional fishing gears coexist with commercial gears. The traditional gears comprise mainly gill or drift nets, lift nets, handlines, bag nets, barrier nets, push or scoop nets and fish traps (both stationary and portable), while commercial gears are made up of trawl nets and seine nets. During the last decade from 1980 to 1989, the average annual number of units of gear[2] used in fishing was 23,921 in Peninsular Malaysia (Table 2.2). Some 79 percent of these gears were found on the West Coast. The breakdown of gear types by region revealed that many gill or drift nets were used by fishermen on the West Coast of Peninsular Malaysia (47 percent of total gear used as shown in Table 2.2).

---

[2] *A vessel operating single gear type constitutes a unit of gear. However, there may be instances where a vessel operates two or more gear types. The number of gear used refers to the number of gear types used by a vessel.*

Table 2.2 Average Annual Number of Units of Different Fishing Gears in Operation in Peninsular Malaysia, 1980-89

	West Coast		East Coast	
Type of gear	Number	Percent	Number	Percent
Trawl	4,933	26	1,132	23
Fish seine	305	2	274	6
Anchovy seine	96	*	81	2
Other seine	1,215	6	64	1
Gill/drift net	8,875	47	1,258	25
Handlines	1,115	6	1,301	26
Bag net	737	4	106	2
Other[1]	1,707	9	720	15
Total	18,985	79[2]	4,936	21[2]

[1] Includes other traditional gears such as lift nets, stationary and portable traps, barrier nets or scoop nets and miscellaneous nets.

[2] Denotes percent of average annual number of fishing gear units in operation in Peninsular Malaysia during the same period.

* Denotes negligible percentage.

Source : Annual Fisheries Statistics, various years.

Trawl nets were the next most important gear in terms of number, followed by other traditional gears such as handlines. Although seine nets such as fish seines and anchovy seines were the least in number, they are nevertheless important gears in catching fish. The fish seine is particularly important in catching pelagic fishes while the anchovy seine is the principal gear used in the catching of anchovy in Malaysia. Similar patterns of gear used on the East Coast can be observed. Gill or drift nets and trawl nets were also the more popular gears used, but handlines were, on the average, the most in number on the East Coast during the period from 1980 to 1989 (Table 2.2).

A breakdown of licensed vessels between 1980 and 1989 according to their size and gear type is presented in Table 2.3. A majority of vessels using gill or drift nets were either less than 10 GRT in size or were powered by outboard engines. A similar pattern can be observed in Table 2.3 for vessels operating other traditional gear types such as handlines and bag nets. Owing to the smaller size of their vessels, fishermen using traditional gears are operating closer to the shore and are thus considered as inshore fishermen. By constrast, a majority of the vessels with commercial gears are powered by inboard engines and have a larger size. For example, most trawl vessels were above 25 GRT while the largest number of fish seines were found in

Table 2.3 Average Annual Number of Licensed Vessels by Gear Group, Power Source and Tonnage Class, Peninsular Malaysia, 1980-89

Tonnage class	Trawl	Fish seine	Anchovy seine	Other seine	Drift net	Hand line	Bag net	Other	Total
Non-powered	0	2	10	71	1,039	533	78	237	1,970
	(0)	(*)	(4)	(7)	(8)	(16)	(14)	(16)	(8)
Outboard-powered	0	0	2	316	5,187	694	122	472	6,793
	(0)	(0)	(1)	(31)	(39)	(21)	(22)	(32)	(27)
Inboard-powered:									
< 9.9 GRT	827	17	38	605	6,100	1,397	362	408	9,754
	(19)	(3)	(16)	(10)	(46)	(42)	(64)	(28)	(39)
10 - 24.9 GRT	1,967	117	77	14	882	678	3	291	4,029
	(46)	(17)	(33)	(1)	(7)	(20)	(*)	(20)	(16)
25 - 39.9 GRT	852	214	36	1	17	18	0	29	1,167
	(20)	(32)	(16)	(*)	(*)	(1)	(0)	(2)	(5)
40 - 69.9 GRT	547	285	47	1	2	2	0	12	896
	(13)	(42)	(20)	(*)	(*)	(*)	(0)	(1)	(4)
70 GRT & above	71	42	22	1	1	1	0	9	147
	(2)	(6)	(10)	(*)	(*)	(*)	(0)	(1)	(1)
Total	4,264	677	232	1,009	13,228	3,323	565	1,458	24,756

Note : Figures in parentheses denote percent of total number of units within the gear type.

* Denotes negligible percentage.

Source : Annual Fisheries Statistics, various years.

the size category of 40 to 70 GRT. Owing to their larger size, trawl and seine vessels are allowed to operate in waters further away from the shoreline.

There were on the average 68,924 fishermen employed to man the vessels and gears between 1980 and 1989. A larger proportion of fishermen were found on the West Coast (some 64 percent as shown in Table 2.4) as compared to the East Coast of Peninsular Malaysia. Data on fishermen employed according to gear type have shown that most fishermen were employed to operate gill or drift nets, constituting some 47 percent and 27 percent respectively for the West and East Coast. Trawl nets on the West Coast and handlines on the East Coast were used by the second largest number of fishermen. Fishermen employed to work on fish seines are quite numerous, ranking third on both the East and West Coasts. It can also be seen from Table 2.4 that the seine nets, on average required the largest crew, ranging from 11 crew members for other seines on the East Coast to 24 for anchovy seines on the West Coast. Fish seine operations on average require 15 to 18 crew members. For trawl nets, the number of crew required ranges from two to three while gill or drift nets required more crew members, ranging from an average of two on the West Coast to five on the East Coast.

Annual fish landings between 1980 and 1989 in Peninsular Malaysia on average amounted to 602,237 metric

Table 2.4 Average Annual Employment by Gear Type in Peninsular Malaysia, 1980-89

Gear type	Employment No.	Employment Percent	Av. no. of units of gear used[1]	Av. no. of fishermen per gear
West Coast:				
Trawl	9,557	21.71	4,933	2
Fish seine	4,714	10.71	305	15
Anchovy seine	2,307	5.24	96	24
Other seine	2,092	4.75	1,215	2
Drift net	20,561	45.72	8,875	2
Handline	1,939	4.41	1,115	2
Bag net	939	2.13	737	1
Others	1,940	4.33	1,707	1
Sub-total	44,013	63.86[2]	18,985	2
East Coast:				
Trawl	3,485	13.99	1,132	3
Fish seine	4,894	19.65	274	13
Anchovy seine	1,013	4.07	81	13
Other seine	734	2.95	64	11
Drift net	6,755	27.12	1,258	5
Handline	5,573	22.37	1,301	4
Bag net	49	0.20	106	1
Others	2,408	9.67	720	3
Sub-total	24,911	36.14[2]	4,936	5

[1] Adapted from Table 2.2.

[2] Denotes percent of total fishermen employed in Peninsular Malaysia.

Source : Annual Fisheries Statistics, various years.

tons. It should be noted that the West Coast contributes about 70 per cent of the fish landed per year (Table 2.5). The average annual value of fish landed in Peninsular Malaysia in the last decade was approximately $405,552,000. Comparisons between East and West coast revealed that a metric ton of fish landed on the West Coast has a higher value. Similarly, catch per fisherman is higher for the West Coast. On the other hand, landings per vessel are slightly higher for the East Coast as compared to the West Coast.

Even though traditional gears accounted for about 60 per cent of all gear units in operation (as shown in Table 2.2), they contribute only about 22 per cent to the landings (Table 2.6). Traditional gears on the East Coast have contributed more to landings than they have on the West Coast. Amongst the traditional gears, the contribution to landings by gill or drift nets was the highest, averaging about nine per cent per annum. For the commercial gears, trawl nets, especially those on the West Coast made the highest contribution to landings, followed by fish seines (Table 2.6). In terms of gear productivity, it can be noted in Table 2.6 that the productivities of commercial gear units were far greater than those of traditional gear units. The ranking of gears according to unit productivity is as

Table 2.5 Average Annual Landings, Landed Values, Fishing Fleet Size and Number of Fishermen Employed in Peninsular Malaysia, 1980-89

	West Coast		East Coast	
	Number	Percent	Number	Percent
Landings (mt)	422,133	70	180,104	30
Landed values (1000$)	793,274	72	312,278	28
Licensed vessels (number of units)	17,933	72	7,074	28
Fishermen (number)	45,750	65	25,169	35
Catch per vessel (mt)	24	n.a.	25	n.a.
Catch per fisherman (mt)	9	n.a.	7	n.a.
Value per mt ($/mt)	1,879	n.a.	1,733	n.a.

Note : n.a. denotes not applicable.

Source : Annual Fisheries Statistics, various years.

Table 2.6 Average Annual Landings by Gear Type, West Coast, East Coast and Peninsular Malaysia, 1980-89

	Trawl	Fish seine	Anchovy seine	Other seine	Drift net	Hand line	Other	Total
West Coast:								
Landings (mt)	217,408	61,315	23,866	17,000	35,768	5,538	29,312	389,559
(%)	55.81	15.74	6.13	4.13	9.18	1.42	7.52	100.00
No. of gear units	4,933	305	96	1,215	8,875	1,115	2,444	18,985
Catch/gear unit	44.07	201.03	248.60	13.99	4.03	4.97	11.99	75.53
East Coast:								
Landings (mt)	56,752	59,350	7,090	1,032	14,543	19,696	21,590	183,337
(%)	30.96	32.37	3.87	0.56	7.93	10.74	11.78	100.00
No. of gear units	1,132	274	81	64	1,258	1,301	826	4,936
Catch/gear unit	50.13	216.61	87.53	16.13	11.56	15.14	26.14	37.14
Peninsular Malaysia:								
Landings (mt)	274,160	120,665	30,956	18,032	50,311	25,234	50,902	572,896
(%)	47.86	21.60	5.40	3.20	8.78	4.40	8.89	100.00
No. of gear units	6,065	579	177	1,279	10,133	2,416	3,270	23,921
Catch/gear unit	45.20	208.40	174.89	14.10	4.97	10.44	15.57	23.95

Source : Annual Fisheries Statistics, various years.

follows: fish seines, anchovy seines, trawl, other traditional gears, other seines, handlines and drift nets.

It can be inferred from the above that the West Coast fishing centres have achieved and maintained a predominant position in the Malaysian fishing industry. The primary reason is the larger concentration of more capital intensive or large scale fishing vessels and gears on the West Coast. The high absolute and relative profitability of fishing on the West Coast, in conjunction with a larger pool of innovative fishermen and entrepreneurs with sufficient funds and skills to capitalise on this potential, have led to the introduction and wide scale adaptation of a continuous series of technological innovations on the West Coast (Yap, 1977). The West Coast fishery has been more profitable than that on the East Coast because there is greater accessibility to fishing grounds rich in various prolific and highly priced inshore species. Moreover, the fishing grounds and fishing ports are spatially and temporally closer to the wealthy urban markets of the West Coast and thus enjoy a technologically and economically more efficient marketing system.

2.4 The Fisheries Resource System in the Study Area

The study area is located on the West Coast of Peninsular Malaysia. It encompasses five states, namely

Perlis, Kedah, Pulau Pinang, Perak and Selangor. Pulau Pinang, Perak, Selangor, and to some extent Kedah, are the most developed states in Malaysia. They are located in the industry belt of the country where many industries, such as the electronic and textile industries are established. The strategic location of this area with its ports at Pulau Pinang and Port Klang in Selangor, coupled with other factors, such as easy access to raw materials and labour, investment incentives provided by the Government and political stability, have all contributed to this rapid development of industries in the region.

The region is also endowed with rich natural resources. For example, tin is found in Perak and Selangor. Agricultural plantations of rubber, oil palm, coconut, fruit orchards can be found in all parts of this region; and beautiful beaches as well as scenic natural environments are found in Pulau Pinang, Kedah and Perak. The rich endowment of resources in the region has helped in the industrial development and will likely continue to do so in the future. The fishery resource has contributed substantially to the growth and development of the fishery industry in the region in particular and the country in general.

In attempting to manage the small pelagic fishery in this region, it is important to have an understanding of the entire gamut of the fishery. Hence this section provides a brief account of the general profile and characteristics of the fishery in the study area.

Historically, the study area is the most important fishing region in the country. The region has been the centre for fishing technology adoption since almost all the major fishing gears were initially adopted in this region and spread to the rest of the country from here. For example, the use of the large stationary trap at the begining of the century, the motorization of purse seine vessels during the thirties, the use of lures by the purse seine fleets, the adoption of synthetic fibre nets, and the introduction and subsequent proliferation of trawl gear in the mid-sixties were all begun here (Yap, 1977).

The central importance of the study area in the fishing industry in Malaysia can also be seen from its contribution to total catch, the size of its fishing fleet and the number of fishermen engaged in fishing. Over the period 1980 to 1989, the region's fish landings accounted for more than 90 percent and 65 percent of West Coast's and Peninsular Malaysia's landings respectively, both in terms of quantity and value (Department of Fishery, 1981 - 1990). The fleet size in the region during this period accounted for about 76 percent of that on the West Coast and about 54 percent of that in Peninsular Malaysia, while fishermen employed to man these vessels constituted about 80 percent and 51 percent respectively of those employed on the West Coast and in Peninsular Malaysia.

A large proportion (54%) of the fishing vessels in the study area is comprised of vessels below 25 GRT, while 34 percent of these vessels are non-powered or are powered by outboard engines (Table 2.7). The proliferation of the small size vessels is mainly because of the narrow strip of fishing area along the Straits of Malacca. Nevertheless, a small number of larger size vessels can be found in the northern states of Kedah and Perlis as the Straits of Malacca widen there.

Traditional fishing methods and gears are dominant in the study area. Notably, gill or drift nets are the most widely adopted gears by fishermen, accounting for about 41 percent of the total gear used here (Table 2.8). A sizeable number of vessels with trawl gear (30%) are also used. These trawlers are of various sizes, but a majority of them are mini-trawlers of a size of less than 25 GRT. A large fraction of the seine gear vessels are of bigger size, but there are relatively few fish and anchovy seines present in this region.

Malaysia lies in the tropics and its fishery resource is distinctively different from that found in temperate

Table 2.7 Average Annual Number of Vessels by Power Source and Tonnage Class, in Northwest Peninsular Malaysia, 1980-89

Tonnage class	Number	Percent
Non-powered	910	7
Outboard-powered	3,721	27
Inboard-powered:		
Below 10 GRT	5,477	40
10 - 24.9 GRT	2,010	14
25 - 39.9 GRT	840	6
40 - 69.9 GRT	678	5
70 GRT & above	96	1
Total	13,731	76[1]

[1] Denotes percent of average annual number of licensed vessels on the West Coast of Peninsular Malaysia for 1980-1989.

Source : Annual Fisheries Statistics, various years.

Table 2.8 Average Annual Number of Units of Fishing Gears in Operation, Northwest Peninsular Malaysia, 1980-89

Gear type	Number of units	Percent
Trawl	4,566	30
Fish seine	305	2
Anchovy seine	96	1
Other seine	1,159	8
Gill/drift net[1]	6,218	41
Handline[1]	894	6
Bag net[1]	646	4
Others[1,2]	1,189	8
Total	15,073	79[3]

[1] Denotes traditional gears.

[2] Includes other traditional gears such as lift nets, stationary and portable traps, barrier nets, push or scoop nets and miscellaneous nets.

[3] Denotes percent of average annual number of units of fishing gears in operation on the West Coast of Peninsular Malaysia from 1980-1989.

Source : Annual Fisheries Statistics, various years.

countries. One of the important characteristics of the fishery resource in Malaysia, and hence of the fishing grounds of Northwestern Peninsular Malaysia, is the existence of a large number of species, a majority of which are of commercial value. About seventy species or species groups have been listed in the official fisheries statistics.

There are more than 15 species of small pelagic fishes of commercial importance which are listed in the fisheries statistics. The term "small pelagic fishes" refers to an arbitrary classification of a diverse group of fishes that inhibit the upper surface layers of the water column above the continental shelf. They generally have smaller asymptotic sizes[3], shorter life spans, reduced intensity of seasonal oscillations in a number of cyclical features such as growth, fat content, migratory behaviour etc., higher fecundities and higher natural mortality (Pauly, 1989). They are primarily plankton feeders.

Small pelagic fishes are among the most important species groups harvested off the coast of Northwest Peninsular Malaysia as the contribution of these species to total marine fishery production in 1980 to 1989 ranged from

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[3] *The asymptotic size is the size the length of the fish approaches as it ages.*

22% to 40% (Table 2.9). Of the total pelagic landings, small pelagic fishes formed over 90% of the catch in the same period, equivalent to about 37% of the total fish catch. The landings of small pelagic fishes are concentrated in only a few species or species groups. Average annual landings of each species group from 1980 to 1989 for the study area are presented in Table 2.10. The figures show that nine of the top twenty fish species groups landed are small pelagics. The average landings of Indian mackerel, a small pelagic species, was the highest among all species groups during the period (Table 2.10). Other small pelagic species groups landed, in order of their importance include anchovies, round scads, hardtail scads, sardines, selar scads, eastern little tunas, mullets and goldbanded scads. In the subsequent analyses, these species will be arbitrarily grouped into four major categories namely, Indian mackerel, scads, sardines and tunas. The anchovies will not be included in the study because they are mainly caught by the anchovy purse seiners.

Fish seines are the most important gear for catching the small pelagics in the study area. This gear caught more than 70 percent of scads, sardines and tuna and about 61 percent of Indian mackerel during 1980 to 1989 (Table 2.11). Pelagic trawling by trawlers is mainly for the Indian mackerel, scads and sardines. Although drift nets are the

Table 2.9 Marine Fish Landings by Species Group, Northwest Peninsular Malaysia, 1980-89

		Pelagics						% of small pelagics to		
Year	Total production (mt)	Small pelagics (mt)	Big pelagics (mt)	Total pelagics (mt)	Total demersal (mt)	Total fish (mt)	Total invertebrate (mt)	Total production	Total fish	Total pelagics
1980	475,447	116,765	8,482	125,247	158,326	283,573	191,874	25	41	93
1981	410,370	103,883	9,256	113,139	162,606	275,745	134,625	25	38	92
1982	410,810	122,557	11,519	134,076	150,646	284,722	126,088	30	43	91
1983	422,721	133,410	11,452	144,862	166,188	311,050	111,671	32	43	92
1984	325,874	130,935	6,529	137,464	126,940	164,404	61,470	40	50	95
1985	306,151	98,607	9,128	107,735	136,778	144,513	61,638	32	40	92
1986	305,409	71,827	11,828	83,655	158,167	241,822	63,587	24	30	86
1987	481,628	117,603	14,748	132,351	249,812	382,163	99,465	24	31	89
1988	406,609	104,153	10,950	115,103	207,349	322,452	84,157	26	32	90
1989	468,219	103,212	8,648	111,860	233,478	345,338	122,881	22	30	92
Average	401,324	110,295	10,254	120,549	175,029	295,578	105,746	27	37	91

Source : Annual Fisheries Statistics, various years.

Table 2.10 Important Fish Species Groups off the Coast of Northwest Peninsular Malaysia, 1980-89

Rank	Species group		Average landings (mt)	% share to total fish landings	Cumulative percentage
1	Indian mackerel	SP[1]	51,220	31.42	31.42
2	Anchovies	SP	23,122	14.18	45.60
3	Round scads	SP	9,434	5.79	51.60
4	Jewfish	DM	6,900	4.23	55.62
5	Hardtail scads	SP	5,795	3.55	59.17
6	Threadfin bream	DM	5,702	3.50	62.67
7	Sardines	SP	5,360	3.29	65.96
8	Selar scads	SP	4,454	2.73	68.69
9	Spanish mackerel	BP	4,094	2.51	71.20
10	Pomfret	BP	3,928	2.41	73.61
11	Eastern little tuna	SP	3,880	2.38	75.99
12	Mullet	SP	3,151	1.93	77.92
13	Rays	DM	2,941	1.80	79.72
14	Marine catfish	DM	2,279	1.40	81.12
15	Wolf herring	BP	2,233	1.37	82.49
16	Tongue fish	DM	2,233	1.37	83.86
17	Yellow striped trevally	SP	2,196	1.35	85.21
18	Shad	DM	2,059	1.26	86.47
19	Ribbon fish	DM	1,888	1.16	87.63
20	Chicunda shad	DM	1,806	1.11	88.74

[1] SP denotes small pelagic; BP denotes big pelagic and DM denotes demersal species.

Source : Annual Fisheries Statistics, various years.

Table 2.11 Average Annual Catch (mt) of Small Pelagics by Major Gears in Northwest Peninsular Malaysia, 1980-89

	Small pelagic species				
Gear type	I. mackerel	Scads	Sardine	Tuna	Misc.
Trawl	13,632 (26)	3,658 (17)	956 (18)	3 (*)	942 (4)
Purse seine	31,279 (61)	17,103 (78)	4,063 (76)	2,852 (74)	2,306 (8)
Drift net	5,953 (12)	436 (2)	132 (2)	727 (19)	2,866 (10)
Others	356 (1)	682 (3)	209 (4)	298 (7)	21,925 (78)
Total	51,220 (100)	21,879 (100)	5,360 (100)	3,880 (100)	28,039 (100)

Note : Figures in parentheses denote percent of catch of the species by the gear.

* Denotes negligible percentage.

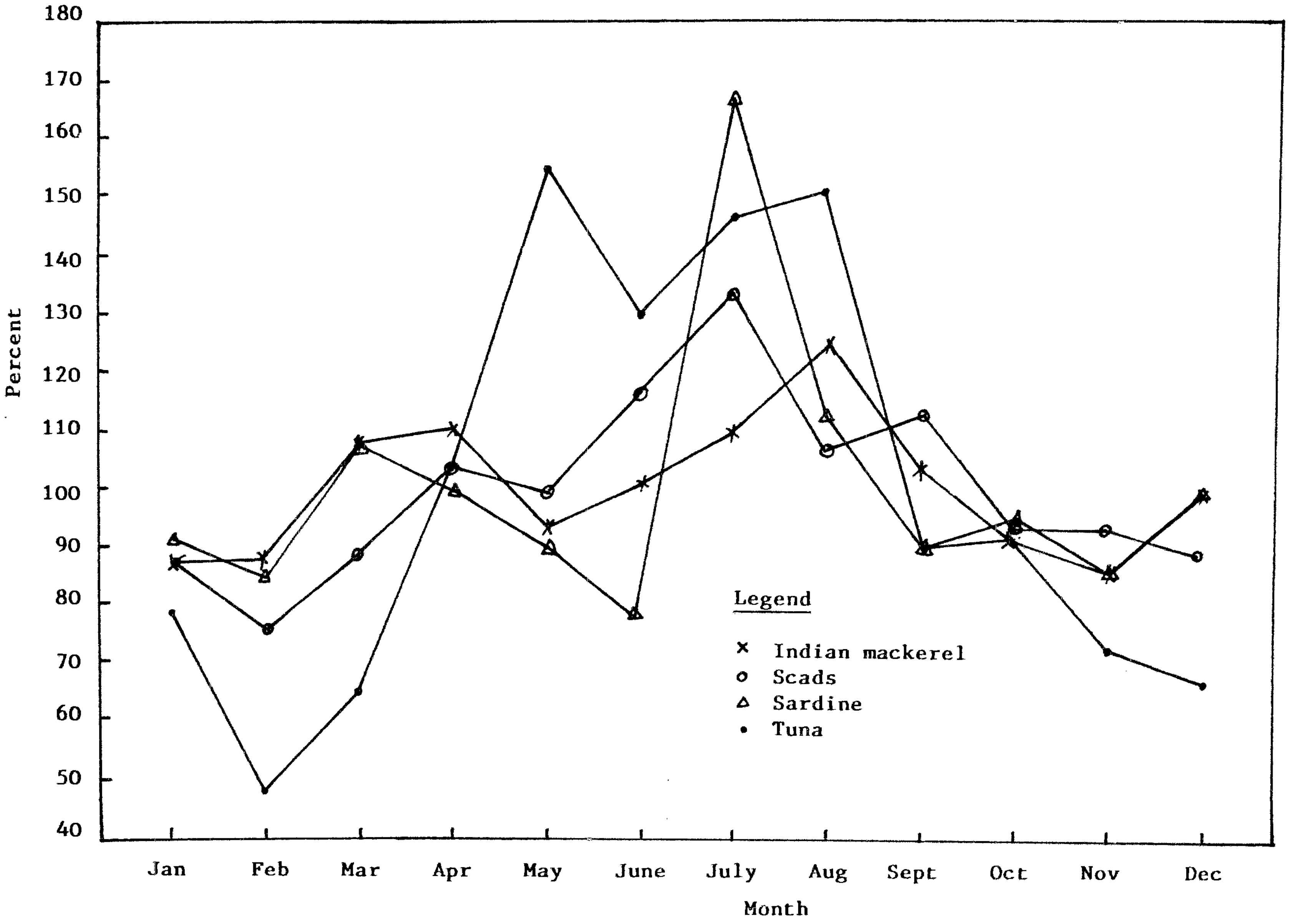
Source : Annual Fisheries Statistics, various years.

most abundant gear used in the study area, their catch of small pelagics is small compared to that of trawl nets and fish seines. A large proportion of miscellaneous small pelagic species, caught by other gears (78%) consists primarily of catches of anchovy by the anchovy seines.

Discernible monthly oscillations in the landings of small pelagic fishes are observed in the study area. The seasonal indices of landings of four important groups of small pelagic fishes on the West Coast, and hence in the study area, are presented in Figure 2.2. The indices were computed by calculating the twelve-month moving average of landings, taking the difference between the landings of a particular month and the moving average, and then averaging the differences over the years for a particular month. The procedure was followed in order to eliminate any cyclical and trend components inherent in the data for landings. Peak catches occur in the months of July and August and for tuna in May as well. The monthly variations in catches are more severe for sardines and tunas.

There have been very few studies of the seasonal migration patterns of small pelagic species in Malaysia. Available information indicates that the purse seine and trawl fisheries in the study area exploit a single cohort stock of Indian mackerel which breeds and feeds in waters

Figure 2.2 Seasonal Catch Indices of Major Small Pelagic Fishes on the West Coast, 1980–89



near Pulau Langkawi and which exhibits no marked migratory pattern (Chong and Chua, 1974).

2.5 The Present State of the Fishery Industry in Peninsular Malaysia

The fishery industry in Peninsular Malaysia is beset by three major problems. First, the available resource appears to be overexploited, particularly in the inshore areas on the West Coast. The overexploitation is a consequence of open access to the resource. It has caused overcrowding on the fishing grounds, which has caused conflicts among fishermen using different types of gear. Moreover, that too many fishermen are chasing too few fish implies that incomes earned by these fishermen are low.

Overexploitation of the fishery resource can be shown by comparing the data on catch and potential yield. Concerning the assessment of the fishery resource potential, several estimates are available but there exist considerable variations among them depending on the method of assessment, timing and area surveyed (see for examples Tiews, 1976; Pathansali, 1974, 1976; Shaari and Chai, 1976; Chong, 1973). Therefore these estimates at best provide only an indication of the actual status of the fishery resource potential.

A more recent estimate by the Fisheries Research Institute of Malaysia in 1980, puts the total potential yield of both pelagic and demersal species off the coasts of Peninsular Malaysia at about 662,000 metric tons (Table 2.12). The West Coast has a potential yield of 255,000 metric tons which is much lower than that of the East Coast, with its 407,000 metric tons. The demersal resources on both coasts, however, are much larger than the pelagic resources.

The fish catch on the West Coast of Peninsular Malaysia in the last decade far exceeded the sustainable potential. For example, the catch in 1980 and 1989 was 90 percent higher than the sustainable yield, but was only about 28 percent higher in 1985 (Table 2.12). The resource base on the East Coast is still able to support higher levels of exploitation. Overall, the sustainable catch level has been exceeded for Peninsular Malaysia as a whole in recent years.

Another sign of overfishing, especially on the West Coast, is shown by the increase in landings of trash fish, a large proportion (more than 80 percent in 1981) of which consists of undersized, commercially valuable species (Sharom, 1984). Figure 2.3 reveals that the proportion of trash fish in total landings by all gear types is higher on the West Coast than on the East Coast for 1980-1989. Approximately 36 percent of West Coast landings were

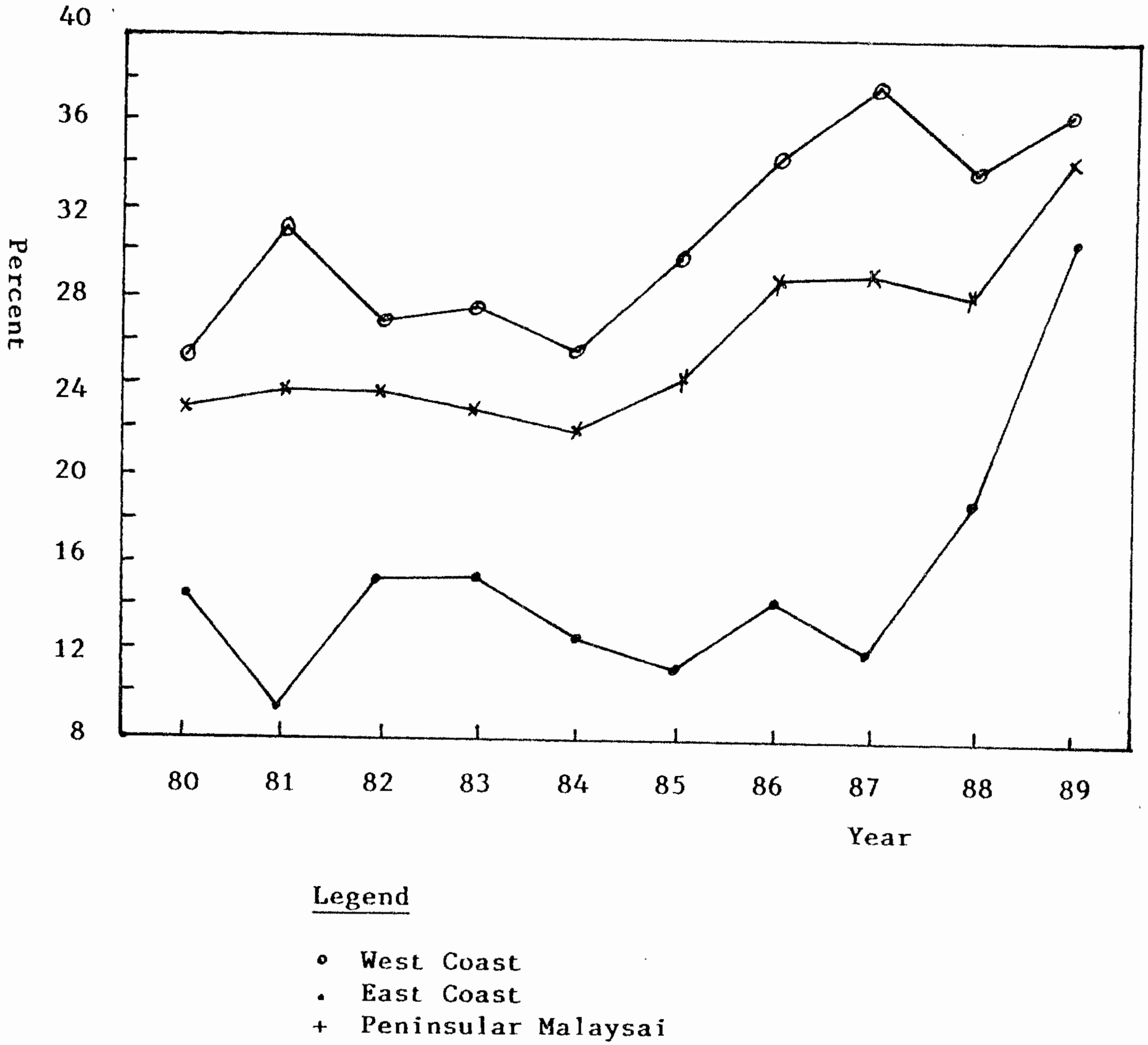
Table 2.12 Fishery Resource Potential and Exploitation in Peninsular Malaysia

Region	Potential	Exploitation		
		1980	1985	1989
East Coast	407,000	130,403 (32.04)	135,737 (33.35)	257,550 (63.28)
Demersal	247,000			
Pelagic	133,000			
West Coast	255,000	493,495 (193.5)	327,124 (128.3)	489,334 (191.9)
Demersal	167,000			
Pelagic	88,000			
Peninsular Malaysia	662,000	623,898 (94.24)	462,861 (69.92)	882,492 (133.3)

Note : Figures in parentheses represent percent of total potential catch.

Source : Fishery Research Institute, Penang, 1980.

Figure 2.3 Percent of Trash Fish in Total Landings, 1980-89



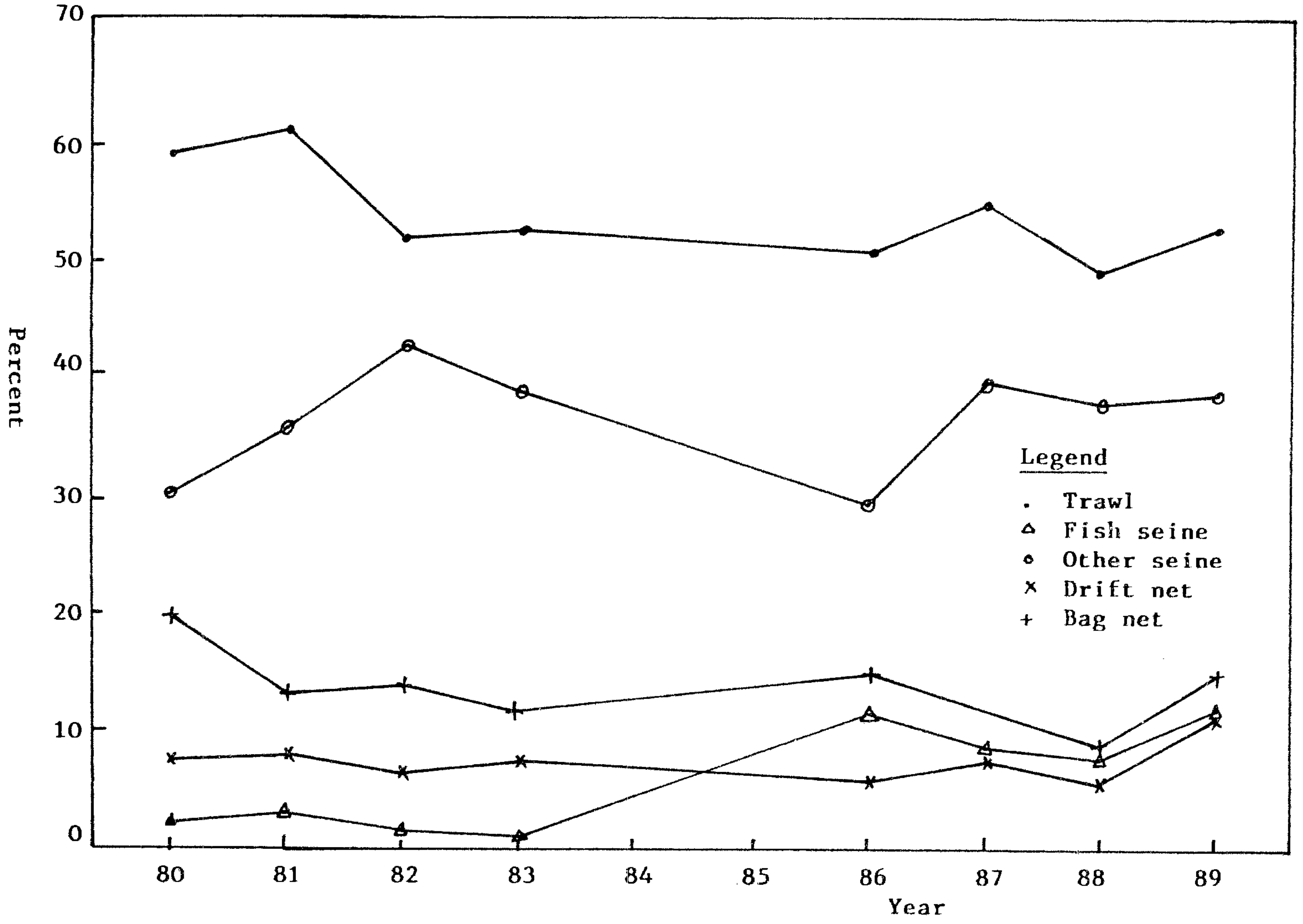
comprised of trash fish in 1989, while on the East Coast, the proportion was about 30 percent. Trash fish landings on both coasts show an increasing trend. The high proportion of trash fish to total landings, especially on the West Coast, is supported by a number of case studies (see for examples Khoo, 1976; Lam and Pathansali, 1976; Yap, 1973).

A breakdown of trash fish landings by gear type is shown in Figure 2.4. The percentage of trash fish landed by trawl nets was the highest, averaging more than 50 percent of total trawl landings from 1980 to 1989. This trend is mainly due to the indiscriminate nature of fishing by trawl gear. Drift nets and fish seines contribute the least to trash fish landings. Among all traditional gears, other seines, such as beach seines, have the highest percentage of trash fish in total landings.

Other signs of overfishing include the extinction of certain commercially valuable species of fish, notably *Lactarius lactarius*, and increased landings of squid on which the fish feed. Based on these gross symptoms, it can be concluded in general that fishery resources in Peninsular Malaysia, particularly off the Strait of Malacca on the West Coast, have been biologically overfished.

Overexploitation of the resource has resulted in intense competition among fishermen using different gears to

Figure 2.4 Percent of Trash Fish in Total Landings by Gear Type, West Coast,1980-89



exploit the same fishery resource. As a consequence of excessive fishing capacity in pursuit of limited resources, crowding externalities on the fishing grounds and gear conflicts have occurred. Many incidents of blatant encroachment of trawlers into the fishing grounds of artisanal fishermen have occurred and they are resented by the artisanal fishermen because the trawlers which fish indiscriminately have destroyed juvenile fish and inshore spawning grounds. They have also caused substantial damage to the nets and gears of artisanal fishermen, thereby adversely affecting the incomes of the latter group. Some of these incidents of gear conflict have escalated into confrontations and clashes between the trawl and artisanal fishermen. The severity of gear conflicts can be gauged from the fact that between 1970 and 1975, 1,200 boats (about 400 trawlers and 800 inshore fishing boats) were involved in such conflicts, resulted in more than 60 boats sunk and 23 fishermen killed (Goh, 1976).

The problem of fishermen's poverty can also be partially linked to overexploitation of fish resources, since increasing fishing pressure reduces the fish stock in the long run and subsequently the catch rate and profit which ultimately leads to low income and poverty. In fact, about 73% of the fishing households in Peninsular Malaysia in 1970 were reported to be in poverty[4]. Since then the incidence of poverty within the sector has declined to 63 percent in 1975, 55 percent in 1978, 45 percent in 1980, 26 percent in 1984, and 25 percent in 1987 (Malaysia, 1989; Ubaidullah, 1986; World Bank, 1983). Poverty among fishing households has declined despite meagre improvements in fish stocks. The reduction in poverty has mainly ensued from improved fishing technology (which increases income of fishermen in the short run), rising prices of fish due to increasing consumer prosperity, and government development efforts in providing training and extension services, provision of infrastructural facilities, marketing, and relocation of fishermen to other gainful employment.

From the social and political standpoints, effective fishery management is needed to help in further reducing and possibly eradicating poverty and in eliminating the ensuing conflicts that exist among fishermen.

2.6 Fisheries Management

Although fisheries management in Malaysia began during the colonial period of British Malaya, the crux of the

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[4] *Poverty in Malaysia is measured by a minimum level of income known as the poverty line of income for a five-persons household. A household is considered to be in poverty if total household income (converted to a five-persons equivalent) is on or below this poverty level of income.*

present management regulations is embedded in the Fisheries Act 1963. A number of supplementary regulations were subsequently enacted to deal with details in the operation and control of the fishery industry. The regulations include: (1) The Merchant Shipping Ordinance 1952; (2) the Fisheries (Cockles Conservation and Culture) Regulations 1964; (3) the Fisheries (Maritime) Regulations of 1967; (4) the Fisheries (Prohibition of Method of Fishing) Regulation 1971; (5) Fisheries (Prohibition of Import of Piranhas) Amendment Regulations 1979; (6) the Fisheries (Amendments) Regulation 1980; and (7) the Fisheries Act 1985 (see Appendix A for detail on these regulations). The implicit objectives of these management regulations and policies are as follows (Jahara and Yamamoto, 1988):

(1) the conservation and management of fisheries resources;
(2) the exploitation and utilization of these resources in the national interest;
(3) the collection and compilation of fishery statistics;
(4) settling disputes among fishermen.

In order to achieve the objective of settling disputes among fishermen, the Fisheries Regulations 1980 further addressed the following objectives:

(1) to eliminate the competition and the ensuing conflict between artisanal and trawler fishermen in the inshore waters;

(2) to restructure the ownership pattern of fishing units within the context of the New Economic Policy[5];

(3) to equitably distribute fishing throughout the waters under jurisdiction of Malaysia;

(4) to prevent overexploitation of the fisheries resources in the inshore waters; and

(5) to promote the development of offshore industrial fisheries.

Based on these objectives, it can be said that fishery management in Malaysia has been oriented primarily to fulfill social and biological goals, with little attention being given to economic efficiency in resource utilization.

Fisheries management in Malaysia is couched mainly in terms of limited entry licensing. The Fisheries (Maritime) Regulations 1967, for example, contained detailed specifications of activities requiring licenses; specified

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[5] *The New Economic Policy was inaugurated in 1971 as the overriding economic policy for Malaysia from 1970 to 1990 due to the general feelings of dissatisfaction and frustrations over the inequitable distribution of income and wealth among the racial groups in the country. These feelings had led to the most serious racial riots in the country history. The New Economic Policy has in it a two-pronged objectives: (1) to reduce and eventually eradicate poverty by raising income levels and employment opportunities for all Malaysians, irrespective of race; and (2) to accelerate the process of restructuring Malaysian society to correct the economic imbalance so as to reduce and eventually eliminate the identification of race with economic functions (Second Malaysia Plan, 1971-75).*

the terms and conditions attached to the licenses; stated the compensation for damage caused by fishing appliances and penalties for violation of the rules; stipulated the amount of license fees and deposits for fishing stakes and fishing appliances; and established specific terms and conditions on trawling with regards to fishing grounds, trawling time, minimum mesh size for trawl nets of 25 mm as measure at the cod end, landing places, and prohibited use of beam trawlers.

The above regulations were strengthened by the Fisheries (Amendments) Regulation 1980, enacted in response to the problems of overexploitation and overcapitalization in inshore waters. The main focus of the 1980 Regulations was the allocation of fishing grounds through zoning and area licensing. Specifically, four main zones were established under this regulation:

Zone A -- within 5 miles from the shoreline; is reserved for traditional fishing gears owned and operated by fishermen themselves.

Zone B -- between 5 and 12 miles; is reserved for trawlers and purse seiners less than 40 GRT, owned and operated by fishermen themselves.

Zone C -- between 12 and 30 miles; is reserved for trawlers and purse seiners greater than 40 GRT, wholly owned and operated by Malaysian fishermen.

Zone D -- beyond 30 miles; is reserved for foreign or partially Malaysian-owned fishing vessels of greater than 70 GRT.

It should be noted that fishing vessels which are allowed to fish in a zone close to the shoreline such as in Zone A can tresspass into zones further away but the reverse is not permitted.

The area or zone licensing is primarily aimed at protecting artisanal fishermen. By reserving the innermost zone to small boats operating traditional fishing gears, it also aimed to diffuse competition and conflict between artisanal fishermen and the more aggressive trawler fishermen. Recently, the Government has imposed a moratorium on new licenses issued for fishing boats in Zones A and B. However, new licenses could still be issued to larger boats of above 40 GRT in Zones C and D. The rationale for these measures may be to limit overcrowding in the inshore waters and to encourage larger boats to fish in grounds further away from the shoreline.

Besides the above provisions, the 1980 Regulation also increased the minimum trawl net mesh size from 25 mm to 40 mm as measured at the cod end. The main concern of this measure is to increase the minimum size and weight of fish captured to prevent depletion of the resources. Strict prohibition of the use of beam and pair trawls is also imposed owing to the destructive nature of these gears on fish stocks.

The Fisheries Act 1985 is primarily aimed at controlling encroachment of foreign vessels into the Malaysian EEZ. It imposes heavy fines on them when they are apprehended. For local fishermen encroaching into waters beyond the provisions of their licenses, fines or imprisonment or both can also be imposed. However, the efficacy of these regulations in managing fishery resources is questionable as fishermen have in the past ignored such restrictions due to inadequate enforcement.

Fisheries management through limited licensing aims at removing excessive fishing effort in the inshore waters in order to improve resource productivity and returns to fishermen. However, for it to be successful, it is crucial that the number of licenses be issued to regions, states and districts commensurate with resource availability. Unfortunately, there is a paucity of both biological and socio-economic information and analyses in the fishery sector (Sharom, 1984). Detailed statistics and adequate information on the resource potential, which could form the basis for determining optimal license allocations, are either seriously lacking or not available at all. Although fishermen are required to keep data on catch and effort, no measures have been taken to verify the data recorded in their logs. Because of the data problem, it is extremely difficult to assess the extent of overfishing, to arrive at any definite conclusions about the status of the fisheries resources and to determine the number of licenses to be issued. Moreover, the few resource surveys are merely indicative and do not provide conclusive evidence of overfishing.

Applied research on the modifications and innovations adopted by various types of gear are also lacking. Consequently it is difficult to determine precisely the extent of capital stuffing in the fishing industry. As will be discussed in a later chapter, "capital stuffing" by vessels can render the objective of effort reduction unattainable even though an initially optimal number of licenses has been issued to vessels.

Another problem related to the limited licensing program is the issue of "who should be awarded the limited licenses" and "who should leave". In Malaysia, it is difficult to identify who has been in the fisheries due to the prevalence of part-time fishermen and illegal fishing vessels (Sharom, 1984). Because of weak and ineffective enforcement, a fairly substantial number of vessels (in particular the mini-trawlers of less than 10 GRT) have been operating illegally undisturbed by the laws. After some time, the authority is forced to recognize the existence of these boats due to political pressure, and has to grandfather them into the licensing scheme. The existence of the illegally operating vessels is also due to lack of compensations provided to those who might have been displaced (Sharom, 1984). As such, those fishermen affected might be reluctant to destroy their old boats and they ultimately resort to fishing illegally in waters that are off-limit to them.

Several problems exist with regards to area or zone licensing regulation. First, for administrative, biological or cost considerations, it may not be practical to divide the fisheries into distinct areas. Moreover, fishing grounds in the open seas are rarely clearly demarcated or identifiable. Second, there may exist differences in resource availability and productivity between various grounds and because of seasonal fluctuations or the migratory patterns of the fish stocks, fishermen might not readily agree to harvest the ground allocated to them. For example, trawl fishermen felt that they had been discriminated against and strongly opposed the regulation which excluded them from waters within the 5-mile zone. These waters are rich in prawn resources. Third, the regulation has created some socio-economic issues. With the implementation of the regulation, fishermen operating mini-trawlers of less than 10 GRT have to choose from one of the three options: (1) to convert to a larger boat capable of operating in the outer zones specified for trawlers; (2) to maintain the same boat and switch to traditional gear so that they can still operate in the 5-mile zone; and (3) abandon their boats completely and work for another boat as an ordinary deckhand or seek alternative employment in the non-fishing sector. Given the economic status and lack of financial resources, it is unlikely that these fishermen will adopt either of the first two options. The third option may not be practical as well since there are already surplus fishermen in the industry and moving to non-fishing employment entails relocation costs. Hence, it appears that many mini-trawler fishermen will be displaced and unemployed.

Enforcement and surveillance is one of the many serious weaknesses in the management and conservation of fisheries in Malaysia. Lack of personnel, vessels, and sufficient funds for enforcement and surveillance, make it difficult to ensure fishermen's compliance with the regulations, in particular in dealing with unlicensed boats and illegal fishing gear. In view of the extended jurisdiction to 200-miles by Malaysia, the enforcement and surveillance agencies, such as the Marine Police and the Department of

Fishery, are also saddled with added responsibilities for curbing illegal fishing by foreign vessels in the EEZ.

2.7 Summary

The fishery industry in Peninsular Malaysia has been dominated historically by the West Coast. This is clear as total catch, fleet size and the number of fishermen directly employed are the highest there. Within the West Coast fishery, the study area is the most important fishing region, contributing a major proportion of total landings, fleet size and employment.

The fishery resource system in the study region can be characterized as multispecies and multigear. The small pelagics represent the most important species groups harvested by three major gear types, namely, trawl nets, fish purse seines and gill or drift nets. The dominant small pelagic species harvested in the study area include Indian Mackerel, scads, sardine and tuna.

One major and persistent problem with regards to the Malaysian fisheries is that the resource has been overexploited, especially on the West Coast of Peninsular Malaysia. The overfishing problem is indicated by such signs as: (1) the levels of exploitation are, in general, over and above the level the resource can sustain, as shown by a number of resource surveys; (2) the virtual disappearance of certain species of commercial importance; and (3) the increased landings of trash fish of which a large proportion is comprised of undersized, commercially valuable species.

Two other issues are pertinent to the fishery sector in Malaysia. The existence of excessive capacity in pursuit of limited resources has caused crowding externalities on the fishing grounds. The intense competition for the limited resources among the various gear types in the past have developed into open confrontations and resulted in the loss of lives and property. The problem of persistent poverty among fishing households can also be linked to the overexploited state of the fishery resources. Hence, from the biological, social and political standpoints, effective management of the fishery resources is needed. The economic rationale for fishery management will be discussed in more detail in the next chapter.

Fishery management in Malaysia is guided mainly by biological and social objectives, with little attention paid to economic efficiency of resources used. Area licensing is the major management scheme followed. However, the scheme did not provide an effective means of controlling fishing effort in Malaysia, due to the existence of several social problems. They include: (1) the inability of the fisheries management authority to determine the optimal number of licenses to be issued; (2) the existence of unlicensed vessels and illegal fishing; (3) the failure of some fishermen to agree to fish in the zones allocated to them because of differences in productivity and species mix in the various zones. A further discussion of licensing schemes and other fishery regulations will be presented in the next chapter.

Chapter 3

THEORY OF FISHERIES MANAGEMENT

There are many problems associated with renewable fishery resources. Among others, the problems of stock flow dynamics, externalities in production, the relation between the fisherman and his natural environment, social control or regulation, public investment, and the economic implications of property rights, are all important in the economic analysis of fishing. The "open-access" problem of the fishery resource is perhaps the most widely discussed problem in the fishery literature (Gordon, 1954; Hardin, 1973; Eckert, 1979).

The open-access problem arises from the unrestricted access to the resource system by users. There are adverse interactions in the form of externalities among these users (Howe, 1979). Fishing externalities are understood as external effects imposed by individual fishermen on other users. The costs of these effects (or, in rare cases, the benefits) are not explicitly internalised by the former. Generally, the major types of externalities in most fisheries may be identified as follows (Agnello and Donelley, 1976):

1. Stock externalities occur when entry of fishermen significantly decreases the biomass of the fish population and hence increases the harvesting costs of other fishermen.

2. Crowding externalities arise when vessel congestion on the fishing grounds increases marginal fishing costs.

3. Fishing gear and selectivity externalities exist when the type of gear and mesh size used changes the population dynamics of the target species and associated by-catches.

4. Interspecies externalities occur due to specific species interactions such as predator-prey relationships. A fishery that harvests the prey stock will cause the biomass of the predator species to decline and thereby increases the costs of fishing for a fishery that harvests the predator stock.

3.1 Rationale for Fisheries Management

Due to the open-access nature and the myriad of problems confronting an unregulated fishery, it has been argued that if the fishery is left to its own devices, it would entice excessive levels of fishing effort to the effect that resource rent[1] from fishing will be completely

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[1] Resource rent is defined as total revenue in excess of costs of fishing (including normal returns to labour and capital) and the intramarginal rent or producer's surplus.

dissipated. This could also cause the destruction of a stock in extreme cases.

The rent dissipation, open-access problem of an unregulated fishery can be illustrated by the Gordon-Schaefer model[2] as shown graphically in Figure 3.1. In this model, the biological relationship of a fishery is often represented by a logistic growth function that exhibits the commonly observed density-dependent growth of fish stocks (Schaefer, 1954). It is from this growth function that a sustainable yield-effort curve showing the effect of fishing activities on the fish stocks is derived. Schaefer (1957) incorporated primary economic variables, namely, constant unit output prices and fishing costs into this biological model to form the bio-economic or the Gordon-Schaefer model of fishery.

The Gordon-Schaefer model shows a long-run, steady state relationship in a fishery. In the long run, fishing effort in an open-access fishery will be expanded until a point where total revenue equals total costs. The corresponding level of fishing effort at this long-run

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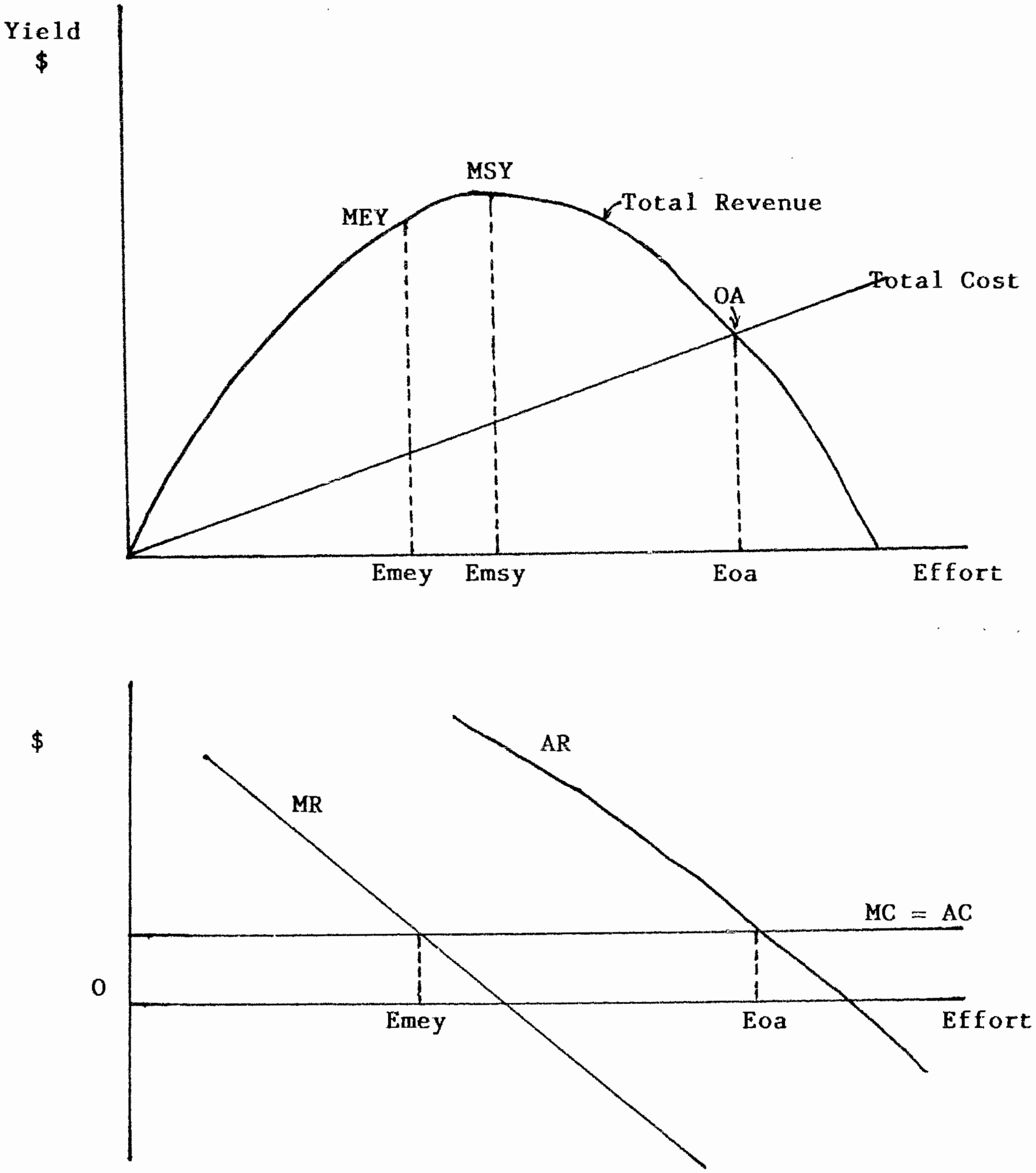
[2] *The model presented here is a constant price static model. For a variable price static model, see Copes (1970). For dynamic version of the constant price model, see Clark and Munro (1975).*

equilibrium point is shown as E_{oa} in Figure 3.1. The open-access equilibrium is at E_{oa} since in a competitive context where entry into and exit from a fishery is unregulated, any positive resource rent would induce effort to enter the fishery until such rent is driven down to zero. On the other hand, rational fishermen will reduce their effort level if there is negative rent in the fishery. If the negative rent persisted long enough and/or if fishery investments are malleable, some fishermen may even exit from the fishery. The exit of fishing effort reduces the negative rent until equilibrium is restored again at the point of zero resource rent (E_{oa}). The dissipation of resource rent signifies economic overfishing.

It can be argued conversely that if the fishery is being regulated or managed, for instance, if fishing effort is regulated and reduced from E_{oa} to E_{mey} as shown in Figure 3.1, substantial resource rent can be generated which will increase benefits to society. Moreover, societal welfare will also be improved if excess inputs released by the reduction of fishing effort can be used to increase production elsewhere in the economy. Thus from an economic standpoint, operating a fishery at the open-access equilibrium is inefficient.

Yield from the fishery at open-access equilibrium, as shown in Figure 3.1, is smaller than the maximum sustainable

Figure 3.1 A Simple Bioeconomic Fishery Model: the Gordon-Schaefer Model



yield obtainable. However, it should be noted that the total revenue and total cost curves may intersect to the left of MSY in a fishery where the fish species are of low value or where fishing costs are high. Also, in rare instances, the open-access equilibrium point may coincide exactly with the MSY point. In the case depicted in Figure 3.1, the fishery is said to be biologically overexploited. In this case, the population level corresponding to E_{oa} is smaller than that which yields the maximum sustainable yield and would be smaller still if the average costs of fishing effort were lower.

The dissipation of resource rent, economic inefficiencies, low fish biomass and yields below the maximum sustainable yield associated with the open-access equilibrium point, are often the stated rationale for the management of a fishery. The issues that remain are concerned with the extent and the means of managing the fishery. The former is related to the goals or objectives of fisheries management while the latter deals with the methods of regulating fisheries. These issues will be discussed in the succeeding sections.

3.2 Fisheries Management Objectives and Goals

Fisheries management aims at achieving certain societal goals or objectives through the use of appropriate regulatory instruments. Over the years, many management goals and objectives have been proposed or declared (for example, Smith, 1979; FAO, 1983; Lawson, 1984; Clark, 1985; Regier and Grima, 1985; Charles, 1988). They include: (1) resource conservation, (2) food production, (3) generation of economic wealth, (4) generation of reasonable incomes for fishermen, (5) maintaining employment of fishermen, (6) maintaining the well-being and viability of fishing communities, (7) generation of foreign exchange through fish exports, and (8) generation of consumers' welfare. It should be noted that the objectives listed above are often being specified as single objective options, both in theory and in practice. More recently, however, fisheries management increasingly is carried out based on multiple objective criteria (Smith, 1979; Panayotou, 1982; Opaluch and Bockstael, 1984; Krauthamer et al., 1987; Charles, 1989).

Until the early sixties, while fisheries biologists constituted the dominant authority in fisheries management, maximum sustainable yield (MSY) was often advocated as the single most important goal in fisheries management. This management objective in fact originated as early as the thirties in the work of Hjort et al. (1933) which showed the existence of maximum sustainable yields for fishery stocks. As shown in Figure 3.1, the effort level corresponds to MSY is at E_{msy}. The rationale for advocating MSY as an appropriate management goal was that since MSY represents the maximum sustainable yield obtainable from a fishery, harvesting at effort levels exceeding E_{msy} will cause reduction in the population level of the stocks and thereby constitute biological overfishing. On the other hand, effort levels below E_{msy} will cause biological underfishing and there will be wastage of resources as the maximum biological potential of the stocks is not fully utilised. Therefore, it was then argued that any level of harvests other than MSY was socially unjustifiable since an opportunity to feed the protein-deficient poor and suffering of the world would be lost.

When economists seriously began to enter the field of fishery management in the early sixties, they pointed out that the MSY objective is not economically optimal. This is because fishery production involves the use of factors of production other than the fish stock itself. The E_{msy} level of harvest utilised excessively other factors of production, causing marginal costs of fishing to exceed marginal revenue and thereby constituted economic overfishing. Economists therefore prescribed the E_{mey} level of fishing when equating marginal revenue to marginal cost of fishing that maximizes economic benefits from the fishery. As shown in Figure 3.1, this economic objective (MEY) is more conservative than the biological goal (MSY) since it requires a lower level of fishing effort and hence a larger fish stock. While the economic goal calls for a lower level of fish supply and may appear undesirable in the face of food shortages, economists argue that inputs of labour and capital released by moving from E_{msy} to E_{mey} can be more productively employed in other food production enterprises such as agriculture and aquaculture (Copes, 1989).

Since the early seventies, it has been held that management objectives based solely on economic criteria are too narrow. Reference is made to the fact that (1) real world fishery systems are extremely complex and there are many goals and objectives confronting fishery managers; and (2) there is a myriad of social, economic, cultural, political and institutional factors which impact on fisheries management, particularly in developing countries (Alverson and Paulik, 1973; Rothschild, 1983). As a result, the optimum sustainable yield (OSY) which incorporates some or all the factors mentioned above was proposed and advocated. However, much confusion exists concerning the concept of OSY. How the various factors can be accounted for in estimating and defining OSY remains fuzzy as the plethora of methods developed to estimate it suggests (Roedel, 1975; Larkin, 1977).

An alternative way of avoiding the problem above is to treat the various factors as different objectives rather than lumping them into a single objective as in OSY. Thus, in a multiple objective setting, fishery management may be perceived as trying to achieve a set of objectives such as the biological objective of resource conservation, the economic objective of maximizing resource rent and/or socio-political objectives of maximizing employment in fisheries-dependent communities and a more egalitarian distribution of income. When a fishery is explicitly managed on a multiple objective basis, there must be a proper choice of balance between these objectives since they are often non-complementary. This balancing task is properly a task for policy makers. Moreover, the existence of multiple objectives also necessitates the use of suitable methods in order to provide meaningful analyses. To date, application of analytical economics to realistic multiple objectives fishery problems are not commonplace despite the existence of a well-developed methodology (Keeney and Raifa, 1976). Most studies utilize either multidimensional welfare economics, multi-attribute analysis or the goal programming technique. For instance, Hannesson (1981) refers to several goal programming studies in connection with Norwegian fisheries and Padilla (1991) used a goal programming technique to analyse the trade-offs between the generation of resource rent and employment for small-pelagic fisheries in the Philippines. Mueller and Wang (1981) advocated the formalism of multidimensional welfare economics. Healey (1984) utilized multi-attribute analyses in dealing with the New England herring fishery and the Skeena River salmon fishery of British Columbia. Other studies that employ multiple objectives model include those of Bishop et al. (1981), Drynan and Sandiford (1985) and Charles (1989).

Irrespective of what objectives are to be included in a multiple objective analysis, these objectives by themselves are not sufficient to define an optimal policy. Appropriate weightings are required before the results of a fishery management regime can be judged. The determination of the desired weighting of the objectives remains the responsibility of policy makers.

3.3 Fisheries Management Regulations

While there is much debate over the appropriate objectives of fishery management, discussions concerning the choice of management approaches and regulatory instruments also abound in the fishery literature. This section reviews the principal fisheries management regulations proposed and applied to real world fisheries.

The central premise of the open-access problem in a fishery is that excessive fishing effort has been exerted upon the fish stocks to the extent that the resource rents are completely dissipated. It has been asserted that the open-access problem is related to the absence of individual property rights over the fish stocks. As a result, solutions have been devised to bestow total or partial property rights on fishery resource users in order to rationalize the fishery.

There are several ways to manage a fishery. These alternatives either limit fishing effort or limit harvest to the desired levels as needed to achieve the objectives of management. Historically, limited entry licensing schemes which aimed at controlling fishing effort (inputs) have been the most widely practised method of fishery rationalization (see for example Rettig and Ginter, 1978). On the other hand, fishermen/boat quotas (also refered to as "enterprise allocations" or "quantitative rights") which attempt to control harvests through limits on individual outputs are perhaps the most popular in recent theoretical discussions of fisheries economics and management (see, for example, Neher et al., 1989). The above rationalization schemes basically bestow property rights on individual fishermen or fishing enterprises. A third major type of fisheries management scheme involves the granting of geographically defined property rights to fishing communities and is often referred to as territorial use rights in fisheries (TURFs). In addition to the above principal schemes, other regulations may be instituted to "fine-tune" these schemes to conform with other management goals such as conservation of stocks or to make the principal schemes more effective, e.g. to reduce "capital stuffing"[3] in limited entry schemes. The stock conservation objective may be met by the control of fishing inputs such as restrictions on boats, gears and the length of fishing time through seasonal closure. Financial disincentive schemes such as taxes or royalties on harvest or fishing inputs can be used to make the principal schemes more effective. A detailed discussions of these regulations will be presented in later sections.

Given the many fishery management alternatives, the choice among them should be based on certain criteria. These criteria include (Anderson, 1986):

1. Acceptence and support by a majority of fishermen involved in the fishery concerned. In the absence of such support, a management scheme is almost doomed to failure since fishermen are ingeneous and are able to circumvent most management regulations. Moreover, this will make monitoring and enforcement ineffective or costly.
2. Flexibility. This is needed because management alternatives need to adapt to frequently changing

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[3] *"Capital stuffing" will be described in Section 3.3.1.*

biological, social and economic environments. Also, flexibility is needed to address possible loopholes in management regulations.

3. Economic efficiency. This criterion ensures the largest possible contribution of fishery exploitation to the economy and the adoption of new and more efficient fishing technology. Thus, fishery management regulations should be cognizant of all the costs involved, including implementation and enforcement costs. The inadequacy of institutional structures in monitoring and enforcing fishery regulations, particularly in developing countries, and the complexity of regulation increases the costs, thereby constraining the design of efficient management regulations.
4. Social implications. The management regulations should also take into considerations the wealth distribution and employment aspects. These aspects will affect the acceptence of the regulations by the fishermen involved.

3.3.1 Limited entry licensing

The limited entry licensing scheme, in its various forms, is designed to restrict inputs of labour and/or capital in the fishing industry and to circumscribe their use (Rettig and Ginter, 1978; Crutchfield, 1979; Scott, 1979; Clark, 1980; Pearse, 1980). A limited entry licensing scheme essentially restricts the number of fishermen and/or fishing vessels operating in a fishery in order to improve both the yield and economic performance of the fishery. The limited entry licensing scheme is a relatively flexible method and has been widely adopted in many fishery management systems.

In theory, a well formulated limited entry licensing scheme would have the following (FAO, 1983):

1. Determine the catching power of the various fishing units.
2. Control the fishing power by limiting factor(s) having a major effect on the catching power of the fishing units.
3. The number of licenses issued should correspond to the optimal level of effort.
4. Allow the licensed fishermen to make the adaptations and innovations they see fit.
5. Control overall effective fishing effort at the desired level by retiring excess catching capacity resulting in a gain in efficiency.

However, several issues exist in practice which need to be addressed. They include among others:

1. The number of licenses to be issued and how they should be allocated.

2. Which component(s) of fishing effort should be licensed -- the fishermen, the gear, the vessel or all of these?
3. Should fees be charged for licenses or should licenses be issued free?
4. Should licenses be transferable?

The issue of determining the correct number of licenses is complex and rather difficult to resolve. The complexity of the problem depends on the nature of the fishery involved. The correct number of licenses should correspond to the desired level of fishing effort which in turn is determined by the objectives of management. The controversies surrounding the choice of appropriate management objectives have been discussed previously. Moreover, the problem of which component(s) of fishing effort should be licensed remains since fishing effort is a composite variable comprising vessel configuration, crew skill and experience, fishing time and area of operation. The multidimensional nature of fishing effort may diminish any economic improvement in the harvesting process from limited entry licensing schemes, because the licenses only restrict certain aspects of the fishing effort. For example, in the British Columbia salmon fishery, the number of vessels was considered a proxy for the amount of fishing effort. In this case, even though the licensing scheme was successful in reducing the number of vessels in the fishery, fishing effort actually increased (Fraser, 1977; Pearse and Wilen, 1979). This was because there were possibilities for fishermen to substitute one vessel attribute for another such as the use of greater engine power or installing more sophisticated fish finding or navigational equipment. These improvements caused fishing capacity to expand to well beyond the pre-regulation level, hence the costs of fishing escalated resulting in greater economic inefficiency. This phenomenon is known as "capital stuffing or seepage" in the literature (Crutchfield, 1979). Limited entry licensing schemes to be successful must restrict all aspects of fishing effort. However, this could be nightmarishly expensive in terms of enforcement and may inhibit the introduction of cost-efficient technological innovations.

The problem of determining the number of licenses is compounded when multipurpose fishing fleets or a heterogeneous fleet exploit a common fishery. With the former, complications arise because vessels move from targeting one species to another depending on profitability. One way to deal with this type of fishery, as suggested by Meany (1977), is to issue licenses for the entire fishery, and allow fishermen to catch all species, accompanied by a fee schedule that discourages harvesting of overfished species. In the case of a heterogeneous fleet, differences in the productivity of gears and in vessel capacity have to be taken into account when setting the number of licenses.

Licenses can be allocated initially in a number or ways. They can be granted based on equity considerations under a "grandfather" system to individuals already in the fishery. This system, however, may not reduce the actual amount of fishing effort employed in the fishery initially. However, fishing effort may be reduced over time through attrition in a non-transferable license scheme where licenses expire at the time when fishermen retire. If a faster rate of effort reduction is desired, a buy-back programme for the licenses may be introduced. Licenses can also be auctioned off or sold in a market. Such a system however, will not benefit small-scale, artisanal fishermen who do not have the necessary financial resources to bid for the licenses.

The allocation of licenses is closely related to the controversial issue of transferability. Transferability of licences will enhance individual property rights and these licenses can be traded freely among individuals. The purported advantages of transferability include efficiency in use, continuity in operation and ease of administration since licenses can be transfered relatively free and costless (Crutchfield, 1979). However, Copes (1988a) has argued against license transferability. First, fishery rationalization through limited entry licensing scheme promised the generation of positive resource rents. These rents will create expectations of greater benefits by the license holders. This give rise to an "expectations trap" whereby the value of the licenses escalate. If licenses are transferable and can be sold, the license price will include a premium equivalent to the expected future earnings of the license. If this happen, only the original license holders will benefit from the scheme since subsequent generations of license holders will only earn what they have paid to acquire their licenses. Copes(1988) described this as a "transitional gains trap" and argued that transferable licenses will not increase fishing incomes in the long-run. In fact, incomes of succeeding generation of license holders may be reduced with transferable licenses. This is because they will have to incur higher investment costs, on average, owing to the inclusion of license values in their investment. If a fishery experiences frequent unpredictable variations in catch and costs, the net returns of fishermen will be volatile. As a result, these fishermen tend to be financially more vulnerable.

Non-transferable licenses, on the contrary, will avoid the problems stated above. As licenses are non-transferable and non-marketable, licenses will have no value and the expectations trap and the transitional gains trap will disappear. Moreover, non-transferable licenses will reduce the problem of capital stuffing. As the number of these licenses could be reduced by retirement of fishermen, any significant increase in catching capacity of vessels through capital stuffing could be reduced by speeding up the process of license attrition. In this way, beneficial technological innovations would not be inhibited.

Two management issues arise if there is limited entry with non-transferable licenses. First, retiring fishermen should be compensated, on equity grounds, for the investment they havemade in their vessels, which would be withdrawn from the fishery. The second issue concerns succession. A system of succession that is both socially equitable and economically efficient would have to be determined when the fleet was reduced to the optimum size. Succession of licenses could be done by following a list of priority; for example, starting with skipper of a vessel, the senior deckhand and so on.

3.3.2 Catch quotas

Regulation of total allowable catch (TAC) and individual quotas (IQ) are aimed at controlling directly the level or quantity of harvest. These regulations are primarily based on the biological potential of the fish stocks and they will have positive effects on the conservation of the fish stock. In this respect, the TAC can be a highly flexible management tool. More information may be gained about perturbations in the level of fish stocks as the season progresses. These changes in the level of fish stocks can be accounted for by revising the initial TAC accordingly. However, difficulties and adverse effects may arise with multispecies fisheries and technologically interdependent fisheries. In the context of multispecies fisheries, fishermen attempt to fill the quota with the most valuable species, which may lead to their extinction.

TAC regulation by itself without restraints on fishing capacity of individual vessels and entry may not be economically efficient and may not prevent the dissipation of resource rent. In an attempt to increase their share of the TAC, fishermen tend to expand the harvesting capacity of their vessels through capital stuffing. This will result in the mobility and catching power of their vessels increasing. The "race for fish" by these vessels as soon as the fishing season opens will result in these seasons becoming progressively shorter. A well-documented example with TACs is the Pacific halibut fishery, where catches rose from 47 million pounds in 1933 to 58 million pounds in 1950, but the number of vessels increased proportionately more during the same period and the fishing season needed to be shortened accordingly (Crutchfield and Zellner, 1962; Copes and Cook, 1981). This example shows that with a successfully enforced TAC but without restriction on entry, the gains in fishery's productive potential may not be matched by the economic improvement. The "race for fish" also creates "peak-load" problem for the processing and marketing sectors of the fishing industry. The concentration of harvesting at the beginning of the open season implies that prices paid by the processors will be low thereby affecting fishermen's incomes. Moreover, the increased quantity of fish landed requires additional storage and freezing facilities. If these facilities have no alternative use during the closed season, there will be wastage of resources. Furthermore, preservation of fish landed implies additional costs to fishermen and consumers and lower quality as well.

The economic performance of TACs can be improved if they can be apportioned into smaller units and allocated to individual fishermen or boats (Christy, 1973; Moloney and Pearse, 1979; Scott and Neher, 1981; Clark et al., 1989). Under this scheme, a system of quasi-property rights is established which helps resolve the problems of absence of property rights (Scott and Johnson, 1985). Furthermore, as individual fishermen are guaranteed a specific entitlement to the catch, they do not have to race one another to secure their share as quickly as possible before the TAC is filled and the fishery is closed. As a result, fishermen can spread effort optimally across the entire season and use the most cost-efficient configuration of equipment and manpower to fulfill their quota. In addition, fishermen will find little need to fish in bad weather or under other dangerous circumstances in order to maintain their share of the catch. They can also achieve higher sale revenues by avoiding harvest gluts. The absence of a mad scramble for fish and the most economical configurations of inputs used under an IQ scheme also imply that there will not be a need to regulate capital stuffing and technological innovations will not be inhibited.

The economic efficiency of an IQ scheme is enhanced if the quotas are made transferable. The emergence of a quota market and the prospect of rents would lead the more efficient operators to buy out the quota entitlements of the less efficient fishing units. In the process, both buyers and sellers of quotas could share in the net benefits of the rents that would be generated by the accompanying reduction in fishing effort.

Although the touted advantages of ITQs make the scheme look impressive, serious problems may be encountered depending on the particular nature of a fishery. As noted by Copes (1986a), the problem of "transitional gains trap" as discussed in the previous section will not be solved by ITQ. Also, ITQ schemes are doomed to fail in the fisheries of most developing countries where many fishermen are involved and there are numerous fish landing points. This makes monitoring and checking of catches impractical. In such a situation, there is a great tendency for fishermen not to report or to under-report their catches, consequently leading to established quotas being persistently exceeded. Another problem with the ITQ concerns the multispecies characteristics of tropical fisheries. In these types of fisheries, as noted by Copes, the chances for fishing operators' catch to conform precisely to the proportions of various species quotas are almost nil. If quota is set for the species assemblage, there is a tendency for fishermen to "high-grade" the species, i.e. to retain high value species while dumping the low value fish in order to get the greatest value from their quota. Other problems mentioned by Copes with an ITQ scheme include: data fouling, residual catch management, unstable stocks, short-lived species, flash fisheries, real time management, seasonal variations, spatial distribution of effort, TAC setting, and industry acceptence.

3.3.3 Territorial use rights in fisheries (TURFs)

The major fisheries rationalization schemes reviewed thus far, *viz* limited entry licensing and quota schemes bestow property rights upon individuals. On the other hand, alternative management schemes have been designed to grant rights of use to a community over the fishery resource within a specific area and for a specific period of time (Panayotou, 1983). Such schemes are commonly known as territorial use rights in fisheries (TURFs). As pointed out by Lawson (1984), TURFs are a potentially effective fisheries management scheme in developing countries:

> "The most effective method of control exists where it is possible geographically and physically to delineate a territory in a way in which all fishing which takes place within it can be monitored and controlled and which can, if possible, be supervised by the fishing community itself or by its elected leaders".

The main advantage of TURFs is that government is able to give to the local community many of the functions and responsibilities of management and enforcement such as the determination and distribution of benefits, the acquisition of information and resolution of conflicts within fishing communities. This is especially true in multispecies, multigear tropical fisheries where monotoring and enforcement of fisheries regulations by government authorities are extremely costly, if not impossible compared to management by users themselves.

TURFs have existed for a long time throughout the world in countries such as in Brazil, Oceania, Ivory Coast, South Korea, Japan, Sri Lanka and Papua New Guinea (Panayotou, 1983; Lawson, 1984). However, little effort has been made to encourage TURFs (Charles, 1988) because of its limited applicability. Rettig (1989) has pointed out that TURFs will be more successful if the fish stock is less mobile. Moreover, successful application of TURFs depends heavily on there being the social and cultural traditions that favoured the emergence of these rights in fisheries such as in rural societies of Japan. Such socio-cultural requisites may not exist in contemporary societies which are undergoing rapid changes and hence TURFs may not be readily acceptable to these societies.

3.3.4 Fine-tuning regulations

The principal fisheries rationalization schemes have been reviewed in the previous sections. However, there are other regulations which either supplement the major rationalization schemes and make the latter more effective or are implemented in order to fulfill specific objectives such as biological conservation, or to diffuse conflicts among fishermen using different types of gears. These regulations are collectively known as fine-tuning regulations. They include among others: restrictions on fishing gear and technology; area licensing, closed area, and season; and financial disincentives.

3.3.4.1 Restrictions on fishing gears and technologies

Historically, restrictions on fishing gears and vessels appear to be commonly adopted regulations. Vessel restrictions aimed at restricting the physical characteristics of vessels such as the dimensions, tonnage, horsepower of engines and ancillary equipments. Gear restrictions attempt to limit the type, size and number of fishing gears used. At the extreme, gear restrictions may involve a complete ban on the use of certain types of gear in particular areas. The major advantages for adopting these regulations are ease of implementation and their ability to conserve fish stocks. However, these regulations are inflexible and they limit the freedom of fishermen in the adoption of new fishing technologies, thus limiting the support they receive from fishermen.

Waugh (1984) argued that there are situations which require the use of this category of regulations. Mesh size regulation, for instance, is justifiable to ensure optimal age-at-first capture. This is consonant with Beverton and Holt's argument that there is an age of first capture for each rate of fishing mortality that maximizes yield and this age should be the target of mesh-size regulation. Without such a regulation, fishermen will tend to use the finest mesh possible resulting in growth overfishing. In addition, some gears that fish indiscriminantly, which alter the biology of fish stocks adversely, should be prohibited.

Regulations that impact on fishing vessels and technologies may be justified if capital stuffing is rampant, which renders the principal rationalization schemes, in particular the limited entry licensing scheme, less effective in preventing rent dissipation. Moreover, fishermen may be forced to adopt new technologies prematurely in times of rapid change due to the fear of a price disadvantage and/or a possibility of decline in their share of the catch. Thus, regulations on gears and technologies help to fine-tune the major rationalization schemes and consequently may help in avoiding complete rent dissipation.

3.3.4.2 Area licensing, closed area and season

Closed area and season regulations aim at improving the biological productivity of fish resources. In the case of closed areas, the regulation may forbid fishing, particularly in spawning areas or in areas of concentration of juvenile fish. Closed seasons, however, are used to prohibit fishing at a certain period of time, in particular at times when the spawners or juveniles congregate and are especially vulnerable to capture. Both regulations alone may not be adequate however to achieve the conservation objective for pelagic fisheries if the stock is overexploited in other areas or times where no management schemes are in place. Thus, these regulations are mainly supplementary to other management schemes.

Similar to closed area regulation, area licensing regulation is used when licenses are issued to particular groups of fishermen to operate in a particular area in the sea to the exclusion of others. Area licensing and closed areas are useful management tools for resolving conflicts among some mutually incompatible gear types. Moreover, as Wilen (1988) has noted, with a limited entry scheme alone, there still may exist excessive mobility and movement of vessels trying to take advantage of openings in fisheries over different areas. As a result, congestion and interference occur as large numbers of vessels converge on a small area where the fishery opening is located. Hence, while average catches may increase with limited entry, the average cost of fishing may remain high and this renders limited entry schemes less effective in preventing rent dissipation. This was demonstrated by the British Columbia roe herring fisheries in the late 1970s. Thus area licensing may aid in avoiding vessels congregating in particular areas at particular times, thereby preventing the escalation of average costs of fishing and enhancing the effects of limited entry scheme.

3.3.4.3 Financial disincentive regulations

The fundamental argument for this type of regulation is that since fishermen respond positively to any rent in the fishery by expanding effort, this response can be nullified if the rent in the fishery is appropriated by the government authority which is entrusted with managing the resource. Rent can be removed either by increasing the costs of fishing through a fee for acquiring fishing licenses or by taxes on each unit of effort; or by reducing the price of harvest through taxes or royalties on output.

Taxes or royalties on output are often suggested in theoretical discussions as a possible management device. Meany (1977) and MacConnell and Norton (1978) state that this device constitutes one way of controlling fleet capacity in order to achieve the MEY level. Furthermore, by introducing differential taxes, i.e. by applying a higher tax on a more heavily exploited species, effort can be channelled towards less heavily exploited fisheries. However, the use of taxes or royalties in practice seems to confined to the supplementary objectives of raising revenue for the government as an offset to management costs or to obtaining a share of the rent for the public.

Rejection of taxes or royalties as a practical means of pursuing optimality in management is due to lags and the unpredictability of their impact (Copes, 1988b). Furthermore, income levels of fishermen in open-access fisheries are already low. Imposing this regulation on these fishermen appears to be socially and politically unacceptable because this will put additional hardship on the fishermen. As mentioned by Beddington and Rettig (1983), taxes would have to rise if they are to reduce effort to counter stock declines. However, for political and social reasons it would be quite difficult to increase taxes on fishermen at exactly the same time that their expected catch has been reduced. However, this type of regulation may be effective and socially and politically acceptable when it is used to supplement the primary rationalization scheme, particularly limited entry schemes. In this case, when a limited entry scheme has successfully reduced fishing effort to the optimal level, resource rent will be generated. The rent can then be appropriated, in whole or in part, by the management authority. This removes or reduces the incentives for entry of more fishing effort. Moreover, the regulation may help to reduce the capital stuffing problem if limited entry licenses are made non-transferable.

In practice, license fee regulation has been more widely adopted to supplement limited entry schemes because of the ease and lower cost of implementation. License fees can be adjusted and collected from time to time (usually once a year) when licenses are renewed. In the case of taxes on catch, implementation and enforcement becomes more difficult especially in fisheries where there are wide distributional channels and numerous landing points, such as is the case with the small pelagic fishery in Malaysia. This would increase the costs of collection of these taxes. Also, illegal marketing channels may develop or fishermen may try to cheat by falsifying sales records in order to avoid paying the taxes.

3.4 Summary

This chapter has reviewed the literature on the theory of fisheries management. The need for fisheries management stems from the fact that resource rents will be completely dissipated due to economic inefficiency and the fear that fish stocks may be driven to extinction in an open-access, unregulated fishery.

A general observation from the preceding review is that the literature dealt mainly with temperate fisheries in developed countries, while only a handful had addressed the multi-species, multi-gear, multi-objective tropical fisheries in developing countries. The multi-objective nature of fisheries resource harvesting in developing countries like Malaysia needs to be explicitly taken into consideration due to the fact that social, economic, political and institutional considerations are equally important, if not more pressing than biological and technological aspects. Thus, management of fisheries resources needs to incorporate all these important considerations and aspects.

There is a great variety of management tools being proposed and used in managing fisheries resources throughout the world. The nature of small-pelagic fisheries in Peninsular Malaysia can be characterised as multi-species, multi-gear, with numerous participants and wide distribution channels and marketing outlets. A limited entry licensing scheme with some fine-tuning regulations appears to have some potential for success in managing the fisheries. An analytical model for evaluating alternative management regulations will be developed and presented in the next chapter.

Chapter 4

Description of the Mathematical Model

Real world fisheries are complex. They are multidimensional systems consisting of biological, economic, social, cultural, political, institutional components and their interactions. Thus analysing these systems requires an interdisciplinary approach. Moreover, many of the system component interactions are nonlinear and random effects are often inherent in the system. The complexity of analysing fishery models is further compounded by the need for dynamic considerations as well.

4.1 Analytical Approach

Many different approaches have been proposed and used to aid in the management of real world fisheries. These include static or dynamic analyses in a deterministic or stochastic framework. The earlier and perhaps the most widely used approach in the economic analysis of fisheries management was mainly cast in a static and deterministic framework. For example, the analytical model by Gordon (1954) and Schaefer (1957) which has been discussed in Chapter 3 has since become a classic in the field of fishery management. The advantages of the static and deterministic approach are that it is simple to estimate and is easily adapted to economic analysis. Because of its economic applicability, most economists until the recent past have relied on the static and deterministic model in fishery management studies. However, the ease of using this model may be at the expense of ignoring the complexity of the biological dynamics. Consequently, predictions of the behaviour of fisheries in the real world based on these parameters may be less accurate. Nevertheless, these models are still useful as they provide indications of the extent of overfishing and as a result, management regulations are imposed to limit the intensities of fishing in order to better achieve the stated management objectives.

With the advancement in econometric and mathematical methods as well as the advent of sophisticated computer technologies, dynamic analyses of fisheries management have been made possible. The dynamic fisheries models are considered superior to their static counterparts because fisheries resources are renewable and intertemporal predictions of the availability of the resource stocks and other variables pertaining to the fishery production can appropriately reflect the behaviour of the fisheries over time and thereby allow management to be undertaken intertemporally. The common approaches used in dynamic analyses of fisheries management include optimal control theory (e.g. Quirk and Smith, 1969; Clark, 1976), mathematical or dynamic programming (Anderson et al., 1981; Meuriot, 1981; Logan, 1984) and system simulation (Gates and Norton, 1974; Huppert et al., 1974; Lampe et al., 1974; Anderson et al., 1981; Curtis, 1979; Charles, 1989). However, optimal control theory and mathematical programming techniques have limited practical applicability in complex real world multispecies, multigear and multiobjective fisheries because these techniques are intractable and suffer from the problems of "curse of dimensionality" (Fair, 1974; Clark, 1990). In addition, the existence of an optimal solution in a multidimensional control problem may not be automatically ensured (Clark, 1990; Schriber, 1991). On the other hand, a system simulation approach is less elegant and may not provide an optimal solution but is more tractable. Hence it represents a potential technique to be used to analyse the performance of alternative management strategies in real world fisheries.

According to Manetsch and Park (1982), the system simulation approach is a problem-solving process to obtain particular time solutions of a mathematical model corresponding to specific assumptions regarding model inputs and values assigned to parameters. Shannon (1975) defines simulation as the process of designing a model of a real system and conducting experiments with this model for the purpose of either understanding the behaviour of the system or of evaluating various strategies for operating the system. Because simulation models are not constrained by the limitations of optimization techniques stated above, they appear more suited to the analysis of complex management problems. They allow in particular for more flexibility in the design of experiments and the analysis of alternative policies. In fact, the results obtained from simulation permit a better appraisal of the most relevant factors influencing the system and eventually these findings may be used to respecify the problem in an optimization context if judged necessary. A comprehensive system simulation approach that involves biological, economic and institutional dimensions is aimed at providing integrated guidelines for renewable resource management (Walters, 1980; Ervik et al., 1981).

In order to achieve the objectives of the study, a system simulation approach will be used. The overall system structure and the theoretical description of the various models are presented in the following sections.

4.2 Model Structure

It has been well observed by many in managing fisheries resources that effective management requires a thorough understanding on the part of the managers of the biological, economic and social, political as well as the institutional components of the fishery system. Much fisheries research in the past has been piecemeal in its approach, leading to partially or sometimes completely erroneous management. It is recognized that the inclusion of all the components in a single model may be empirically impossible due to the lack of adequate data and/or the complexity of the interactions among the various components of the model which render it difficult to analyse. The literature on fisheries management however, has recognised the need to incorporate three major components in any fishery system model: (1) the biological; (2) the social and economic; and (3) the management components.

The underlying structure of the system model used in this study comprises the three submodels noted above. The biological submodel describes the population dynamics of the fisheries whereby changes in the biomass of the fish stocks are determined by the recruitment, growth of individual fish, and natural and fishing mortalities. The social and economic submodel describes the revenues and costs from harvesting the fish stock using a composite input called fishing effort. Changes in fishing effort are determined by economic and social factors. Finally, the management submodel describes the policies and regulations that might be instituted by fisheries managers. These policies and regulations are likely to affect fishing effort or harvest and are aimed at improving the social benefits attainable from the fishery.

The three submodels are interconnected by various interfacing variables. As shown in Figure 4.1, the connection between the biological and economic submodels is through the harvest variable. Social profits from the fisheries, employment, consumer's surplus and crew income interconnect the economic and management submodels. Finally, fishery biomass and effort become the interfacing variables between the biological and management submodels.

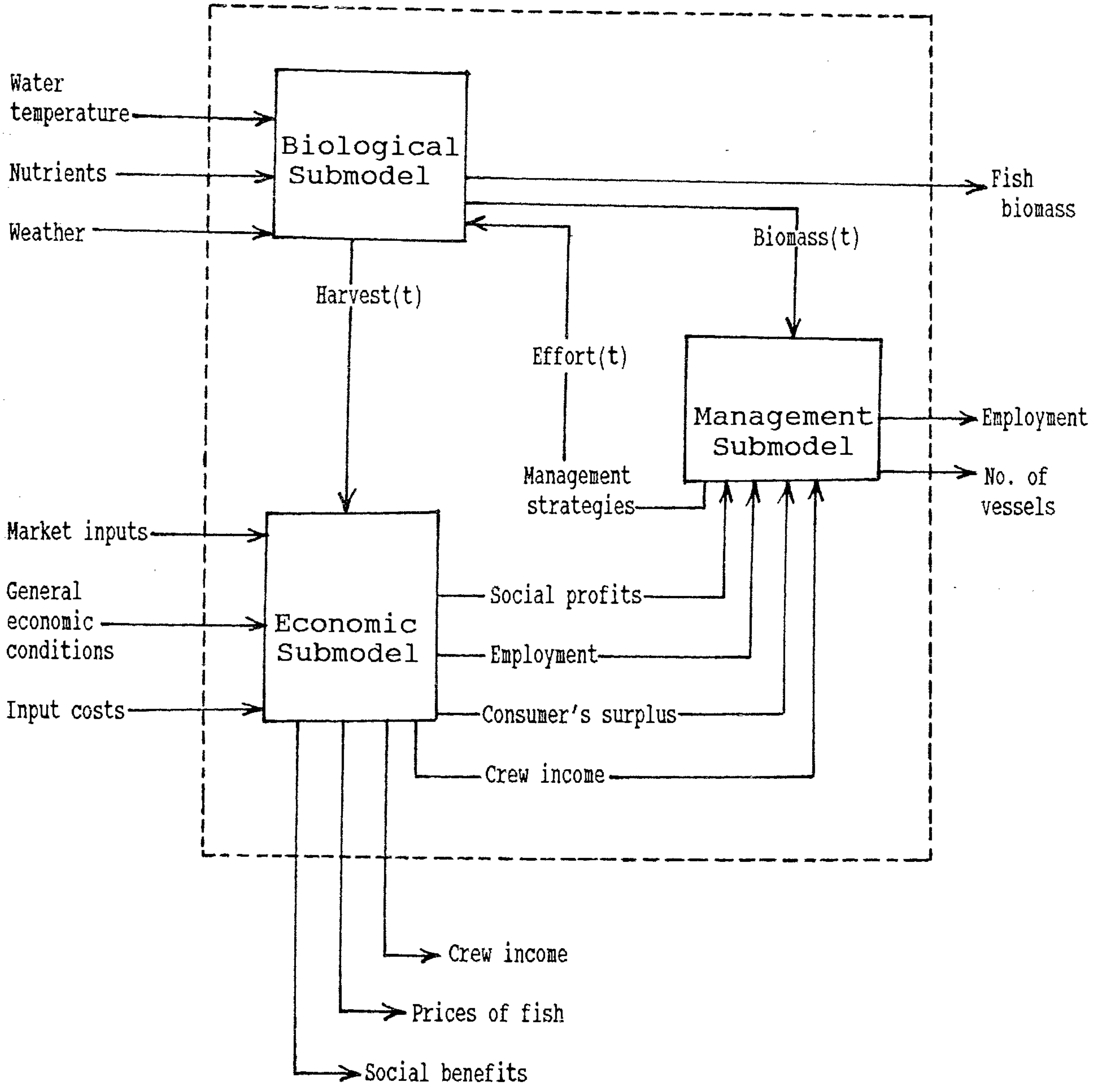
4.3 Biological Submodel

The literature on fishery biology dealing with single-species temperate zone fisheries abounds compared to that on the multispecies, multigear tropical fisheries, although the latter has been increasing notably in recent years. The small pelagic fishery in this study is characterised by multispecies and multigear. Therefore, the appropriate biological submodel should encompass these characteristics.

Generally, the biology and population dynamics of a multispecies fishery are modelled by one of the following approaches:

1. Surplus production models used to determine the biomass for all species (Brown et al., 1976; Pope, 1979).

Figure 4.1 Simplified Structure of System Model



2. Interactive production models which include specific terms in the growth function of each stock in order to take account of the impact of fishing on other species (Horwood, 1977; Pope, 1979; Sparre, 1980; Majkowski, 1981).
3. Interactive analytic models which take into account explicitly the growth, mortality, age class and stock recruitment relationships (Anderson and Ursin, 1977; Helgason and Gislason, 1979; Pope, 1979; Sparre, 1980; Gislason and Helgason, 1985; Gislason and Sparre, 1987; ICES, 1984, 1986, 1987).
4. Trophic-dynamic models which expand the basic interactive models into the whole ecological systems to account for trophic assemblage, food, energy flows, etc. (Sainsbury, 1982; May, 1984; Polovina, 1984).

On the other hand, there are relatively few models explicitly addressing problems of technological interaction. Notable contributions in this respect include those of Paulik et al. (1967), Ricker (1975), Hilborn (1976), and Murawski (1984).

The relevance of any of these models depends on the characteristics of technological interaction, species mixture and data availability. With a highly mixed catch and relatively non-selective fishing, surplus production models are appropriate. However, if interspecies dynamics and interactions are important in a fishery with a few species which are commercially dominant, interactive models may be used to explicitly take into account the interspecies dynamics.

The analytical models provide a more elaborate representation of the fishery dynamics by taking account of fish growth, mortality, age class and stock recruitment relationships. They are less dependent on the ability to measure effort in dynamic, multispecies fisheries (Beverton and Holt, 1954; Ricker, 1975) in comparison to the production models (Schaefer, 1957; Pella and Tomlinson, 1969; Fox, 1970). However, the overriding factor in determining the type of model to be used is the quality and quantity of available data (Sparre et al., 1989). If data are available for an advanced analytical model then such a model should be used since they are analytically more realistic. On the other hand, there may be situations where limited data are available for an analytical model, particularly in developing countries where limited resources and capabilities exist for collecting these data. In such situations, a less data-demanding method such as a surplus production model must be used. The surplus production models use time-series data on catch per unit of effort which is available for most fisheries.

In the context of the present study, the surplus production model is used as the biological basis for the fishery system. However, it should be recognised that small pelagic fish stocks usually do not fit well into traditional population dynamic models and assumptions, thus making their assessment the most unreliable among all fisheries (Beverton, 1983; Beverton et al., 1984). The production model is used here primarily because data on the population parameters such as length, weight, recruitments, mortalities etc. for small pelagic fisheries in Malaysia are at best sparse and are mostly unavailable (Chullasorn and Purwito, 1986). Furthermore, Csirke (1988) has argued that fluctuations in abundance of individual small pelagic stocks is usually much wider than that of the main species in the complexes taken together. The surplus production model considers these species complexes as one whole and thus provides for relative stability in overall stock abundance.

The theory of surplus production models for a single species has been thoroughly reviewed in for example Ricker (1975), Caddy (1980), Gulland (1983) and Pauly (1984). In this model, it is assumed that a simple stock-growth relationship exists which is useful when little is known about factors affecting fish production. Given a constant environment with limited food supply, biologists generally hold the idea that the unexploited fish population increases toward the maximum carrying capacity of the environment. At the level of maximum stock size, recruitment and growth are just sufficient to offset natural mortality and there will be no surplus production. If fishing mortality is introduced, the biomass will be reduced, resulting in more efficient use of food and generation of surplus production. With a sufficiently high level of effort, the stocks will be fished down to the point where surplus production is at the maximum sustainable yield as used to be desired by biologists. With even higher levels of fishing effort, the fish stocks will be biologically overexploited.

In the absence of fishing, Graham (1935) assumed that the instantaneous percentage rate of change in the population biomass over time $(1/X_i)(dX_i/dt)$ is directly proportional to the difference between the biomass maximum carrying capacity K_i, and the biomass X_i itself, as follow:

$$(4.1) \qquad dX_i/dt = r_i X_i(K-X_i); \qquad r_i>0$$

where r_i denotes the intrinsic growth rate for species i. If X_i denotes population biomass at time t and if r_i and K_i are constants, equation (4.1) can be rewritten as:

$$(4.2) \qquad \dot{X}_i=r_i X_i[1-(X_i/K_i)]$$

With fishing, the fish stock will be subjected to fishing mortality, thereby reducing the biomass and yielding a catch. In surplus production models, the harvest or yield of species i at time t (H_i) is usually assumed to be a function of total fishing mortality of all gears on species i at time t (F_i) and of population biomass of species i at the time of fishing. Thus the harvest of species i at time t can be expressed as:

(4.3) $$H_i = F_i X_i$$

The rate of change of population biomass at time t with fishing can thus be written as:

(4.4) $$\dot{X}_i = r_i X_i[1-(X_i/K_i)] - (F_i X_i)$$

In the steady state, $\dot{X}_i$ is equal to zero. That is, the natural growth rate is equal to the rate of harvest. Thus with the steady state assumption equation (4.4) becomes:

(4.5) $$r_i[1-(X_i/K_i)] = F_i$$

In the single-species fishery literature, fishing mortality is most often specified as linearly related to the standardised fishing effort at time t (E) (for example, Beverton and Holt, 1957; Schaefer, 1957; Gulland, 1983), although alternative forms have been suggested for various species (Peterman and Steer, 1981). The relationship can be expressed as:

(4.6) $$F_i = q_i E$$

where q_i denotes a constant catchability coefficient for species i.

The equilibrium population biomass for species i at a constant level of fishing effort can be derived by substituting (4.6) into (4.5):

$$(4.7) \qquad X_i = K_i[1-(q_iE)/r_i]$$

and substituting (4.7) into (4.3), the equilibrium harvest of species i at time t is:

$$(4.8) \qquad H_i = K_iq_iE[1-(q_iE)/r_i]$$

Equation (4.8) or its variants will be used to compute the equilibrium harvest of species i in the simulation to be discussed later. As noted, the single most important variable in equation (4.8) is fishing effort. The computation of a standard measure of fishing effort and the corresponding assumptions made will be discussed further in the next chapter.

In a multispecies and multigear fishery, equation (4.6) implies that the fishing gears fish individual species indiscriminately or the species have coincidental geographic distributions so that they are equally available to all fishing gears. In the latter case, the species will be caught in proportion to their relative abundance. Thus each unit of standardized fishing effort will generate proportional fishing mortality on each vulnerable species inhabiting the area of coincident distribution and effort is directed to species assemblage rather than targetted to an individual species (Murawski, 1984). The coefficients of proportionality between fishing effort and fishing mortality are reflected in the vector of catchability coefficients. The catchability coefficients will vary among species due to differences in availability and vulnerability to the gears.

The relationship between catch and effort as shown in equation (4.8) pertains to that of species i. However, in a multispecies, multigear fishery, the total catch of species i is the aggregate sum of the catch of the species by all gear types. Therefore, total catch of species i ought to be decomposed into catch of species i by gear j at time t (H_{ij}). In general, H_{ij} is proportional to the amount of effort of gear j directed to species i. Hence, an increase in effort of gear j directed to species i will cause H_{ij} to increase and vice versa. Similarly, changing the effort of gear j directed to species i will also affect the catchability coefficient of species i. The effects of changes in directed effort on the catchability coefficient of species i can be accounted for in the surplus production model by fitting a yield curve for each set of directed effort of gear j to species i, resulting in a family of curves being generated. However, data on directed effort by gear are usually unavailable. Lacking such data, the H_{ij} is derived in this study by assuming that the ratio of (H_{ij}/H_i) is a constant proportion of the ratio of $(\bar{H}_{ij}/\bar{H}_i)=\Theta_{ij}$, where $\bar{H}_{ij}$ and $\bar{H}_i$ are respectively the time-averaged harvest of species i by gear j and the time-averaged total harvest of species i. With this assumption, H_{ij} can be computed as:

$$H_{ij} = \Theta_{ij}H_i \tag{4.9}$$

Models that relate surplus production (or sustainable yield) to measures of stock abundance or fishing mortality are an important tool in the assessment and management of exploited fish stocks. However, their use with small pelagics, as has been applied in this study requires that particular attention be paid to some of the model limitations and constraints, specifically with regards to the assumptions of constant carrying capacity and catchability coefficients.

Environmental changes will affect the carrying capacity of the system and the stock abundance by affecting reproduction, food supply, larval survival, growth, recruitment, etc. Since most small pelagic species are filter feeders or particulate plankton feeders, their relative low trophic level and early position in the food chain allow these stocks to reach high biomass levels. As noted in MacCall (1984), the more direct the link between the physical environment and the adult fish stock, the less buffering there is in the response of the fish to the environmental change. Extreme changes in environmental conditions may severely affect stock abundance thereby causing the collapse of the small pelagic fisheries unless a corresponding reduction in effort is made. This is exemplified by the collapse of the anchovy fisheries off the coast of Peru (Csirke, 1987).

The effects of environmental changes on the carrying capacity of the system can be incorporated in surplus production models by fitting a curve for each set of environmental conditions that represents a sequence of different carrying capacity levels (Gulland and Garcia, 1984). This approach will generate a family of surplus production curves. However, as there are no adequate data on stock abundance or environmental conditions, the approach suggested above will not be followed in this study. Moreover, as shown in Chapter 2, the study area does not experience extreme environmental conditions.

Changes in the catchability coefficients caused by changes in stock size and/or environmental conditions make surplus production models difficult to use in practice, unless reliable measures of abundance or fishing mortality can be obtained. Departure from the assumption of constant catchability coefficients is particularly marked for small pelagic fish (MacCall, 1984). The catchability coefficients are affected by the behaviour of the fish and the way fishing effort is measured. Reduced abundance of small pelagic fish may cause the area over which they are distributed to decrease. Even if the geographical distribution is not changed, reduced abundance can affect the catchability. For example, the fish may form fewer schools but the average size of each school may remain about the same. Assume that the total fishing time remains the same. In this case, since the number of schools is reduced, the searching time for each school will be prolonged. On the other hand, the total hauling time will be reduced since the hauling time for each school is approximately the same because the size of each school remains the same but there are fewer schools to be hauled in this case. In a different case, the average size of small pelagic schools may be smaller while the number of schools is not drastically altered. Under these circumstances, the hauling time for each school will be shortened and the extra time will be used to search for new schools. Again, the searching time will be prolonged while the total hauling time is reduced, assuming total fishing time is unchanged. Thus effort should be measured in terms of both searching and catching times so that changes in catch per unit of effort reflects more readily the changes in real abundance of the stock (Csirke, 1988). The fishing effort of various gears used in this study encompass both the searching and catching times. A more detailed discussion of measuring effort will be provided in Chapter 5.

4.4 Economic Submodel

The economic submodel, similar to the biological submodel is only a subsystem of a larger system. This submodel describes the benefits and costs of fishing operations. In this submodel, the inputs of labour, capital and materials required in the fishery operations are supplied by the surrounding economy while the latter also serves as an outlet for the outputs of the former. The values of these input-output flows are determined with the help of prices which are determined by the overall economic system. In this way the overall economic system influences the economic submodel. However, it is assumed that there are no reverse influences occurring.

4.4.1 Prices and demand

Prices play a major role in determining the dynamics of a fishery as they determine revenues, profits and the amount of effort applied to the fishery. In a multispecies fishery, relative prices will determine the way in which fishermen allocate their effort and consequently this will determine the relative state of exploitation of each species within the fishery.

In the fishery literature, prices are either considered as exogenously determined and therefore are fixed or they can be variable in response to the conditions of supply and demand. In general, the former is appropriate if prices are determined on an international basis or when landings represent a very small share of the overall market. In this case, the dynamics of the fishery essentially correspond to supply adjustments in response to exogenous price levels. However, where prices are endogenous, any regulation of the fishery will not only affect the producers, but also the consumers. Fishery managers need to measure and weigh relative changes in consumer and producer welfare implied by alternative regulations.

The market price in a competitive market is determined by the market clearing mechanism of supply and demand. In fisheries, landings constitute primary supply and can be assumed to be exogenous in the short run since they are determined in the short run by such factors as weather, resource availability, environment etc. which are beyond fishermen's control. Over a longer period, however, fishermen can respond to changes in prices and stock abundance by adjusting their fishing strategies and thus, adjusting the supply of each species. The other important source of supply in the context of small pelagic fishes in Peninsular Malaysia is imports, especially from Thailand.

While recognizing the process of landing adjustments, the price and demand equations are estimated assuming that the primary supply is exogenously determined.

The market structure of the small pelagic fishery in Peninsular Malaysia consists of three levels: ex-vessel, wholesale and retail. The ex-vessel demand originates from wholesalers and indirectly reflects retail and consumer demand. Ideally, an integrated market model should be specified where the supply and demand equations of all market levels are estimated simultaneously, and where the model incorporates the interactions at all market levels. This approach has the advantage of modelling marketing practices (e.g. Farrell and Lampe, 1965; Bockstael, 1977; Storey and Willis, 1978), but at the expense of complicating fishery management models. It is expected that in the context of quarterly or annual models, ex-vessel demand will essentially reflect final demand if all levels of market are competitive. Due to these reasons, the demand equation at the ex-vessel level is usually estimated in fishery management modelling while the impact of the upper markets are explicitly recognized. The resulting derived demand equation thus incorporates not only the determinants of ex-vessel demand but also the major determinants of upper markets . Since ex-vessel supply is exogenous, the market clearing situation will be obtained primarily through price adjustments, even if some quantity adjustments are brought about through changes in inventories[1]. As a result, market price is considered as the dependent variable in the demand model.

The major explanatory variables included in the demand equations are total quantity supplied of the demanded species as well as the main shifters of final demand such as prices of substitutes, income and population. Fish prices can also be influenced by numerous other factors such as fish size, price expectations and seasonal variations in demand and supply. While these factors are significant shifters of demand, they will not be explicitly incorporated into the overall model[2]. However, their effects will be embodied in the intercept and error terms.

The estimated price equation for each of the i species included in the model is specified in log-linear form as in (4.10). This functional form has also been used in empirical studies of the demand for other fish products (see for example DeVoretz, 1982).

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[1] *In the context of small pelagic fisheries in Malaysia, the effects of inventory adjustments on price changes may not be significant since a major proportion (more than 80%) of the landings are consumed fresh or frozen.*

[2] *The exclusion of these factors from the demand equations was due to unavailability of data.*

$$(4.10) \qquad \ln P_{it} = \alpha_{0i} + \alpha_{1i}\ln Q_{it} + \Sigma_u \alpha_{ui}\ln P_{ut} + \alpha_{5i}\ln I_t$$

where P_{it} denotes ex-vessel price of species i at time t;

Q_{it} represents total quantity supplied of species i at time t;

P_{ut} are prices of fish species other than i at time t;

and I_t denotes per capita income at time t.

From utility theory, the functional forms chosen for the estimating equations should satisfy some requirements (Goldberger, 1967; Deaton and Muellbauer, 1980; Phlips, 1983). These properties include:

(1) Homogeneity of degree zero with respect to prices and money income.

(2) Own (direct) substitution effect is negative.

(3) Symmetry of cross-substitution effects.

(4) Separability: commodities can be partitioned into two or more subsets and the total utility is invariant with or without grouping.

(5) Non-negative prices.

(6) Non-negative quantities.

In addition to the above restrictions, the use of aggregate time series data as opposed to micro level survey data creates some general problems. It is generally assumed that the function is estimated for a representative consumer. Otherwise it is difficult to invoke consumer theory to validate the empirical results. The additional requirements by aggregating over time include:

(7) Average income elasticity equals individual income elasticity.

(8) Independence of income and prices.

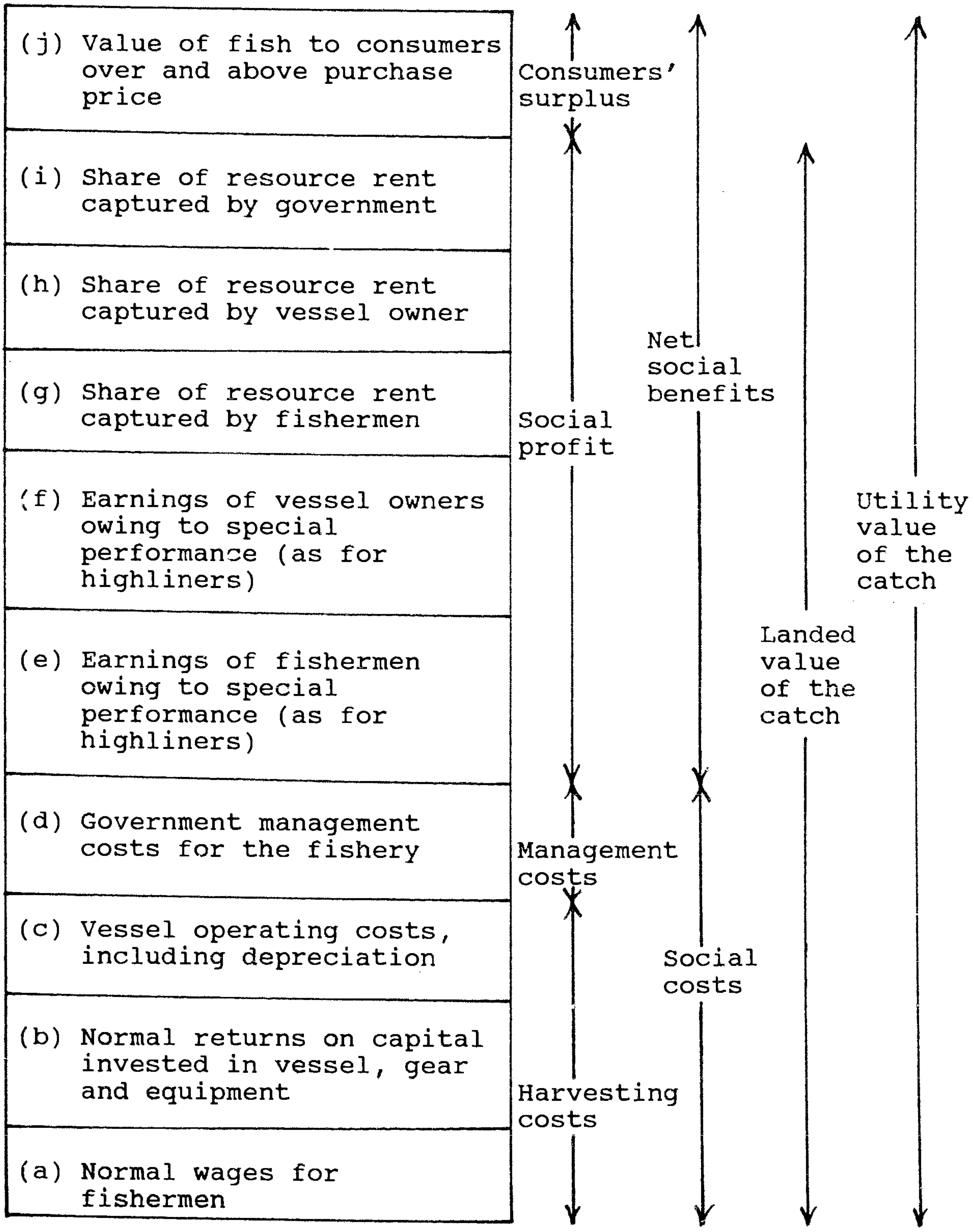
(9) Constancy of tastes.

For the log-linear form equation specified in (4.10), properties (5) and (6) are satisfied. Furthermore, the function also assumes constant elasticity with respect to the independent variables. The other properties of the demand function, however, may or may not be satisfied by the functional form when empirical estimation of (4.10) is carried out.

4.4.2 Profits and benefits

The benefits derived from a fishery include consumer's surplus, resource rent and intramarginal rent (producer's surplus) (see Figure 4.2). The resource rent and producer's surplus together constitute social profits from exploiting the fishery. Social profits correspond to revenues over and above payments necessary to keep the factors of production in their present use and reflect both short-run returns to fixed factors (quasi-rent) and long-run returns to scarce factors (resource rent). Specifically, social profits can

Figure 4.2 Schematic Representation of Benefit-Cost Relationships in Fish Harvesting



Source: Copes, 1986b.

be defined as net revenues or losses assuming that capital and labour are paid at their opportunity costs[3]:

(4.11) $SP_t = \Sigma_j(TR_{jt}-VC_{jt}-FC_{jt}-OCE_{jt})$

where SP_t denotes social profits at time t;

TR_{jt} represents total gross revenue for gear j at time t;

VC_{jt} represents variable costs for gear j at time t;

FC_{jt} is fixed costs for gear j at time t; and

OCE_{jt} denotes opportunity costs of effort for gear j at time t.

The full specification of the social profits equation is as follows:

(4.12) $SP_t = \Sigma_j[\Sigma_i(P_{it}H_{ijt})+RBC_{jt}-E_{jt}(texp_j+cexp_j+\pi_j)-FC_{jt}]$

Fish species other than the small pelagics caught by the major gears considered in the study constitute by-

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[3] *Theoretically, social profits should include resource rents and intramarginal rents of highliner vessels. To estimate the intramarginal rents for highliners, the data set has to be divided into 2 categories, namely, one for the highliners and the other for the marginal vessels. However, the available data set precluded such a division. Therefore, the social profits estimated here represent mainly the resource rents captured by an average vessel in the fleet while the intramarginal rents accrued to highliners have been averaged out. These intramarginal rents may be small. Thus social profits in subsequent sections of this report may be interpreted as consisting mainly of resource rents.*

catches. They are not modelled explicitly but are considered exogenous. The total quantity of these species harvested multiplied by their average price constitute revenues derived from by-catches (RBC_{jt}).

Fishing costs can be classified as fixed, variable and opportunity costs. Fixed costs are incurred irrespective of whether a fishing unit is operative or not since they are 'sunk' capital investment costs which cannot be recouped at short notice without undue losses (Panayotou, 1985). Fixed costs consist mainly of the cost of depreciation of the fishing assets.

Variable or operating costs are those that are incurred only when operating a fishing unit. Two types of operating costs are distinguishable. They are running costs such as fuel, oil, ice, food, nets and their maintenance, expenses for fish aggregating devices all of which depend on fishing effort; and labour or crew costs. The running costs per unit of effort for gear j is denoted by the variable $texp_j$ while the labour or crew costs are denoted by the variable $cexp_j$.

The computation of labour or crew costs requires particular attention. Instead of being paid a fixed wage per unit of time worked, fishermen or crew members of a fishing boat are often remunerated based on a share of revenue received from boat's catch. In fact, the share system is the dominant system of crew remuneration in the marine fishing industry in Malaysia in general and in the study area in particular (Firth, 1966; Selvadurai and Lai, 1977; Yap, 1977; Jahara, 1984; Md. Ferdous, 1990). Ignoring the controversy surrounding the social desirability of remuneration by share system[4], the sharing arrangement as it is practised in Malaysia is rather complicated. In principle, the sharing system can be distinguished by two important elements, namely, fish prices and operating costs. Under a fixed-price sharing system, the owner of the fishing vessel buys the catch from his fishing crew at fixed prices. The prices paid by the vessel owner are determined by whether or not all costs related to fishing trips are explicitly taken into account. If these costs are paid by the vessel owner, the price offered will be low, and vice versa. Irrespective of who bears the costs, the revenues from the catch are then shared between boat owner and crew members. In contrast, under the current-price sharing system, the boat owner sells the fish landed at the current market prices. From the gross proceeds of the sale, the

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[4] *For more detailed discussions of the social desirability of a share system of remuneration in the marine fishery industry, see for example FAO, 1961; Crutchfield and Zellner, 1963; Holsman, 1969; Selvadurai and Lai, 1977; and Sutinen, 1979.*

operating costs of the fishing trip are deducted. The net proceeds are then shared between the owner and the crew.

Irrespective of a fixed-price or current-price sharing system, the operating costs of fishing are implicitly or explicitly shared by the vessel owner and crews. The net proceeds after deducting operating costs are then shared between them according to some predetermined formula. Thus, if total crew share of the net proceeds for gear j is denoted by $shcr_j$, then crew expenses is given by:

$$(4.13) \qquad cexp_{jt} = (\Sigma_i(P_{it}H_{ijt})+RBC_{jt}-E_{jt}texp_j)shcr_j$$

In the study area, the most commonly practised sharing arrangement is to have crew shares of 50% for trawls and purse seines and 67% for drift nets (Md. Ferdous, 1990).

One of the variables used in evaluating the performance of alternative management regulations in simulations is income to individual crew members. From (4.13), individual crew member's income for each gear j at time t ($CINC_{jt}$) can be computed as:

$$(4.14) \quad CINC_{jt} = cexp_{jt}/(crew_jV_{jt})$$

where $crew_j$ denotes average number of crew members for vessel operating gear type j.

The opportunity cost of effort for gear j (π_j) represents the benefits foregone by keeping input factors (which include fishing asset and labour) that produced a unit of fishing effort in their present use. In practice, it is very difficult to measure the opportunity cost of fishing effort. However, following the method by Wilen (1976), the π_j can be estimated directly from the equation describing the dynamics of effort which will be discussed in more detail in the next section.

In addition to the social profits, the net benefits derived from the exploitation of the fishery should include a measure of the satisfaction which consumers derive from the consumption of various quantities of fish. Consumer's surplus was used to reflect this benefit. Various concepts of measuring consumer's surplus have been discussed in the literature. The earliest formulation was by Dupuit (1844) in terms of marginal utility. This was later replaced by Marshall's (1890) idea of taking the area under the Marshallian (uncompensated) demand curve[5]. Hicks (1956) had proposed measuring consumer's surplus by taking areas under the compensated or Hicksian demand curves and over a price rather than quantity change. The resultant two consumer's

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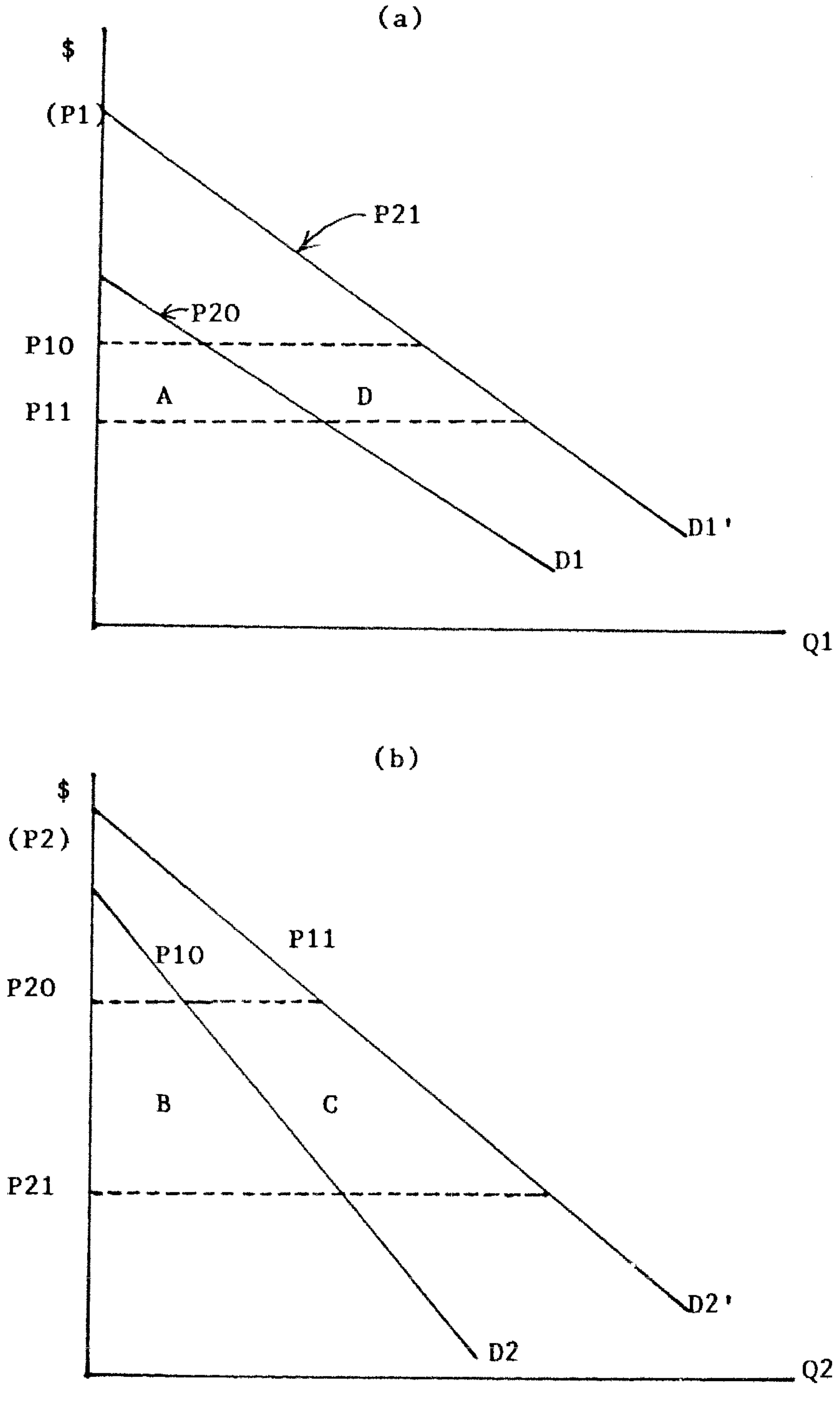
[5] *The area under the ex-vessel demand curves includes not only the consumer's surplus but also any abnormal returns to the distribution sectors.*

surpluses are known as compensating variation (CV) and equivalent variation (EV). Detailed discussions of these various measures of consumer's surplus can be found in, for example, Deaton and Muellbauer (1980) and Varian (1987). There is much debate over which concept provides the best measure of consumer's surplus (see for example Burns, 1973; Seade, 1978; and Willig, 1976).

In real world situations, a policy change will affect several prices. Graphically, consumer's surplus in multiple price change situations can be analysed using a hypothetical case as shown in Figure 4.3 (see Johansson, 1991). In the figure, a case of two closely substituted commodities is depicted. If the price of commodity 1 falls from P_{10} to P_{11}, the consumer's surplus is equal to area A in Figure 4.3a, assuming that the price of commodity 2 remains constant at P_{20}. Similarly, income stays constant, since a demand curve depicts the relationship between quantity demanded of a commodity and its price, *ceteris paribus*.

In the market for commodity 2, there is also a simultaneous fall in its price from P_{20} to P_{21}. The price fall of commodity 1 will in general cause a shift in the demand curve for commodity 2 to D_2'. Since the price of commodity 1 has already been reduced, the correct procedure is to evaluate consumer's surplus using the D_2' curve, which is drawn on the assumption that P_1 is held constant at P_{11}.

Figure 4.3 Multiple Price Changes and Consumer's Surplus for a Hypothetical Two-Commodities Case



Thus the consumer's surplus in market 2 is equal to area B+C. The money measure of the utility gain of the combined fall in the two prices is equal to area A+B+C.

If the demand functions for the two commodities can be represented by the following equations:

$$(4.15)\qquad Q_1 = \beta_{10}P_1^{\beta 11}P_2^{\beta 12}I^{\beta 13}$$

$$(4.16)\qquad Q_2 = \beta_{20}P_1^{\beta 21}P_2^{\beta 22}I^{\beta 23}$$

The consumer's surplus, using the procedure described above, can be estimated mathematically as follows:

$$(4.17)\qquad CS = \int_{P10}^{P11} [(\beta_{10}P_{20}^{\beta 12}I^{\beta 13})P_1^{\beta 11}]dP_1 + \int_{P20}^{P21} [(\beta_{20}P_{11}^{\beta 21}I^{\beta 23})P_2^{\beta 22}]dP_2$$

$$= (C_1)[(1/\beta_{11})+1]P_1^{[(1/\beta 11)+1]}\Big|_{P10}^{P11} + (C_2)[(1/\beta_{22})+1]P_2^{[(1/\beta 22)+1]}\Big|_{P20}^{P21}$$

where $C_1 = (\beta_{10}P_{20}^{\beta 12}I^{\beta 13})$.

and $C_2 = (\beta_{20}P_{11}^{\beta 21}I^{\beta 23})$.

The above measure will be used to estimate the consumer's surplus due to simultaneous changes in the prices of Indian mackerel (P_1) and scads (P_2). However, it should be noted that the measure is dependent on the path of price changes. If the path is reversed, i.e. by lowering P_2 first and then followed by lowering P_1, the consumer's surplus in this case is the area (A+D+B) in Figure 4.3. Unless the area C equals area D, the two measures of consumer's surplus will be different. This is known as the path-dependency problem in the literature (Johansson, 1991). This problem can be overcome by estimating either the CV or the EV of price changes under compensated demand curves. In practice, the compensated demand curves are unobservable, but they can be derived from expenditure functions. However, data on household expenditures are not available for estimating the expenditure functions. Thus it is not possible to estimate CV or EV in this study. Willig (1976) and Just et al. (1982) have shown that the measurement error between the consumer's surplus using an ordinary market demand curve and the CV or EV is likely to be small if income effects are small. Furthermore, in comparing the effects of alternative policies on consumer's surplus, the path-dependency problem may not be serious if a path is consistently being followed.

Maintaining high direct employment in the fishery sector is also considered as an important goal to be achieved in fishery management in Malaysia. Total direct employment at time t can be calculated as follows: First, the number of vessels of gear type j at time t is computed by dividing standardized fishing effort of gear j at time t by the average fishing power, and average fishing days of the gear type at time t. Direct employment for gear type j can then be calculated by multiplying the number of vessels of gear type j by average number of crew per vessel of the gear. Finally, summing direct employment of all gear types, total direct employment at time t is obtained as shown in equation (4.18):

$$(4.18) \quad TEMP_t = \Sigma_j\{crew_j(E_{jt}/(P_jFday_{jt}))\}$$

where E_{jt}, P_j and $Fday_{jt}$ denote standardised fishing effort at time t, average fishing power and fishing days at time t respectively for gear j.

4.5 Management Submodel

The small pelagic fisheries in Peninsular Malaysia are characterised by multispecies, multigear, numerous marketing channels and relatively short-lived species. As has been discussed in a previous chapter, the individual transferable quota scheme is unsuitable as a management tool for such fisheries (Copes, 1986a). A limited entry program appears more appropriate. However, a limited entry scheme alone that restricts the amount of fishing time or the number of vessels in the fishery, will not be fully effective as fishermen will respond to the regulation by changing their input configurations to produce more effort and thereby reduce the effectiveness of the program. In order to ensure the effectiveness of the regulatory measure undertaken, the dynamic behaviour of fishermen needs to be explicitly taken into consideration. While studies of fish population dynamics abound in the literature, considerably less attention has been paid in fishery models to addressing the long-term adjustment dynamics of fishing efforts by fishermen.

The original impetus in theoretical modelling to incorporating fishing effort dynamics into the "traditional" fishery systems is due to Smith (1968). In his model, Smith postulated that fishing effort (assumed to be determined by the number of vessels) changed over time in response to the availability of profits in the fishery. If profits in a fishery are positive, this would tend to attract more vessels to the fishery. On the other hand, if profit conditions are poor, then fishing effort may contract over time. If, however, there is neither positive profit nor loss in a fishery, fishing effort will tend to remain unchanged.

Recently, severel researchers have examined factors other than profit which determine the dynamics of fishing effort (Opaluch and Bockstael, 1984; Doeringer et al., 1986; Panayotou and Panayotou, 1986; Krauthamer et al., 1987; Charles, 1988, 1989). These factors include the social, economic and cultural backgrounds of fishermen, the characteristics of fishing vessels and gears and some threshold of potential returns in alternative employment for fishermen efforts or an industry "cutoff" rate of return to entrepreneurs (Wilen, 1976). Due to the lack of time-series data on these variables they will not be included in the model here.

In real world fisheries, effort will respond accordingly to the types of regulation being imposed. Thus there exists obvious interaction between regulation and amount of effort exerted by fishermen which will determine how an industry and regulatory structure will evolve. These interactions therefore, need to be explicitly accounted for in regulated fishery models (Wilen, 1985). The models of the dynamics of effort presented below provide a crude representation of the interactions between effort and regulations in an open access fishery under the various regulatory measures proposed in this study.

4.5.1 Open access fishery

The dynamics of effort for each gear type may be described by the equation as follows (Wilen, 1976)[6]:

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[6] *The derivation of the equation is presented in Appendix B.*

(4.19) $\dot{E}_{jt} = \Omega_j[((\Sigma_i(P_{it}H_{ijt})+RBC_{jt}-C_jE_{jt})/E_{jt})-\pi_j]$

where $\dot{E}_{jt}$ denotes time rate of change of effort for gear j at time t;

C_j is harvesting costs per unit effort for gear j;

π_j represents opportunity cost of a unit of effort for gear j; and

Ω_j is a "response parameter" indicating how fast effort of gear j responds to excess profits.

Equation (4.19) shows that whenever total net revenues per unit of effort for gear j, i.e. $[(\Sigma_i(P_{it}H_{ijt})+RBC_{jt}/E_{jt})-C_j]$, are greater than the opportunity cost π_j of effort for gear j, effort entry will occur. On the other hand, if total net revenues per unit of effort for gear j are less than the opportunity costs of effort for gear j, effort will exit the fishery. In an equilibrium fishery, $\dot{E}_{jt} = 0$ or there is no entry or exit of fishing effort of gear j. This will happen only if net revenues per unit of effort for gear j are equal to its opportunity costs. The "response parameter Ω_j and the opportunity cost of effort π_j can be estimated directly from equation (4.19) above. For the purpose of estimation, $\dot{E}_{jt}$ is replaced by $(E_{j,t+1} - E_{jt})$.

4.5.2 Regulated fishery

A variety of regulation measures has been reviewed in Chapter 3. In general, limited entry schemes are potentially more effective than quota regulations for the fishery in this study as discussed there. Regulating effort by limiting the number of vessel licenses only, however, provides incentives for remaining fishermen to increase their fishing effort either by increasing the catching capacity of their vessels through "capital stuffing" or by increasing their fishing times, thereby defeating the purpose of the regulation. In order to design more effective regulatory schemes, supplementary schemes must somehow be imposed on individual decision makers to remove the incentives for increasing effort and to cause them to supply effort to the efficient levels. Supplementary schemes normally proposed in the literature include license fees, a tax on effort, and a tax on fish. However, as reviewed in Chapter 3, taxes can be complicated and difficult to implement in practice, hence they will not be considered in this study. On the other hand, license fees have been frequently used as a supplementary regulation to a limited entry scheme. Excess effort in the fishery may be removed by issuing the desired number of limited entry licenses to vessels. The displaced vessels and fishermen should be appropriately compensated through a buy-back programme. Once this is accomplished, license fees can be used to appropriate all or some of the rents generated in the rationalized fishery. The appropriation of these rents should not cause any hardship to the remaining fishermen.

On the contrary, the license fees can be pooled into a fund for the buy-back programme which can be used to retire more vessels if "capital stuffing" is a serious problem or the license fees may be used to offset the costs of initial rationalization of the fishery. If licenses are non-transferable, the "capital stuffing" problem may be reduced by license attrition.

A limited entry, non-transferable license scheme supplemented by license fees will be evaluated in this study. The effects on fishing effort of this regulation can be represented in equation (4.20) as follows:

$$(4.20) \quad \dot{E}_{jt} = \Omega_j[((\Sigma_i(P_{it}H_{ijt})+RBC_{jt})/E_{jt}) - C_j - \pi_j - LF_j]$$

where LF_j denotes license fee per unit of effort for gear j. If the fishery is managed so that the desired level of effort is obtained and then license fees are levied to appropriate completely the rent generated in the fishery, E_{jt} will be zero. This allows the full license fee to be calculated from (4.20). However, the management authority may not charge full license fees for reasons to be discussed later. Under these scenarios, equation (4.20) will be used to calculate changes in effort.

It has been suggested in the literature that a possible solution to fishery problems in the developing world lie outside the fishery sector (Panayotou, 1980; Smith, 1981).

This is because incomes in the fishery sector for developing countries are low. Moreover, maintaining a high level of employment is a principal development goal of these countries. One way of reducing fishing effort is to create more employment outside the fishing sector. As more jobs are available and the demand for labour in other sectors increases, the opportunity costs of fishermen's effort would increased. Furthermore, fishermen can be retrained to acquire skills in more productive jobs. This will also increase the opportunity costs of fishermen's effort. Thus increased opportunity costs of fishermen's effort is a possible management alternative which will be evaluated in this study. The effects of increased opportunity costs on fishing effort can be represented by equation (4.21) as follows:

$$\dot{E}_{jt} = \Omega_j[((\Sigma_i(P_{it}H_{ijt})+RBC_{jt})/E_{jt}) - C_j - (1+\sigma)\pi_j] \tag{4.21}$$

where σ denotes a rate of increase in the opportunity cost of fishermen per unit of effort.

Finally, a management scheme that combined the two management alternatives discussed above will also be evaluated. The effects of this combined regulation is shown in equation (4.22).

$$\dot{E}_{jt} = \Omega_j[((\Sigma_i(P_{it}H_{ijt})+RBC_{jt})/E_{jt})-C_j-(1+\sigma)\pi_j-LF_j] \tag{4.22}$$

The underlying mathematical specifications of the model have been described in this chapter as a set of interrelated sub-models. In the next chapter, this model is applied to small pelagic fishery on the Northwestern Coast of Peninsular Malaysia. The formulation of the empirical model involves the evaluation of the parameters and some modification of the specifications of the general mathematical model.

Chapter 5

Parameters Estimation and Empirical Model Specification

The mathematical model presented in Chapter 4 is applied to the small pelagic fisheries on the Northwestern Coast of Peninsular Malaysia. Estimates of the model parameters are derived in this chapter. For most models in general, there exists a definite trade-off between the realism of model specification and model data requirements. Given the large number of parameters to be estimated, some estimates had to be based on limited empirical evidence. The empirical model presented in this chapter is based on three premises:

(1) The model reflects a regional approach to the joint management of Indian mackerel, scads, sardines, and tuna resources in the Northwestern region of Peninsular Malaysia, extending from the state of Perlis to the state of Selangor. Each resource is assumed to be a single, homogeneously distributed stock. It is also assumed that each resource exhibits no marked migratory pattern (Chong and Chua, 1974).

(2) The prices and catches of species not specifically modelled (by-catches) are considered as exogenous.

(3) The model essentially addresses the behaviour and regulation of the trawl, purse seine and drift net fleets. The fishing efforts of other gears are considered to be exogeneous and not significantly affecting the state of the resource or the yield of the above mentioned fleets.

The parameters estimated in this chapter pertain to the fishery's dynamics under the present situation. For the purpose of conducting sensitivity analysis and validation, this will constitutes the "base case".

5.1 Standardization of Fishing Effort

One of the vital variables in stock assessment by fisheries biologists or in determining the success of fishery management and policies by economists and social scientists is fishing mortality. Therefore accurate and precise measures of this parameter deserve particular attention.

Normally the absolute values of fishing mortality will not be known, but estimates can be made using statistics of fishing effort. Fishing mortality is assumed to be proportionate to the amount of fishing effort exerted by various fishing gears. The coefficient of proportionality is known as the catchability coefficient in the literature. Generally, the catchability coefficient is assumed to be constant over the period under study. However in real world fisheries, this assumption may often be violated since catchability will obviously change when the characteristics of the vessels, the gear used and the strategy of the fishermen change. For example, changes in the configurations or the size of vessels will change the fishing power of the gear and hence change the catchability coefficient. However, with appropriate choice and standardization of units of fishing effort to reflect the relative change in the fishing power of vessels and gears, the assumption of constant catchability coefficient may remain valid.

The relative fishing power for the vessels and gears used in the small pelagic fisheries in this study can be computed as in equation (5.1) (Robson, 1966; Gulland, 1983):

$$P_{cj} = \bar{U}_{cj}/\bar{U}_s \tag{5.1}$$

where P_{cj} = estimated fishing power of vessels using gear j in tonnage class c.

$\bar{U}_{cj}$ = average catch per unit of effort for vessels using gear j in tonnage class c.

$\bar{U}_s$ = average catch per unit of effort for vessels of a particular gear in a particular tonnage class which is used as a standard.

The weighted average fishing power among the various tonnage classes is used as the fishing power of a particular gear type (P_j). The ratio of the number of vessels in a particular tonnage class to the total number of vessels for the gear is used as the weight. Once the fishing power has been calculated, the standardized fishing effort exerted by gear j can be computed as:

$$(5.2) \qquad E_{jt} = (P_j T_{jt} V_{jt})$$

where E_{jt} = standardized fishing effort of gear j at time t.

T_{jt} = average fishing days of vessels j at time t.

V_{jt} = number of vessels j at time t.

The standardized effort for the various gears used for the period between 1968 and 1990 are presented in Table 5.1. The figures in Table 5.1 represent aggregate effort for all species in the study area and not merely effort directed to small pelagic species. Drift nets are used as the standard gear since they are the largest in number. Note that data on fishing days of the drift net fleet was not categorised by tonnage classes. The data were obtained or adapted from various issues of the Annual Fisheries Statistics.

Equation 5.2 indicates that fishing effort of gear type j at time t changes due to changes in the fishing power, the number of vessels at time t, or the average fishing days at

Table 5.1 Standardized Effort for Gears Used in Small Pelagic Fishery, in Northwest Peninsular Malaysia, 1968-1990

	Standardized effort (1000 days)				
Year	Drift net	Purse seine	Trawl	Others	Total
1968	728	8,734	10,770	1,782	22,013
1969	763	8,088	10,629	2,132	21,612
1970	783	7,466	10,479	2,403	21,130
1971	775	6,797	10,361	2,695	20,628
1972	754	6,124	10,243	5,336	22,458
1973	722	6,407	10,121	6,491	23,747
1974	634	5,662	9,997	3,852	20,145
1975	805	5,088	9,904	3,806	19,603
1976	734	4,403	9,807	2,623	17,567
1977	682	3,742	9,825	1,779	16,028
1978	731	3,242	9,903	2,300	16,175
1979	794	2,969	10,045	2,641	16,449
1980	836	2,514	10,078	3,872	17,300
1981	877	2,390	9,971	2,953	16,192
1982	980	2,451	9,891	4,796	18,118
1983	1,125	3,057	9,838	4,344	18,364
1984	1,238	3,050	8,852	3,696	16,836
1985	1,244	2,880	8,795	2,140	17,059
1986	1,332	2,964	8,761	1,839	14,896
1987	1,440	2,970	8,706	2,019	15,135
1988	1,576	2,923	8,795	2,861	16,155
1989	1,349	1,812	10,126	2,964	16,251
1990	1,388	2,142	10,214	3,134	16,878

time t for the gear. In the model in this study, changes in fishing effort are due to changes in the number of vessels.

5.2 Parameters of Surplus Production Models

The Schaefer surplus production model is represented by equation (4.5) in Chapter 4. The equation shows that total catch of species i at time t is a parabolic function of units of standardized fishing effort at t. The estimation of this function requires a nonlinear technique. However, this problem can be overcome by first computing the catch per unit of effort for species i at time t ($CPUE_{it}$) as:

$$(5.3) \qquad CPUE_{it} = H_{it}/E_t$$

where E_t denotes the units of standardized fishing effort. Equation (4.5) can then be transformed into a linear function relating $CPUE_{it}$ and E_t as in equation (5.4). After incorporating the error term, equation (5.4) can thus be estimated using ordinary least squares technique.

$$(5.4)\ CPUE_{it} = q_iK_i - q_i^2K_iE_t/r_i + \epsilon_i; \quad \text{if } E_t \leq r_i/q_i.$$

Although the Schaefer surplus production function has been widely used in fishery modelling because of its simplicity, other variants of surplus production models have also been developed. One alternative suggested by Fox (1970) (based on the Gompertz growth form) is to consider an exponential specification of equation (5.4) as:

(5.5) $\mathrm{Ln}(\mathrm{CPUE}_{it}) = a_i - b_i E_t + \epsilon_i$

Thus, the Fox model shows a linear relationship between the logarithm of CPUE_{it} and E_t.

Pella and Tomlinson (1969) have developed a generalised surplus production model which specifies the equilibrium catch per unit effort function as:

(5.6) $\mathrm{CPUE}_{it} = (K_i q_i^{m-1} - K_i q_i^{m} E_t / r_i)^{1/m-1}$

The generalised model allows the exploration of a family of production curves by varying m, and choosing the value that gives the best statistical fit. In the Schaefer model, m=2, and for the Fox model, $m \rightarrow 1$. The model is apparently superior with its variable functional form. Its drawback, however, is that an extensive computer searching is required for estimation of the parameters. Moreover, many studies that have used the model have found that the optimal functional form closely approximates the fixed form Gompertz and logistic models (Schaefer, 1970; Hongskul, 1975). Fox (1975) concluded that in cases of short time series, it is better to estimate the fixed form models and choose that which provides the superior fit.

An extension of the Schaefer model had been made by Schnute (1977). In his model, changes in CPUE are not only a function of present and past effort, but depend on ai moving average of CPUE. Past fishing effort is included in the model to account for the effect of past history of the fishery on the catch. The Schnute model which can be estimated using ordinary least squares, is specified as follows:

$$(5.7) \qquad \mathrm{Ln}(\overline{CPUE}_{it}/\overline{CPUE}_{i,t-i}) = r_i + q_i[(\bar{E}_{t-1}+\bar{E}_t)]/2 + (r_i/q_iK_i)[(\overline{CPUE}_{i,t-1}+\overline{CPUE}_{it})/2] + \epsilon_i$$

Where $\overline{CPUE}_{it} = (CPUE_{it}CPUE_{i,t-1})^{1/2}$

The main advantages of the Schnute model are its greater theoretical plausibility and its direct estimation of r_i and q_i. All other models require q_i to be independently estimated -- an exceedingly difficult task. Unfortunately, the Schnute model requires the estimation of three coefficients with n-1 observations (n being the number of observations) thus reducing the accuracy and efficiency of the estimates for short data series.

Schnute, Schaefer and Fox models were used to estimate the equilibrium yield function in this study. The F-statistics and R^2, together with the signs and significance of the coefficients, were used to judge the 'best fit' model for each small pelagic species. The formulae for estimating the values of MSY, associated effort and CPUE levels, and coefficients of the equilibrium yield function for each model, are given in Appendix C1. The formula used to obtain independent estimates of the average catchability coefficients needed for the Schaefer and Fox models is also given in Appendix C2.

The results of the 'best fit' surplus production models for the species are summarised in Table 5.2 while the results of all the estimated equations are presented in the Appendix Tables 1 through 12. For Indian mackerel, the Schnute model appears to fit well and the regression is significant at the 5% level with an R^2 of 0.58. All the estimated coefficients are significant at the 1% or 5% levels and conform to their expected signs.

The Fox model provides a good fit for the scad and sardine species while the tuna species appears to be fitted well with the Schaefer model. The coefficients of determination R^2 are 0.49 and 0.50 respectively for the scad and sardine species and both regressions are significant at the 1% level. However, the Durbin-Watson statistic of 0.95 for scad indicates that serial correlation is present. This problem might be overcome by incorporating lagged effort into the regression. However, due to the short data series and the desire to preserve as many degrees of freedom as possible, lags were not used. The estimated coefficients for both regressions are significant at the 1% and 5% levels and their signs are as expected. As for tuna, the regression is

Table 5.2 Results of Regression for 'Best Fit' Surplus Production Model for each Small Pelagic Species

Species	Model[1]	R-Sq.	F[2]	D-W	a	b(10-5)	c
Indian mackerel	3	0.58	10.90	2.14	2.31*** (4.59)	-9.80*** (-4.66)	-0.13** (-2.16)
Scads	2	0.49	20.14	0.95	2.53*** (4.14)	-14.64*** (-4.49)	- -
Sardines	2	0.50	20.91	1.10	1.74** (2.46)	-17.22*** (-4.57)	- -
Tuna	1	0.50	20.57	1.18	0.66*** (5.97)	-2.70*** (-4.54)	- -

[1] 1 = Schaefer model.
2 = Fox model.
3 = Schnute model.

[2] For Schaefer and Fox models, the degrees of freedom are (1,21).
For Schnute model, the degrees of freedom are (2,18).

*** = significant at the 1% level.
** = significant at the 5% level.

significant at 1% level with an R^2 of 0.50. The Durbin-Watson statistic again shows the presence of serial correlation. All the estimated coefficients are significant at the 1% level and conform to *a priori* expectations.

From the regression equations, estimates of the catchability coefficient, intrinsic growth rate, carrying capacity, maximum sustainable yield and the associated standardized effort for each small pelagic species were calculated. These estimates are shown in Table 5.3. The catchability coefficient for Indian mackerel is the highest among all the important small pelagic species in the study area while those for scads are the lowest. Tuna has the lowest carrying capacity of 83,714 mt compared to 3,214,726 mt for scads which is the highest. Comparison of the catch per unit of effort at MSY with the average catch per unit of effort for the period between 1980 and 1990 revealed that all the small pelagic species in the study area have been biologically overfished.

As discussed in Chapter 4, the harvest of species i by gear j can be estimated by multiplying the total harvest of species i at time t (H_{it}) by the weighting factor Θ_{ij}. These weights for the period between 1980 and 1990 are summarised in Table 5.4.

Table 5.3 Estimates of Catchability Coefficients, Intrinsic Growth, Carrying Capacity, Maximum Sustainable Yield and Associated Levels of Effort for each Small Pelagic Species

Species	q(10-5)	r	K	MSY (mt)	E_{msy} (1000d)	$CPUE_{msy}$ (kg/d)	CPUE[1] (kg/d)
Indian mackerel	9.8011	2.308	187,040	107,900	11,777	9.16	2.21
Scads	0.3905	0.027	3,214,726	31,545	6,831	4.62	0.95
Sardines	0.7658	0.044	743,973	12,172	5,807	2.10	0.15
Tuna	0.7884	0.194	83,714	4,033	12,222	0.33	0.16

[1] Denotes average CPUE from historical data.

Table 5.4 Weighting Factors (Θ_{ij}) for each Small Pelagic Species and for each Gear Type

	Gear type			
Species	Trawl	Purse seine	Drift net	Total
Indian mackerel	0.271	0.591	0.138	1.00
Scads	0.185	0.794	0.021	1.00
Sardines	0.241	0.755	0.031	1.00
Tuna	0.003	0.874	0.185	1.00

5.3 Price Equations

In the price equations, the price of each species is regressed against quantity supplied, prices of other species, per capita income and seasonal dummy variables. Due to the relatively short annual time-series data (from 1983 to 1990), quarterly data were used instead. Moreover, the use of quarterly data allows the incorporation of seasonal dummy variables. For the simulation, the quarterly demand model will be converted to an annual model.

Data for estimating the price equation were obtained from various sources. The price data were obtained and adapted from reports prepared by the Malaysian Fisheries Development Authority (or LKIM) while data for quantity supplied were gathered from Annual Fisheries Statistics. Ideally, total quantity supplied should include the quantity imported for each species. However, since available data on fresh fish imports were not diasggregated by species, they could not be used. In addition, a significant portion of the landings in Peninsular Malaysia was exported, especially to Singapore and data on the exported quantities were similarly not disaggregated by species. It was assumed that the quantities of each species imported and exported were approximately balanced. Thus the data for total quantity supplied used in the price equation included the total quantity of each small pelagic species landed in Peninsular

Malaysia. Data on income and population for computing per capita income were obtained from various issues of Economic Reports. However, these data were given annually. They are converted to quarterly data using the technique and weights given by Conte (1989).

The regression results for each small pelagic species are given in Table 5.5[1]. The seemingly unrelated regression technique was used due to the possible presence of contemperaneous correlations between the error terms of the equations. In addition, some variables with nonsignificant parameters from an earlier regression were dropped to conserve degrees of freedom. Also, prices of tuna were dropped since these prices are determined primarily in the international market. For Indian mackerel, the regression result shows a high R^2 and significant coefficient estimates for quantity supplied and per capita income. These coefficients have the expected signs. The resultant own-

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[1] *The regression results reported in Table 5.5 pertain to nominal income and prices. Ideally, real prices and income should be used. Regressions using real prices and income were performed and the results were statistically inferior to those reported in Table 5.5. Moreover, quarterly consumer price indices were not available. Converting annual consumer price indices to quarterly ones using the technique and weights given by Conte (1989) and using these quarterly indices to compute real prices and incomes appears to give rise to the inferior results.*

Table 5.5 Ex-Vessel Price Equation Estimates for Small Pelagic Species

	Ln(price) of small pelagic species			
	I. mackerel	Scads	Sardines	Tuna
Ln of:				
Intercept	-6.337*** (-5.24)	2.169*** (3.35)	0.179 (0.14)	-3.513 (-1.80)
Price of I. mackerel	- -	0.481*** (5.82)	0.040 (0.23)	- -
Price of scads	0.511*** (3.54)	- -	0.801** (3.02)	- -
Price of sardines	0.124 (1.23)	0.308*** (3.19)	- -	- -
Quantity of I. mackerel	-0.123** (-2.52)	- -	- -	- -
Quantity of scads	- -	-0.082* (-1.84)	- -	- -
Quantity of sardines	- -	- -	0.050 (0.88)	- -
Quantity of tuna	- -	- -	- -	-0.149 (-0.24)
Per capita income	1.246*** (7.19)	- -	- -	1.259*** (6.05)
D1[1]	- -	- -	- -	0.166** (2.43)
D2[1]	-0.097** (-2.46)	0.053 (1.33)	- -	- -
R^2	0.88	0.69	0.34	0.61

[1] D1=1 for quarter 1.
D2=1 for quarter 2.

Figures in parentheses denote t-ratio.

*** = significant at the 1% level.
** = significant at the 5% level.
* = significant at the 10% level.

price elasticity is -8.13[2]. Scads and sardines are substitutes for Indian mackerel as indicated by the significant positive estimates for their prices. For scads, the regression is also significant with a relatively high R^2 of 0.69. The coefficients for quantity supplied of scads and prices of Indian mackerel and sardines are significant and have the expected signs. The results show that Indian mackerel and sardines are substitutes for scads. The own-price elasticity of demand for scads is -12.14.

For sardine and tuna, the regression results show that quantity supplied for neither species affects its own price. This may be attributed to the fact that both these species are traded in international markets[3] and hence their domestic prices are influenced more by external prices. Therefore, in subsequent analyses, prices for sardine and tuna are treated as exogenously determined. However, since the price of tuna is significantly affected by per capita

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[2] *Price flexibility can be defined as* $f=d\ln P/d\ln Q$ *while own-price elasticity is defined as* $E=d\ln Q/d\ln P$*. Therefore, own-price elasticity is equal to the inverse of price flexibility.*

[3] *In 1989, the quantities of tuna exported and imported were respectively 14,928 mt (or 110% of total tuna landings) and 13,928 mt (or 102% of total tuna landings) while the quantities of sardines exported and imported were respectively 1,421 mt (or 11% of total sardine landings) and 13,661 mt (or 105% of total sardine landings).*

income, the price of tuna in later analyses will be adjusted by the income trend.

Besides the estimates above, the ordinary and two-stage least squares techniques were also used to estimate the price equations. The two-stage least squares technique was used to account for the possible simultaneity relationships among the equations. The results, however, were inferior with fewer significant coefficients. Hence these estimates will not be used in this study and are not reported here. The results of the ordinary least squares on the other hand, did not differ greatly from those presented here. However, the results of the seemingly unrelated regression were used for the reason stated earlier.

The price model also requires an estimate of the foreseeable trend of per capita income. In fact, such a variable may be used to reflect trends in both income and taste. This trend ($\dot{I} = dI/dt$) is introduced essentially for the purpose of conducting sensitivity analysis. The per capita income trend was estimated by regressing per capita income on time.

5.4 By-Catch Revenues

As discussed in Chapter 4, fish species other than small pelagics caught by the major gears constitute by-catches. They are not modelled explicitly but are considered to be exogenous. The revenues from by-catches are considered to be proportional to total small pelagic catches in the study. The implicit assumption is that the species mix in the catch by each fleet remains approximately the same irrespective of the level of effort. The coefficient of proportionality between by-catch revenues and the small pelagic catch for each of the three major gear types for the period between 1980 and 1990 is as follows:

Trawl net: RBC_t = \$10.707

Purse seine: RBC_p = \$0.107

Gill/Drift net: RBC_g = \$3.495

The data for the computation of these revenues were obtained from the Annual Fisheries Statistics compiled by the Department of Fisheries of Malaysia.

5.5 Cost Structure

Data on fishing costs are not given in the Annual Fisheries Statistics. However, these data may be obtained from the results of surveys conducted by various researchers over the years (Jahara and Wells, 1982; Fredericks et al., 1985; Md. Ferdous, 1990). The cost of fishing for the simulation in this study is obtained from a survey by Md. Ferdous (1990). The reasons for using these data are: (1) the survey has been conducted recently in 1989 and covered the area of this study; and (2) the survey was conducted on the three major gear types, namely, trawl net, purse seine and drift net, in the study area. The various components of fishing costs have been discussed in Chapter 4. In Table 5.6, the annual fishing costs per vessel for each of the three major gear types are presented.

The annual trip costs per fishing day for each gear type in year t is computed by first multiplying the annual trip expenses per vessel by the number of vessels, then adjusting by the consumer price index in year t (1980=100) and dividing by the total standardized effort in year t. The average annual trip costs per day fished for trawl, purse seine and drift net between 1980 and 1990 are respectively $15.63, $8.65 and $31.29. The drift net fleet has the highest average annual trip costs per day fished because the fleet has much lower standardized fishing effort.

Crew remuneration is based on the share system. The crew expense can be computed using equation (4.13) in Chapter 4. The annual fixed cost of fishing for each gear type in year t is computed by multiplying the fixed cost per vessel in Table 5.6 by the number of vessels in year t. The opportunity costs of vessels and fishermen's labour will be computed directly from the effort dynamic equations to be discussed in the next section.

Table 5.6 Average Annual Costs of Fishing per Vessel for Trawl, Purse Seine and Drift Net, in Northwest Peninsular Malaysia, 1989

	Average annual cost ($) for		
Item	Trawl	Purse seine	Drift net
Diesel/Petrol	22,433	37,407	1,862
Lubricant	1,131	1,789	271
Ice	5,208	13,873	781
Containers	2,838	2,303	534
Food	3,302	6,675	1,011
Miscellaneous	1,789	2,684	558
Maintenance	5,901	8,352	1,352
Total trip costs	42,602	73,083	6,370
Fixed costs	3,012	5,436	499

Source : Md. Ferdous, 1990.

5.6 Equations for the Dynamics of Effort

The equation for the dynamics of effort for each gear type to be estimated is described by (4.19) and the results are presented in Table 5.7. The data used in the estimation were obtained and adapted from the Annual Fisheries Statistics of Malaysia from 1968 to 1990. The seemingly unrelated regression was used in the estimation since this technique takes into account the contemperaneous correlation between the error terms of the equations. Except for the $\Omega_j \pi_j$ of the drift net fleet, the parameter estimates for all gear types are significant and are correctly signed. The R^2 ranged from 0.21 for trawl to 0.35 for purse seine and are reasonable since the social and cultural variables which are important determinants of effort dynamics are not included in the equations.

The estimated coefficients showed that for every dollar increase in profit per thousand standardized fishing days,the fishing effort of trawl, purse seine and drift net will increase by 0.0627, 0.0365, and 0.0043 thousand standard fishing days respectively. The opportunity cost per thousand standardized fishing days (π_j) for trawl, purse seine and drift net fleets are respectively $9,068, $10,824, and $7,480 (see Table 5.8). The relative magnitudes of the opportunity costs for various gear types are as expected, with purse seine having the highest opportunity cost.

Table 5.7 Results of Regression for the Equations for Dynamics of Effort

	Gear type		
	Trawl	Purse seine	Drift net
Ω	0.0627** (2.88)	0.0365*** (3.77)	0.0043*** (3.84)
$\Omega\pi$	-568.57* (-1.67)	-395.06*** (-4.95)	-32.162 (-1.39)
R^2	0.21	0.35	0.31

Figures in parentheses denote t-ratio.

*** = significant at the 1% level.
** = significant at the 5% level.
* = significant at the 10% level.

Table 5.8 Estimated Opportunity Cost of Effort per thousand Standardized Fishing Days for each Gear Type

Gear type	Opportunity cost ($)
Trawl	9,068.10
Purse seine	10,823.56
Drift net	7,479.53

As discussed in Chapter 2, various regulations have been used to manage fisheries resources in Malaysia. Zonal or area licensing and mesh size regulations are the most important regulations which have been used. Even though these regulations have been in place, they are not totally effective in preventing overexploitation of the resource, owing to noncompliance problems. Illegal fishing still exists. However, because of the existence of these regulations, the present situation in the fishery is far from resembling an open access fishery. There may be a small amount of resource rent generated in the fishery and this rent accrues to vessel owners and fishermen. The management authority charges only a token amount as a management cost or license fee, so that no rent is captured by the government.

In order to reflect the fact that there is a limitation on the number of licenses issued to fishing vessels, the number of vessels has to be constrained. However, fishing effort at time t can still be increased by raising the number of days each vessel fishes up to some maximum. Denoting the maximum number of days a vessel of type j can fished per year by $MDAY_j$, the maximum effort per year for each gear type j can be calculated as:

$$(5.8) \quad MFEFF_j = P_jV_jMDAY_j$$

The value of MDAY for a representative trawl, purse seine and drift net vessel is respectively 300 days, 280 days and 280 days per year. These values are slightly higher than those historically observed. In the simulation, effort levels are constrained by this equation so that the solutions are consistent with the current maximum effort levels of the fleet.

5.7 Model Simulation

The mathematical model specified in Chapter 4 and the empirical model presented in the sections above are used to simulate the small pelagic fisheries in Northwestern Peninsular Malaysia over time. The DYNAMO ("dynamic models") computer simulation language is used in the simulation. Through the DYNAMO program, real-world systems can be modelled, compiled and executed so that their dynamic behaviour over time may be traced, imitated or simulated by a computer (Pugh, 1983). A brief description of the DYNAMO program is presented in Appendix D.

In the following section, the initial conditions of the "base-case" simulation will be presented and discussed. This is followed by the descriptions of sensitivity analysis where the parameter values in the "base-case" model are altered. Finally, simulation models of various management regulations will be set-up and discussed. The results of these simulations will be discussed in the next chapter.

5.7.1 Initiation of the "base-case" model

As mentioned earlier, the "base-case" represents the existing situation of the small pelagic fisheries in the study area. Three types of input are required to execute the "base-case" model: (1) the parameters of the model (e.g. catchability coefficients, price flexibilities), (2) the initial values of the state variables (e.g. initial fleet size) and (3) the values of variables reflecting management regulations such as license fees.

The required parameters and constants of the model, as estimated and reported in previous sections are presented in Table 5.9. A total of 64 parameters and constants are required for the present application to the small pelagic fishery of Northwest Peninsular Malaysia.

The simulation model also requires that the initial values of the state variables be specified. These variables include standardized fishing effort, ex-vessel prices and per capita income. Note that standardized fishing effort also represents a management or control variable. The initial values of these variables are given in Table 5.10. The initial values for ex-vessel prices and per capita income correspond to those of 1990. The initial values for

Table 5.9 Description and Values of the Model's Parameters and Constants (Base Case)

Parameter	Simulator name	Definition	Base value
A_i	A(Kemb)	Intrinsic growth rate - Mackerel	2.3083
	A(Scad)	Constant in CPUE regression -Scads	2.5341
	A(Sar)	-Sardines	1.7366
	A(Tuna)	-Tuna	0.6644
B_i	B(Kemb)	Catchability coefficient -Mackerel	9.8011e-5
	B(Scad)	Coefficient of effort in CPUE regression -Scads	0.1464e-3
	B(Sar)	-Sardines	0.1722e-3
	B(Tuna)	-Tuna	0.2695e-4
C	Ccap(Kemb)	Carrying capacity -Mackerel	187,040
θ_{ij}	Kfactor	Weighting factor for Mackerel by -trawl	0.271
		-seine	0.591
		-drift	0.138
	Sfactor	Weighting factor for Scads by -trawl	0.185
		-seine	0.794
		-drift	0.021
	Safactor	Weighting factor for Sardines by -trawl	0.214
		-seine	0.755
		-drift	0.031
	Tfactor	Weighting factor for Tuna by -trawl	0.001
		-seine	0.814
		-drift	0.185
BCR_j	Bcr(trawl)	Proportion of by-catch revenue to small pelagic catch -trawl	10.707
	Bcr(seine)	-seine	0.107
	Bcr(drift)	-drift	3.495
$texp_j$	Texp(G)	Trip expenses ($/std. day) -trawl	15.63
		-seine	8.65
		-drift	31.29

Table 5.9 continued..

$fexp_j$	Fc(G)	Fixed cost ($/vessel)	-trawl	3,012
			-seine	5,436
			-drift	499
$Shcr_j$	Shcr(G)	Crew share	-trawl	0.5
			-seine	0.5
			-drift	0.67
π_j	Oc(g)	Opportunity cost ($/1000days)	-trawl	9,068.1
			-seine	10,823.6
			-drift	7,479.5
Ω_j	Eresp(G)	Effort response parameter	-trawl	0.0627
			-seine	0.0365
			-drift	0.0043
σ	Sigma	Rate of increase in opportunity costs of effort		0
V_j	Vessel(G)	Number of vessels	-trawl	2,886
			-seine	318
			-drift	7,521
P_j	Fpow(G)	Average relative fishing power	-trawl	12.66
			-seine	35.87
			-drift	1
$Mday_j$	Mday(G)	Maximum number of fishing days per year	-trawl	300
			-seine	280
			-drift	280
Ptmax	Maxpt	Maximum ex-vessel price for tuna ($/mt)		1,232
$\dot{I}$	Idot	Income trend		0.0001
$Crew_j$	Acrew(G)	Average crew member per vessel	-trawl	4
			-seine	17
			-drift	2
α_{0i}		Intercept of price equation	-Mackerel	-6.337
			-Scads	2.169

Table 5.9 continued..

α_{1i}		Coefficient for landings	
		-Mackerel	-0.123
		-Scads	-0.082
α_{2i}		Ex-vessel price of Scads in Mackerel equation	0.511
α_{3i}		Ex-vessel price of Sardines in Mackerel equation	0.124
α_{2i}		Ex-vessel price of Mackerel in Scads equation	0.487
α_{3i}		Ex-vessel price of Sardines in Scads equation	0.308
α_{5i}		Per capita income -Mackerel	1.246
		-Tuna	1.259
Lf_j	Lfe(G)	License fee -trawl	0
		-seine	0
		-drift	0

Source: A_i, b_i and C are from Table 5.2.

Θ_{ij} are from Table 5.4.

Bcr_j are from page 141.

$texp_j$ and $fexp_j$ are from page 142.

$Shcr_j$ are from Chapter 4.

π_j are from Table 5.8.

Ω_j are from Table 5.7.

V_j are from Annual Fisheries Statistics, 1980-90.

P_j are computed from equation 5.1.

$Crew_j$ are from Md. Ferdous (1990).

α_{0i}, α_{1i}, α_{2i}, α_{3i}, α_{5i} are from Table 5.5.

Table 5.10 Initial Values for Variables in 'Base Case' Simulation

Variable name	Simulator name	Defination		Initial value
E_{jt}	FEFF.K(G)	Standardized fishing effort		
		(1000 days)	-trawl	10,180
			-seine	2,650
			-drift	1,217
I_t	INCOME.K	Per capita income ($/person)		6,176
P_{it}	PK.K	Ex-vessel price of Indian mackerel ($/mt)		1,920
	PS.K	Ex-vessel price of scads ($/mt)		1,060
	PT.K	Ex-vessel price of tuna ($/mt)		1,170

fishing effort, however, represent the average values between 1980 and 1990 since the estimated equations for the dynamics of effort were based on the average changes for this period.

In addition, the model requires the specification of the management variables or parameters. These variables include the rate of increase in the opportunity cost of effort and the license fee. Their values for the base case are set to zero in order to reflect the current situation in the fishery.

For executing the simulation, the model is supplied with initial values for standardized fishing effort of the three types of fleet. These initial values are used to compute the catches, the net revenues, the prices, the social benefits, and the change in fishing effort in the first period. The values of the standardized fishing effort are revised in the next period based on the change in effort in the first period and all values of other variables in the model for the corresponding period are recalculated. Iterations will continue into the third period based on the values of the change in effort in the second period and the corresponding values of other variables are again recomputed. The process of iteration will continue until the last period of simulation as specified in the "SPEC" statement of the DYNAMO programme. The last period is chosen so that no significant changes in the results will occur after this period. The results of the simulation for every period can be saved on a result file to be viewed, plotted or manipulated for calculating averages.

5.7.2 Sensitivity analysis

Sensitivity analysis was conducted for the purpose of validating the model. The analysis was done for 10 cases and focusses on the parameters which were, *a priori*, judged to be most important in determining the behaviour of the model and for which estimates were unreliable. These cases were presented in Table 5.11.

The changes in parameter values as presented in Table 5.10 can be grouped into 3 categories: (1) those affecting technical aspects of the fishing fleets (cases 2, 6, 7, 8); (2) those affecting the values of catches and economic returns (cases 3, 4, 5,); and (3) combinations of (1) and (2). The effects of these changes and the results of the sensitivity analysis will be discussed further in the next chapter.

5.7.3 Management alternatives and performance

It has been argued in Chapter 3 that limited entry regulation has the greatest potential among other management tools to be successful in the context of fisheries

Table 5.11 Sensitivity Analysis: Description of Cases and Changes in Parameter Values

Cases	Description	Parameter changes	
1	Base case		None
2	Higher weighting factor for trawl and drift net fleets	Θ_{ij}	+10%
3	Higher by-catch revenue	Bcr_j	+5%
4	Higher trip expenses	$texp_j$	+5%
5	Income trend	$\dot{I}$	=0.5%
6	Faster effort response	Ω_j	+5%
7	Small number of vessels	V_j	-20%
8	Greater relative fishing power for trawl and seine	P_j	+5%
9	Combination of cases 2,7, and 8	-	-
10	Combination of cases 6,7, and 8	-	-

management in Malaysia. Limited entry regulation alone however, will surely induce expansion of fishing effort in the form of capital stuffing and/or longer fishing times thereby undermining the intent of the regulation. Therefore, limited entry regulation has to be accompanied by other fine-tuning regulations in order to be effective. However, as discussed in Chapter 2, current fine-tuning measures in Malaysia such as limitations on vessel size and fishing area, as stipulated in the zonal regulation were not effective in curtailing the expansion of fishing effort. Measures such as gear restrictions and a continuous buy-back program are difficult to model. Gear restrictions are also difficult to enforce. These measures, therefore, will not be discussed here. The fine-tuning regulations to be modelled, and have some chances of being successfully implemented in Malaysia include license fees and increased employment opportunities outside the marine fishery sector. These management alternatives have been described in Chapter 4. A detailed discussion on the operationalization of these alternatives will be presented in a later chapter.

In this study, the behaviour of the fishery is simulated and analyzed under the following management alternatives:

(1) Pure limited entry: Fishing effort is reduced in steps of 10%[4].

(2) Limited entry and a license fee:

(a) Fishing effort is reduced to the desired level as in (1) and the entire rents are appropriated by the management authority in the form of license fees;

(b) As in (a) but the rents appropriated by the management authority are reduced to 75% and 50% of (a)..

(3) Increased opportunity cost of effort:

Excess fishing effort is reduced by increasing the opportunity cost of fishing effort by 50%, 100% and 200%.

(4) Combination of (2a) and (3).

The evolution of the fishery under the various alternative management schemes (including the "base-case") are compared and evaluated by observing the behaviour of performance variables over time. These performance variables include: yield, level of fishing effort, ex-vessel prices,

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[4] *Variable rates of effort reduction for various fleets can be incorporated into the simulation model. However, a large number of combinations of these rates would have to be considered. Owing to time constraints, they will not be carried out in this study.*

social profits, consumer's surplus, direct employment, and individual fisherman's incomes.

Chapter 6

Simulation results

The results of the simulation model presented in Chapter 5 are reported and discussed in this chapter. In the first section, the dynamics of the small pelagic fishery on the Northwest Coast of Peninsular Malaysia under the 'base case' conditions will be discussed. Included in the discussions are the results of sensitivity analyses which were conducted for the purpose of validating the model. The evolution of the fishery and the resulting economic performance under various management schemes as described in Chapter 5 will also be presented.

Simulation was first conducted under an open-access situation, without imposing any restriction on the level of effort. The purpose is to explore the nature of the dynamics and the characteristics of the equilibrium. It was observed that the fishery tends to a long-run equilibrium after a period of approximately 70 years, with total fishing effort settled at a level of 20.51 million standard fishing days. Catches of all small pelagic species will be low at this long-run equilibrium level. The catches for Indian mackerel, scads, sardine and tuna at the long-run equilibrium are respectively 48,520 mt, 12,830 mt, 3,405 mt and 2,289 mt. Similarly, social profits will be low at this long-run equilibrium. In fact, social profits for trawl and purse seine fleets will be negative (-$0.6 million and -$0.006 million respectively) while that for drift net fleet will be positive at $2.55 million. Thus, total social profit will be low at $1.91 million.

6.1 Base Case Results

Base case conditions correspond to the values of the parameters and initial conditions derived in Chapter 5. In addition, the level of effort is constrained to a maximum limit to reflect the fact that the fishery is currently being regulated by limitation of vessel number. The value of the main variables at different time periods are summarized in Table 6.1. The results are reported for both the short-term transient period and long-term steady state conditions. The results indicate that the level of total fishing effort increased by 1% in the long run over the initial conditions. A breakdown in terms of gear type indicate that fishing effort of trawl, and drift net in the long run increase by 0.4% and 14% respectively while the effort for the purse seine fleet decreased by 0.9%.

As a consequence of the long run increase in fishing effort, the sustainable yield of the small pelagic species considered in the study has decreased. The sustainable yields of Indian mackerel, scads, sardine and tuna decrease

Table 6.1 Evolution of the Fishery under Base Case Conditions

Variable Name[1]	Definition	1st year	5th year	10th year	Average	
					1-15	86-100
FEFF(TR)	Fishing effort (1000 days)	10,180	10,960	10,960	10,911	10,960
FEFF(PS)	Fishing effort (1000 days)	2,650	2,941	2,901	2,897	2,872
FEFF(D)	Fishing effort (1000 days)	1,217	1,778	2,088	1,848	2,106
TOTFEFF	Total effort (1000 days)	17,380	19,010	19,280	19,077	19,270
HAR(M)	Harvest (mt)	83,520	67,220	64,110	66,395	64,247
HAR(S)	Harvest (mt)	17,210	14,820	14,450	14,730	14,465
HAR(SA)	Harvest (mt)	4,951	4,089	3,958	4,057	3,964
HAR(T)	Harvest (mt)	3,408	2,892	2,792	2,872	2,796
PR(M)	Ex-vessel price ($/mt)	1,579	1,542	1,548	1,550	1,571
PR(S)	Ex-vessel price ($/mt)	1,045	954	956	959	963
PR(T)	Ex-vessel price ($/mt)	1,170	1,173	1,176	1,174	1,221
CS	Consumer's surplus (million $)	14.55	18.96	18.35	17.88	17.54
SP(TR)	Social profits (million $)	173.00	92.94	80.65	89.78	81.39
SP(PS)	Social profits (million $)	16.68	0.20	-1.02	1.57	0.02
SP(D)	Social profits (million $)	54.65	31.88	24.65	29.55	24.61
TOTSP	Total social profits (million $)	244.30	125.00	104.30	119.88	106.03
TOTBEN	Total social benefits (million $)	258.90	144.00	122.60	145.55	123.56
EMPLOY(TR)	Employment (1000 man-years)	11.87	12.78	12.78	12.72	12.78
EMPLOY(PS)	Employment (1000 man-years)	5.71	6.32	6.25	6.21	6.19
EMPLOY(D)	Employment (1000 man-years)	12.95	18.04	22.22	19.66	22.40
EMPLOY	Employment (1000 man-years)	30.52	38.02	41.25	39.13	41.37
CINC(TR)	Crew income (1000$)	23.09	15.73	14.77	15.48	14.83
CINC(PS)	Crew income (1000$)	8.25	5.33	5.14	5.39	5.31
CINC(D)	Crew income (1000$)	10.59	5.25	4.02	4.94	4.00

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[1] Gear types are identified by the letters in parentheses: (TR) for trawl, (PS) for purse seine, (D) for drift nets while species are identified by these letters: (M) for Indian mackerel, (S) for scads, (SA) for sardines and (T) for tuna.

by 3.2%, 1.8%, 2.3% and 2.6% respectively. These results also support the fact that overexploitation of these species, both in a biological and an economic sense, will occur.

The ex-vessel prices of Indian mackerel, scads and tuna increased in the long run by 1.4%, 0.4% and 4.0% respectively. Increases in the ex-vessel price of the former two species are due to the impact of the decrease in landings and the slight increase in per capita income level of 0.1% per year while the ex-vessel price increase of tuna is solely due to the effect of per capita income increases.

The estimation of consumer's surplus due to changes in prices was discussed in Chapter 4. Only the consumer's surpluses of Indian mackerel and scads are considered in this study since these two species have downward sloping demand curves. The consumer's surplus decreased from $17.88 to $17.54 million (representing a 1.9% decrease for the simulation period). The decrease in consumer's surplus is the result of price increases of the two species considered.

The social profits of all the major gears decrease by 11.5% for the simulation period (from $120 to $106 million). In the context of this study, the positive aggregate social profits can be attributed to the fact that the fishery in the study area has been subjected to some degree of management. However, the distribution of these rents among the major gears are far from egalitarian. Purse seine gear whose catch depends largely on small pelagic fishes are earning the lowest profits in the earlier periods ($1.58 million or $0.55 per standard fishing day in the earlier periods and decreasing to $0.02 million or $0.01 per standard fishing day in the later periods). As shown in Table 6.1, trawl and drift net fishermen are getting higher positive social profits. However, the social profits for trawl gear decrease from $89.78 to $81.39 million (about $8.2 and $7.4 per standard fishing day respectively for earlier and later periods). For drift net fishermen social profits decrease on the average from $29.55 to $24.61 million. In terms of returns per standard fishing day, the social profit of drift net fishermen is the highest among all the gears (about $11.7). This may be attributed to the high by-catch revenue per standardized fishing day for the drift net, which may be the result of the Zonal regulation currently enforced in the Malaysian fishery. The regulation allocates Zone A to drift net fleets and other traditional gears. As discussed in Chapter 2, this Zone is rich in marine resources, in particular the prawn resources which fetch a high price. As a result of the high social profits generated by drift net and trawl fleets, pressure to expand the fishing effort of these fleets is mounting. In addition, the high social profits generated in fishing grounds in Zone A may lure the trawler fleets, especially those in the small tonnage class to encroach upon the fishing grounds of drift net fleets. This can give rise to gear conflict between trawler and drift net fleets as discussed in Chapter 2. The Zonal regulation is difficult to enforce given the limited enforcement capabilities of the management authority. Moreover, dividing the stock into arbitrary zones without considerations to the biological characteristics of the stock, is not consonant with biological management since the stock should be managed as a single biological unit. Therefore, alternative and much easier enforced regulatory mechanisms need to be devised and implemented. This will be discussed in more detail in the last chapter.

Total social benefit is equal to the sum of consumer's surplus and social profit. The average undiscounted social benefit at the later fifteen-year period is 15.1% lower than the average social benefit at the initial fifteen-year period.

The average annual incomes of individual crew members manning trawl, purse seine and drift net fleets are respectively $14,830, $5,310 and $4,000 at the end of the simulation period. This can be translated into $1,236, $443 and $333 per month. Income to crew members per month for the three types of gear in the first year are respectively

$1,924, $688 and $883. Thus income of crew members for all gear types decreased somewhat over the years due to increases in fishing effort.

6.2 Sensitivity Analysis

The changes in parameter values considered are presented in Table 5.11. In case 2, the effects of effort of various gear types targetting on the small pelagic species are examined. In this context the weighting factor for trawl and drift nets fleets have been increased by 10% since these gears are more likely to direct their effort increasingly towards the small pelagic species if fishing these species proves to be more profitable. A large proportion of the purse seine effort, on the other hand, has already been directed to the small pelagic species and therefore is not likely to increase much. These changes are normalized by dividing each weighting factor by the sum of the weights, resulting in higher weighting factors for trawl and drift net but lower for purse seine as compared to the base case. The effects of changes in the response parameter of fishing effort to profit is examined in case 6. A higher response parameter value will drive effort and catches toward the equilibrium levels at a faster rate. Cases 7 and 8 examine the effects of a smaller number of fishing vessels and a higher relative fishing power of trawl and purse seine fleets in the fishery. These parameters affect the maximum level of fishing effort. Cases 9 and 10 will examine the effects of combinations of the above changes in parameter values.

The effects of changes in several economic factors, namely, higher by-catch revenue, higher trip expenses, and positive income trend are examined in cases 3, 4 and 5. Increases in revenues from by-catches should cause fishing effort to approach the maximum level at a faster rate, in particular the effort of the trawl and drift net fleets since these fleets earn a large proportion of their revenues from by-catches. Increases in trip expenses, on the other hand will lower net revenues and thereby cause the fishing effort of the fleets to approach the maximum level at a slower rate. Increases in trip expenses also measure indirectly the effect of inflation on the fishery. Per capita income increases will affect the price levels of small pelagic species, except for scads and sardine. Consequently, this increases net revenues and hence increases fishing effort in the short run. In the long run, increases in per capita income will cause prices to increase due to increased demand, but catches will be reduced in the long run when fishing effort increases. Hence, the net effect on revenue of long-run per capita income increases is uncertain, depending on the relative impact of price increases and catch reductions.

The results of the sensitivity analyses are presented in Table 6.2. In general, the base case results are not very sensitive to changes in parameter values except for cases 7, 8 and their combinations. It should be noted that the number of vessels (case 7) and fishing power (case 8) form part of the fishing effort which is the control variable in this study. Due to the reduction in the number of vessels, the maximum level of effort for the trawl and purse seine fleets in this case is lower than the initial levels, hence the levels of effort for these fleets are maintained at their respective maximum throughout the simulation period. Similarly, the maximum effort level for the drift net fleet is also lower than the initial level. The overall level of total effort is constant or almost constant at the maximum level of effort throughout the simulation period and is at a lower level than that of the base case.

The catches of all small pelagic species considered in this study are the highest for case 7 because of the lowest maximum level of fishing effort exerted on the fishery, which reduces the extent of overexploitation. Consequently, prices of Indian mackerel and scads are at their lowest levels due to the negative effect of catches on price levels. Low prices in turn raise the surpluses for consumers of Indian mackerel and scads. Increased catches

Table 6.2 Results of Sensitivity Analysis, Base Case Conditions[1]

Variable	Case number[2]									
	1	2	3	4	5	6	7	8	9	10
FEFF(TR)	10,911	10,911	10,911	10,911	10,911	10,911	8,770	11,396	9,206	9,206
	10,960	10,960	10,960	10,960	10,960	10,960	8,770	11,510	9,206	9,206
FEFF(PS)	2,897	2,639	2,889	2,860	2,886	2,933	2,551	2,782	2,676	2,676
	2,872	2,797	2,889	2,843	2,962	2,941	2,551	2,709	2,678	2,678
FEFF(D)	1,848	1,872	1,865	1,846	1,848	1,860	1,634	1,823	1,634	1,634
	2,106	2,106	2,106	2,106	2,106	2,106	1,685	2,106	1,685	1,685
TOTFEFF	19,077	18,931	18,996	18,948	18,976	19,034	16,279	19,328	16,847	16,847
	19,270	19,191	19,284	19,240	19,358	19,340	16,330	19,650	16,900	16,900
HAR(M)	66,395	67,928	67,184	67,733	67,403	66,745	92,110	63,301	87,913	87,920
	64,247	65,112	64,048	64,582	63,191	63,432	91,760	59,668	87,510	87,510
HAR(S)	14,730	14,940	14,852	14,919	14,718	14,799	18,923	14,400	18,032	18,033
	14,465	14,569	14,440	14,504	14,342	14,370	18,840	13,950	17,950	17,950
HAR(SA)	4,057	4,132	4,101	4,124	4,110	4,082	5,600	3,944	5,259	5,260
	3,964	3,999	3,956	3,977	3,921	3,930	5,568	3,785	5,228	5,228
HAR(T)	2,872	2,914	2,890	2,908	2,897	2,814	3,673	2,766	3,544	3,545
	2,796	2,824	2,790	2,807	2,763	2,770	3,662	2,649	3,532	3,532
PR(M)	1,550	1,550	1,553	1,551	1,559	1,555	1,460	1,571	1,476	1,476
	1,571	1,566	1,571	1,569	1,674	1,574	1,462	1,593	1,476	1,476
PR(S)	959	964	966	964	967	966	909	973	929	929
	963	961	963	962	993	964	922	972	918	918
PR(T)	1,174	1,174	1,174	1,174	1,174	1,174	1,174	1,174	1,174	1,174
	1,221	1,221	1,221	1,221	1,232	1,221	1,221	1,221	1,221	1,221
CS	17.88	18.08	17.75	18.00	17.65	17.55	30.33	16.04	27.98	27.98
	17.54	17.95	17.75	17.70	13.30	17.14	32.91	15.37	30.19	30.19
SP(TR)	89.78	113.92	107.43	91.77	94.81	92.17	233.49	70.53	230.12	208.30
	81.39	101.26	93.57	78.43	78.14	78.19	231.90	54.28	228.28	206.50
SP(PS)	0.56	1.15	1.68	1.41	1.64	0.41	20.40	0.83	14.12	16.15
	0.22	2.12	2.20	2.17	5.31	-1.47	20.08	1.93	13.80	15.82
SP(D)	29.55	34.84	33.42	30.74	31.10	30.32	56.58	27.86	58.56	52.88
	24.61	28.89	27.10	24.17	23.99	23.90	55.55	20.63	56.48	51.81
TOTSP	119.88	149.92	142.52	123.91	127.55	122.90	310.47	99.22	301.80	277.33
	106.30	130.16	120.70	102.61	114.55	78.41	307.53	76.84	298.56	274.13
TOTBEN	137.76	168.00	160.27	141.91	145.20	140.45	340.80	115.26	329.78	305.31
	123.57	148.11	138.14	120.31	127.85	95.55	340.44	92.21	328.75	304.32
EMPLOY	39.13	38.71	38.78	38.52	38.60	38.82	33.09	37.75	33.10	33.09
	41.37	41.21	41.41	41.31	41.56	41.52	33.64	40.74	33.64	33.64
CINC(TR)	15.48	17.45	16.94	15.71	15.95	15.74	31.30	14.51	31.35	29.22
	14.83	16.38	15.78	14.60	14.57	14.58	31.14	13.09	31.17	29.05
CINC(PS)	5.39	5.51	5.59	5.55	5.58	5.39	8.99	5.73	8.10	8.47
	5.31	5.32	5.31	5.31	5.31	5.06	8.93	5.59	8.04	8.40
CINC(D)	4.94	5.63	5.51	5.26	4.46	5.19	8.47	5.00	8.59	8.04
	4.00	4.39	4.22	3.96	3.94	3.93	8.06	3.64	8.17	7.64

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[1] The values for each variable or case refer to average of the first and last 15 years respectively of a 100-year run.

[2] All variables are defined in Table 6.1 and cases in Table 5.11.

of small pelagic fishes also account for the high social profit of the purse seine fleet which depends largely on this fishery. On the other hand, social profits for trawl and drift net fleets are lower than those in the base case. The reason could be the reduction in the revenue from by-catches caused by reduced levels of fishing effort for these fleets. The incomes to crew members of purse seine and drift net fleets do not vary greatly since their effort levels changed only slightly as compared to the base case. However, the income of crew member for the trawl fleet is much higher than in the base case because the effort level, and hence the operating cost for the trawl fleet is very much lower. The total number of fishermen in direct employment is reduced since there is a lower level of fishing effort.

The effects of increases in the fishing power of the trawl and purse seine fleets on the fishery, as shown in case 8, are completely reversed. Increases in the fishing power of the fleets may occur due to technological improvements in the fishing gears, larger vessel size, or "capital stuffing". Increases in fishing power of the fleets will increase the maximum level of fishing effort, since fishing power forms part of the fishing effort. As a result, the maximum total fishing effort is higher in this case than in the base case. Increases in fishing effort will reduce catches for all the small pelagic species, raising the price levels, and reducing consumer's surplus (Table 6.2). Consequently, total social surplus will decrease. Incomes to individual crew members, in particular those working on the trawl fleets, are lower in the long run than in the base case.

The sensitivity analysis indicated that the base-case model is not very sensitive to small changes in parameter values. This shows that the base-case model is quite robust. Also, the sensitivity analysis as presented in case 7 provides some evidence that reducing the effort levels applied to the small pelagic fishery can increase the harvest of these species, increase consumer's surplus and improve incomes to the crew members. The issue that remains is whether and how this reduction in effort levels can be sustained. This then forms the subject of the discussions in the subsequent sections.

6.3 Pure Limited Entry Regulation

Limited entry regulation represents one of a number of alternative regulations that can provide improvements to those in the fishery and benefits to society. In addition, as has been discussed in previous chapters, limited entry licensing is one of the regulations that is more likely to be successful in the context of the multispecies, multigear fisheries of Malaysia. In this section, the results of reductions in effort levels will be presented and discussed. The discussions will first focus on the issue of how much effort needs to be removed based on biological, economic and social criteria. The evolution of the fishery for a chosen policy of entry limitation will then be presented and discussed.

As mentioned in Section 5.7.3, under a pure limited entry regime, we examine scenarios in which fishing effort is reduced in steps of 10% from the base case effort level. The biological consequences of the regime are presented in Table 6.3. The policy preferences that result in the catches of Indian mackerel, scads, sardine and tuna being closest to the MSY for these species are respectively 1D,1G,1G and 1D. For the small pelagic species as a whole, policy 1E provides the highest yield. With this policy, the scads and sardines are biologically overexploited while the Indian mackerel and tuna are underexploited.

The social and economic consequences of alternative effort reduction policies are shown in Table 6.4. The highest average total social benefit (which is the sum of social profits and consumer's surplus) over a simulation period of 50 years is obtained from policy 1F ($565 million). Note that these benefits are computed based on the assumption that revenue from by-catches is proportional

Table 6.3 Biological Impact of Effort Reduction through a Pure Limited Entry Policy

	Harvest (mt)				
Policy[1]	I. mackerel	Scads	Sardines	Tuna	Total
Base case	83,520	17,210	4,951	3,408	109,100
1A	94,240	19,430	5,796	3,737	123,200
1B	101,900	21,760	6,732	3,960	134,300
1C	106,400	24,160	7,748	4,076	142,400
1D	107,900	26,500	8,815	4,086	147,300
1E	106,400	28,670	9,886	3,990	148,900
1F	101,700	30,430	10,880	3,787	146,800
1G	93,990	31,510	11,690	3,478	140,700

[1] The alternative effort reduction policies are defined as follows: 1A=10%, 1B=20%, 1C=30%, 1D=40%, 1E=50%, 1F=60% and 1G=70% reduction in effort from the Base Case.

to the small pelagic catches as discussed in Chapter 5 and that consumer's surplus from by-catches are not included in the total social benefits.

The income for individual crew members of all gear types is the highest for Policy 1G. However, with this policy, the level of direct employment will be reduced to a low of 3,830, 2,060,and 6,670 man-years for trawl, purse seine and drift net fleet respectively. If the number of vessels remained the same as at the base case level, this policy would imply that the average number of days fishing per year for the three gear types would be respectively 90, 84 and 83. As shown in Table 6.4, there is an inverse relationship between the level of fishing effort and income for individual crew members. On the other hand, there is a direct relationship between the level of effort and direct employment. Thus, there is a trade-off between the level of crew income and direct employment. The proper choice of an appropriate policy based on these trade-offs is essentially the task of policy makers.

Based on the social benefits, the biological consequences, the crew income and the employment considerations, Policy 1F may be appropriate and represents an improvement over the base case.

Table 6.4 Social and Economic Impacts of Effort Reduction through a Pure Limited Entry Policy

Policy[1]	Average social benefit[2] (million $)	Average crew income of[2]		
		Trawl (1000$)	Purse seine (1000$)	Drift net (1000$)
Base case	131.32	15.21	5.39	4.41
1A	229.42	22.29	6.57	6.41
1B	339.25	31.32	8.94	8.36
1C	427.71	41.44	11.63	10.76
1D	495.30	53.14	14.77	13.47
1E	541.56	67.27	18.63	16.65
1F	564.55	85.49	23.72	20.66
1G	562.63	111.60	31.21	26.27

[1] The alternative effort reduction policies are defined as follows: 1A=10%, 1B=20%, 1C=30%, 1D=40%, 1E=50%, 1F=60% and 1G=70% reduction in effort from the Base Case level.

[2] Average over a simulation period of fifty years.

The evolution of the fishery and the bio-socioeconomic impact of Policy 1F over a period of 50 years are depicted in a series of graphs in Figures 6.1 to 6.5. In Figure 6.1, total effort was initially reduced to 8 million days and reached the maximum level of effort[1] of about 10 million days in year 2 and thereafter. In terms of the level of fishing effort for individual fleets, it can be seen from Figure 6.1 that all the fleets expanded their effort to the maximum level after year 2. The above observations are consistent with the theoretical argument that a limited entry scheme by itself would not be able to produce fully the desired impact on the fishery. This is because the fishery will be highly profitable after rationalization and thus will entice fishermen to expand their fishing effort to some extent through expanding their catching capacity and/or extending the fishing days in order to capture a larger portion of the resource rents. The additional fishing effort can be reduced by a further reduction in licenses. Alternatively, the management authority can alter the incentive for effort expansion by appropriating the resource rents through the imposition of license fees. The license fee regulation has the advantage of generating public revenue which can be used to reduce the cost of retiring

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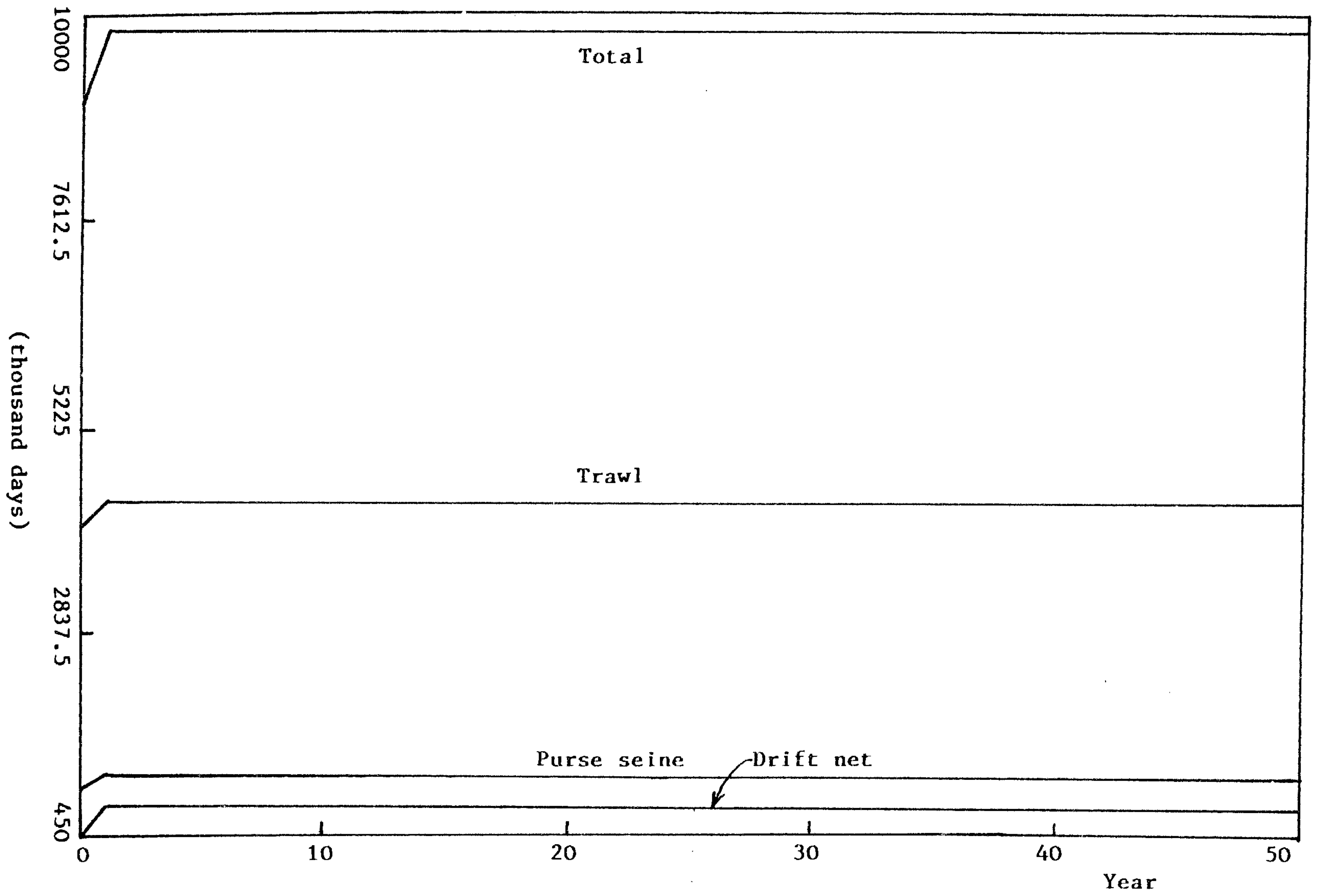
[1] *The maximum level of effort in this case is also reduced by 60% of the maximum level of effort of the base case.*

Figure 6.1 Evolution of Fishing Effort, Policy 1F



fishing effort. The effects on the fishery of imposing a license fee will be discussed further in the next section.

Due to total effort expansion, catches of scads and sardines declined, since they are overexploited, while catches of Indian mackerel and tuna increased because of the underexploited states of these species at Policy 1F (Figure 6.2). The increased catch for Indian mackerel has resulted in the general decline in the ex-vessel price level as shown in Figure 6.3. The price of scads decreased initially in spite of a decrease in landings which could be due to the strong substitution effect between Indian mackerel and scads. The increase in the price of tuna is solely due to the increase in per capita income overtime.

The social surpluses and income for fishing crew members are depicted in Figures 6.4 and 6.5 respectively. The consumer's surplus derived from consuming Indian mackerel and scads is increased due to decreases in the prices of these species overtime (Figure 6.4). The social profits for the trawl fleet increased initially but declined after year 4 to $375 million. The social profits for the purse seine and drift net fleets, however, declined, as their fishing effort increased. The overall total social benefits show a slight increasing trend initially, which indicates that the increases in consumer's surplus more than offset the decreases in social profits. The annual income

Figure 6.2 Evolution of Harvest Levels, Policy 1F

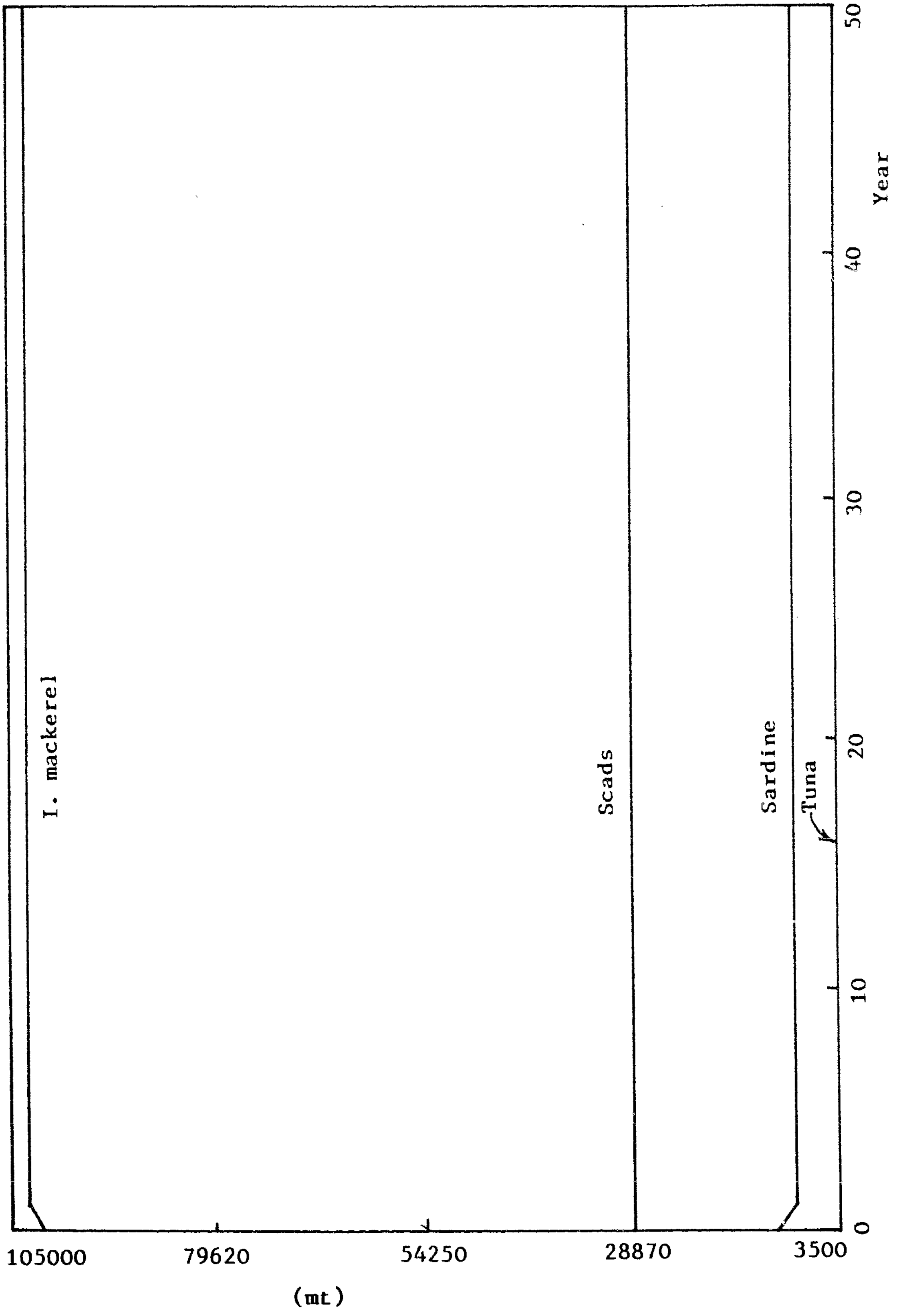


Figure 6.3 Evolution of Ex-Vessel Prices, Policy 1F

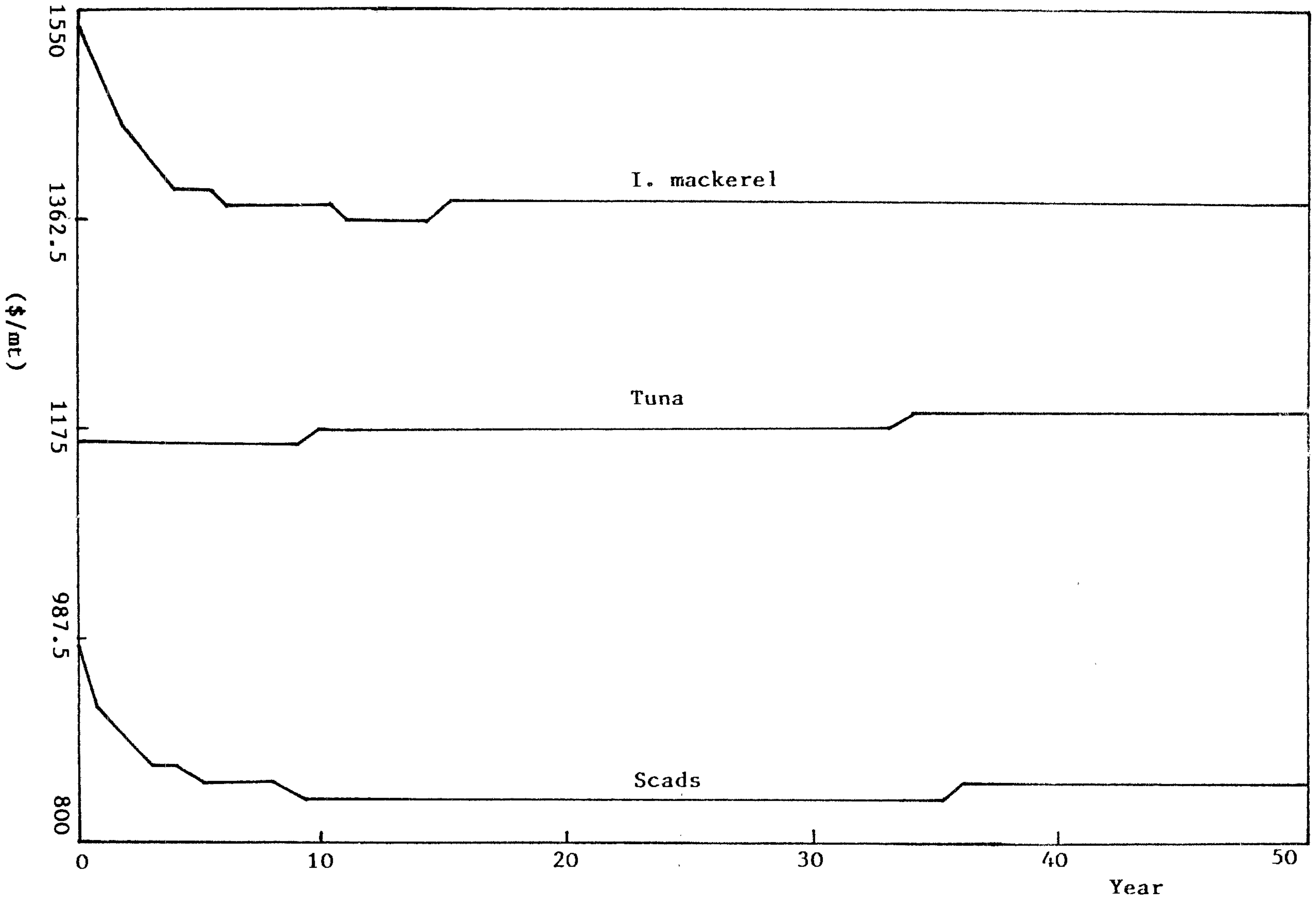


Figure 6.4 Evolution of Social Surpluses, Policy 1F

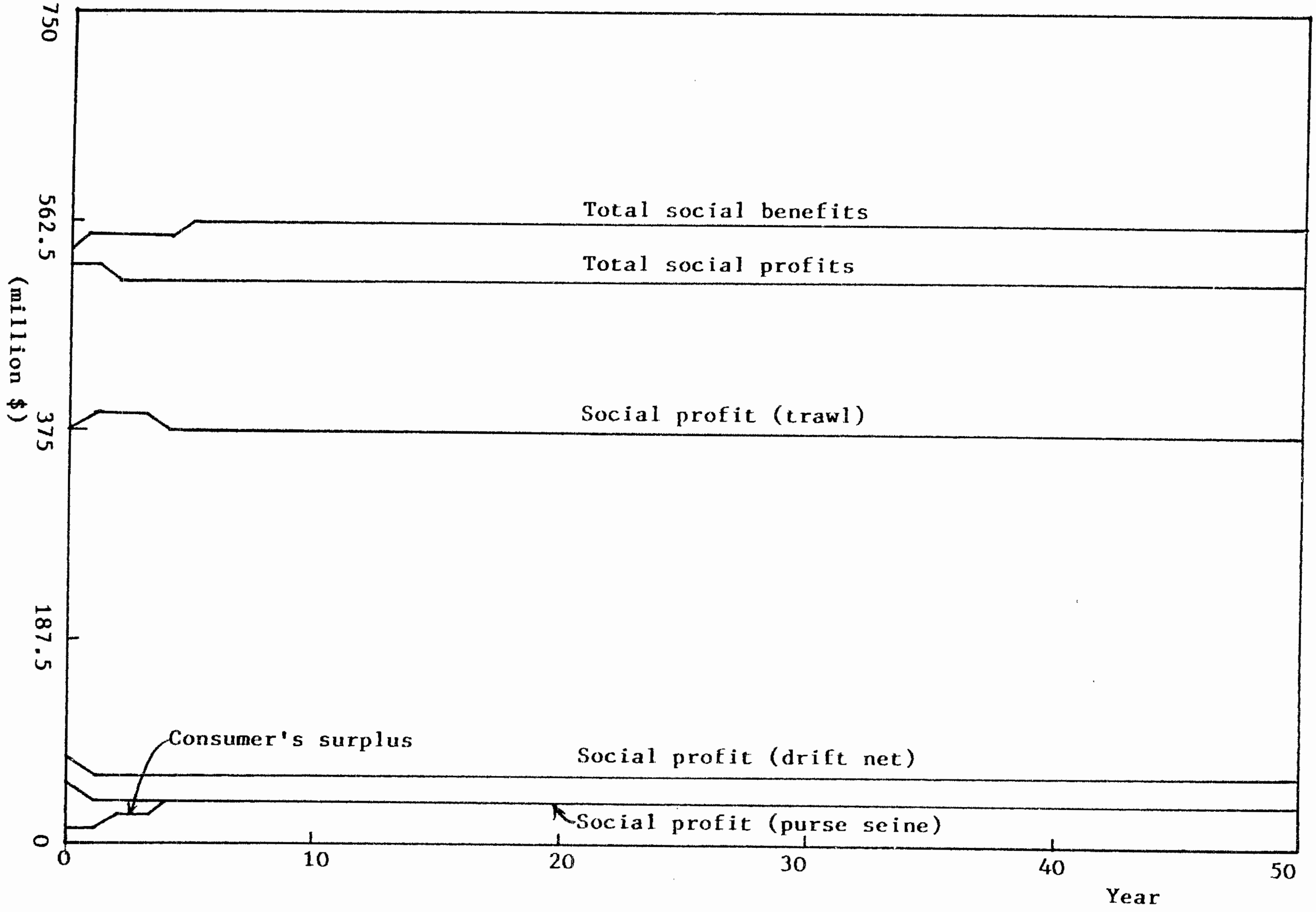
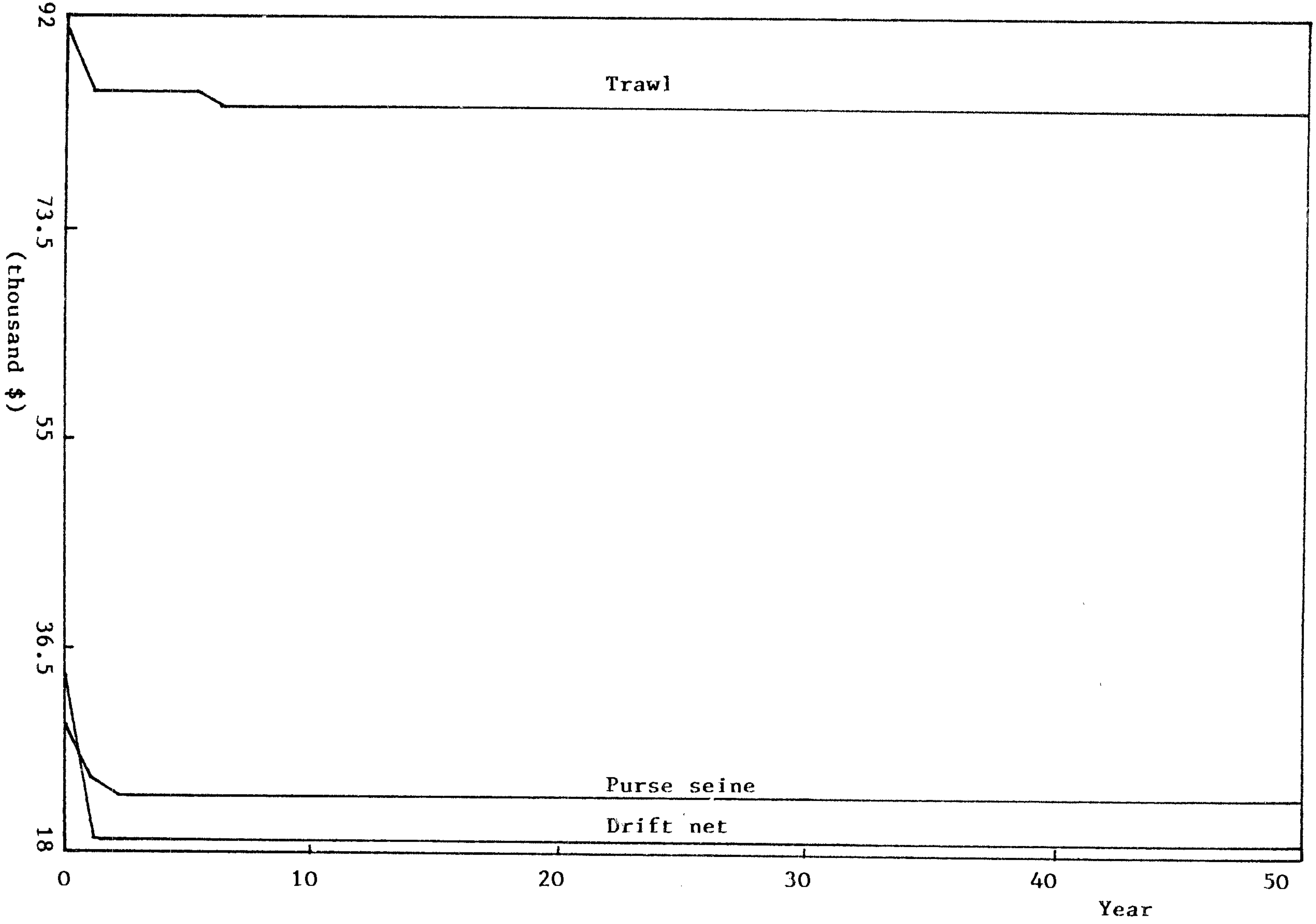


Figure 6.5 Evolution of Annual Crew Income, Policy 1F



for individual crew members generally declined after an initial high level (Figure 6.5). Income for individual crew members of drift net fleet suffers the most severe drop due to the effect of effort expansion which reduces the catches and revenue from small pelagic species. Furthermore, the greatest drop in the individual crew income of the drift net fleet can be attributed to decreases in income from by-catches since by-catch revenue is assumed proportional to the small pelagic catches.

The results in this section show that under a limited entry scheme, if fishing effort is reduced by 50% of the base-case level, maximum sustainable yield for the small pelagic fishery will be attained. Further reduction of fishing effort to a level equivalent to 40% of the base-case level, will allow the greatest social benefits to be obtained. However, a limited entry scheme by itself will not produce the desirable outcome in the long run as shown by the results. This is because fishermen will respond to the positive social profits generated in the rationalized fishery by increasing their effort, thereby partially eroding the social profits. In order to maintain fishing effort at the desired level, the incentives to expand fishing effort have to be removed. This will be discussed in detail in the next section.

6.4 Limited Entry and License Fee Regulation

The evolution of the fishery under Policy 1F as presented in the previous section has shown that the fishery will expand its effort to the maximum level for the case due to the existence of positive social profits. This expansion is consistent with theoretical predictions. However, if the additional social profits generated after rationalization of the fishery are completely removed (which is denoted Policy 2A), the fishery can be sustained at the level of Policy 1F, as shown in Figures 6.6 to 6.10. The licence fees collected from the three major gears are respectively \$388.2 million, \$57.9 milion and \$83.0 million. Per vessel, the license fees per annum are \$327,043, \$432,090 and \$32,046 for trawl, purse seine and drift net respectively. These fees can be used to partially offset the cost of management or the cost of a buy-back program[2]. Note that purse seine vessels pay the highest fee.

Complete removal of rents from the rationalized fishery may not get support from the remaining fishermen and vessel owners, since they generally expect to share some of these rents. In addition, the license fees per vessel for the purse seine and trawl fleets appear to be rather high. In

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[2] *For more detail description of a buy-back program, see for example, Pearse (1982) and Copes (1986b).*

this context, the fishery management authority may consider sharing of the rents with fishermen. The evolution of the fishery and the bio-socioeconomic impacts of Policy 2B (75% of rents are removed as license fees) and Policy 2C (50% of rents are removed) are shown in Figures 6.6 to 6.10.

The evolution of fishing effort, as shown in Figure 6.6, reveals that fishing effort increases to a higher level, the lower the rate of extraction of resource rents by the management authority. This observation is consistent with theoretical prediction that positive rents induce effort entry and expansion. As a consequence, the levels of harvest of the small pelagic species are lower for Policy 2C than Policy 2A, as shown in Figure 6.7. Since ex-vessel prices are inversely proportional to landings, the ex-vessel prices of Indian mackerel and scads are higher for Policy 2C than for Policy 2A (Figure 6.8). In Figure 6.9, the evolution of social benefits under Policy 2A and 2C are presented. The consumer's surplus is slightly lower for Policy 2C since prices are higher under this policy. Aggregate social profit is higher for Policy 2C. This may be expected since more rents are retained by the fishermen and vessel owners under Policy 2C. Total social benefits are the same since license fees are merely transfer payments. Incomes to individual crew members for all gear types are lower for Policy 2C as shown in Figure 6.10. The

Figure 6.6a Evolution of Purse Seine and Drift Net Effort, Policies 2A, 2B and 2C

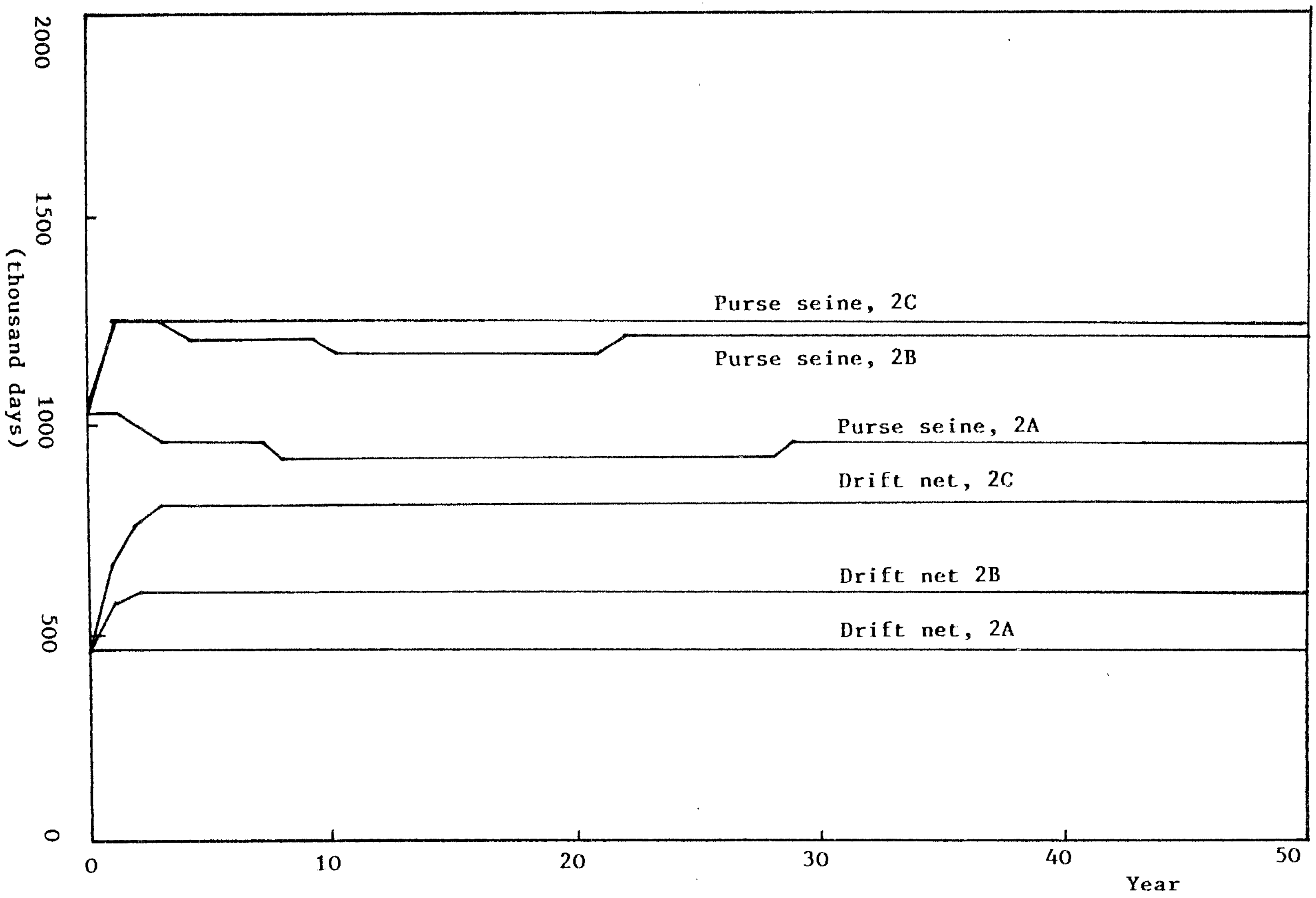


Figure 6.6b Evolution of Trawl and Total Effort, Policies 2A, 2B and 2C

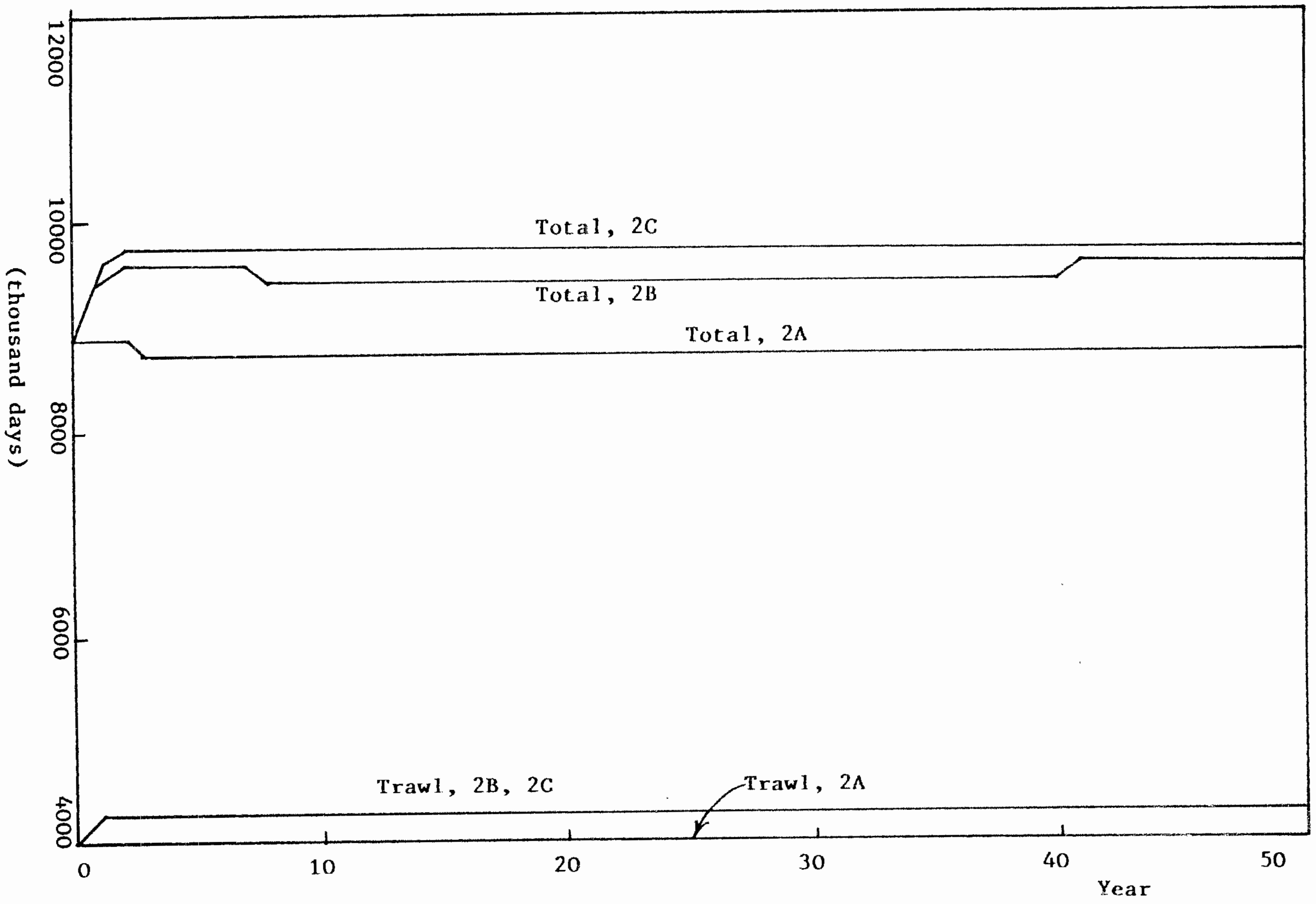


Figure 6.7a Evolution of Indian Mackerel and Scad Harvests, Policies 2A, 2B and 2C

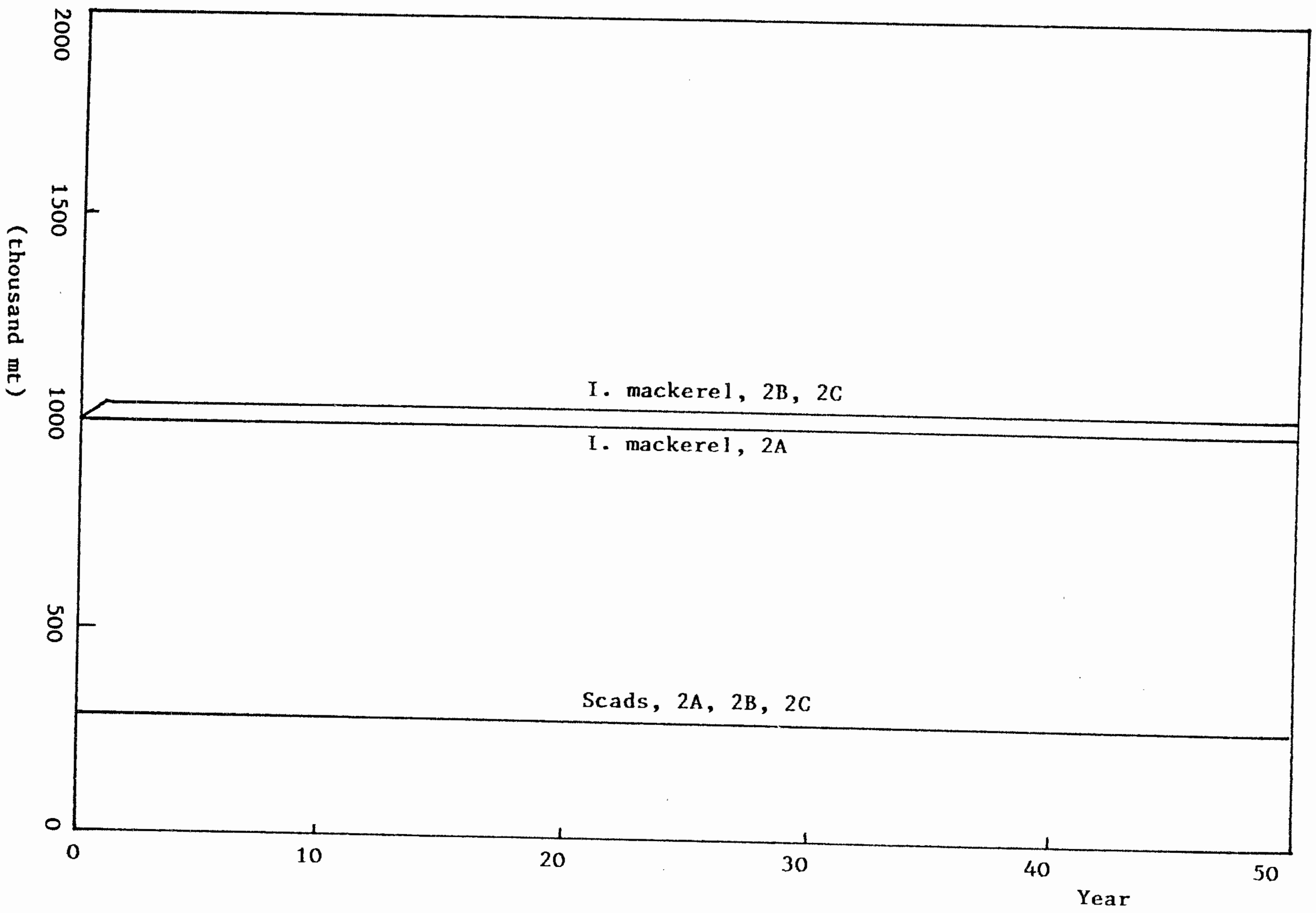


Figure 6.7b Evolution of Sardine and Tuna Harvests, Policies 2A, 2B and 2C

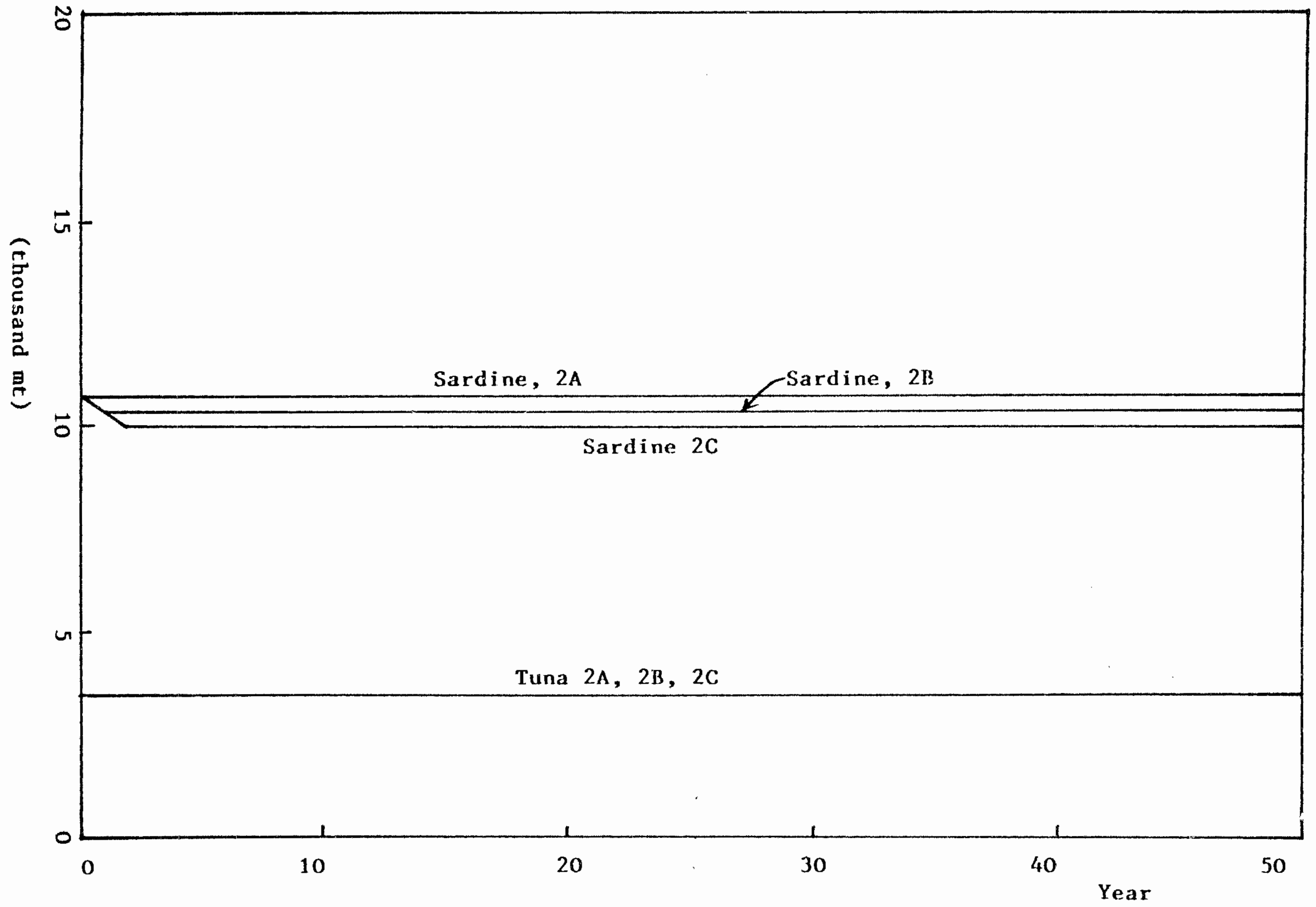


Figure 6.8 Evolution of Ex-Vessel Prices, Policies 2A, 2B and 2C

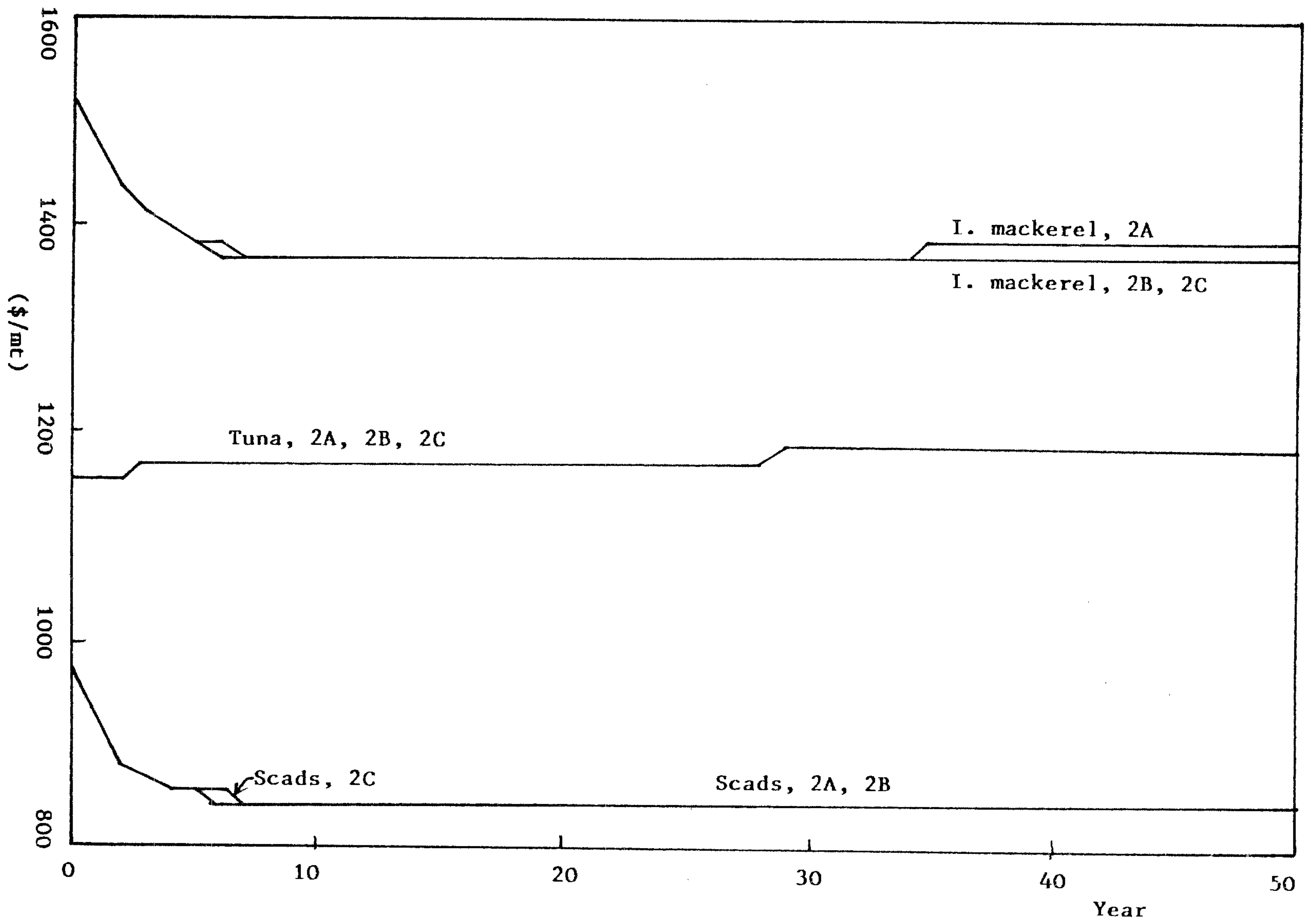


Figure 6.9a Evolution of Consumer's Surplus, Policies 2A, 2B and 2C

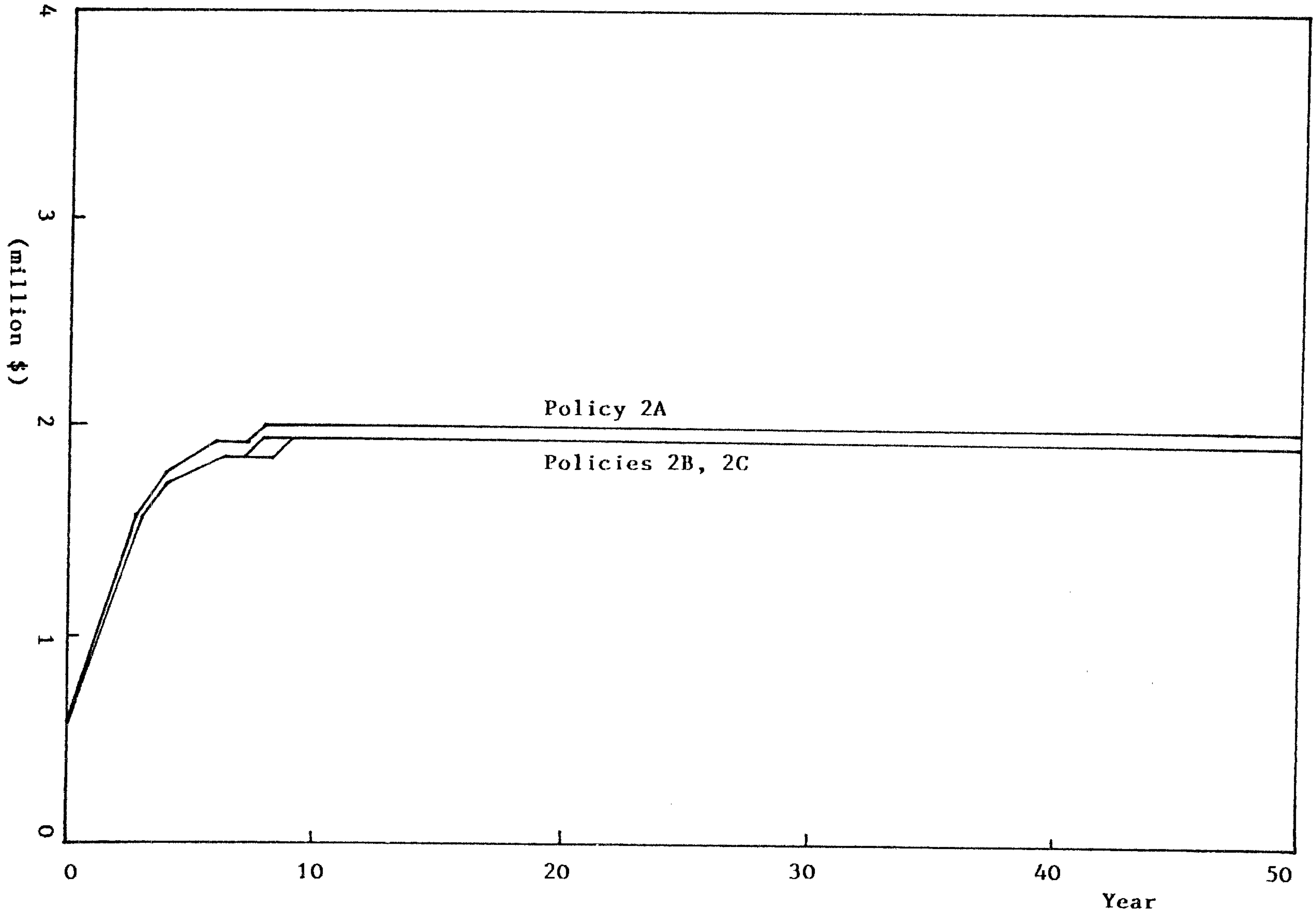


Figure 6.9b Evolution of Total Social Profits and Total Social Benefits, Policies 2A, 2B and 2C

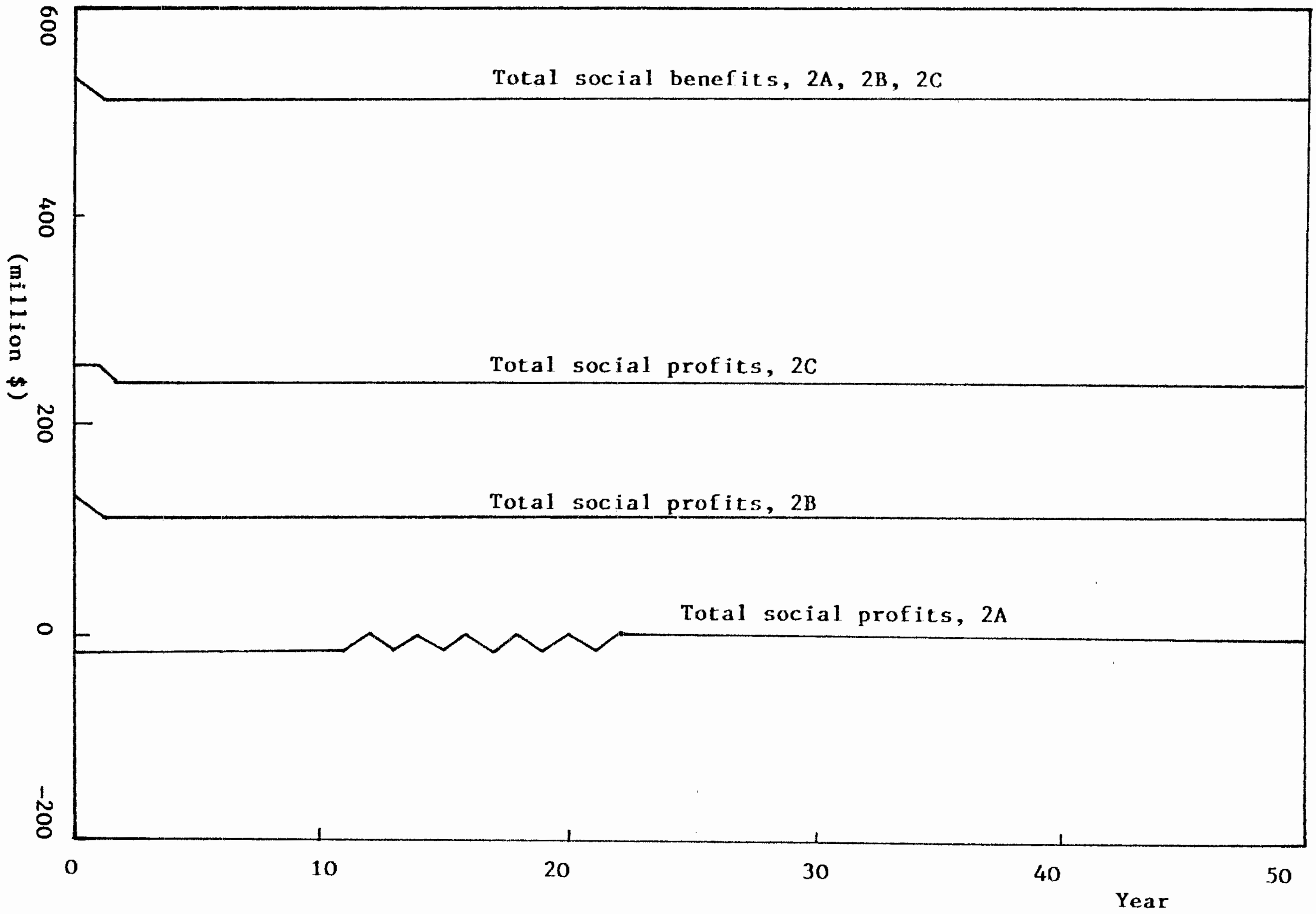


Figure 6.10a Evolution of Annual Crew Income for Trawl, Policies 2A, 2B and 2C

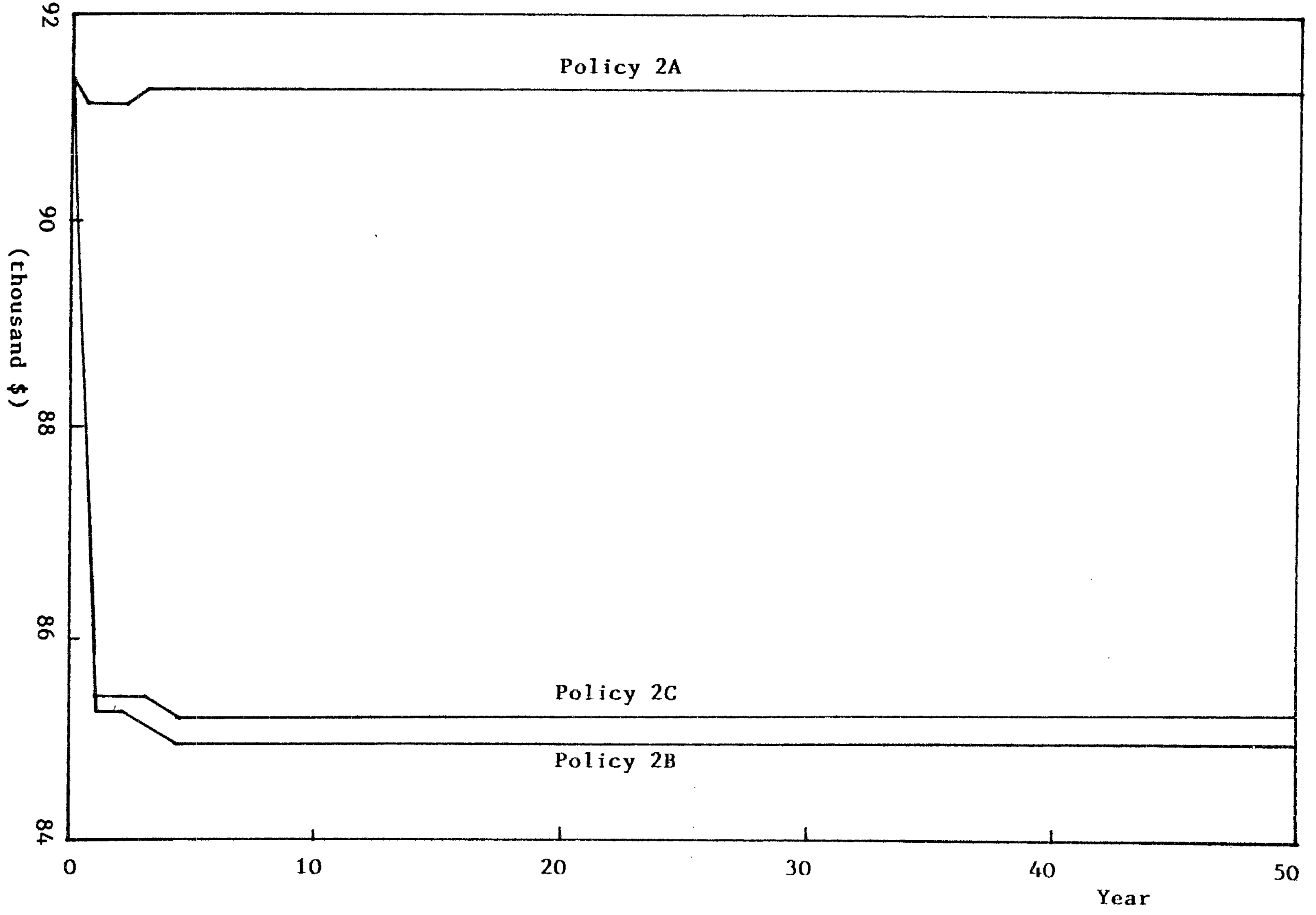
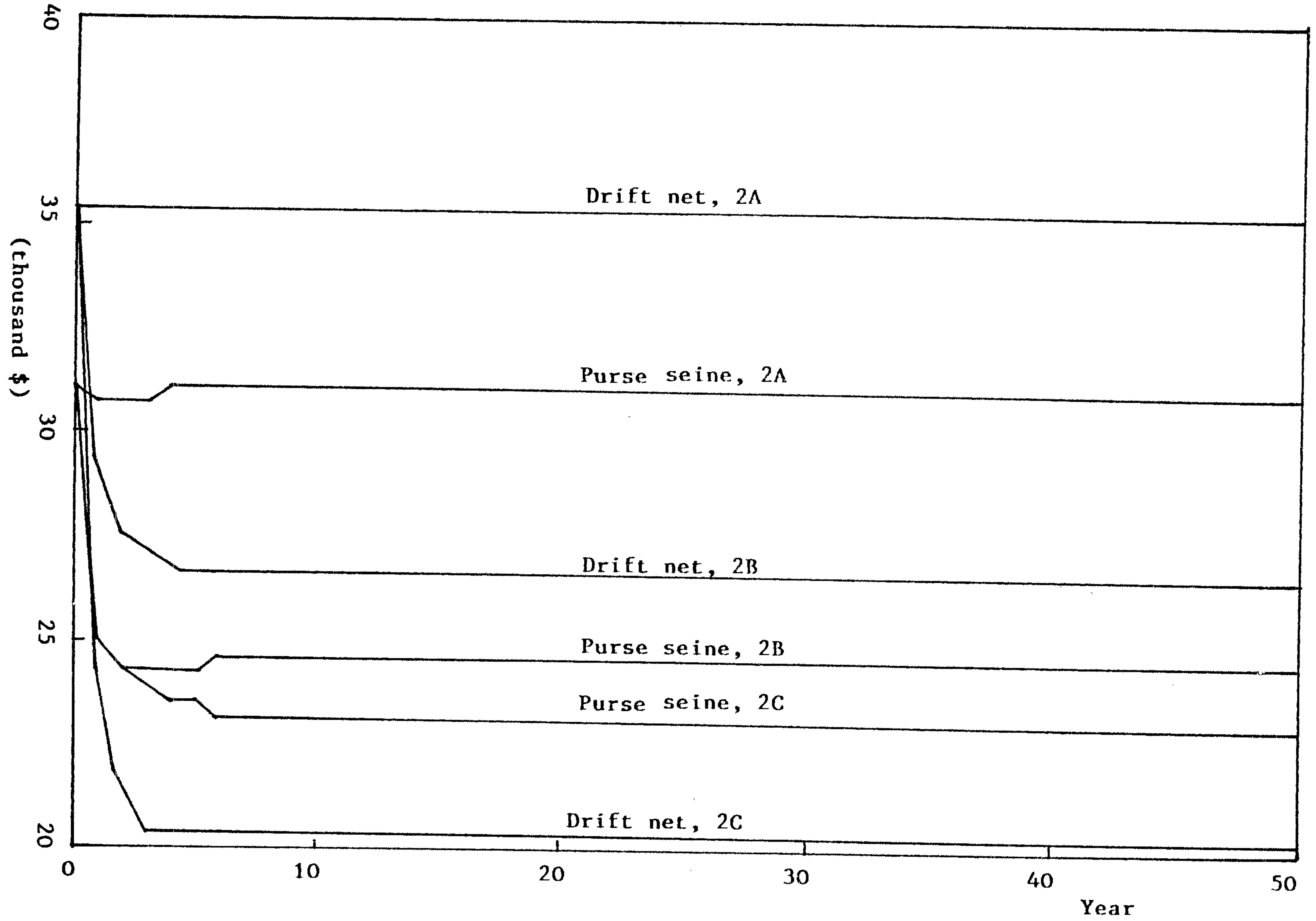


Figure 6.10b Evolution of Annual Crew Income for Purse Seine and Drift Net, Policies 2A, 2B and 2C



higher social profits and lower crew incomes for Policy 2C imply that this policy is beneficial to vessel owners but is detrimental to crew members and consumers. One possible way to correct the bias in benefits distribution of this policy is to rebate 50% of the license fees to vessel owners only if they compensate their crew members by increasing the crew share of the gross profits.

Low income for individual crew members under Policy 2C may be attributed to greater number of crews being employed as effort expands through increased number of vessels, with more rents being retained by fishermen. The average total employment of all gears over a 50 year period increases from Policy A to B to C (Table 6.5). This is mainly attributable to increased employment in the trawl and drift net fleets. Employment in the purse seine fleet, however, declines because of the decrease in catches of small pelagic fishes with increases in fishing effort, thereby reducing the profits of the purse seine fleet, which depends largely on small pelagic landings.

6.5 Increased Opportunity Cost of Effort

One fishery management alternative that has often been suggested in the fishery literature is to increase employment opportunities in other sectors of the economy so that excess fishing inputs, especially fishermen's labour

Table 6.5 Average Employment for Various Levels of License Fees

Policy[1]	Employment (man-years)			
	Trawl	Purse seine	Drift net	Total
2A	4,706	2,089	5,113	11,908
2B	5,105	2,620	6,769	14,494
2C	5,105	2,743	8,850	16,698

[1] The rate at which rents are charged as license fees are classified as follows: 2A=100%, 2B=75% and 2C=50%.

can be channelled into these sectors. The aim would be to increase productivity within and outside the fishery sector. This strategy, it is argued, is particularly beneficial in economies where employment is a major policy concern. Increased employment opportunities in other sectors at wages exceeding marginal wages in the fisheries sector implies that the opportunity costs of fishermen's labour (and thus of fishing effort) will increase. Increasing opportunity costs of effort will reduce social profits and this may induce voluntary exit of fishing effort which has the advantage over a limited entry scheme of not requiring enforcement. As mentioned in Chapter 4, the opportunity costs of fishing effort may be increased by creating job opportunities in other sectors of the economy with higher productivity. This process may be aided by retraining fishermen to acquire skills in sectors with higher productivity. In order to examine the impacts of increased opportunity cost on the fishery, this management alternative is modelled in this study by increasing the opportunity costs of effort by 50% (Policy 3A), 100% (Policy 3B) and 200% (Policy 3C). The evolution and bio-socioeconomic impacts of these policies are presented and compared in Figures 6.11 to 6.15.

Depending on the extent of increase in the opportunity cost of effort, fishing effort may increase or decrease. As shown in Figure 6.11, with Policy 3A and 3B, the increase in the opportunity cost is not high enough to off-set the profits and rents of the trawl and drift net fleets. As a result, the effort of these fleets will increase until it reaches the base case equilibrium level. However, with Policy 3C, the increase in the opportunity cost of effort has caused the level of effort of the trawl fleet to decrease. Overall, total fishing effort increases with Policies 3A and 3B but decreases slightly with Policy 3C.

From the biological perspective, increases in fishing effort will cause the sustainable harvest of small pelagic species to decline and *vice versa*. This is shown in Figure 6.12 where landings of all species of small pelagic fishes are the lowest for Policy 3A and these landings increase with Policies 3B and 3C. It is interesting to note that landings of Indian mackerel and tuna under Policy 3C increase initially, reaching a maximum and then decreasing with the further reduction of fishing effort.

The social and economic impacts of increased opportunity costs of effort are shown in Figures 6.14 and 6.15. The consumer's surplus is the highest for Policy 3C, while total social profit is higher for Policy 3A. Overall,

Figure 6.11a Evolution of Purse Seine and Drift Net Effort, Policies 3A, 3B and 3C

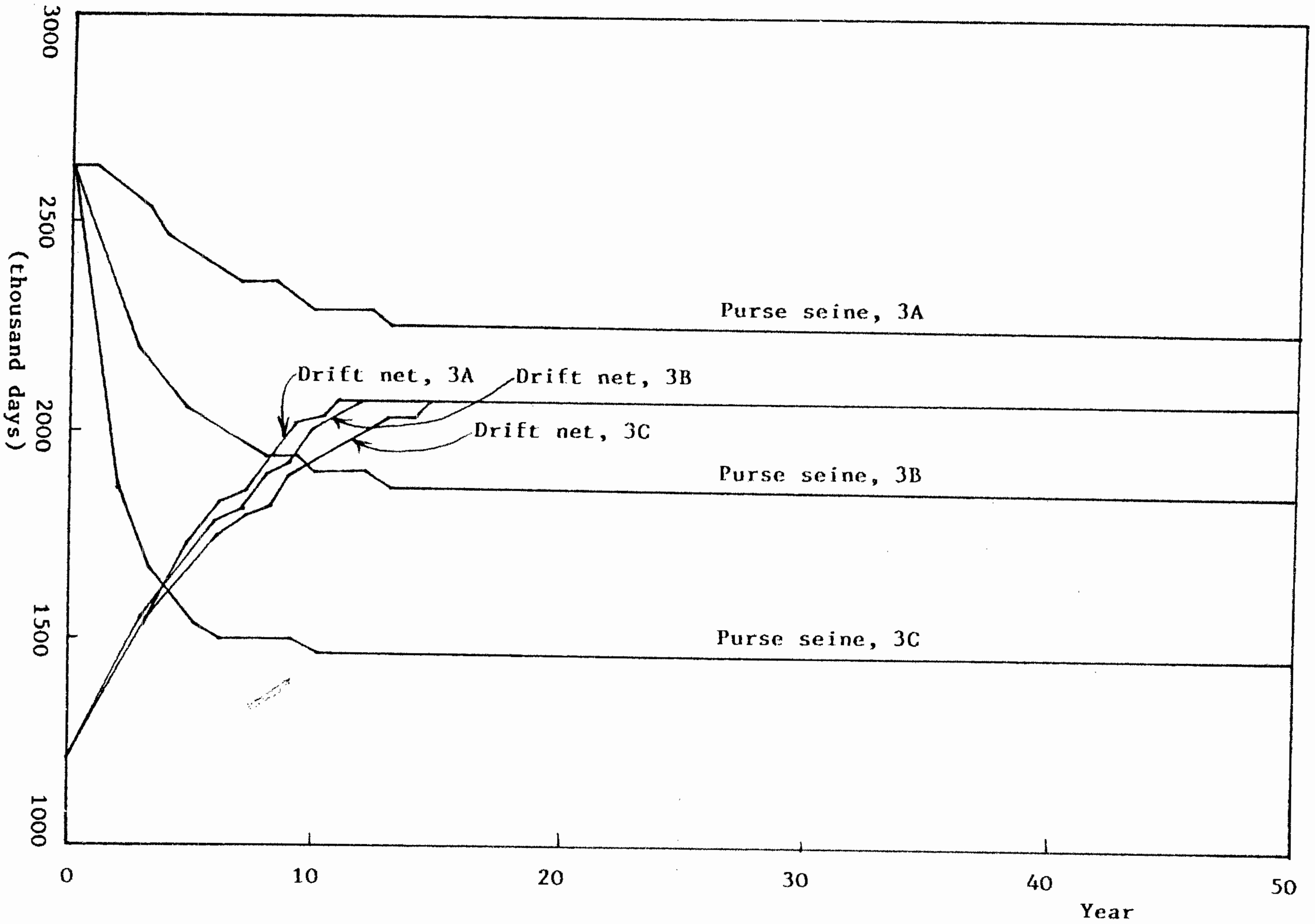


Figure 6.11b Evolution of Trawl and Total Effort, Policies 3A, 3B and 3C

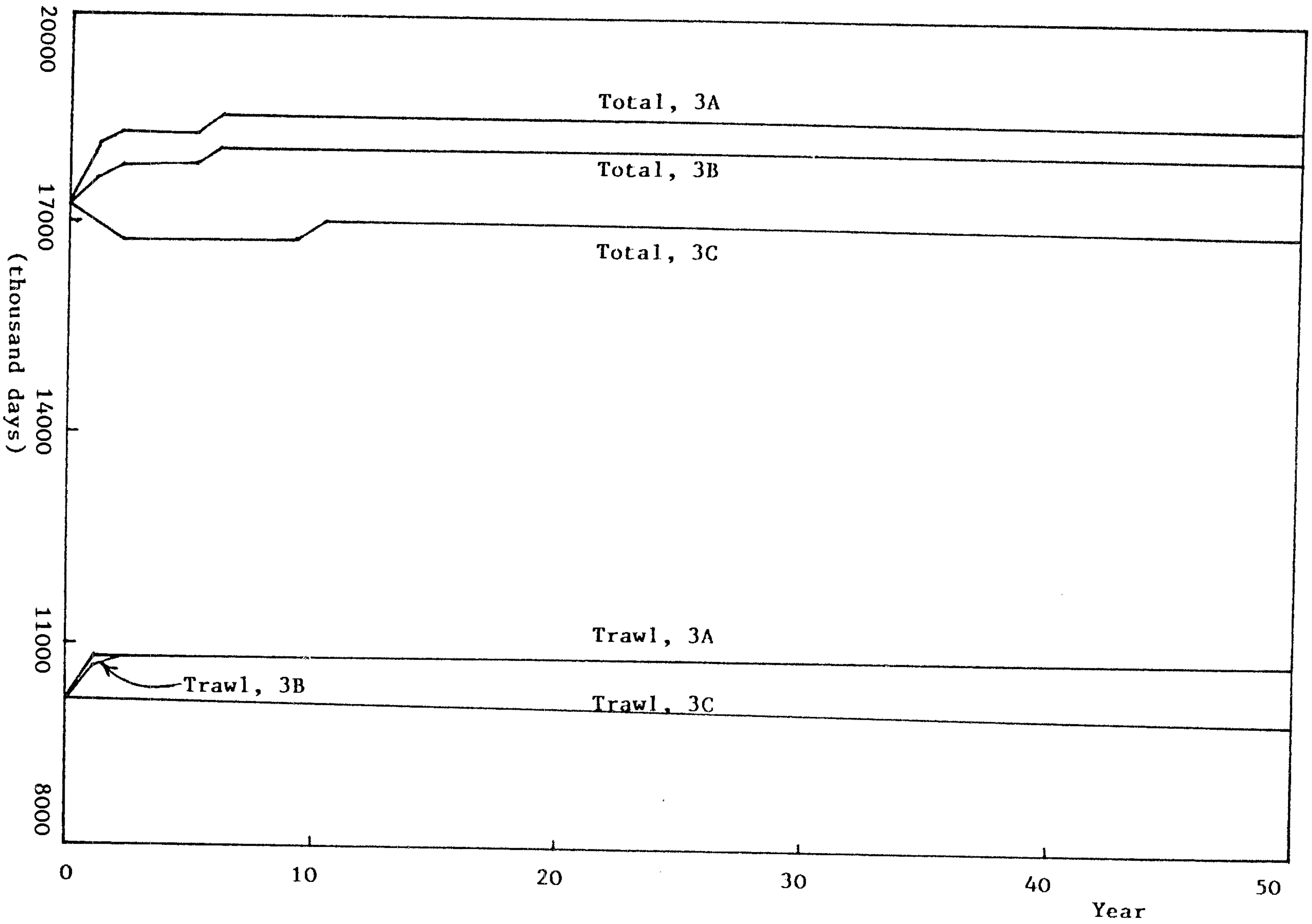


Figure 6.12a Evolution of Indian Mackerel and Scad Harvests, Policies 3A, 3B and 3C

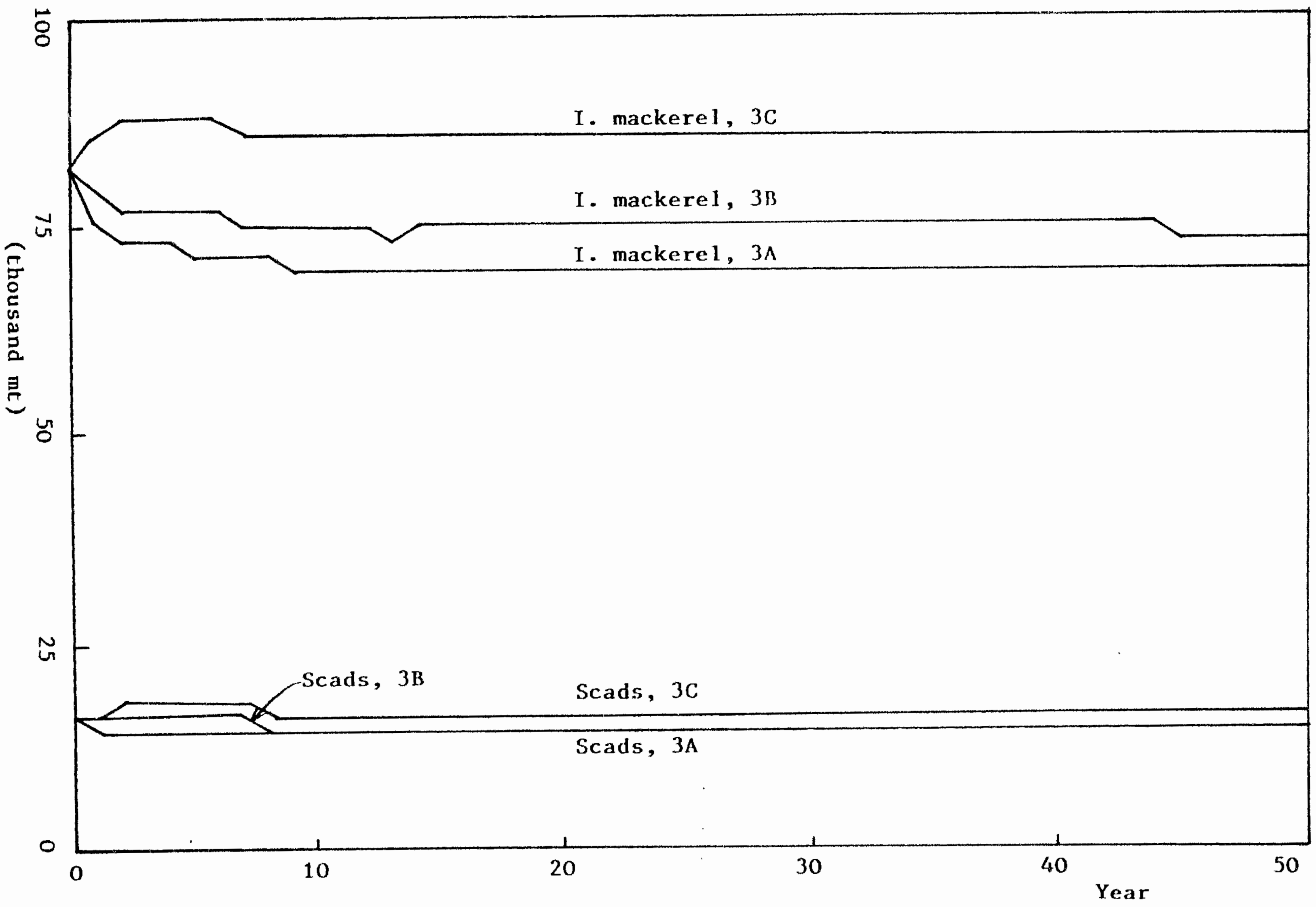


Figure 6.12b Evolution of Sardine and Tuna Harvests, Policies 3A, 3B and 3C

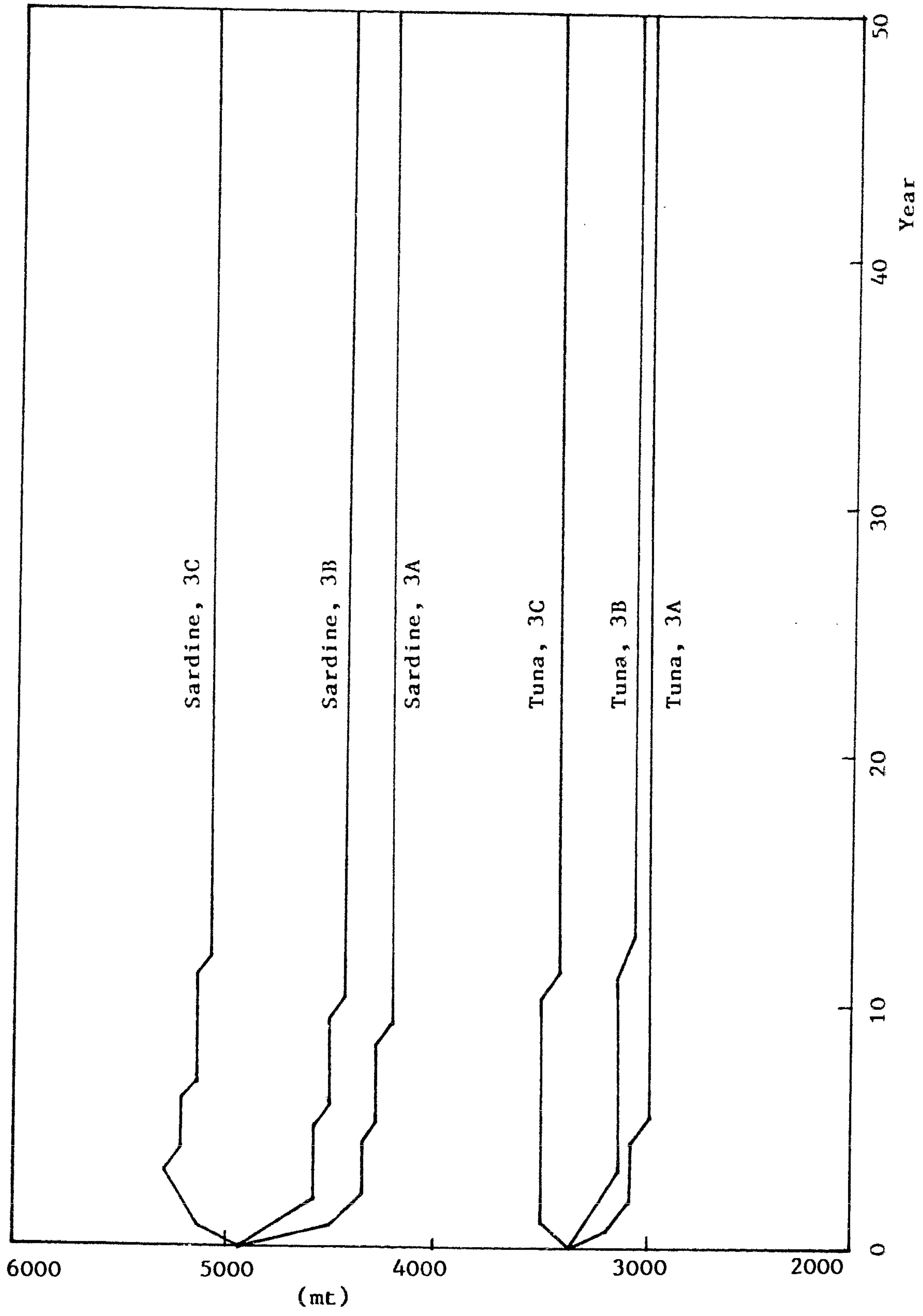


Figure 6.13 Evolution of Ex-Vessel Prices, Policies 3A, 3B and 3C

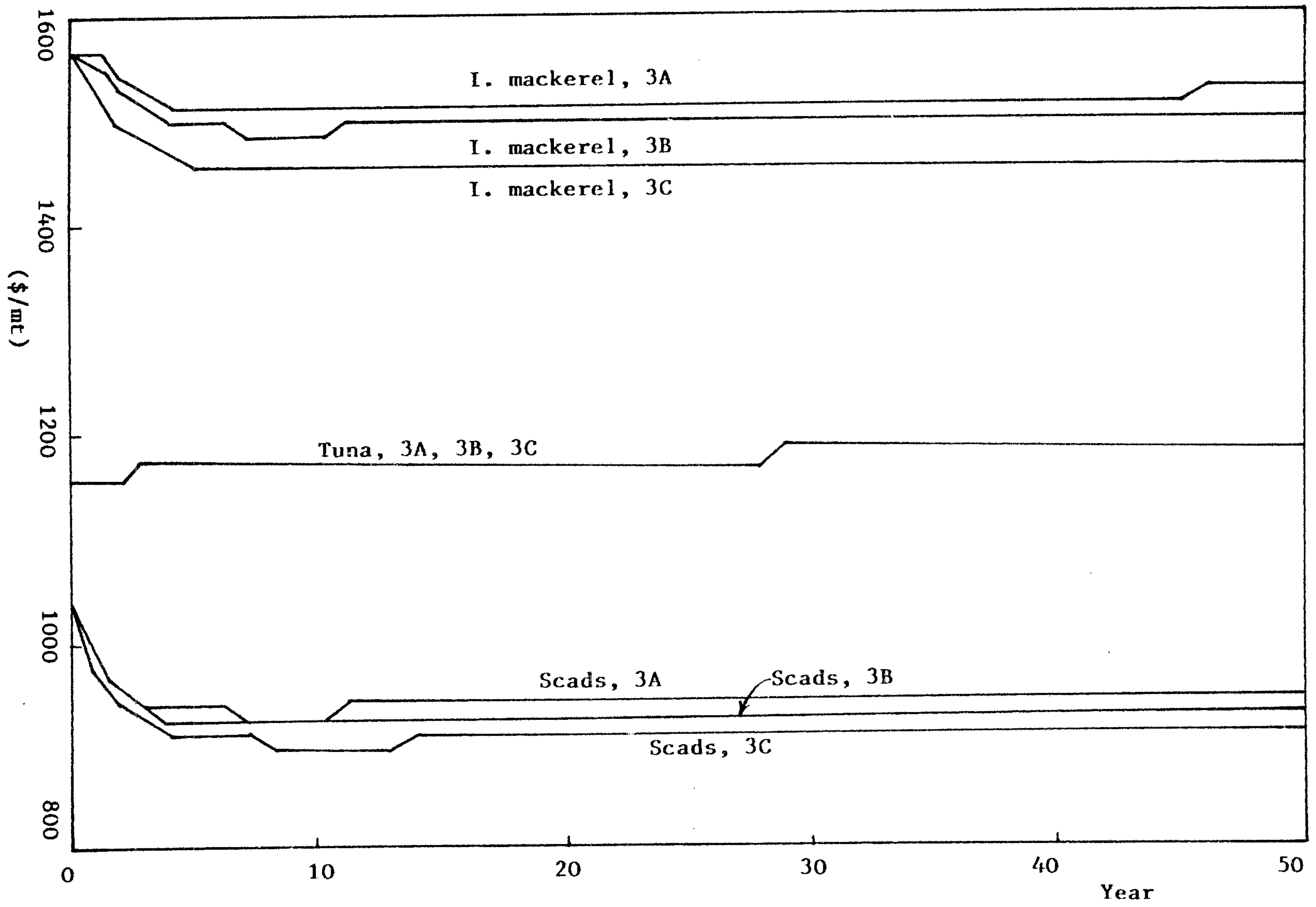


Figure 6.14a Evolution of Consumer's Surplus, Policies 3A, 3B and 3C

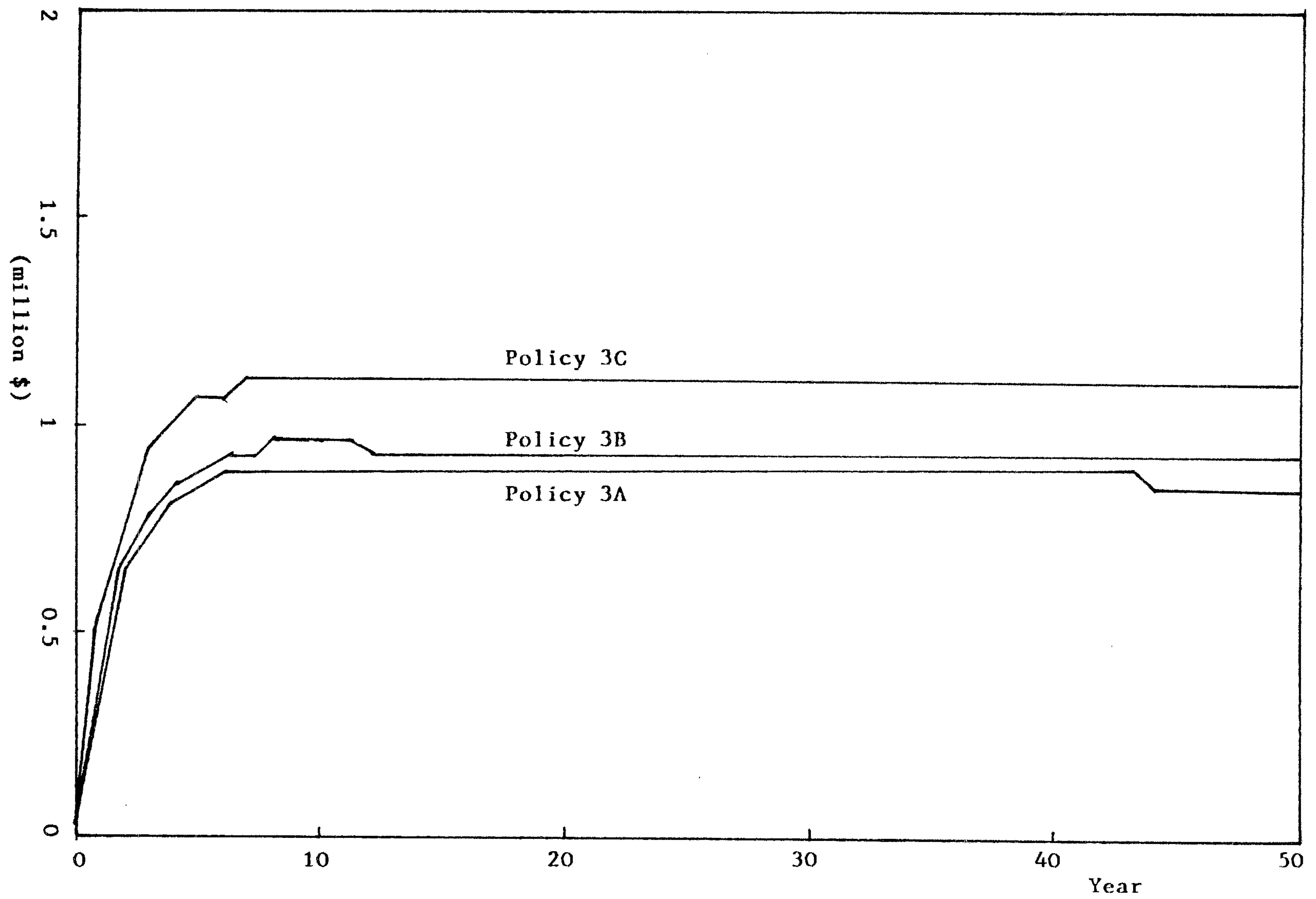
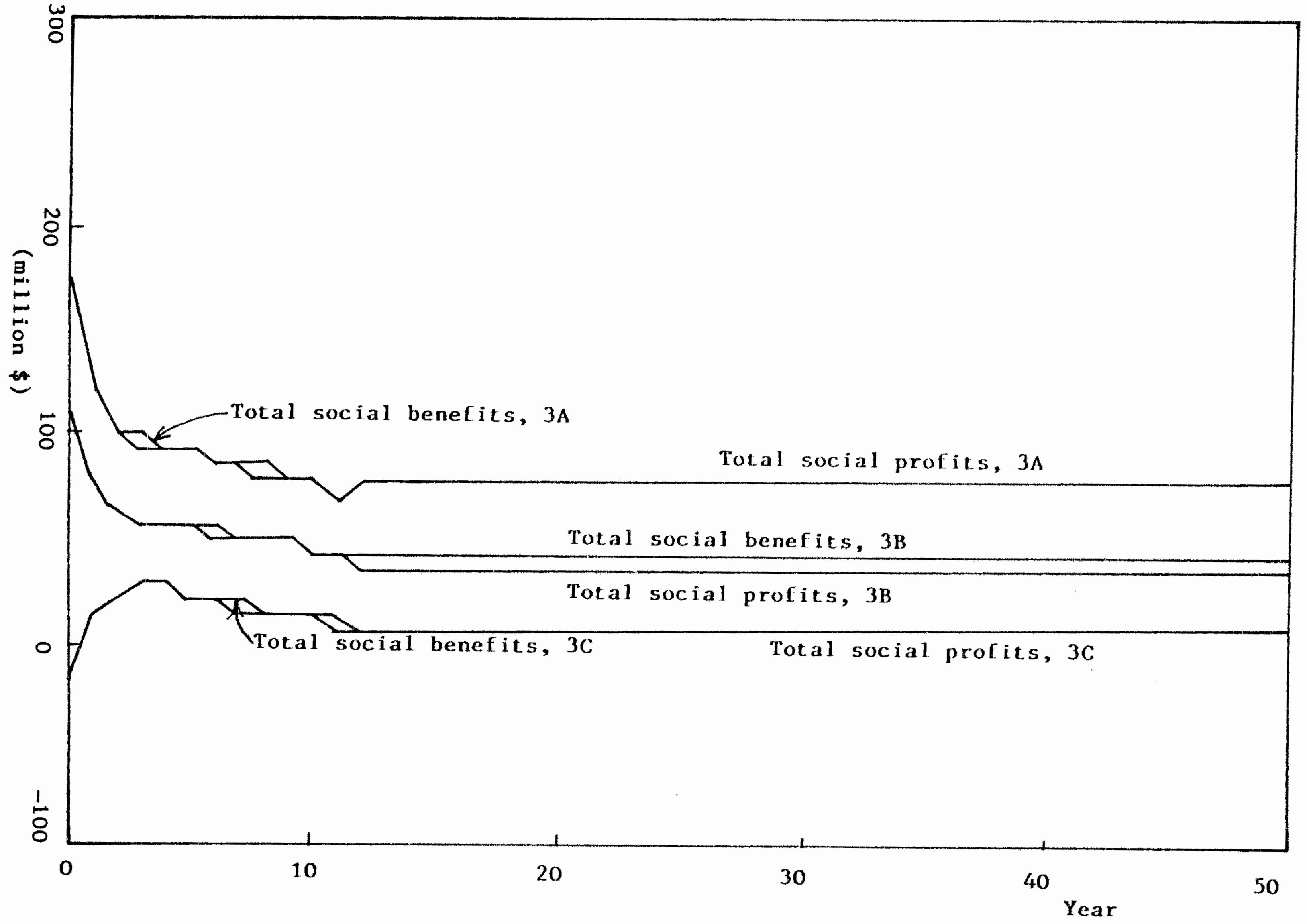


Figure 6.14b Evolution of Total Social Profits and Total Social Benefits, Policies 3A, 3B and 3C



total social benefits are the highest for Policy 3A[3]. The crew income, as shown in Figure 6.15, is the highest under Policy 3C because the reduction in effort has caused the number of crew members employed to decrease, thereby raising crew income. The average annual employment over a period of 50 years is presented in Table 6.6. Average total employment declined from Policy 3A to 3C, mainly because of the drastic decrease in crew employment by the trawl fleet, and to a lesser extent by the drift net fleet. Average crew employment of the purse seine fleet remained approximately the same.

The results presented above show that increasing the opportunity cost of fishing effort induces voluntary rather than regulated (forced) exit of fishing effort. However, several problems may be encountered with this policy. Generally, it is not easy to raise the opportunity cost of fishing effort by 50%, let alone 100% or 200%. This would require sustained growth at a high rate in the overall

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[3] *The additional wages earned by those fishermen who are employed in the non-fishing jobs are not included in the computation of the social benefits. This is because we need to consider not only the benefits to society due to increases in non-fishing employment, but also the costs of creating these jobs, and of retraining fishermen to acquire the skills to take up these employment should also be considered. In the absence of information regarding these costs, it is not possible to determine the net benefits to the society.*

Figure 6.15a Evolution of Annual Crew Income for Trawl, Policies 3A, 3B and 3C

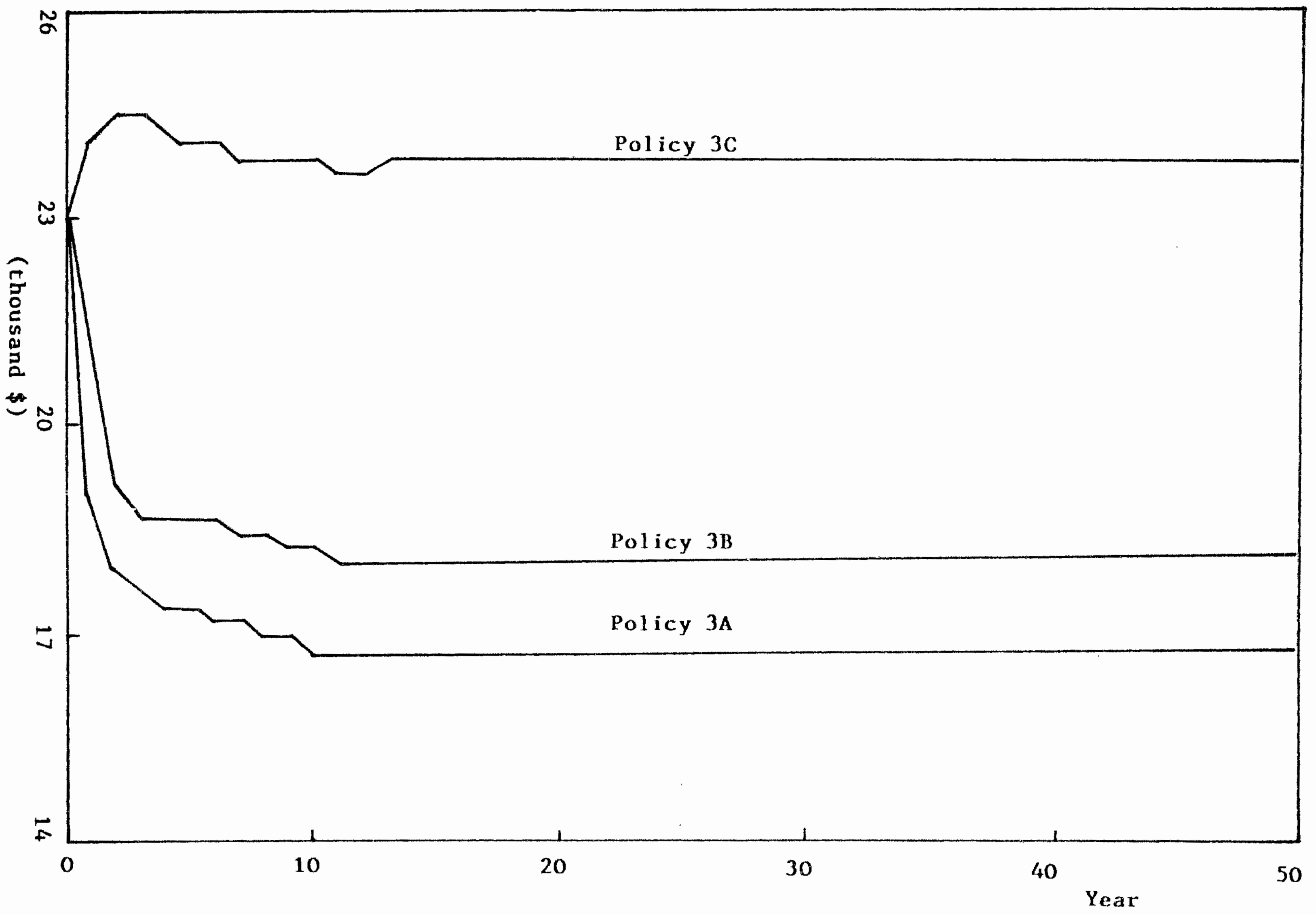


Figure 6.15b Evolution of Annual Crew Income for Purse Seine and Drift Net, Policies 3A, 3B and 3C

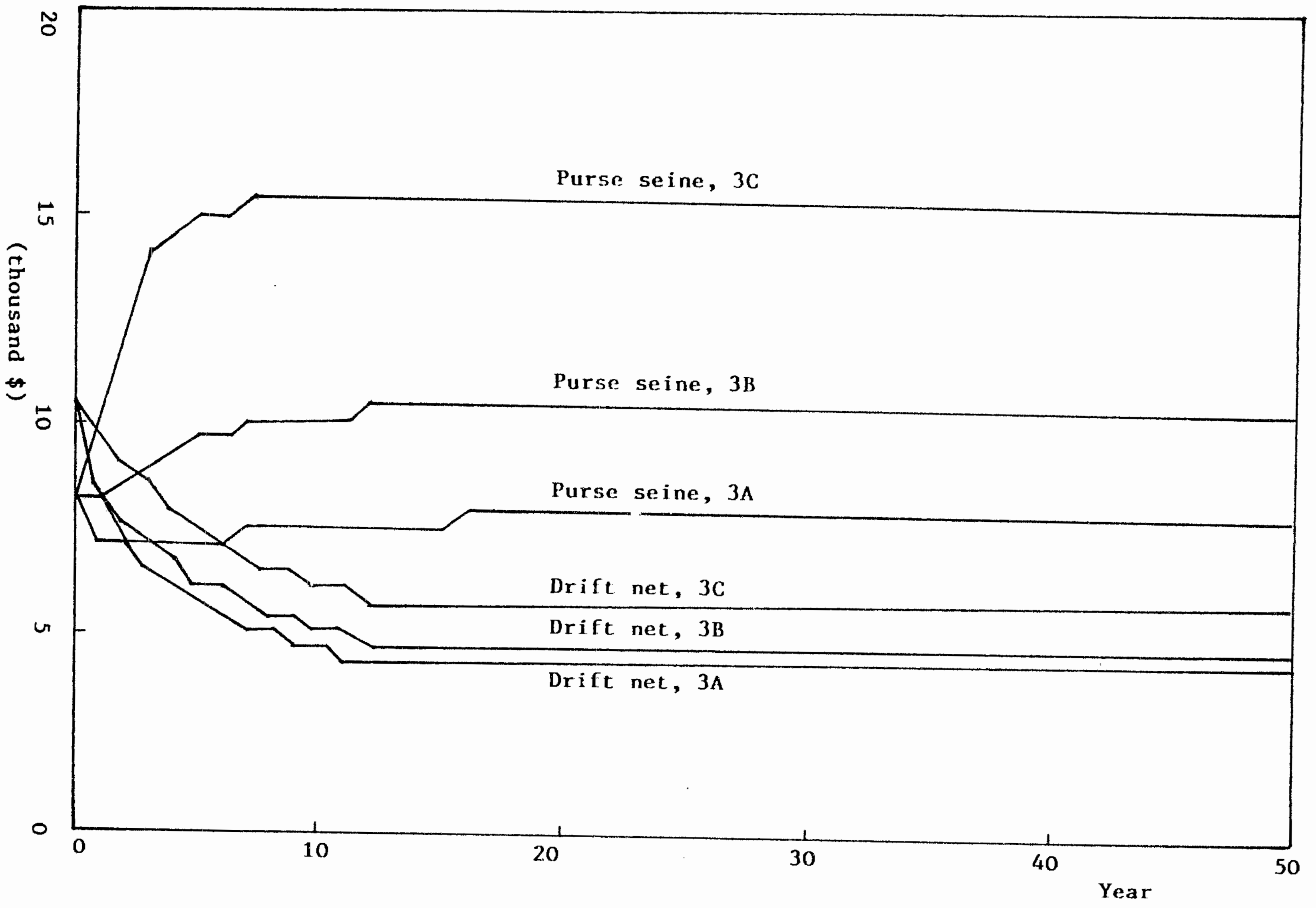


Table 6.6 Average Employment for Various Rates of Increase in the Opportunity Cost of Effort

	Employment (man-years)			
Policy[1]	Trawl	Purse seine	Drift net	Total
3A	12,758	4,991	21,487	39,236
3B	12,751	4,179	21,411	38,341
3C	11,845	3,329	21,276	36,450

[1] The rate of increase in the opportunity cost of effort are classified as follows: 3A=50%, 3B=100% and 3C=200%.

economy. Thus, the feasibility of this strategy by itself may be in doubt in practice. In addition, fishermen are required to make structural adjustments through retraining to acquire skills in occupations with higher productivity and better remuneration. Moreover, they may need to make social adjustments as well, because of geographical and occupational relocations. All of these adjustments require substantial costs which may have to be born by society.

One possible major impediment to the successful implementation of this strategy is the uncertainty of the response of fishing effort. This is because social, cultural, psychological and/or political factors affect effort level as well as profits and rents. However, these other factors are not considered in this study due to the absence of relevant time-series data. Consequently, the predictions of the model are put into doubt. Future effort should be expanded to collect the necessary data so that more accurate estimates of effort response parameters may be obtained, thereby improving the accuracy and reliability of the results.

6.6 Combination of Regulations

A successful regulation will bring about biological and socio-economic improvements in the fishery, but the chances of success will depend on the acceptibility of the regulation by the fishing industry. As discussed in previous sections, reducing fishing effort by 60% of the base case level coupled with levying of license fees to appropriate all the resource rents provides the greatest economic improvement to the small pelagic fishery. However, this may not be acceptable to the fishing industry as the level of license fees required is high. The acceptability may be improved by reducing the level of license fees levied on fishing vessels. Moreover, adjustments by increasing the opportunity costs of fishing effort by 100% or 200% may be difficult to achieve because of the required high and sustained economic growth and the heavy adjustment costs involved. However, by combining the regulations stated above in a moderate way, similar improvements may be brought about in a way more acceptable by the fishing industry. The combined regulation (Policy 4A) considered here involves a 60% reduction in fishing effort from the base case, a 50% increase in the opportunity cost of effort and license fee levies for trawl, purse seine and drift net fleet of respectively $311,626, $389,851 and $31,398 per vessel. The license fees are calculated in such a way so that they will appropriate completely the resource rents in the fishery.

The evolution and the bio-socioeconomic impacts of Policy 4A are presented in Figures 6.16 to 6.20. These results are compared with those of Policies 2A and 3A. As shown in Figure 6.16, total fishing effort and effort for all the fleets are the highest under Policy 3A. From the biological and harvest standpoints, the sustainable harvests of all small pelagic species are the lowest for Policy 3A since the equilibrium level of effort is the highest under this policy (Figure 6.17). The difference in the sustainable harvest for the small pelagic species under Policies 2A and 4A is insignificant since there is not much difference between total effort under these policies.

From the perspective of social and economic benefits, as shown in Figure 6.19, the consumer's surplus is the lowest for Policy 3A. This may be attributed to the low levels of harvest of all small pelagics species for Policy 3A which keep prices high. Consequently, consumer's surplus is low because of the inverse relationship between consumer's surplus and prices. Total social profit is the highest under Policy 3A since fishermen or vessel owners keep a portion of the rents generated in the fishery. Total social benefits, on the other hand, are the highest for Policy 2A because the management authority had appropriated the rents generated in full, to maintain fishing effort at the desired level and no rent is lost through effort expansion. The incomes to individual crew members by gear types for various policies are shown in Figure 6.20. It appears that annual average crew income for all gear types

Figure 6.16a Evolution of Purse Seine and Drift Net Effort, Policies 2A, 3A and 4A

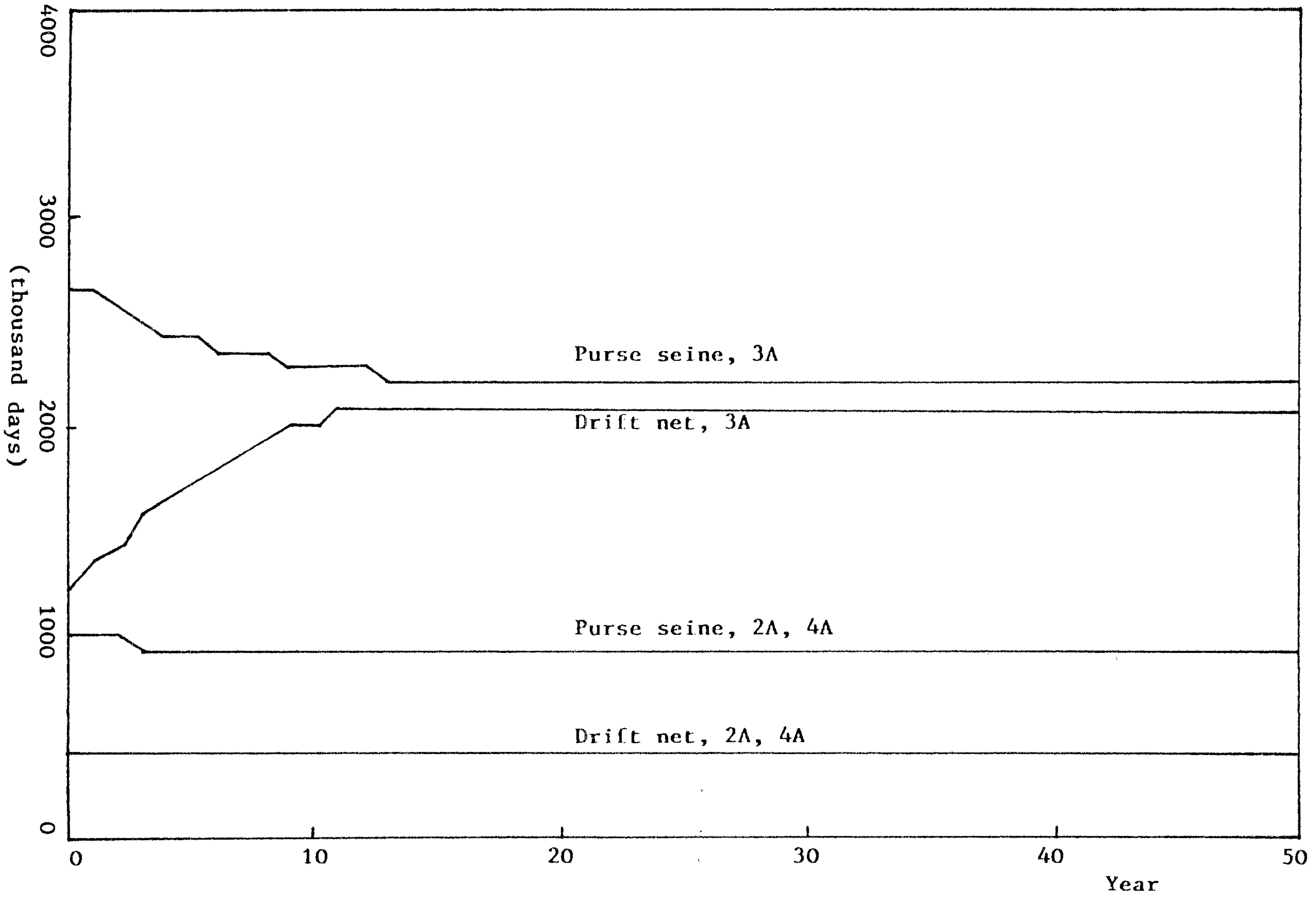


Figure 6.16b Evolution of Trawl and Total Effort, Policies 2A, 3A and 4A

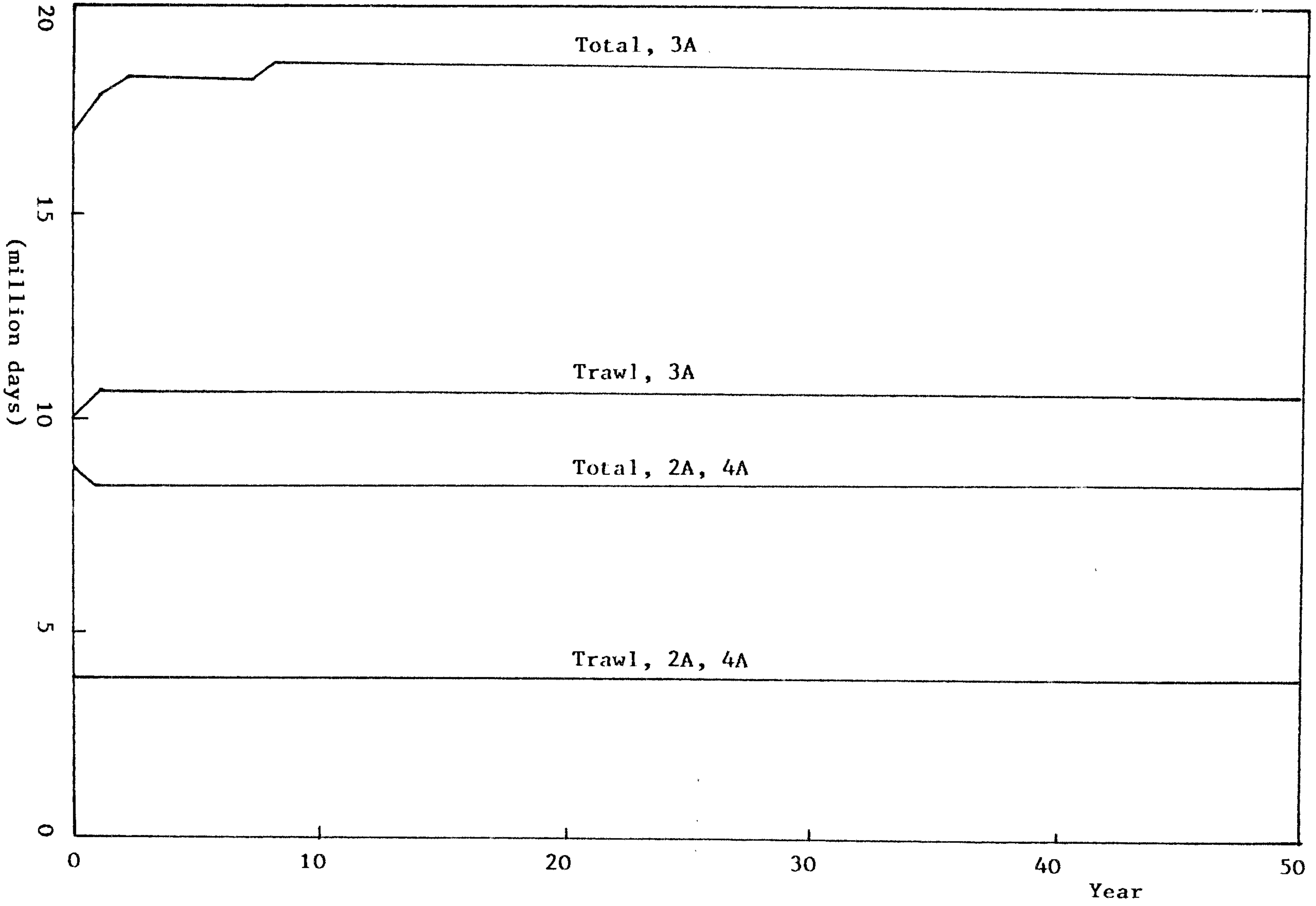


Figure 6.17a Evolution of Indian Mackerel and Scad Harvests, Policies 2A, 3A and 4A

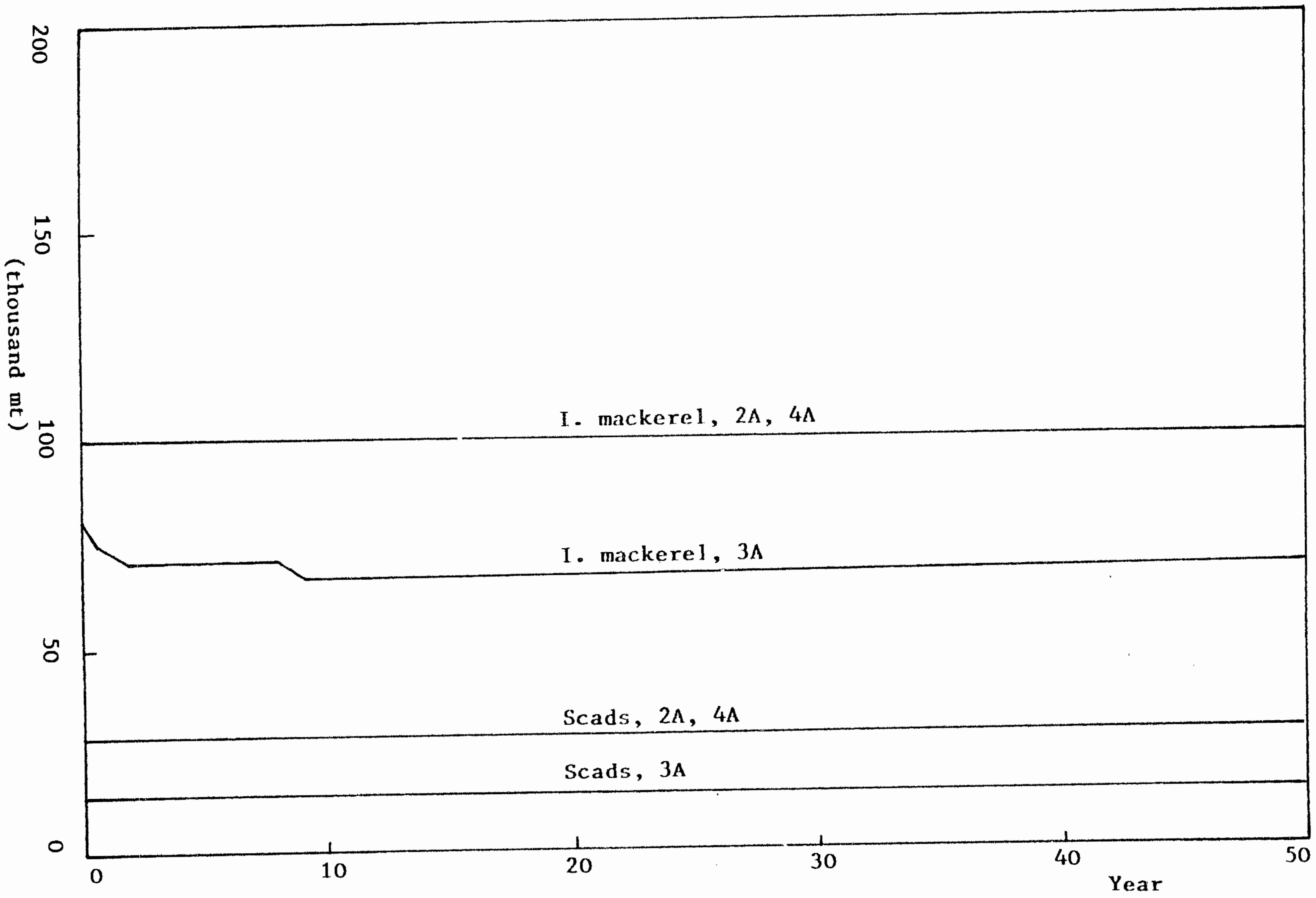


Figure 6.17b Evolution of Sardine and Tuna Harvests, Policies 2A, 3A and 4A

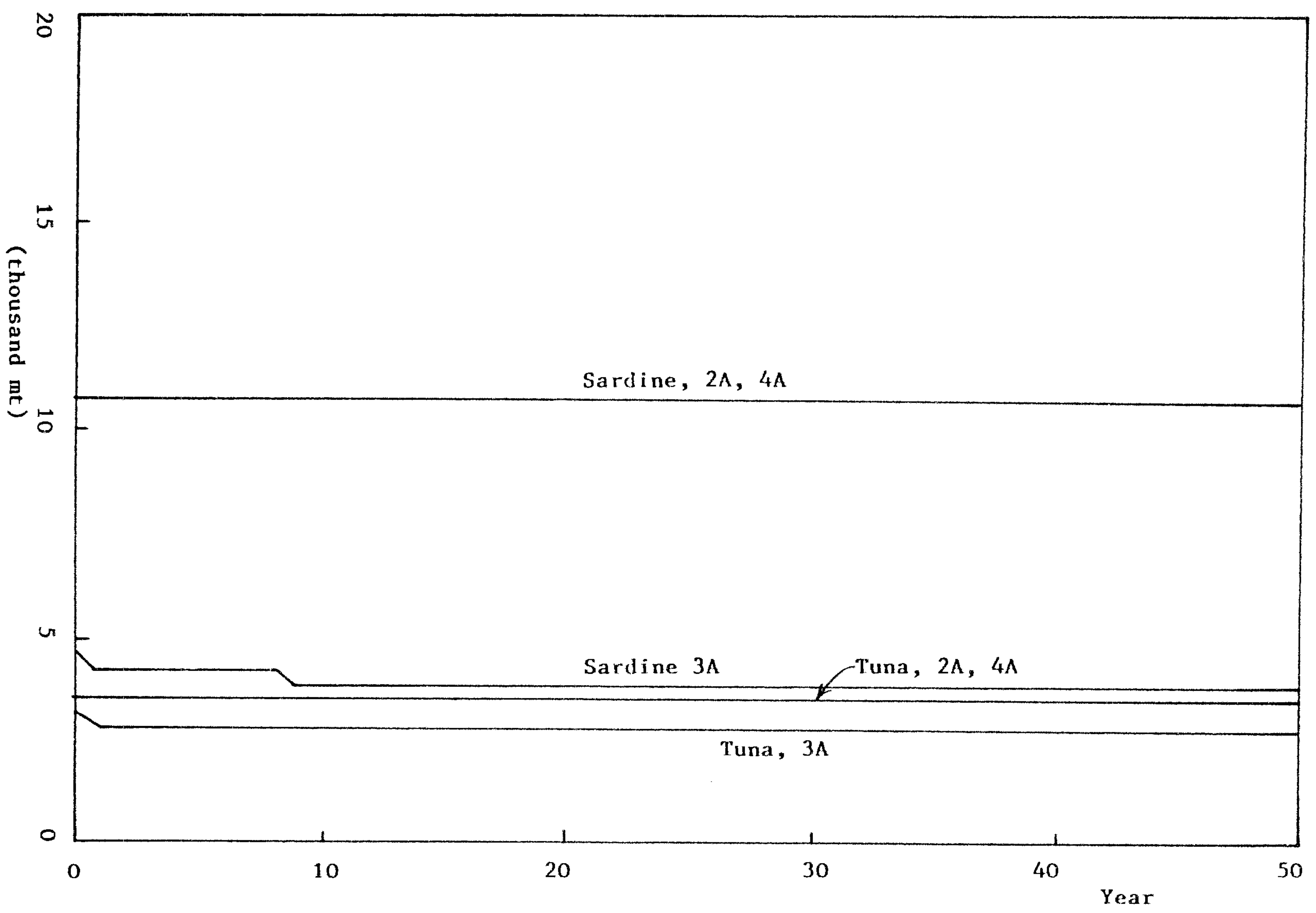


Figure 6.18 Evolution of Ex-Vessel Prices, Policies 2A, 3A and 4A

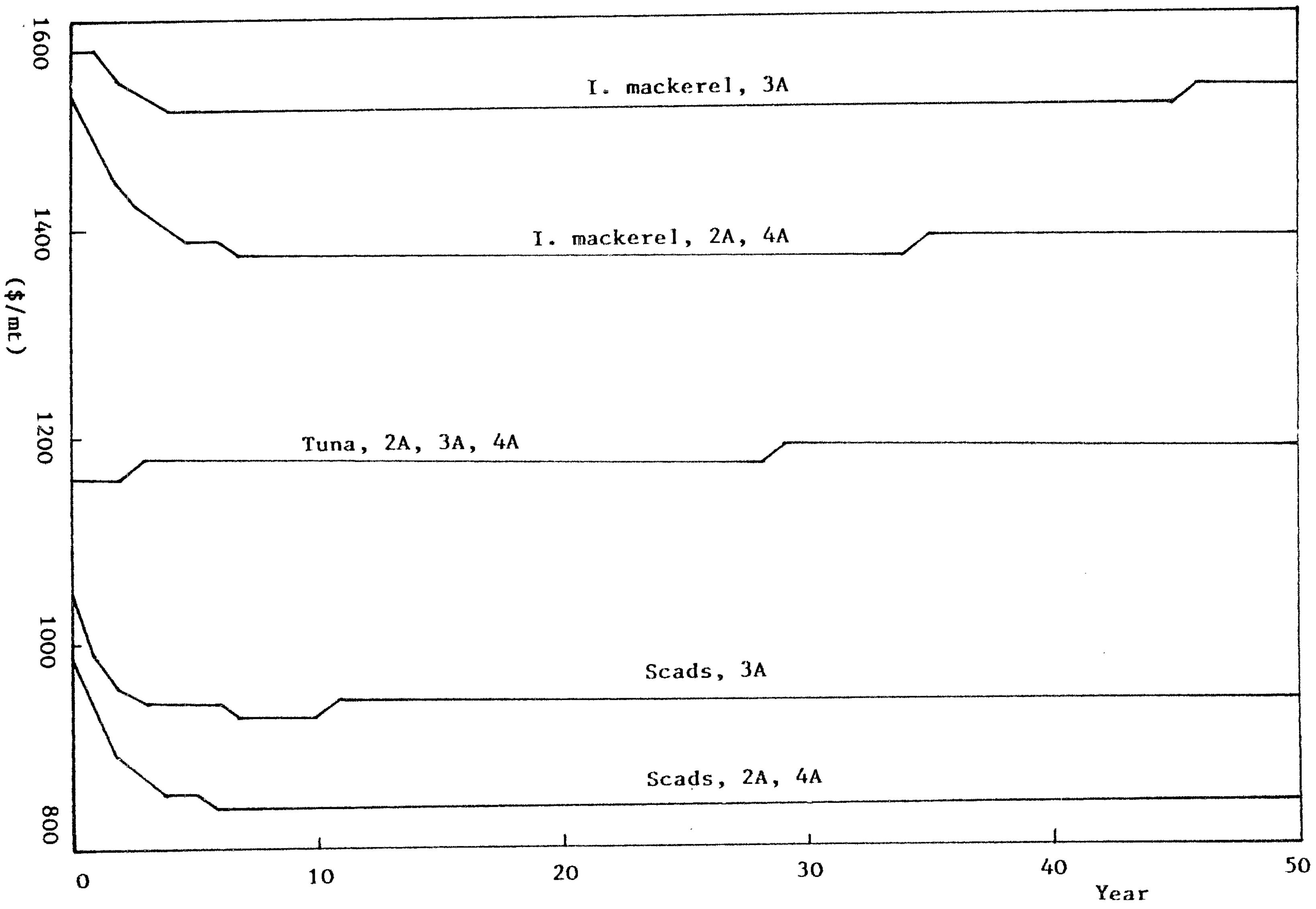


Figure 6.19a Evolution of Consumer's Surplus, Policies 2A, 3A and 4A

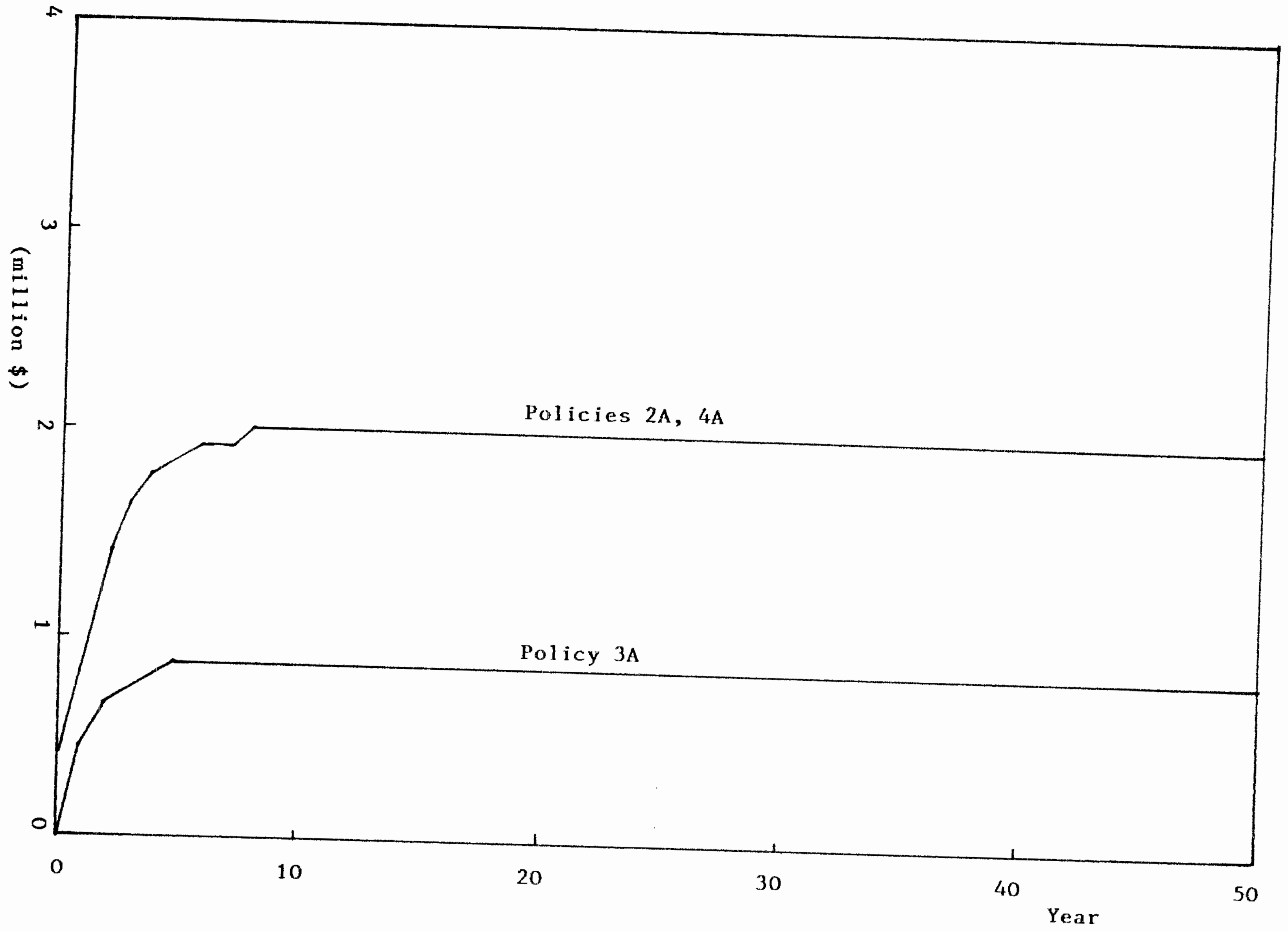


Figure 6.19b Evolution of Total Social Profits and Total Social Benefits, Policies 2A, 3A and 4A

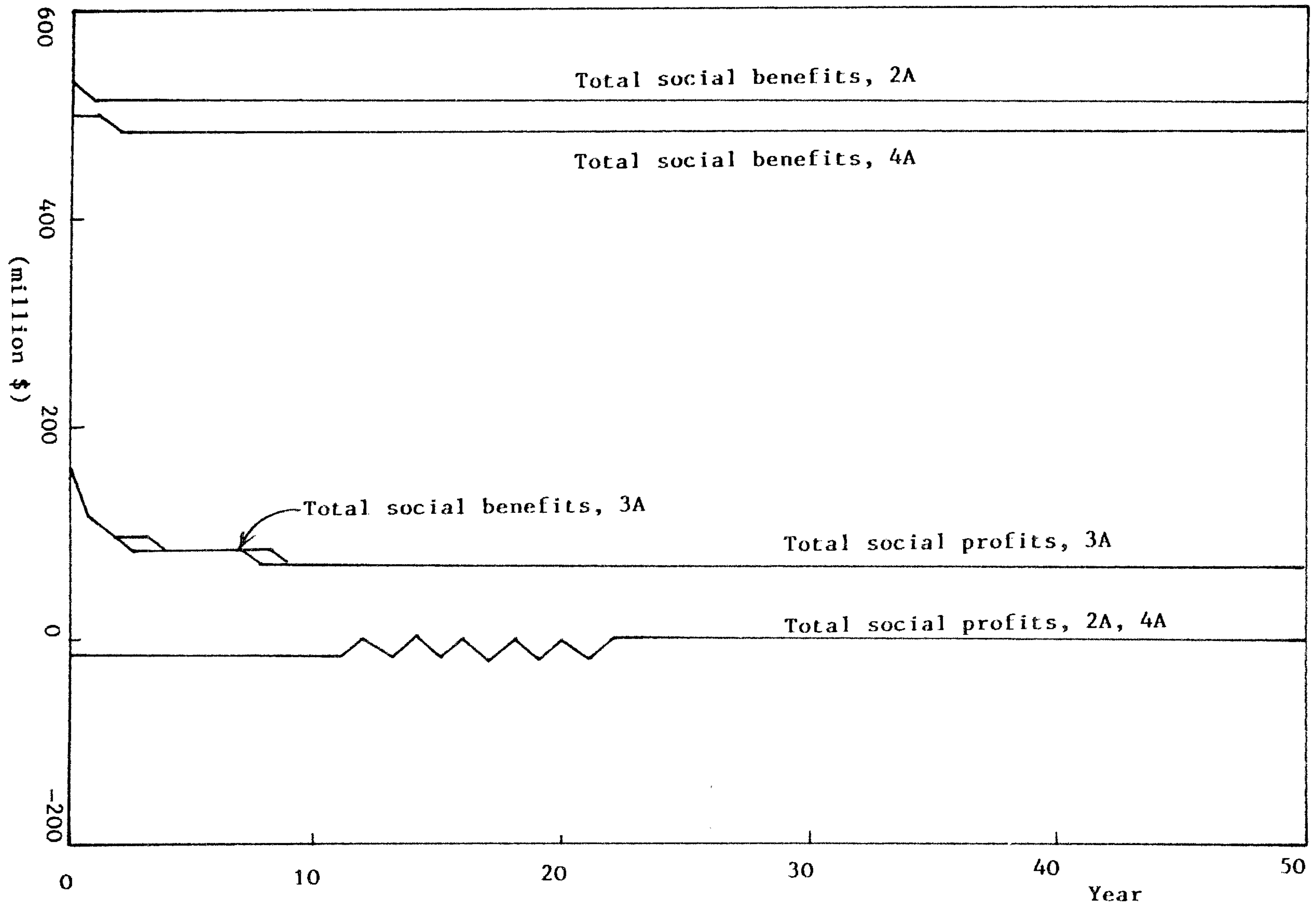


Figure 6.20a Evolution of Annual Crew Income for Trawl, Policies 2A, 3A and 4A

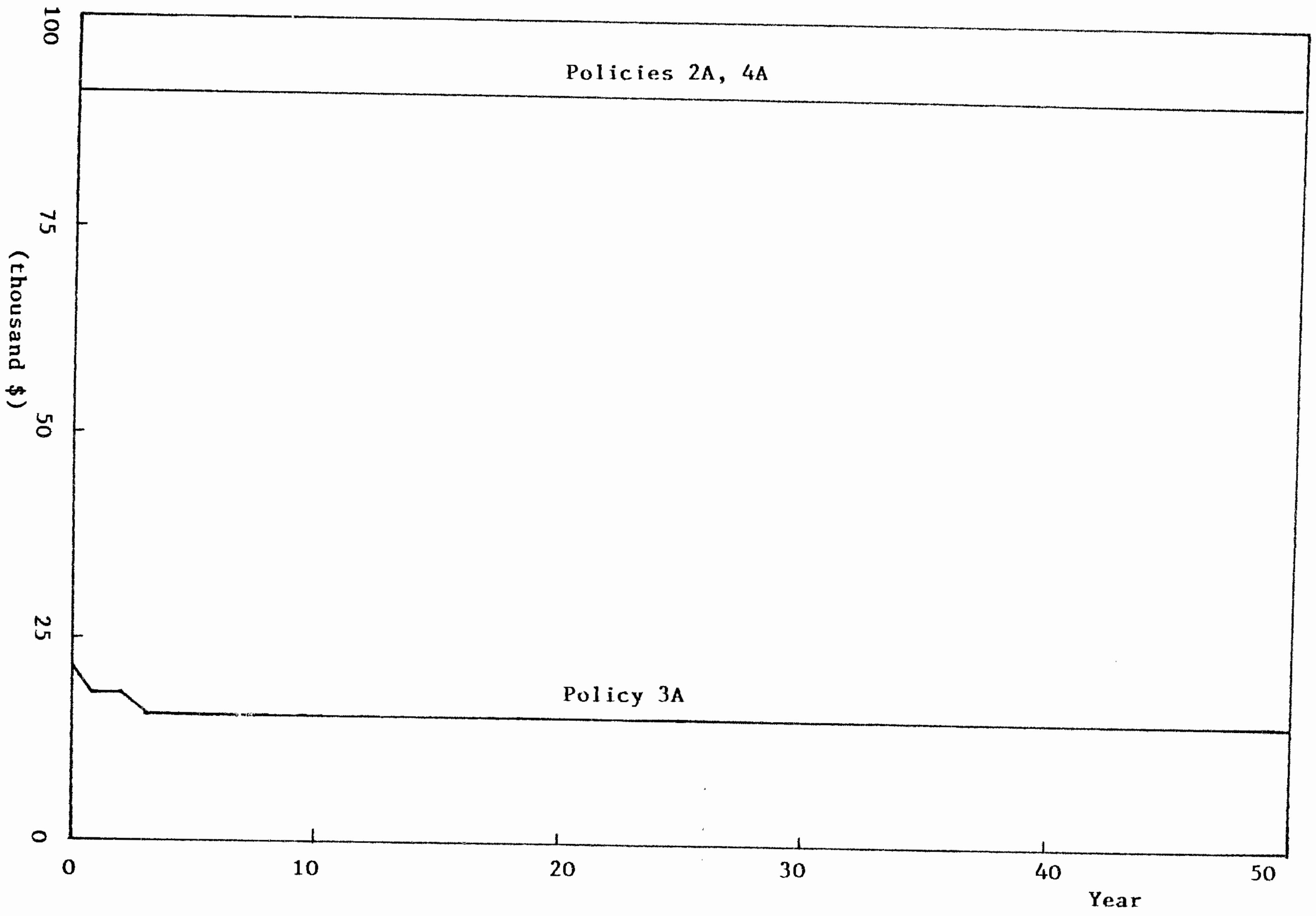
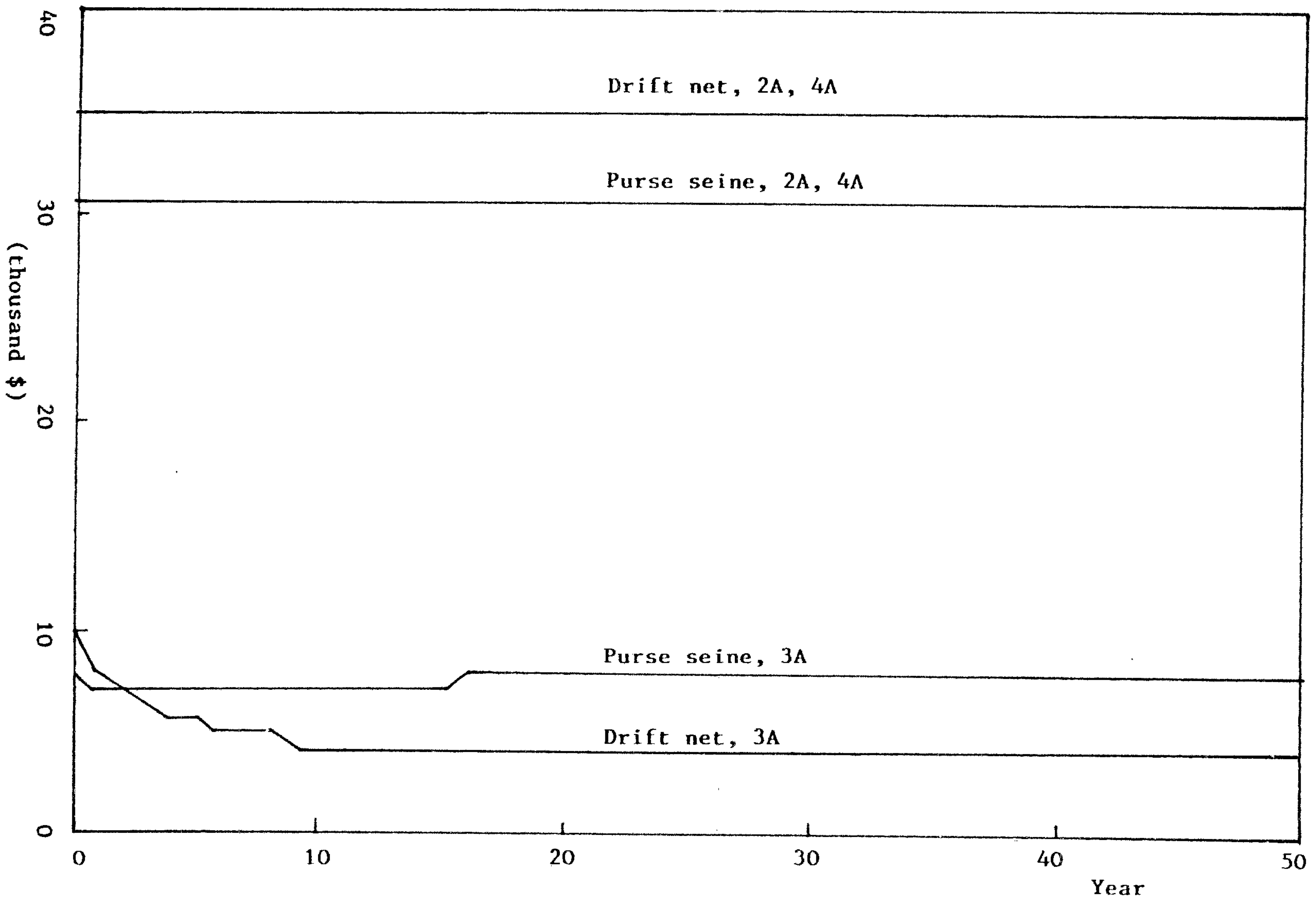


Figure 6.20b Evolution of Annual Crew Income for Purse Seine and Drift Net, Policies 2A, 3A and 4A



under Policy 3A are the lowest, since fishing effort and hence employment are the highest for this policy.

The above comparisons have demonstrated some clear advantanges for Policy 4A. From the standpoints of fishery biology and harvest, as well as crew income, Policies 2A and 4A seem to be better. Policy 4A however, is better from the social standpoint and in terms of acceptability by the fishing industry. The latter is particularly important for achievement of the success in policy implementation.

Chapter 7

Summary, Conclusions and Implications

7.1 Summary

Fisheries resources in Malaysia have been biologically and economically overfished as is evident from some overall indicators such as (1) catches over and above the sustainable potential of the resource; (2) increased landings of trash fish of which a large proportion consists of undersized commercially valuable fish; and (3) virtual disappearence of certain commercial species. Theoretically, overexploition in fisheries results in adverse effects on resource productivity and stability, and in economic inefficiency in harvesting, in the form of dissipation of the resource rent. Management measures are needed in order to deal with these problems. In Malaysia, two other problems are also pertinent to the fishery industry, namely, persistent poverty among fishing households and gear conflicts resulting from the crowding externalities.

The Malaysian Government has long recognised the problems plaguing the fishing industry and has initiated measures to manage the resource. However, the impacts of the management measures undertaken to date are far from satisfactory. The ineffectiveness of the measures undertaken appears to stem from the fact that there is a lack of detailed knowledge of the resource and of the participants in the fishery. As a result, policies and decisions have been made disjointedly on an *ad hoc* basis and have not been fully supported by either fishery participants or politicians, thus leading to implementation failures.

It is well recognised that the management of a multispecies, multigear tropical fishery like that of Malaysia is complex. The use of optimization techniques such as dynamic programming and control theory is problematic, as they suffer from the problems of "curse of dimensionality" and convergence. On the other hand, system simulation is a more tractable problem solving technique for realistic fishery models. However, it is less elegant and may not provide optimal results.

The general objective of this study has been to develop a bio-socioeconomic simulation model to analyse the performance of alternative management strategies for the small pelagic fishery on the Northwestern Coast of Peninsular Malaysia. The small pelagic fishery is chosen for the following reasons: (1) a large proportion of the pelagic fish landed consists of the small pelagic species; (2) the landings are mainly destined for the domestic market, constituting an important source of protein to domestic consumers; and (3) the small pelagic fishery provides most of the revenue for purse seiners and is also an important source of revenue for trawlers and inshore driftnetters.

The simulation model used in this study is based on three main sub-components and their inter-relationships: biological, economic and management. The biological sub-model uses a specification of the Schaefer surplus production model and its variates, i.e. the Fox and Schnute models. The Fox model provides the best fit for scads and sardine species while the Schaefer and Schnute models provide a good fit for tuna and Indian mackerel species respectively. Ideally, the biological sub-model should also consider using alternative population dynamics models such as the analytical model of Beverton and Holt or the trophic-ecological model, with the best model being chosen on the basis of theoretical plausibility and practical reality. Unfortunately these models could not be estimated due to lack of data. Future effort should be made to collect the data necessary for estimating these models.

The economic sub-model consists of a set of demand equations and is also used to determine the economic returns and surpluses for the fishing industry. Demand is modelled as a set of interrelated price equations reflecting potential substitution among species. The empirical results show that demands for Indian mackerel and scads are endogeneously price-determined while those for sardine and tuna are determined mainly by exogeneous prices as these species are traded in international markets. Thus consumers derive surpluses from the consumption of Indian mackerel and scads. In the determination of economic returns, revenues from small pelagic species were estimated by multiplying the annual average price and catch from 1968 to 1990 for each small pelagic species or species group. Revenues from by-catches were modelled as a constant proportion of the total small pelagic catch by each type of fleet. There is a lack of consistent time-series data on the costs of fishing incurred by the fleets. The fishing costs in this study were obtained from a survey by Md. Ferdous (1990) in the study area, and have been adjusted by the consumer price index. However, more realistic results may be obtained if data on these costs could be collected, or appropriately estimated by alternative methods, such as conducting research to derive these data series by monitoring the trends of major components of fishing costs.

The management sub-model was developed based on the premise that management regulations are aimed at influencing the behaviour of fishery participants and hence they should be explicitly accounted for. The effects of management regulations are examined via the equations for the dynamics of effort which capture the response of fishing effort to the level of profits and rents generated by the fishery. From the theoretical perspective, the response of fishing effort is influenced by social and cultural factors. Ideally these variables should be explicitly incorporated in the model. Their exclusion however, is again due to data deficiencies and their effects are implicitly captured in the opportunity costs of fishing effort.

The simulation model was applied to the small pelagic fishery on the Northwest Coast of Peninsular Malaysia. The application illustrates that a large number of parameters are required and their estimation is often difficult. Sensitivity analysis was used to evaluate the impact of estimation errors and uncertainty. In general, the simulation results of the base case, which correspond to the present situation in the fishery, are generally relatively insensitive to small changes in the values of the main parameters, except for changes in the values of fishing power of vessel and the number of vessels in each fleet

The simulation model was also used to evaluate several alternative management schemes for the fishery. Since the individual transferable quota scheme is generally unsuitable for the fishery (Copes, 1986a), the management alternatives considered in this study centred around limited entry schemes and their fine-tunings. These schemes are:

(1) Pure limited entry whereby fishing effort is reduced in steps of 10%.

(2) Limited entry coupled with levying of licence fees.

(3) Removal of excess fishing effort by relocating fishermen in more highly remunerated alternative occupations, thereby increasing the opportunity costs of fishing effort.

(4) Combinations of (2) and (3) above.

7.2 Conclusions and Implications

From the analyses, it may be concluded that at the present level of fishing effort, the small pelagic fish in the study area have been biologically and economically overfished. An initial reduction of effort to 50% of the current level would result in achieving approximately maximum sustainable yield. However, to achieve an economic optimum, the fishing effort needs to be reduced initially by 60% of the base case level.

Fishing effort is composed of three basic components: catching power of the gear, number of fishing vessels and number of days fished. Restricting any or all of these components in general may bring about a reduction in fishing effort.

Catching power of fishing gear may be restricted by imposing gear restrictions or gear rationing. However, as discussed in Chapter 3, this method may be extremely costly to enforce because every aspect of the fishing gear needs to be restricted. Otherwise "capital stuffing or seepage" will occur. Furthermore, restricting each and every aspect of fishing gear might inhibit useful technological innovations.

Removing excess vessels from the fishery may also reduce fishing effort to the desirable level. In this case, the owners whose vessels have been removed have to be compensated through a buy-back program. However, experience in other fisheries with such a program, for example the Pacific coast fisheries of Canada has shown that this is very costly. In particular, such a program would add a significant financial burden to a developing country like Malaysia. Furthermore, the scheme lacks flexibility. This is because when a vessel is removed, it will not be used to fish again. In times of a sudden upsurge in resource abundance, which is likely to occur in small pelagic fisheries, the reduced number of vessels with lower capacity will not be able to catch the entire surplus yield, leading to wastage of resources.

Another method of reducing fishing effort is by time rationing. In time rationing, the number of active vessels remains intact, but the number of fishing days for each vessel is reduced to some desired level. There are several advantages of this method of fisheries rationalization. Time rationing may be a useful measure if the management authority cannot afford the costs of rationalization through buying back vessels or because the authority finds it difficult to retire vessels initially to the desired level of effort. It is flexible in the sense that the fishing days of vessels can be increased or decreased in accordance with any increase or decrease in abundance of the resource. Furthermore, this method may be able to reduce gear conflicts, if not completely eliminate them, by allocating different times for the fishing operations of different gears. Enforcement may be more effective if vessels fishing at different times can be easily identified and recognized. Extra funds for the setting up of a buy-back progam will not be needed as no vessel will be forced to exit the industry. However, the effects on economic efficiency are ambiguous. On the one hand, reducing the number of days fished results in idle vessel capacity, thereby increasing economic inefficiency. On the other hand, fishermen may save on the variable costs of fishing since there are fewer operational days under time rationing.

Restricting fishing effort alone will not achieve the objective of fisheries rationalization as fishermen would be able to increase catching capacity through "capital stuffing". This will cause fishing effort to increase to the maximum level of effort. Levying of a license fee to remove the entire rents generated in the fishery as a result of an initial reduction in effort is a "fine-tuning" regulation which complements effort limitation. However, charging a full license fee would be excessive, in particular for the purse seine and trawl fleets which would have to pay annually about $432,000 and $327,000 per vessel respectively. This level of the license fee appears to be more socially and politically unacceptable. Setting license fees at some level below the level of resource rent may be socially acceptable. However, fishing effort will then increase to some extent since the availability of rents will induce fishermen to expand their effort. Moreover, as shown by the results, the annual remuneration received by crew members of the various gears deteriorates as the level of the license fees decreases. One possible way to resolve this is to rebate vessel owners the unappropriated portion of the rent on the condition that crew shares be increased.

An alternative way of removing fishing effort from the fishery, as has often been suggested in the literature, is to get fishermen to accept alternative employment in non-fishery sectors. Fishermen will be lured into these occupations if the remuneration is higher than that currently earned by a fisherman. The impact on fishing effort of an increase in opportunity costs is analysed. It is shown that fishing effort would be reduced only if this opportunity cost were raised by more than 100%. The reduction in fishing effort, however, will not take place abruptly but will be spread over some period of time. It is, of course, difficult to raise productivity and opportunity costs by more than double, in particular for a developing country like Malaysia. Nevertheless, productivity and opportunity cost may be increased if fishermen are retrained to acquire the skills necessary for them to make the structural adjustments.

Regulations that combine an effort reduction by 60% of the current level, increase opportunity costs by 50% and charge license fees at a rate lower than the level levied by a policy of limited entry and full appropriation of rents through license fees appear to be socially and politically acceptable. This is because increase in the opportunity cost allows fishing effort to adjust through voluntary exit. From the biological perspective, this policy is appropriate since the levels of harvest of the small pelagic species would be close to the maximum sustainable yield. From the social and economic standpoints, this policy results in high social surpluses, and the highest levels of crew income compared to other management alternatives considered in this study. The high social surpluses and crew incomes are at the expense of direct fishery employment. However, with measures such as job creation and skill training providing displaced fishermen with employment in non-fishing sectors, the problem of employment may be addressed. Thus, the combined policy is biologically, socially and economically viable.

7.3 Limitations and Extension of the Study

One major constraint of this study is the availability of data. This constraint limits the study of many of the interesting aspects of the fishery. For example, lack of data on most of the biological parameters of the fishery caused surplus production models to be the only biological model that could be used in this study. Absence of time-series data on many social and cultural variables resulted in overly simple equations for the dynamics of fishing effort being specified. Similarly, the unavailability of household expenditure data had prevented the estimation of expenditure functions to be used in estimating compensating (CV) or equivalent variation (EV), thereby putting the accuracy of estimating consumer's surplus using a path-dependence method into doubt. The aggregate nature of the data set made it impossible to estimate intramarginal rents of highliners in the fishery, since the estimation of the intramarginal rents requires the data set to be divided into two groups: one for the highliners and the other for the marginal fishermen. In addition, the unavailability of time-series data on costs did not allow the analysis of technological improvement, in particular with respect to the use of cost-efficient technology and "capital stuffing". Therefore, the priority task in the study of fishery management in Malaysia is to collect and compile these data.

The model and analysis in this study can be modified and extended in a number of ways. The assumption of equilibrium yield in the surplus production models is particularly restrictive. Subject to data availability, other biological or the ecological models could be used to represent the biology of the fishery. The behaviour of fishermen in supplying effort needs to be modelled with greater detail as studies have shown that many social and cultural variables influence the effort supply decisions of fishermen. Estimation of market demand for small pelagic fishes may be improved by incorporating all levels of marketing into the model. The consumer's surplus can be estimated more accurately and theoretically more consistently by deriving it from an expenditure function. Resource rents should be differentiated from intramarginal rents. This may be done by performing different simulations for highliners and marginal fishermen.

Uncertainties exist in fishery resource exploitation. They include uncertainty in resource availability, in prices, in production, in the supply of fishing effort, in fishermen's response to management regulations and so on. For a more realistic representation of the fishery, the model should incorporate these uncertainties.

In simulation, the rate of decrease in fishing effort was taken to be equal among the various gear types. Cases where the rates differ by gear type should also be examined. In addition, the optimal allocation of fishing effort among the various gear types might be determined if programming methods were built into the simulation model.

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APPENDICES

Appendix A

Fisheries Legislation of Malaysia

Type of Legislation	Acts and Regulations	Detailed Provision and Specification of Activities
A. National Jurisdiction	1. Emergency (essential Powers) Ordinance No. 7, 1969.	Limit territorial waters to 12 nautical miles.
	2. Continental Shelf Act 1966.	Rights with respect to exploration and exploitation of natural resources vested in Federal Government.
B. Management	1. Fisheries Act 1963.	Provide power to the Federal Minister to make regulations for the control of marine and estuarine fisheries.
	a. Merchant Shipping Ordinance 1952.	Controls the licensing of fishing vessels.
	b. Fisheries (Cockles Conservation & Culture) Regulations 1964.	Licensing for collection of cockles and for direct purchasing of cockles; regulate minimum size of cockles to be harvested.
	c. Fisheries (Maritime) Regulation 1967	Provides detailed provisions and specification of activities requiring licenses.
	d. Fisheries (Prohibition of Method of Fishing) Regulation 1971.	Prohibit use or possession of certain types of destructive gear.

Appendix A continued..

	e. Fisheries (Prohibition of Import of Piranhas) Amendment Regulations 1979.	Prohibition of import, sale and culativation of piranhas.
	f. Fisheries (Amendments) Regulation 1980.	Specified allocation of fishing grounds, larger mesh size adn license limitation.
	2. Fisheries Act 1985.	Provides power to the Federal Minister to make regulations for the control and management of marine and estuarine fisheries. Imposition of heavy fines on illegal foreign fishing vessels.
C. Development	Lembaga Kemajuan Ikan Malaysia Act 1973.	To promote and develop effective management of fishery enterprises, credit facilities; to promote, stimulate, facilitate and undertake economic and social development of fishermen's associations.
E. Organization	Investment Incentive Act 1968.	Provides certain incentives for both domestic and foreign investment in pioneer fisheries related industries.
F. Fishing Vessels & Merchant Shipping Regulation	1. Boat Rules 1953 2. Merchant Shipping (Amendment) Act 1973. 3. Examination of Engine Drivers Rules 1953.	Registration, licensing, construction and equipment standards for fishing vessel and manning and certification requirements.

Appendix A continued..

	4. Examination for Certificates of Competency and Efficiency (Amendment) Rules 1974.	
G. Pollution	Environment Quality Act 1974.	Pollution prevention and control under the responsibility of the Environment Division, Ministry of Science, Technology and Environment.

Source : Jahara and Yamamoto, 1988.

Appendix B

Derivation of Equation for the Dynamics of Effort

The basic premise for deriving the equation for the dynamics of effort for each gear type j is the assumption that effort entry into or exit from the fishery is a function of the existence of resource rent. If rent is positive, effort will enter into the fishery and vice versa. Thus, the effort entry-exit equation of gear type j at time t can be specified as (Smith, 1968; Wilen, 1976):

$$\text{(B1)}\quad \dot{E}_{jt} = \Omega_j\{[\Sigma_i(P_{it}H_{ijt})+BCR_{jt}-c_jE_{jt}-\pi_jE_{jt}]/E_{jt}\}$$

Here P_{it} is price per unit harvest of species i, H_{ijt} is harvest of species i by gear j, BCR_{jt} is the revenues from by-catches, c_j is cost of harvest per unit of effort of gear j, π_j is opportunity cost of effort, E_{jt} is the total effort of gear j, and Ω_j is a "response parameter" indicating how fast effort responds to resource rents.

By integrating the above equation over the interval in question, we have

$$\text{(B2)}\quad \int_{sT}^{(s+1)T}(E_{jt})dt =$$

$$\int_{sT}^{(s+1)T}\Omega_j[(\Sigma_i(P_{it}H_{ijt})+BCR_{jt}-c_jE_{jt})/E_{jt}]dt-\Omega_j\pi_jT$$

Assuming that T is a fixed interval of time (e.g., a year) and define for each integer s=0,1,......T,

$$\text{(B3)}\quad E_{js} = 1/T\int_{sT}^{(s+1)T}E_{jt}dt$$

Where $\bar{E}_{js}$ is the "time-average" effort during year s. Further assuming that E_{jt} is uniformly distributed over the interval in question. This assumption may be reasonable for the small pelagic fisheries in the Northwest Peninsular Malaysia since fishing is carried out throughout the year. The "time-average" of E_{jt} is then simply the average value over that period, i.e. $\bar{E}_{js}=E_{js}$. Similarly, it is assumed that the rate of harvest is uniform over period s, and in addition that $P_{it}=P_{is}$ and $c_jE_{jt}=c_jE_{js}$, then equation (B2) becomes:

$$\text{(B4)}\quad 1/T[E_{j,t+1}-E_{jt}] = \Omega_j[(\Sigma_i(P_{it}H_{ijt})+BCR_{jt}-c_jE_{jt})/E_{jt}]-\Omega_j\pi_j$$

Setting T equal to 1 year and incorporating appropriate error term, the above equation becomes:

$$\text{(B5)}\quad [E_{j,t+1}-E_{jt}] = \Omega_j[(\Sigma_i(P_{it}H_{ijt})+BCR_{jt}-c_jE_{jt})/E_{jt}]-\Omega_j\pi_j+\epsilon_j$$

which is linear in the parameter Ω_j and thus can be estimated using ordinary least squares method.

Appendix C1

Formulae for Calculating MSY, Effort at MSY and CPUE at MSY

(1) Schaefer Model (Hongskul, 1975:169)

Estimated function:

$$CPUE_i = a_i - b_i E$$

Where $a_i = q_i K_i$

$b_i = q_i^2 K_i / r_i$

and q_i = catchability coefficient for species i

K_i = carrying capacity for species i

r_i = intrinsic growth rate for species i

Maximum sustainable yield (MSY_i) = $(0.25 a_i^2)/b_i$

Effort at MSY = $(0.5 a_i)/b_i$

CPUE at MSY = $(0.5 a_i)$

(2) Fox Model (FAO, 1989:243-247; Hongskul, 1975: 169)

Estimated function:

$$Ln(CPUE_i) = a_i - b_i E$$

Where $a_i = Ln(q_i K_i)$

$b_i = q_i / r_i$

and q_i = catchability coefficient for species i

K_i = carrying capacity for species i

r_i = constant of the intrinsic growth rate for species i

Maximum sustainable yield (MSY_i) = $(1/b_i)\exp(a_i-1)$

Effort at MSY = $(1/b_i)$

CPUE at MSY = $\exp(a_i-1)$

(3) Schnute Model (Schnute, 1977:588)

Estimate function:

$$\mathrm{Ln}(\overline{CPUE}_{it}/\overline{CPUE}_{i,t-1}) = a_i - b_i[(\bar{E}_{i,t-1}+\bar{E}_{it})/2] - c_i[(\overline{CPUE}_{i,t-1}+\overline{CPUE}_{it})/2]$$

Where $a_i = r_i$

$b_i = q_i$

$c_i = r_i/q_iK_i$

and q_i = catchability coefficient for species i

K_i = carrying capacity for species i

r_i = intrinsic growth rate for species i

Maximum sustainable yield (MSY_i) = $(a_i{}^2)/(4c_ib_i)$

Effort at MSY = $a_i/2b_i$

CPUE at MSY = $a_i/2c_i$

Appendix C2

Integral Method for Calculating the Catchability Coefficient for Schaefer's and Fox's Models

(1) Catchability coefficient (q) in year t

$$q_t = \mathrm{Ln}[|(zU_t^{1-m} + (1/b))/(zU_{t+1}^{1-m} + (1/b))|]/(zm-z)$$

Where $z = -(a/b)-E$

a and b are the estimated coefficients in Schaefer's and Fox's models

E = standardized effort

m = constant parameter with a value of 2 for the Schaefer's model and a value of 1.001 for the Fox's model

t = year.

(2) Average catchability coefficient over N years

$$\bar{q} = \exp(\sum_{t=1}^{N-1} \mathrm{Ln}(|q_i|)/N-1)$$

Source: Fox (1975).

Appendix D

Brief Description of the Program DYNAMO

DYNAMO is a computer program for building, compiling and executing continuous simulation models. It is an effective tool for simulating dynamic feedback models and it has been used to study business, social, economic, biological, psychological, and engineering systems. The language can be easily learned without the need of programming knowledge. Error checking is thorough and errors are reported in English. Output is easily specified through simple DYNAMO statements. In the following sections, a brief description of DYNAMO's basic principles, variable types, notation conventions, initialization, output and reruns will be presented. Detailed knowledge about DYNAMO can be obtained from Pugh (1983).

The basic tool of continuous simulation is the process of integration. Integration is essential to representing the process of change in real system. Since digital computers cannot integrate exactly, integration in DYNAMO is approximated as the accummulated sum of rectangles of width DT (Delta Time), with the rates held constant over each interval. DYNAMO either uses a simple fixed-step-size (constant DT), first order integration (Euler's) method, or it uses a variable-step-size Runge-Kutta method to control the accuracy of a simulation by comparing a third-order Taylor series solution to a second-order one. Runge-Kutta methods have the advantage of being able to change step-size when appropriate, thereby reducing both inaccuracies due to computer round-off error and the cost (in computer time) of the simulation. Variables whose values are calculated by integration are called "level" (L) variables in DYNAMO. They accumulate the effects of changes in the "rate" variables.

The "rate" (R) variables represent the "net rate of change" of the level variables. Typically, rate variables flow out of one level and into another. Or, they may originate from a "source" or end up in a "sink" outside the system.

Besides the integral relationships, the algebraic relationships are computed in DYNAMO as "auxiliary" (A) equations. The auxiliaries are frequently used as building blocks for the rate equations. As simultaneous equations are not permitted, it must be possible for DYNAMO to order the auxiliary equations so that each auxiliary is computed before it is required for another auxiliary equation.

Built-in functions are other types of equations used in DYNAMO programmes. A built-in function is a shorthand method for indication that a particular mathematical process is to be carried out to compute the value of the function, for example, sine and square root. The built-in functions in DYNAMO fall into five categories:

Delays - DELAY1, DELAY3, DELAYP, DLINF3 and SMOOTH.
Logical - CLIP, MAZ, MIN and SWITCH or FIFZE.
Table look-up - TABHL, TABLE, TABPL and TABXT.
Test input - PULSE, RAMP, SAMPLE, STEP, NOISE and NORMRN.
Trigonometric - COS, EXP, LOGN, SIN AND SQRT.

The actual sequence of computation of DYNAMO begins with the level variables, followed by the auxiliary and then the rate variables. In order to calculate the value of each level variable which depends on its own previous value, DYNAMO must have initial values for all levels. These values are provided on "initial value" (N) equations.

the constants are divided into six groups in DYNAMO. Given constants are defined on special statements which begin with any of these letters: B, C, I, P, SPEC, or T. The six types of given constants are:

1. Boolean (B), whose only meaningful values are 0 and 1, use to select one or another formula for a variable.
2. Constant (C), which assisgns value to a parameter.

3. Given Initial Value (I), used to supply an initial value to one or more levels.

4. Model Parameter (P), used in one or more active equation.

5. Run SPECification (SPEC), which specifies the parameters for a simulation run.

6. Table (T), consists of arrays of numerical values upon which the table look-up functions operate.

Other equation types used in DYNAMO include Exogeneous (E), Supplementary (S), and K. The E statement indicate that the values of the variable are to be supplied by the user from outside the model itself. The S equations are algebraic equations that are computed only to provide output. The K statements are identical to the N equations except that they are recomputed when a model is resumed.

The last step in building a DYNAMO model is to write the control statements which give DYNAMO the information it needs to do the simulation. These statements (SPEC) include information such as the length of the run; the size of the solution interval (DT); how often to produce output; and which variables to output.

DYNAMO provides two forms of output: tabular and plotted. Tabular output is specified by putting the desired variables' names on a PRINT statement. Plotted output is specified by listing the names on a PLOT statement, and all variables will be plotted against TIME, without having to put TIME on the PLOT statement.

When DYNAMO is given a model to run, it first checks the model for errors, reorders the equations, and "compiles" the model into machine language. Before the simulation, DYNAMO generates a listing of the error messages, if any. After a successful compilation and simulation, DYNAMO produces first tabular and/or plotted output. After the BASE run of the model, DYNAMO allows reruns by changing the values of constants and table without any necessity to recompile a model again.

```
*Small Pelagic Fisheries on Northwest Coast of Pen. Malaysia
*Base Case, Bio-Socioeconomic Model
*Four Species, Three Gear Types

NOTE *********Resource or Harvest Section*****************
*Surplus Production Functions

FOR S=KEMB,SCAD,SAR,TUNA
FOR G=TRAWL,SEINE,GILL
A   HARV.K(KEMB)=CCAP(KEMB)*B(KEMB)*TFEFF.K*^
          (1-(B(KEMB)*TFEFF.K)/A(KEMB))
A   HARV.K(TUNA)=TFEFF.K*(A(TUNA)-B(TUNA)*TFEFF.K)
A   HARV.K(SCAD)=TFEFF.K*EXP(A(SCAD)-B(SCAD)*TFEFF.K)
A   HARV.K(SAR)=TFEFF.K*EXP(A(SAR)-B(SAR)*TFEFF.K)
P   A(KEMB)=2.3083
P   A(SCAD)=2.5341
P   A(SAR)=1.7366
P   A(TUNA)=0.6644
P   B(KEMB)=9.8011E-5
P   B(SCAD)=0.1464E-3
P   B(SAR)=0.1722E-3
P   B(TUNA)=0.2695E-4
P   CCAP(KEMB)=187040
A   HAR.K(KEMB,G)=HARV.K(KEMB)*KFACTOR(G)
P   KFACTOR(G)=0.271,0.591,0.138
A   HAR.K(SCAD,G)=HARV.K(SCAD)*SFACTOR(G)
P   SFACTOR(G)=0.185,0.794,0.021
A   HAR.K(SAR,G)=HARV.K(SAR)*SAFACTO(G)
P   SAFACTO(G)=0.214,0.755,0.031
A   HAR.K(TUNA,G)=HARV.K(TUNA)*TFACTOR(G)
P   TFACTOR(G)=0.001,0.814,0.185
A   TRHAR.K=HAR.K(KEMB,TRAWL)+HAR.K(SCAD,TRAWL)+^
            HAR.K(SAR,TRAWL)+HAR.K(TUNA,TRAWL)
A   SHAR.K=HAR.K(KEMB,SEINE)+HAR.K(SCAD,SEINE)+^
           HAR.K(SAR,SEINE)+HAR.K(TUNA,SEINE)
A   GHAR.K=HAR.K(KEMB,GILL)+HAR.K(SCAD,GILL)+^
           HAR.K(SAR,GILL)+HAR.K(TUNA,GILL)
A   TOTHARV.K=TRHAR.K+SHAR.K+GHAR.K

NOTE ************** Fleet Effort ***************************

A   GPROFIT.K(TRAWL)=PRK.K*HAR.K(KEMB,TRAWL)+^
            PRS.K*HAR.K(SCAD,TRAWL)+^
            468*HAR.K(SAR,TRAWL)+PT.K*HAR.K(TUNA,TRAWL)+^
            2319.4*BCR(TRAWL)*TRHAR.K
A   GPROFIT.K(SEINE)=PRK.K*HAR.K(KEMB,SEINE)+^
            PRS.K*HAR.K(SCAD,SEINE)+^
            468*HAR.K(SAR,SEINE)+PT.K*HAR.K(TUNA,SEINE)+^
            2669.49*BCR(SEINE)*SHAR.K
```

```
A   GPROFIT.K(GILL)=PRK.K*HAR.K(KEMB,GILL)+^
           PRS.K*HAR.K(SCAD,GILL)+^
           468*HAR.K(SAR,GILL)+PT.K*HAR.K(TUNA,SEINE)+^
           4709.33*BCR(GILL)*GHAR.K
C   BCR(TRAWL)=10.707
C   BCR(SEINE)=0.107
C   BCR(GILL)=3.495
A   TCOST.K(G)=TEXP(G)*FEFF.K(G)*1000
P   TEXP(G)=15.63,8.646,21.288
A   FCOST.K(G)=FC(G)*VESSEL(G)
P   FC(G)=3012,5436,499
A   CEXP.K(G)=SHCR(G)*(GPROFIT.K(G)-TCOST.K(G))
P   SHCR(G)=0.5,0.5,0.67
C   OC(G)=568.57,395.06,32.16
A   OPC.K(G)=OPP(G)*FEFF.K(G)
C   OPP(G)=9068.1,10823.56,7479.53
A   TOTCOST.K(G)=TCOST.K(G)+FCOST.K(G)+CEXP.K(G)+OPC.K(G)
A   NPROFIT.K(G)=(GPROFIT.K(G)-TCOST.K(G)-^
            FCOST.K(G)- CEXP.K(G))
L   DFEFF.K(G)=DFEFF.J(G)+DT*(FEDOT.JK(G))
R   FEDOT.KL(G)=(ERESP(G)*(NPROFIT.K(G)/(FEFF.K(G))))-^
               ((1+SIGMA)*OC(G)-(LF(G)))
C   LF(G)=0,0,0
P   ERESP(G)=0.0627,0.0365,0.0043
P   RHO=0
A   FEFF.K(G)=MIN(DFEFF.K(G),MFEFF.K(G))
A   MFEFF.K(G)=VESSEL(G)*FPOW(G)*MDAY(G)/1000
C   VESSEL(G)=2886,318,7521
C   FPOW(G)=12.66,35.87,1
A   AFDAY.K(G)=(FEFF.K(G)*1000)/(FPOW(G)*VESSEL(G))
A   LFDAY.K(G)=MIN(AFDAY.K(G),MDAY(G))
C   MDAY(G)=300,280,280
N   DFEFF(G)=IFEFF(G)
I   IFEFF(G)=10180,2650,1217
A   TFEFF.K=SUM(FEFF.K(*))+3329

NOTE **************Price/Demand Functions******************

N   PRK=1920
A   PRK.K=0.0016*(INCOME.K)**1.246*(HARV.K(KEMB))**(-0.123)*^
          (SPS.K)**0.5108*468**0.124
A   SPK.K=SMOOTH(PRK.K,1)
L   INCOME.K=INCOME.J+DT*(IDOT*INCOME.J)
P   IDOT=0.0001
N   INCOME=6176
N   PRS=1060
A   PRS.K=9.223*(HARV.K(SCAD))**(-0.082)*(SPK.K)**0.481*^
          468**0.308
A   SPS.K=SMOOTH(PRS.K,1)
L   SPT.K=SPT.J+DT*(IDOT*INCOME.J)**1.259
A   PT.K=MIN(SPT.K,MAXPT)
P   MAXPT=1232
```

```
N   SPT=1170

NOTE *****************Social Surpluses*******************

A   CSK.K=((CONSK.K)**8.13)*((0.140)*^
          ((PRK.K)**(-7.13)-(1920)**(-7.13)))
A   LCONSK.K=(-6.337)+(1.246)*LOGN(INCOME.K)+^
             (0.511)*LOGN(1060)+^
             (0.124)*LOGN(468)-0.097
A   CONSK.K=EXP(LCONSK.K)
A   CSS.K=(((CONSS.K)**12.136)*((0.09)*((PRS.K)**(-11.136)-^
          (1060)**(-11.136))))
A   LCONSS.K=(2.169)+(0.481)*LOGN(PRK.K)+^
             (0.308)*LOGN(468)+0.0525
A   CONSS.K=(EXP(LCONSS.K)/10)
A   CS.K=-(CSK.K+(CSS.K*10**12.136))
A   SP.K(G)=NPROFIT.K(G)-((1+SIGMA)*OPC.K(G)-LF(G))
A   TOTSP.K=SP.K(TRAWL)+SP.K(SEINE)+SP.K(GILL)
A   TOTBEN.K=TOTSP.K+(CS.K*10**12.136)
A   NVESSEL.K(G)=(FEFF.K(G)*1000)/(FPOW(G)*DAY(G))
C   DAY(G)=271,220,188
A   EMPLOY.K(G)=NVESSEL.K(G)*ACREW(G)
A   TEMPLOY.K(G)=EMPLOY.K(TRAWL)+EMPLOY.K(SEINE)+^
              EMPLOY.K(GILL)
P   ACREW(G)=4,17,2
A   CREWINC.K(G)=CEXP.K(G)/EMPLOY.K(G)

NOTE *************Control Statements********************

SAVE  HARV,TRHAR,SHAR,GHAR,TOTHARV,HAR,FEDOT,FEFF
SAVE  TFEFF,PRK,PRS,PT
SAVE  NVESSEL,EMPLOY,TEMPLOY,CREWINC,SP,TOTSP
SAVE  CSK,CSS,CS,TOTBEN,AFDAY
SPEC  DT=1/LENGTH=50/SAVPER=1/REL_ERR=0.01
→
```

Appendix Table 1 Regression Results of Schaefer Model for Indian Mackerel

```
|_OLS CPUEK STDEFF / RSTAT ANOVA PCOR

REQUIRED MEMORY IS PAR=    3 CURRENT PAR=  254
OLS ESTIMATION
      23 OBSERVATIONS     DEPENDENT VARIABLE = CPUEK
...NOTE..SAMPLE RANGE SET TO:    1,   23

 R-SQUARE =   0.1059     R-SQUARE ADJUSTED =   0.0633
VARIANCE OF THE ESTIMATE-SIGMA**2 =   1.3033
STANDARD ERROR OF THE ESTIMATE-SIGMA =   1.1416
SUM OF SQUARED ERRORS-SSE=   27.369
MEAN OF DEPENDENT VARIABLE =   2.2115
LOG OF THE LIKELIHOOD FUNCTION = -34.6357

MODEL SELECTION TESTS - SEE JUDGE ET.AL.(1985, P.242)
 AKAIKE (1969) FINAL PREDICTION ERROR- FPE =    1.4166
   (FPE ALSO KNOWN AS AMEMIYA PREDICTION CRITERION -PC)
 AKAIKE (1973) INFORMATION CRITERION- LOG AIC =  0.34784
 SCHWARZ(1978) CRITERION-LOG SC =  0.44658
MODEL SELECTION TESTS - SEE RAMANATHAN(1989,P.166)
 CRAVEN-WAHBA(1979) GENERALIZED CROSS VALIDATION(1979) -GCV=  1.4274
 HANNAN AND QUINN(1979) CRITERION -HQ=   1.4516
 RICE (1984) CRITERION-RICE=   1.4405
 SHIBATA (1981) CRITERION-SHIBATA=   1.3969
 SCHWARTZ (1978) CRITERION-SC=   1.5630
 AKAIKE (1974)INFORMATION CRITERION-AIC=   1.4160

                     ANALYSIS OF VARIANCE - FROM MEAN
                      SS          DF          MS                 F
REGRESSION         3.2414          1.       3.2414             2.487
ERROR              27.369         21.       1.3033
TOTAL              30.611         22.       1.3914

                     ANALYSIS OF VARIANCE - FROM ZERO
                      SS          DF          MS                 F
REGRESSION         115.73          2.       57.863            44.397
ERROR              27.369         21.       1.3033
TOTAL              143.10         23.       6.2215


VARIABLE   ESTIMATED   STANDARD   T-RATIO    PARTIAL STANDARDIZED ELASTICITY
  NAME    COEFFICIENT   ERROR      21 DF      CORR.  COEFFICIENT  AT MEANS

STDEFF   -0.14592E-03 0.92530E-04  -1.5770    -0.3254 -0.32541      -1.2238
CONSTANT   4.9179       1.7325      2.8385     0.5266  0.00000E+00   2.2238
```

```
CORRELATION MATRIX OF COEFFICIENTS
STDEFF    1.00000
CONSTANT -0.99052      1.00000
            STDEFF       CONSTANT

DURBIN-WATSON = 0.6090    VON NEUMANN RATIO = 0.6367    RHO =  0.58981
RESIDUAL SUM =  0.95479E-14  RESIDUAL VARIANCE =   1.3033
SUM OF ABSOLUTE ERRORS=   21.386
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.1059
RUNS TEST:    7 RUNS,   11 POSITIVE,   12 NEGATIVE, NORMAL STATISTIC =   -2.3430
```

Appendix Table 2 Regression Results of Schaefer Model for Scads

```
|_OLS CPUES STDEFF / RSTAT ANOVA PCOR

REQUIRED MEMORY IS PAR=    3 CURRENT PAR=  254
OLS ESTIMATION
      23 OBSERVATIONS     DEPENDENT VARIABLE = CPUES
...NOTE..SAMPLE RANGE SET TO:    1,    23

 R-SQUARE =    0.4146     R-SQUARE ADJUSTED =    0.3868
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.13126
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.36230
SUM OF SQUARED ERRORS-SSE=   2.7565
MEAN OF DEPENDENT VARIABLE =  0.95165
LOG OF THE LIKELIHOOD FUNCTION = -8.23787

MODEL SELECTION TESTS - SEE JUDGE ET.AL.(1985, P.242)
 AKAIKE (1969) FINAL PREDICTION ERROR- FPE =    0.14267
   (FPE ALSO KNOWN AS AMEMIYA PREDICTION CRITERION -PC)
 AKAIKE (1973) INFORMATION CRITERION- LOG AIC =  -1.9476
 SCHWARZ(1978) CRITERION-LOG SC =  -1.8489
MODEL SELECTION TESTS - SEE RAMANATHAN(1989,P.166)
 CRAVEN-WAHBA(1979) GENERALIZED CROSS VALIDATION(1979) -GCV=  0.14376
 HANNAN AND QUINN(1979) CRITERION -HQ=  0.14620
 RICE (1984) CRITERION-RICE=  0.14508
 SHIBATA (1981) CRITERION-SHIBATA=  0.14069
 SCHWARTZ (1978) CRITERION-SC=  0.15741
 AKAIKE (1974)INFORMATION CRITERION-AIC=  0.14261

                    ANALYSIS OF VARIANCE - FROM MEAN
                     SS           DF            MS                  F
REGRESSION         1.9526          1.         1.9526              14.876
ERROR              2.7565         21.        0.13126
TOTAL              4.7091         22.        0.21405

                    ANALYSIS OF VARIANCE - FROM ZERO
                     SS           DF            MS                  F
REGRESSION         22.782          2.         11.391              86.783
ERROR              2.7565         21.        0.13126
TOTAL              25.539         23.         1.1104


VARIABLE    ESTIMATED    STANDARD    T-RATIO     PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT    ERROR       21 DF       CORR.  COEFFICIENT   AT MEANS

STDEFF   -0.11326E-03 0.29365E-04  -3.8569     -0.6439 -0.64393      -2.2073
```

```
CONSTANT   3.0522     0.54983       5.5512     0.7712  0.00000E+00   3.2073

CORRELATION MATRIX OF COEFFICIENTS
STDEFF     1.0000
CONSTANT -0.99052      1.00000
            STDEFF        CONSTANT

DURBIN-WATSON = 1.1011    VON NEUMANN RATIO = 1.1512    RHO =  0.43316
RESIDUAL SUM =  0.00000E+00  RESIDUAL VARIANCE =  0.13126
SUM OF ABSOLUTE ERRORS=   6.7584
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.4146
RUNS TEST:    8 RUNS,   11 POSITIVE,   12 NEGATIVE, NORMAL STATISTIC =   -1.9153
```

Appendix Table 3 Regression Results of Schaefer Model for Sardines

```
|_OLS CPUSA STDEFF / RSTAT ANOVA PCOR

REQUIRED MEMORY IS PAR=    3 CURRENT PAR=  254
OLS ESTIMATION
      23 OBSERVATIONS     DEPENDENT VARIABLE = CPUSA
...NOTE..SAMPLE RANGE SET TO:    1,   23

 R-SQUARE =   0.4348     R-SQUARE ADJUSTED =   0.4078
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.12670E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.11256
SUM OF SQUARED ERRORS-SSE=  0.26606
MEAN OF DEPENDENT VARIABLE =  0.27496
LOG OF THE LIKELIHOOD FUNCTION =  18.6489

MODEL SELECTION TESTS - SEE JUDGE ET.AL.(1985, P.242)
 AKAIKE (1969) FINAL PREDICTION ERROR- FPE =   0.13771E-01
   (FPE ALSO KNOWN AS AMEMIYA PREDICTION CRITERION -PC)
 AKAIKE (1973) INFORMATION CRITERION- LOG AIC =  -4.2856
 SCHWARZ(1978) CRITERION-LOG SC =  -4.1869
MODEL SELECTION TESTS - SEE RAMANATHAN(1989,P.166)
 CRAVEN-WAHBA(1979) GENERALIZED CROSS VALIDATION(1979) -GCV=  0.13876E-01
 HANNAN AND QUINN(1979) CRITERION -HQ=  0.14111E-01
 RICE (1984) CRITERION-RICE=  0.14003E-01
 SHIBATA (1981) CRITERION-SHIBATA=  0.13580E-01
 SCHWARTZ (1978) CRITERION-SC=  0.15194E-01
 AKAIKE (1974)INFORMATION CRITERION-AIC=  0.13765E-01

                     ANALYSIS OF VARIANCE - FROM MEAN
                      SS         DF           MS               F
REGRESSION       0.20464         1.       0.20464           16.152
ERROR            0.26606        21.       0.12670E-01
TOTAL            0.47070        22.       0.21396E-01

                     ANALYSIS OF VARIANCE - FROM ZERO
                      SS         DF           MS               F
REGRESSION        1.9435         2.       0.97173           76.698
ERROR            0.26606        21.       0.12670E-01
TOTAL             2.2095        23.       0.96066E-01


VARIABLE    ESTIMATED   STANDARD   T-RATIO    PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT    ERROR     21 DF      CORR.  COEFFICIENT  AT MEANS

STDEFF    -0.36665E-04 0.91231E-05 -4.0190    -0.6594 -0.65936      -2.4732
```

```
CONSTANT  0.95497     0.17082       5.5904     0.7734  0.00000E+00   3.4732

CORRELATION MATRIX OF COEFFICIENTS
STDEFF     1.0000
CONSTANT -0.99052       1.0000
            STDEFF       CONSTANT

DURBIN-WATSON = 1.3571    VON NEUMANN RATIO = 1.4188    RHO =  0.29831
RESIDUAL SUM =  0.72858E-15  RESIDUAL VARIANCE =  0.12670E-01
SUM OF ABSOLUTE ERRORS=   1.9316
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.4348
RUNS TEST:   12 RUNS,   10 POSITIVE,   13 NEGATIVE, NORMAL STATISTIC =   -0.1323
```

Appendix Table 4 Regression Results of Schaefer Model for Tuna

```
|_OLS CPUET STDEFF / RSTAT ANOVA PCOR

REQUIRED MEMORY IS PAR=    3 CURRENT PAR=  254
OLS ESTIMATION
      23 OBSERVATIONS     DEPENDENT VARIABLE = CPUET
...NOTE..SAMPLE RANGE SET TO:     1,    23

 R-SQUARE =   0.4948     R-SQUARE ADJUSTED =   0.4708
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.53759E-02
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.73320E-01
SUM OF SQUARED ERRORS-SSE=  0.11289
MEAN OF DEPENDENT VARIABLE =  0.16452
LOG OF THE LIKELIHOOD FUNCTION =  28.5077

MODEL SELECTION TESTS - SEE JUDGE ET.AL.(1985, P.242)
 AKAIKE (1969) FINAL PREDICTION ERROR- FPE =   0.58433E-02
   (FPE ALSO KNOWN AS AMEMIYA PREDICTION CRITERION -PC)
 AKAIKE (1973) INFORMATION CRITERION- LOG AIC =  -5.1429
 SCHWARZ(1978) CRITERION-LOG SC =  -5.0442
MODEL SELECTION TESTS - SEE RAMANATHAN(1989,P.166)
 CRAVEN-WAHBA(1979) GENERALIZED CROSS VALIDATION(1979) -GCV=  0.58879E-02
 HANNAN AND QUINN(1979) CRITERION -HQ=  0.59876E-02
 RICE (1984) CRITERION-RICE=  0.59418E-02
 SHIBATA (1981) CRITERION-SHIBATA=  0.57620E-02
 SCHWARTZ (1978) CRITERION-SC=  0.64469E-02
 AKAIKE (1974)INFORMATION CRITERION-AIC=  0.58408E-02

                    ANALYSIS OF VARIANCE - FROM MEAN
                     SS          DF            MS              F
REGRESSION       0.11058          1.       0.11058            20.569
ERROR            0.11289         21.       0.53759E-02
TOTAL            0.22347         22.       0.10158E-01

                    ANALYSIS OF VARIANCE - FROM ZERO
                     SS          DF            MS              F
REGRESSION       0.73313          2.       0.36656            68.187
ERROR            0.11289         21.       0.53759E-02
TOTAL            0.84602         23.       0.36784E-01


VARIABLE    ESTIMATED   STANDARD   T-RATIO     PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT   ERROR       21 DF      CORR.  COEFFICIENT  AT MEANS

STDEFF   -0.26952E-04 0.59427E-05  -4.5353    -0.7034 -0.70343      -3.0383
```

```
CONSTANT  0.66439     0.11127       5.9709     0.7933  0.00000E+00   4.0383

CORRELATION MATRIX OF COEFFICIENTS
STDEFF     1.0000
CONSTANT -0.99052       1.0000
             STDEFF       CONSTANT

DURBIN-WATSON = 1.1787    VON NEUMANN RATIO = 1.2322    RHO =  0.38898
RESIDUAL SUM =  0.69389E-15  RESIDUAL VARIANCE =  0.53759E-02
SUM OF ABSOLUTE ERRORS=   1.2815
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.4948
RUNS TEST:    8 RUNS,    10 POSITIVE,    13 NEGATIVE, NORMAL STATISTIC =   -1.8706
```

Appendix Table 5 Regression Results of Fox Model for Indian Mackerel

```
|_OLS LUK STDEFF / RSTAT ANOVA PCOR

REQUIRED MEMORY IS PAR=    4 CURRENT PAR=  258
OLS ESTIMATION
      23 OBSERVATIONS     DEPENDENT VARIABLE = LUK
...NOTE..SAMPLE RANGE SET TO:    1,    23

 R-SQUARE =   0.1351     R-SQUARE ADJUSTED =   0.0939
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.42708
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.65351
SUM OF SQUARED ERRORS-SSE=   8.9686
MEAN OF DEPENDENT VARIABLE =  0.60718
LOG OF THE LIKELIHOOD FUNCTION = -21.8053

MODEL SELECTION TESTS - SEE JUDGE ET.AL.(1985, P.242)
 AKAIKE (1969) FINAL PREDICTION ERROR- FPE =   0.46421
   (FPE ALSO KNOWN AS AMEMIYA PREDICTION CRITERION -PC)
 AKAIKE (1973) INFORMATION CRITERION- LOG AIC = -0.76785
 SCHWARZ(1978) CRITERION-LOG SC = -0.66911
MODEL SELECTION TESTS - SEE RAMANATHAN(1989,P.166)
 CRAVEN-WAHBA(1979) GENERALIZED CROSS VALIDATION(1979) -GCV=  0.46775
 HANNAN AND QUINN(1979) CRITERION -HQ=  0.47567
 RICE (1984) CRITERION-RICE=  0.47203
 SHIBATA (1981) CRITERION-SHIBATA=  0.45775
 SCHWARTZ (1978) CRITERION-SC=  0.51216
 AKAIKE (1974)INFORMATION CRITERION-AIC=  0.46401

                      ANALYSIS OF VARIANCE - FROM MEAN
                       SS           DF            MS                  F
REGRESSION        1.4012          1.        1.4012                3.281
ERROR             8.9686         21.       0.42708
TOTAL             10.370         22.       0.47136

                      ANALYSIS OF VARIANCE - FROM ZERO
                       SS           DF            MS                  F
REGRESSION        9.8807          2.        4.9404               11.568
ERROR             8.9686         21.       0.42708
TOTAL             18.849         23.       0.81954


VARIABLE    ESTIMATED   STANDARD   T-RATIO     PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT    ERROR      21 DF       CORR.  COEFFICIENT  AT MEANS

STDEFF    -0.95944E-04 0.52968E-04  -1.8114    -0.3676 -0.36760       -2.9306
CONSTANT   2.3866      0.99178       2.4064     0.4649  0.00000E+00    3.9306

CORRELATION MATRIX OF COEFFICIENTS
STDEFF     1.0000
```

```
CONSTANT -0.99052      1.00000
            STDEFF       CONSTANT

DURBIN-WATSON = 0.5847    VON NEUMANN RATIO = 0.6112    RHO =  0.64007
RESIDUAL SUM =  0.61062E-14  RESIDUAL VARIANCE =  0.42708
SUM OF ABSOLUTE ERRORS=   11.791
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.1351
RUNS TEST:    7 RUNS,    13 POSITIVE,    10 NEGATIVE, NORMAL STATISTIC =   -2.3052
```

Appendix Table 6 Regression Results of Fox Model for Scads

```
|_OLS LUS STDEFF / RSTAT ANOVA PCOR

REQUIRED MEMORY IS PAR=     4 CURRENT PAR=  258
OLS ESTIMATION
      23 OBSERVATIONS     DEPENDENT VARIABLE = LUS
...NOTE..SAMPLE RANGE SET TO:     1,    23

 R-SQUARE =    0.4896     R-SQUARE ADJUSTED =    0.4653
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.16201
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.40251
SUM OF SQUARED ERRORS-SSE=   3.4022
MEAN OF DEPENDENT VARIABLE = -0.18148
LOG OF THE LIKELIHOOD FUNCTION = -10.6583

MODEL SELECTION TESTS - SEE JUDGE ET.AL.(1985, P.242)
 AKAIKE (1969) FINAL PREDICTION ERROR- FPE =    0.17610
   (FPE ALSO KNOWN AS AMEMIYA PREDICTION CRITERION -PC)
 AKAIKE (1973) INFORMATION CRITERION- LOG AIC =  -1.7372
 SCHWARZ(1978) CRITERION-LOG SC =  -1.6384
MODEL SELECTION TESTS - SEE RAMANATHAN(1989,P.166)
 CRAVEN-WAHBA(1979) GENERALIZED CROSS VALIDATION(1979) -GCV=  0.17744
 HANNAN AND QUINN(1979) CRITERION -HQ=  0.18045
 RICE (1984) CRITERION-RICE=  0.17906
 SHIBATA (1981) CRITERION-SHIBATA=  0.17365
 SCHWARTZ (1978) CRITERION-SC=  0.19429
 AKAIKE (1974)INFORMATION CRITERION-AIC=  0.17602

                     ANALYSIS OF VARIANCE - FROM MEAN
                      SS          DF          MS                 F
REGRESSION         3.2635          1.       3.2635             20.144
ERROR              3.4022         21.      0.16201
TOTAL              6.6657         22.      0.30299

                     ANALYSIS OF VARIANCE - FROM ZERO
                      SS          DF          MS                 F
REGRESSION         4.0210          2.       2.0105             12.410
ERROR              3.4022         21.      0.16201
TOTAL              7.4232         23.      0.32275


VARIABLE   ESTIMATED   STANDARD   T-RATIO    PARTIAL STANDARDIZED ELASTICITY
  NAME    COEFFICIENT   ERROR      21 DF      CORR.  COEFFICIENT  AT MEANS

STDEFF   -0.14642E-03 0.32624E-04  -4.4882    -0.6997 -0.69971       14.963
CONSTANT   2.5341      0.61085      4.1485     0.6711  0.00000E+00  -13.963
```

```
CORRELATION MATRIX OF COEFFICIENTS
STDEFF     1.0000
CONSTANT -0.99052       1.0000
             STDEFF       CONSTANT

DURBIN-WATSON = 0.9479    VON NEUMANN RATIO = 0.9910    RHO =  0.50157
RESIDUAL SUM =  0.38858E-14  RESIDUAL VARIANCE =  0.16201
SUM OF ABSOLUTE ERRORS=   7.6369
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.4896
RUNS TEST:    8 RUNS,   12 POSITIVE,   11 NEGATIVE, NORMAL STATISTIC =   -1.9153
```

Appendix Table 7 Regression Results of Fox Model for Sardines

```
|_OLS LUSA STDEFF / RSTAT ANOVA PCOR

REQUIRED MEMORY IS PAR=    4 CURRENT PAR=  258
OLS ESTIMATION
      23 OBSERVATIONS     DEPENDENT VARIABLE = LUSA
...NOTE..SAMPLE RANGE SET TO:    1,   23

 R-SQUARE =   0.4989     R-SQUARE ADJUSTED =   0.4751
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.21572
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.46446
SUM OF SQUARED ERRORS-SSE=   4.5302
MEAN OF DEPENDENT VARIABLE =  -1.4561
LOG OF THE LIKELIHOOD FUNCTION = -13.9512

MODEL SELECTION TESTS - SEE JUDGE ET.AL.(1985, P.242)
 AKAIKE (1969) FINAL PREDICTION ERROR- FPE =   0.23448
   (FPE ALSO KNOWN AS AMEMIYA PREDICTION CRITERION -PC)
 AKAIKE (1973) INFORMATION CRITERION- LOG AIC =  -1.4508
 SCHWARZ(1978) CRITERION-LOG SC =  -1.3521
MODEL SELECTION TESTS - SEE RAMANATHAN(1989,P.166)
 CRAVEN-WAHBA(1979) GENERALIZED CROSS VALIDATION(1979) -GCV=  0.23627
 HANNAN AND QUINN(1979) CRITERION -HQ=  0.24027
 RICE (1984) CRITERION-RICE=  0.23843
 SHIBATA (1981) CRITERION-SHIBATA=  0.23122
 SCHWARTZ (1978) CRITERION-SC=  0.25870
 AKAIKE (1974)INFORMATION CRITERION-AIC=  0.23438

                    ANALYSIS OF VARIANCE - FROM MEAN
                     SS          DF           MS                F
REGRESSION        4.5110         1.        4.5110            20.911
ERROR             4.5302        21.       0.21572
TOTAL             9.0412        22.       0.41096

                    ANALYSIS OF VARIANCE - FROM ZERO
                     SS          DF           MS                F
REGRESSION        53.277         2.        26.639           123.485
ERROR             4.5302        21.       0.21572
TOTAL             57.807        23.        2.5134


VARIABLE   ESTIMATED  STANDARD   T-RATIO     PARTIAL STANDARDIZED ELASTICITY
  NAME    COEFFICIENT   ERROR      21 DF       CORR.  COEFFICIENT  AT MEANS

STDEFF   -0.17215E-03 0.37645E-04  -4.5729    -0.7064 -0.70636        2.1926
CONSTANT   1.7366      0.70487      2.4637     0.4735  0.00000E+00  -1.1926
```

```
CORRELATION MATRIX OF COEFFICIENTS
STDEFF      1.0000
CONSTANT -0.99052       1.0000
             STDEFF       CONSTANT

DURBIN-WATSON = 1.0964    VON NEUMANN RATIO = 1.1463    RHO =  0.29485
RESIDUAL SUM =  0.92149E-14  RESIDUAL VARIANCE =  0.21572
SUM OF ABSOLUTE ERRORS=   7.7641
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.4989
RUNS TEST:    8 RUNS,    12 POSITIVE,    11 NEGATIVE, NORMAL STATISTIC =   -1.9153
```

Appendix Table 8 Regression Results of Fox Model for Tuna

```
|_OLS LUT STDEFF / RSTAT ANOVA PCOR

REQUIRED MEMORY IS PAR=     4 CURRENT PAR=  258
OLS ESTIMATION
      23 OBSERVATIONS     DEPENDENT VARIABLE = LUT
...NOTE..SAMPLE RANGE SET TO:     1,    23

 R-SQUARE =    0.5839     R-SQUARE ADJUSTED =    0.5641
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.18839
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.43404
SUM OF SQUARED ERRORS-SSE=   3.9562
MEAN OF DEPENDENT VARIABLE =  -1.9931
LOG OF THE LIKELIHOOD FUNCTION = -12.3933

MODEL SELECTION TESTS - SEE JUDGE ET.AL.(1985, P.242)
 AKAIKE (1969) FINAL PREDICTION ERROR- FPE =    0.20477
   (FPE ALSO KNOWN AS AMEMIYA PREDICTION CRITERION -PC)
 AKAIKE (1973) INFORMATION CRITERION- LOG AIC =  -1.5863
 SCHWARZ(1978) CRITERION-LOG SC =  -1.4876
MODEL SELECTION TESTS - SEE RAMANATHAN(1989,P.166)
 CRAVEN-WAHBA(1979) GENERALIZED CROSS VALIDATION(1979) -GCV=  0.20633
 HANNAN AND QUINN(1979) CRITERION -HQ=  0.20983
 RICE (1984) CRITERION-RICE=  0.20822
 SHIBATA (1981) CRITERION-SHIBATA=  0.20192
 SCHWARTZ (1978) CRITERION-SC=  0.22593
 AKAIKE (1974)INFORMATION CRITERION-AIC=  0.20468

                    ANALYSIS OF VARIANCE - FROM MEAN
                 SS            DF            MS                 F
REGRESSION     5.5512          1.          5.5512             29.466
ERROR          3.9562         21.         0.18839
TOTAL          9.5074         22.         0.43215

                    ANALYSIS OF VARIANCE - FROM ZERO
                 SS            DF            MS                 F
REGRESSION     96.916          2.          48.458            257.219
ERROR          3.9562         21.         0.18839
TOTAL          100.87         23.          4.3857


VARIABLE    ESTIMATED   STANDARD   T-RATIO    PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT   ERROR      21 DF      CORR.  COEFFICIENT  AT MEANS

STDEFF   -0.19096E-03 0.35180E-04  -5.4283    -0.7641 -0.76412       1.7770
CONSTANT   1.5487      0.65871      2.3510     0.4565  0.00000E+00 -0.77701
```

```
CORRELATION MATRIX OF COEFFICIENTS
STDEFF     1.0000
CONSTANT -0.99052       1.0000
             STDEFF       CONSTANT

DURBIN-WATSON = 1.1146    VON NEUMANN RATIO = 1.1653    RHO =  0.30913
RESIDUAL SUM =  0.19096E-13  RESIDUAL VARIANCE =  0.18839
SUM OF ABSOLUTE ERRORS=   7.7112
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.5839
RUNS TEST:   14 RUNS,   10 POSITIVE,   13 NEGATIVE, NORMAL STATISTIC =    0.7369
```

Appendix Table 9 Regression Results of Schnute Model for Indian Mackerel

```
|_OLS DK IV1 I2K / RSTAT ANOVA PCOR

REQUIRED MEMORY IS PAR=    4 CURRENT PAR=  249
OLS ESTIMATION
      21 OBSERVATIONS     DEPENDENT VARIABLE = DK
...NOTE..SAMPLE RANGE SET TO:     1,    21

 R-SQUARE =   0.5476     R-SQUARE ADJUSTED =   0.4974
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.41101E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.20273
SUM OF SQUARED ERRORS-SSE=  0.73982
MEAN OF DEPENDENT VARIABLE = -0.10332E-01
LOG OF THE LIKELIHOOD FUNCTION =  5.33395

MODEL SELECTION TESTS - SEE JUDGE ET.AL.(1985, P.242)
 AKAIKE (1969) FINAL PREDICTION ERROR- FPE =   0.46973E-01
   (FPE ALSO KNOWN AS AMEMIYA PREDICTION CRITERION -PC)
 AKAIKE (1973) INFORMATION CRITERION- LOG AIC =  -3.0602
 SCHWARZ(1978) CRITERION-LOG SC =  -2.9109
MODEL SELECTION TESTS - SEE RAMANATHAN(1989,P.166)
 CRAVEN-WAHBA(1979) GENERALIZED CROSS VALIDATION(1979) -GCV=  0.47951E-01
 HANNAN AND QUINN(1979) CRITERION -HQ=  0.48423E-01
 RICE (1984) CRITERION-RICE=  0.49321E-01
 SHIBATA (1981) CRITERION-SHIBATA=  0.45295E-01
 SCHWARTZ (1978) CRITERION-SC=  0.54425E-01
 AKAIKE (1974)INFORMATION CRITERION-AIC=  0.46880E-01

                    ANALYSIS OF VARIANCE - FROM MEAN
                     SS          DF          MS                F
REGRESSION       0.89562          2.      0.44781             10.895
ERROR            0.73982         18.      0.41101E-01
TOTAL             1.6354         20.      0.81772E-01

                    ANALYSIS OF VARIANCE - FROM ZERO
                     SS          DF          MS                F
REGRESSION       0.89786          3.      0.29929              7.282
ERROR            0.73982         18.      0.41101E-01
TOTAL             1.6377         21.      0.77985E-01


VARIABLE   ESTIMATED  STANDARD   T-RATIO    PARTIAL STANDARDIZED ELASTICITY
  NAME    COEFFICIENT   ERROR      18 DF     CORR.  COEFFICIENT  AT MEANS

IV1     -0.98011E-04 0.21039E-04 -4.6584   -0.7393 -0.80735       203.11
I2K     -0.12594     0.58412E-01 -2.1561   -0.4531 -0.37368       21.302
CONSTANT   2.3083     0.50247      4.5939    0.7346  0.00000E+00  -223.41

CORRELATION MATRIX OF COEFFICIENTS
```

```
IV1        1.0000
I2K        0.40409      1.0000
CONSTANT -0.97863     -0.56543      1.00000
             IV1          I2K          CONSTANT

DURBIN-WATSON = 2.1404    VON NEUMANN RATIO = 2.2474    RHO = -0.12008
RESIDUAL SUM =  0.65226E-14  RESIDUAL VARIANCE =  0.41101E-01
SUM OF ABSOLUTE ERRORS=   3.0695
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.5476
RUNS TEST:   14 RUNS,    10 POSITIVE,    11 NEGATIVE, NORMAL STATISTIC =    1.1328
```

Appendix Table 10 Regression Results of Schnute Model for Scads

```
|_OLS DS IV1 I2S / RSTAT ANOVA PCOR

REQUIRED MEMORY IS PAR=    4 CURRENT PAR=  249
OLS ESTIMATION
      21 OBSERVATIONS     DEPENDENT VARIABLE = DS
...NOTE..SAMPLE RANGE SET TO:    1,   21

 R-SQUARE =   0.0183     R-SQUARE ADJUSTED =  -0.0908
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.60299E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.24556
SUM OF SQUARED ERRORS-SSE=   1.0854
MEAN OF DEPENDENT VARIABLE =  0.58271E-01
LOG OF THE LIKELIHOOD FUNCTION =  1.30957

MODEL SELECTION TESTS - SEE JUDGE ET.AL.(1985, P.242)
 AKAIKE (1969) FINAL PREDICTION ERROR- FPE =   0.68913E-01
   (FPE ALSO KNOWN AS AMEMIYA PREDICTION CRITERION -PC)
 AKAIKE (1973) INFORMATION CRITERION- LOG AIC =  -2.6769
 SCHWARZ(1978) CRITERION-LOG SC =  -2.5277
MODEL SELECTION TESTS - SEE RAMANATHAN(1989,P.166)
 CRAVEN-WAHBA(1979) GENERALIZED CROSS VALIDATION(1979) -GCV=  0.70348E-01
 HANNAN AND QUINN(1979) CRITERION -HQ=  0.71041E-01
 RICE (1984) CRITERION-RICE=  0.72358E-01
 SHIBATA (1981) CRITERION-SHIBATA=  0.66451E-01
 SCHWARTZ (1978) CRITERION-SC=  0.79845E-01
 AKAIKE (1974)INFORMATION CRITERION-AIC=  0.68777E-01

                   ANALYSIS OF VARIANCE - FROM MEAN
                    SS           DF          MS                 F
REGRESSION      0.20233E-01      2.      0.10116E-01          0.168
ERROR            1.0854         18.      0.60299E-01
TOTAL            1.1056         20.      0.55280E-01

                   ANALYSIS OF VARIANCE - FROM ZERO
                    SS           DF          MS                 F
REGRESSION      0.91539E-01      3.      0.30513E-01          0.506
ERROR            1.0854         18.      0.60299E-01
TOTAL            1.1769         21.      0.56043E-01


VARIABLE   ESTIMATED  STANDARD   T-RATIO    PARTIAL STANDARDIZED ELASTICITY
  NAME    COEFFICIENT   ERROR      18 DF     CORR.  COEFFICIENT  AT MEANS

IV1      -0.15588E-04 0.33752E-04 -0.46185   -0.1082 -0.15617      -5.7278
I2S      -0.14010     0.24346     -0.57548   -0.1344 -0.19460      -1.9305
```

```
CONSTANT  0.50453     0.87617      0.57583     0.1345  0.00000E+00   8.6583

CORRELATION MATRIX OF COEFFICIENTS
IV1        1.0000
I2S       0.72320      1.0000
CONSTANT -0.98616     -0.81961      1.0000
             IV1         I2S         CONSTANT

DURBIN-WATSON = 1.7526    VON NEUMANN RATIO = 1.8402    RHO =  0.11263
RESIDUAL SUM =  0.14988E-14  RESIDUAL VARIANCE =  0.60299E-01
SUM OF ABSOLUTE ERRORS=   3.9750
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.0183
RUNS TEST:   11 RUNS,   11 POSITIVE,   10 NEGATIVE, NORMAL STATISTIC =   -0.2137
```

Appendix Table 11 Regression Results of Schnute Model for Sardines

```
|_OLS DSA IV1 I2SA / RSTAT ANOVA PCOR

REQUIRED MEMORY IS PAR=    4 CURRENT PAR=  249
OLS ESTIMATION
      21 OBSERVATIONS     DEPENDENT VARIABLE = DSA
...NOTE..SAMPLE RANGE SET TO:    1,    21

 R-SQUARE =   0.1626     R-SQUARE ADJUSTED =   0.0696
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.95489E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.30901
SUM OF SQUARED ERRORS-SSE=   1.7188
MEAN OF DEPENDENT VARIABLE =  0.61170E-01
LOG OF THE LIKELIHOOD FUNCTION = -3.51726

MODEL SELECTION TESTS - SEE JUDGE ET.AL.(1985, P.242)
 AKAIKE (1969) FINAL PREDICTION ERROR- FPE =   0.10913
   (FPE ALSO KNOWN AS AMEMIYA PREDICTION CRITERION -PC)
 AKAIKE (1973) INFORMATION CRITERION- LOG AIC =  -2.2172
 SCHWARZ(1978) CRITERION-LOG SC =  -2.0680
MODEL SELECTION TESTS - SEE RAMANATHAN(1989,P.166)
 CRAVEN-WAHBA(1979) GENERALIZED CROSS VALIDATION(1979) -GCV=  0.11140
 HANNAN AND QUINN(1979) CRITERION -HQ=  0.11250
 RICE (1984) CRITERION-RICE=  0.11459
 SHIBATA (1981) CRITERION-SHIBATA=  0.10523
 SCHWARTZ (1978) CRITERION-SC=  0.12644
 AKAIKE (1974)INFORMATION CRITERION-AIC=  0.10892

                    ANALYSIS OF VARIANCE - FROM MEAN
                    SS          DF          MS               F
REGRESSION      0.33374        2.       0.16687            1.748
ERROR            1.7188       18.       0.95489E-01
TOTAL            2.0525       20.       0.10263

                    ANALYSIS OF VARIANCE - FROM ZERO
                    SS          DF          MS               F
REGRESSION      0.41231        3.       0.13744            1.439
ERROR            1.7188       18.       0.95489E-01
TOTAL            2.1311       21.       0.10148


VARIABLE   ESTIMATED   STANDARD   T-RATIO    PARTIAL STANDARDIZED ELASTICITY
  NAME    COEFFICIENT    ERROR      18 DF      CORR.  COEFFICIENT  AT MEANS

IV1      0.78402E-04 0.51271E-04   1.5292     0.3391  0.57648       27.443
I2SA     0.77415       1.2119     0.63881     0.1489  0.24083       3.0209
```

```
CONSTANT  -1.8023      1.3469      -1.3381    -0.3008  0.00000E+00  -29.464

CORRELATION MATRIX OF COEFFICIENTS
IV1        1.0000
I2SA      0.82016      1.0000
CONSTANT -0.99116     -0.88321      1.0000
            IV1          I2SA        CONSTANT

DURBIN-WATSON = 1.6820    VON NEUMANN RATIO = 1.7661    RHO =  0.09449
RESIDUAL SUM = -0.62311E-14  RESIDUAL VARIANCE =  0.95489E-01
SUM OF ABSOLUTE ERRORS=   5.2318
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.1626
RUNS TEST:   12 RUNS,    9 POSITIVE,   12 NEGATIVE, NORMAL STATISTIC =    0.3269
```

Appendix Table 12 Regression Results of Schnute Model for Tuna

```
|_OLS DT IV1 I2T / RSTAT ANOVA PCOR

REQUIRED MEMORY IS PAR=    4 CURRENT PAR=  249
OLS ESTIMATION
      21 OBSERVATIONS     DEPENDENT VARIABLE = DT
...NOTE..SAMPLE RANGE SET TO:     1,    21

 R-SQUARE =    0.0316      R-SQUARE ADJUSTED =  -0.0760
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.87973E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.29660
SUM OF SQUARED ERRORS-SSE=   1.5835
MEAN OF DEPENDENT VARIABLE =  0.78787E-01
LOG OF THE LIKELIHOOD FUNCTION = -2.65656

MODEL SELECTION TESTS - SEE JUDGE ET.AL.(1985, P.242)
 AKAIKE (1969) FINAL PREDICTION ERROR- FPE =    0.10054
   (FPE ALSO KNOWN AS AMEMIYA PREDICTION CRITERION -PC)
 AKAIKE (1973) INFORMATION CRITERION- LOG AIC =  -2.2992
 SCHWARZ(1978) CRITERION-LOG SC =  -2.1499
MODEL SELECTION TESTS - SEE RAMANATHAN(1989,P.166)
 CRAVEN-WAHBA(1979) GENERALIZED CROSS VALIDATION(1979) -GCV=  0.10264
 HANNAN AND QUINN(1979) CRITERION -HQ=  0.10365
 RICE (1984) CRITERION-RICE=  0.10557
 SHIBATA (1981) CRITERION-SHIBATA=  0.96950E-01
 SCHWARTZ (1978) CRITERION-SC=  0.11649
 AKAIKE (1974)INFORMATION CRITERION-AIC=  0.10034

                    ANALYSIS OF VARIANCE - FROM MEAN
                     SS          DF           MS                F
REGRESSION      0.51655E-01     2.       0.25828E-01          0.294
ERROR            1.5835        18.       0.87973E-01
TOTAL            1.6352        20.       0.81759E-01

                    ANALYSIS OF VARIANCE - FROM ZERO
                     SS          DF           MS                F
REGRESSION      0.18201         3.       0.60670E-01          0.690
ERROR            1.5835        18.       0.87973E-01
TOTAL            1.7655        21.       0.84073E-01


VARIABLE   ESTIMATED  STANDARD   T-RATIO    PARTIAL STANDARDIZED ELASTICITY
  NAME    COEFFICIENT   ERROR     18 DF      CORR.  COEFFICIENT  AT MEANS

IV1      -0.21862E-05 0.35353E-04 -0.61840E-01-0.0146 -0.18010E-01 -0.59413
I2T      -0.84953        1.3157   -0.64568    -0.1505 -0.18805      -1.4705
```

```
CONSTANT  0.24146     0.87957      0.27452      0.0646  0.00000E+00   3.0647

CORRELATION MATRIX OF COEFFICIENTS
IV1        1.0000
I2T        0.60474       1.0000
CONSTANT -0.98397     -0.72444       1.0000
              IV1          I2T          CONSTANT

DURBIN-WATSON = 1.5556    VON NEUMANN RATIO = 1.6334    RHO =  0.13058
RESIDUAL SUM = -0.69389E-16  RESIDUAL VARIANCE =  0.87973E-01
SUM OF ABSOLUTE ERRORS=   4.5736
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.0316
RUNS TEST:   10 RUNS,   12 POSITIVE,    9 NEGATIVE, NORMAL STATISTIC =    -0.5883
```

Appendix Table 13 Results of the Seemingly Unrelated Regression of Demand Equations with Variables having Nonsignificant Parameter Estimates Dropped

```
|_SYSTEM 4
|_OLS LPK LPS LPSA LQK LY D2
|_OLS LPS LPK LPSA LQS D2
|_OLS LPSA LPK LPS LQSA
|_OLS LPT LQT LY D1

MULTIVARIATE REGRESSION--    4 EQUATIONS
 15 RIGHT-HAND SIDE VARIABLES IN SYSTEM
MAX ITERATIONS =       1        CONVERGENCE TOLERANCE =   0.10000E-02
       32 OBSERVATIONS

ITERATION     0 COEFFICIENTS
  0.30566      0.15853     -0.13494       1.4509      -0.86785E-01  0.48384
  0.21155     -0.10109      0.59868E-01  0.14381      0.55504      0.18364E-01
  0.88706E-02   1.2577      0.18331

ITERATION    0 SIGMA
  0.82317E-02
 -0.34306E-02  0.88800E-02
 -0.13545E-02 -0.51759E-02  0.26315E-01
  0.24594E-02  0.22377E-02 -0.53212E-03  0.18020E-01

BREUSCH-PAGAN LM TEST FOR DIAGONAL COVARIANCE MATRIX
   CHI-SQUARE =    11.417      WITH    6 DEGREES OF FREEDOM
LOG OF DETERMINANT OF SIGMA=  -17.692
LOG OF LIKELIHOOD FUNCTION =   101.449

ITERATION    1 SIGMA INVERSE
   174.02
   91.137       179.15
   26.190       39.251       46.927
  -34.295      -33.526      -7.0629       64.130

ITERATION     1 COEFFICIENTS
  0.51079      0.12396     -0.12286       1.2455      -0.97295E-01  0.48144
  0.30768     -0.82394E-01  0.52539E-01  0.40447E-01  0.80097      0.50026E-01
 -0.14889E-01   1.2587      0.16639

ITERATION    1 SIGMA
  0.88067E-02
 -0.52092E-02  0.93826E-02
  0.23130E-03 -0.10139E-01  0.27440E-01
  0.16814E-02  0.21552E-02 -0.16814E-02  0.18113E-01
LOG OF DETERMINANT OF SIGMA=  -18.440
LOG OF LIKELIHOOD FUNCTION =   113.418
```

```
SYSTEM R-SQUARE =  0.9816 ... CHI-SQUARE =   127.77     WITH  15 D.F.

LIKELIHOOD RATIO TEST OF DIAGONAL COVARIANCE MATRIX =   40.401     WITH   6 D.F.VARIABLE
COEFFICIENT   ST.ERROR       T-RATIO
LPS          0.51079         0.14443          3.5366
LPSA         0.12396         0.10117          1.2253
LQK         -0.12286         0.48846E-01     -2.5153
LY           1.2455          0.17333          7.1855
D2          -0.97295E-01     0.39500E-01     -2.4632
LPK          0.48144         0.82757E-01      5.8175
LPSA         0.30768         0.96436E-01      3.1905
LQS         -0.82394E-01     0.44787E-01     -1.8397
D2           0.52539E-01     0.39540E-01      1.3288
LPK          0.40447E-01     0.17560          0.23034
LPS          0.80097         0.26563          3.0154
LQSA         0.50026E-01     0.56637E-01      0.88328
LQT         -0.14889E-01     0.63033E-01     -0.23621
LY           1.2587          0.20814          6.0472
D1           0.16639         0.68610E-01      2.4252
```

```
EQUATION  1 OF  4 EQUATIONS
DEPENDENT VARIABLE = LPK                  32 OBSERVATIONS

 R-SQUARE =   0.8759
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.10839E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.10411
SUM OF SQUARED ERRORS-SSE=  0.28181
MEAN OF DEPENDENT VARIABLE =   7.3360
LOG OF THE LIKELIHOOD FUNCTION =  113.418


VARIABLE    ESTIMATED   STANDARD   T-RATIO    PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT    ERROR     26 DF       CORR.  COEFFICIENT  AT MEANS

LPS         0.51079     0.14443      3.5366     0.5699  0.33166       0.47922
LPSA        0.12396     0.10117      1.2253     0.2336  0.96277E-01  0.10812
LQK        -0.12286     0.48846E-01 -2.5153    -0.4424 -0.15786     -0.16209
LY          1.2455      0.17333      7.1855     0.8155  0.59373       1.4418
D2         -0.97295E-01 0.39500E-01 -2.4632    -0.4350 -0.15816     -0.33156E-02
CONSTANT   -6.3365       1.2083     -5.2443    -0.7170  0.00000E+00 -0.86376

 EQUATION  2 OF  4 EQUATIONS
DEPENDENT VARIABLE = LPS                  32 OBSERVATIONS

 R-SQUARE =   0.6863
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.11120E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.10545
SUM OF SQUARED ERRORS-SSE=  0.30024
MEAN OF DEPENDENT VARIABLE =   6.8826
LOG OF THE LIKELIHOOD FUNCTION =  113.418


VARIABLE    ESTIMATED   STANDARD   T-RATIO    PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT    ERROR     27 DF       CORR.  COEFFICIENT  AT MEANS

LPK         0.48144     0.82757E-01  5.8175     0.7458  0.74147       0.51316

LPSA        0.30768     0.96436E-01  3.1905     0.5233  0.36804       0.28606
LQS        -0.82394E-01 0.44787E-01 -1.8397    -0.3337 -0.18876     -0.11628
D2          0.52539E-01 0.39540E-01  1.3288     0.2477  0.13154       0.19084E-02
CONSTANT    2.1690      0.64719      3.3515     0.5420  0.00000E+00  0.31515
```

```
 EQUATION  3 OF  4 EQUATIONS
DEPENDENT VARIABLE = LPSA              32 OBSERVATIONS

 R-SQUARE =   0.3589
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.31360E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.17709
SUM OF SQUARED ERRORS-SSE=  0.87807
MEAN OF DEPENDENT VARIABLE =   6.3989
LOG OF THE LIKELIHOOD FUNCTION =  113.418


VARIABLE   ESTIMATED  STANDARD   T-RATIO    PARTIAL STANDARDIZED ELASTICITY
  NAME    COEFFICIENT   ERROR     28 DF      CORR.  COEFFICIENT  AT MEANS

LPK       0.40447E-01 0.17560    0.23034     0.0435  0.52076E-01  0.46370E-01
LPS       0.80097     0.26563    3.0154      0.4951  0.66961      0.86151
LQSA      0.50026E-01 0.56637E-01 0.88328    0.1646  0.12710      0.64083E-01
CONSTANT  0.17944      1.2721    0.14106     0.0266  0.00000E+00  0.28042E-01

 EQUATION  4 OF  4 EQUATIONS
DEPENDENT VARIABLE = LPT               32 OBSERVATIONS

 R-SQUARE =   0.6067
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.20701E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.14388
SUM OF SQUARED ERRORS-SSE=  0.57962
MEAN OF DEPENDENT VARIABLE =   7.0946
LOG OF THE LIKELIHOOD FUNCTION =  113.418


VARIABLE   ESTIMATED  STANDARD   T-RATIO    PARTIAL STANDARDIZED ELASTICITY
  NAME    COEFFICIENT   ERROR     28 DF      CORR.  COEFFICIENT  AT MEANS

LQT      -0.14889E-01 0.63033E-01 -0.23621  -0.0446 -0.32878E-01 -0.17469E-01
LY         1.2587     0.20814     6.0472     0.7526  0.74474       1.5067
D1        0.16639     0.68610E-01  2.4252    0.4166  0.33573      0.58633E-02
CONSTANT  -3.5125      1.9549     -1.7967   -0.3215  0.00000E+00 -0.49509
|_STOP
```

Appendix Table 14 Results of the Seemingly Unrelated Regression of Demand Equations

```
|_SYSTEM 4
|_OLS LPK LPS LPSA LPT LQK LY D1 D2 D3
|_OLS LPS LPK LPSA LPT LQS LY D1 D2 D3
|_OLS LPSA LPK LPS LPT LQSA LY D1 D2 D3
|_OLS LPT LPK LPS LPSA LQT LY D1 D2 D3

MULTIVARIATE REGRESSION--    4 EQUATIONS
 32 RIGHT-HAND SIDE VARIABLES IN SYSTEM
MAX ITERATIONS =       1         CONVERGENCE TOLERANCE =   0.10000E-02
       32 OBSERVATIONS

ITERATION     0 COEFFICIENTS
  0.23757       0.16340      0.17146     -0.16138       1.2948      -0.30948E-01
 -0.92155E-01 -0.83928E-02  0.39319      0.17676      0.12745      -0.15660
  0.17937      0.44018E-01  0.10089      0.93931E-01  0.38904       0.39070
 -0.28648E-01  0.72904E-02 -0.32787      0.13512      0.77405E-01  0.65045E-01
  0.34745E-01  0.20046     -0.10034E-01 -0.10867E-01   1.0140       0.17405
  0.39773E-01  0.37392E-01

ITERATION    0 SIGMA
  0.77978E-02
 -0.21209E-02  0.74576E-02
 -0.30940E-02 -0.29878E-02  0.23640E-01
 -0.23349E-03 -0.14622E-02  0.34687E-03  0.16999E-01

BREUSCH-PAGAN LM TEST FOR DIAGONAL COVARIANCE MATRIX
   CHI-SQUARE =     6.3199     WITH     6 DEGREES OF FREEDOM
LOG OF DETERMINANT OF SIGMA=  -17.827
LOG OF LIKELIHOOD FUNCTION =   103.611

ITERATION    1 SIGMA INVERSE
   154.49
   56.092       164.01
   27.216       27.861       49.359
   6.3916       14.310       1.7632       60.111

ITERATION     1 COEFFICIENTS
  0.40271       0.22865      0.11333     -0.10861       1.1608      -0.60299E-01
 -0.11483      -0.29944E-01  0.49106      0.22937      0.18746      -0.10734      -0.19265
0.18225E-01  0.96411E-01  0.68385E-01  0.50208      0.52476
 -0.12775       0.46741E-01 -0.54451      0.11718      0.55670E-01  0.36578E-01
  0.54288E-02  0.33531     -0.53853E-01  0.25632E-02  0.97990       0.16864
  0.24701E-01  0.26328E-01

ITERATION    1 SIGMA
  0.83530E-02
 -0.40522E-02  0.80486E-02
```

```
 -0.57200E-02 -0.55713E-02  0.24603E-01
  0.20701E-03 -0.37880E-02  0.23761E-02  0.17189E-01
LOG OF DETERMINANT OF SIGMA=  -18.823
LOG OF LIKELIHOOD FUNCTION =   119.549

SYSTEM R-SQUARE =  0.9874 ... CHI-SQUARE =   140.03     WITH  32 D.F.
LIKELIHOOD RATIO TEST OF DIAGONAL COVARIANCE MATRIX =   40.046     WITH   6 D.F.

VARIABLE        COEFFICIENT    ST.ERROR       T-RATIO
LPS          0.40271        0.18678        2.1561
LPSA         0.22865        0.11239        2.0344
LPT          0.11333        0.15241       0.74363
LQK         -0.10861        0.63574E-01   -1.7084
LY           1.1608         0.25454        4.5603
D1          -0.60299E-01    0.64218E-01  -0.93898
D2          -0.11483        0.55468E-01   -2.0702
D3          -0.29944E-01    0.55340E-01  -0.54108
LPK          0.49106        0.15846        3.0990
LPSA         0.22937        0.11061        2.0736
LPT          0.18746        0.13551        1.3834
LQS         -0.10734        0.63624E-01   -1.6871
LY          -0.19265        0.35282       -0.54604
D1           0.18225E-01    0.62399E-01   0.29208
D2           0.96411E-01    0.54610E-01    1.7655
D3           0.68385E-01    0.58219E-01    1.1746
LPK          0.50208        0.30709        1.6350
LPS          0.52476        0.31528        1.6644
LPT         -0.12775        0.25797       -0.49519
LQSA         0.46741E-01    0.73471E-01   0.63618
LY          -0.54451        0.60337       -0.90244
D1           0.11718        0.10898        1.0753
D2           0.55670E-01    0.10955       0.50816
D3           0.36578E-01    0.10611       0.34473
LPK          0.54288E-02    0.27884       0.19469E-01
LPS          0.33531        0.27859        1.2036
LPSA        -0.53853E-01    0.18109       -0.29739
LQT          0.25632E-02    0.88658E-01   0.28911E-01
LY           0.97990        0.46623        2.1017
D1           0.16864        0.91316E-01    1.8468
D2           0.24701E-01    0.92648E-01   0.26661
D3           0.26328E-01    0.96074E-01   0.27404
```

```
 EQUATION  1 OF  4 EQUATIONS
DEPENDENT VARIABLE = LPK                  32 OBSERVATIONS

 R-SQUARE =   0.8823
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.11622E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.10780
SUM OF SQUARED ERRORS-SSE=  0.26729
MEAN OF DEPENDENT VARIABLE =   7.3360
LOG OF THE LIKELIHOOD FUNCTION =  119.549


VARIABLE    ESTIMATED   STANDARD   T-RATIO     PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT    ERROR      23 DF       CORR.  COEFFICIENT  AT MEANS

LPS        0.40271      0.18678       2.1561      0.4100  0.26148       0.37782
LPSA       0.22865      0.11239       2.0344      0.3905  0.17759       0.19945
LPT        0.11333      0.15241      0.74363      0.1532  0.91311E-01  0.10960
LQK       -0.10861      0.63574E-01  -1.7084     -0.3356 -0.13955      -0.14329
LY         1.1608       0.25454       4.5603      0.6891  0.55336       1.3438
D1        -0.60299E-01 0.64218E-01 -0.93898     -0.1921 -0.98023E-01 -0.20549E-02
D2        -0.11483      0.55468E-01  -2.0702     -0.3963 -0.18667     -0.39133E-02
D3        -0.29944E-01 0.55340E-01 -0.54108     -0.1121 -0.48677E-01 -0.10204E-02
CONSTANT  -6.4585       1.5197       -4.2499     -0.6632  0.00000E+00 -0.88038

 EQUATION  2 OF  4 EQUATIONS
DEPENDENT VARIABLE = LPS                  32 OBSERVATIONS

 R-SQUARE =   0.7309
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.11198E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.10582
SUM OF SQUARED ERRORS-SSE=  0.25756
MEAN OF DEPENDENT VARIABLE =   6.8826
LOG OF THE LIKELIHOOD FUNCTION =  119.549


VARIABLE    ESTIMATED   STANDARD   T-RATIO     PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT    ERROR      23 DF       CORR.  COEFFICIENT  AT MEANS

LPK        0.49106      0.15846       3.0990      0.5427  0.75629       0.52342
LPSA       0.22937      0.11061       2.0736      0.3969  0.27437       0.21325
LPT        0.18746      0.13551       1.3834      0.2772  0.23260       0.19323
LQS       -0.10734      0.63624E-01  -1.6871     -0.3319 -0.24591      -0.15149
LY        -0.19265      0.35282     -0.54604     -0.1131 -0.14144      -0.23772
D1         0.18225E-01 0.62399E-01  0.29208      0.0608  0.45629E-01  0.66201E-03
D2         0.96411E-01 0.54610E-01   1.7655      0.3455  0.24138       0.35020E-02
D3         0.68385E-01 0.58219E-01   1.1746      0.2379  0.17121       0.24840E-02
CONSTANT   3.1154       1.8641       1.6712      0.3291  0.00000E+00  0.45265
```

```
 EQUATION  3 OF  4 EQUATIONS
DEPENDENT VARIABLE = LPSA                 32 OBSERVATIONS

 R-SQUARE =   0.4252
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.34230E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.18501
SUM OF SQUARED ERRORS-SSE=  0.78729
MEAN OF DEPENDENT VARIABLE =   6.3989
LOG OF THE LIKELIHOOD FUNCTION =  119.549


VARIABLE   ESTIMATED  STANDARD   T-RATIO     PARTIAL STANDARDIZED ELASTICITY
  NAME    COEFFICIENT   ERROR      23 DF       CORR.  COEFFICIENT  AT MEANS

LPK        0.50208     0.30709      1.6350     0.3227  0.64644      0.57561
LPS        0.52476     0.31528      1.6644     0.3279  0.43869      0.56442
LPT       -0.12775     0.25797     -0.49519   -0.1027 -0.13251     -0.14163
LQSA       0.46741E-01 0.73471E-01  0.63618    0.1315  0.11875      0.59874E-01
LY        -0.54451     0.60337     -0.90244   -0.1849 -0.33420     -0.72266
D1         0.11718     0.10898      1.0753     0.2188  0.24525      0.45780E-02
D2         0.55670E-01 0.10955      0.50816    0.1054  0.11652      0.21750E-02
D3         0.36578E-01 0.10611      0.34473    0.0717  0.76559E-01  0.14291E-02
CONSTANT   4.1991      3.4341       1.2228     0.2471  0.00000E+00  0.65622

 EQUATION  4 OF  4 EQUATIONS
DEPENDENT VARIABLE = LPT                  32 OBSERVATIONS

 R-SQUARE =   0.6268
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.23916E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.15465
SUM OF SQUARED ERRORS-SSE=  0.55006
MEAN OF DEPENDENT VARIABLE =   7.0946
LOG OF THE LIKELIHOOD FUNCTION =  119.549


VARIABLE   ESTIMATED  STANDARD   T-RATIO     PARTIAL STANDARDIZED ELASTICITY
  NAME    COEFFICIENT   ERROR      23 DF       CORR.  COEFFICIENT  AT MEANS

LPK        0.54288E-02 0.27884      0.19469E-01 0.0041  0.67382E-02  0.56136E-02
LPS        0.33531     0.27859      1.2036     0.2434  0.27023      0.32529
LPSA      -0.53853E-01 0.18109     -0.29739   -0.0619 -0.51915E-01 -0.48573E-01
LQT        0.25632E-02 0.88658E-01  0.28911E-01 0.0060  0.56600E-02  0.30074E-02
LY         0.97990     0.46623      2.1017     0.4014  0.57979      1.1730
D1         0.16864     0.91316E-01  1.8468     0.3594  0.34027      0.59427E-02
D2         0.24701E-01 0.92648E-01  0.26661    0.0555  0.49839E-01  0.87042E-03
D3         0.26328E-01 0.96074E-01  0.27404    0.0570  0.53122E-01  0.92775E-03
CONSTANT  -3.3066      2.9410      -1.1243    -0.2282  0.00000E+00 -0.46607
|_STOP
```

Appendix Table 15 Results of the OLS Regressions of Demand Equations

```
|_OLS LPK LPS LPSA LPT LQK LY D1 D2 D3 / ANOVA RSTAT

REQUIRED MEMORY IS PAR=   11 CURRENT PAR=  273
OLS ESTIMATION
      32 OBSERVATIONS      DEPENDENT VARIABLE = LPK
...NOTE..SAMPLE RANGE SET TO:     1,    32

 R-SQUARE =   0.8901      R-SQUARE ADJUSTED =   0.8519
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.10849E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.10416
SUM OF SQUARED ERRORS-SSE=  0.24953
MEAN OF DEPENDENT VARIABLE =   7.3360
LOG OF THE LIKELIHOOD FUNCTION =  32.2566

MODEL SELECTION TESTS - SEE JUDGE ET.AL.(1985, P.242)
 AKAIKE (1969) FINAL PREDICTION ERROR- FPE =    0.13900E-01
   (FPE ALSO KNOWN AS AMEMIYA PREDICTION CRITERION -PC)
 AKAIKE (1973) INFORMATION CRITERION- LOG AIC =  -4.2914
 SCHWARZ(1978) CRITERION-LOG SC =  -3.8792
MODEL SELECTION TESTS - SEE RAMANATHAN(1989,P.166)
 CRAVEN-WAHBA(1979) GENERALIZED CROSS VALIDATION(1979) -GCV=  0.15094E-01
 HANNAN AND QUINN(1979) CRITERION -HQ=  0.15689E-01
 RICE (1984) CRITERION-RICE=  0.17823E-01
 SHIBATA (1981) CRITERION-SHIBATA=  0.12184E-01
 SCHWARTZ (1978) CRITERION-SC=  0.20668E-01
 AKAIKE (1974)INFORMATION CRITERION-AIC=  0.13686E-01

                     ANALYSIS OF VARIANCE - FROM MEAN
                      SS          DF           MS                 F
REGRESSION         2.0210          8.        0.25262            23.285
ERROR             0.24953         23.        0.10849E-01
TOTAL              2.2705         31.        0.73242E-01

                     ANALYSIS OF VARIANCE - FROM ZERO
                      SS          DF           MS                 F
REGRESSION         1724.2          9.         191.58         17658.226
ERROR             0.24953         23.        0.10849E-01
TOTAL              1724.4         32.         53.888
```

```
VARIABLE    ESTIMATED   STANDARD   T-RATIO     PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT   ERROR      23 DF       CORR.  COEFFICIENT  AT MEANS

LPS        0.23757     0.19630       1.2103     0.2447  0.15425      0.22288
LPSA       0.16340     0.11591       1.4098     0.2820  0.12691      0.14253
LPT        0.17146     0.15440       1.1105     0.2256  0.13814      0.16582
LQK       -0.16138     0.68049E-01  -2.3715    -0.4433 -0.20735     -0.21291
LY          1.2948     0.25567       5.0645     0.7261  0.61725       1.4990
D1        -0.30948E-01 0.64376E-01 -0.48074    -0.0997 -0.50310E-01 -0.10547E-02
D2        -0.92155E-01 0.55753E-01  -1.6529    -0.3258 -0.14981     -0.31405E-02
D3        -0.83928E-02 0.55713E-01 -0.15064    -0.0314 -0.13643E-01 -0.28601E-03
CONSTANT  -5.9628       1.5406      -3.8704    -0.6280  0.00000E+00 -0.81280

DURBIN-WATSON = 2.2560    VON NEUMANN RATIO = 2.3287    RHO = -0.13214
RESIDUAL SUM = -0.84758E-13  RESIDUAL VARIANCE =  0.10849E-01
SUM OF ABSOLUTE ERRORS=   2.4158
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.8901
RUNS TEST:   16 RUNS,   15 POSITIVE,   17 NEGATIVE, NORMAL STATISTIC =   -0.3383
```

```
|_OLS LPS LPK LPSA LPT LQS LY D1 D2 D3 / ANOVA RSTAT

REQUIRED MEMORY IS PAR=    11 CURRENT PAR=  273
OLS ESTIMATION
      32 OBSERVATIONS      DEPENDENT VARIABLE = LPS
...NOTE..SAMPLE RANGE SET TO:     1,    32

 R-SQUARE =    0.7507      R-SQUARE ADJUSTED =    0.6640
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.10376E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.10186
SUM OF SQUARED ERRORS-SSE=  0.23864
MEAN OF DEPENDENT VARIABLE =    6.8826
LOG OF THE LIKELIHOOD FUNCTION =  32.9702

MODEL SELECTION TESTS - SEE JUDGE ET.AL.(1985, P.242)
 AKAIKE (1969) FINAL PREDICTION ERROR- FPE =    0.13294E-01
   (FPE ALSO KNOWN AS AMEMIYA PREDICTION CRITERION -PC)
 AKAIKE (1973) INFORMATION CRITERION- LOG AIC =  -4.3360
 SCHWARZ(1978) CRITERION-LOG SC =  -3.9238
MODEL SELECTION TESTS - SEE RAMANATHAN(1989,P.166)
 CRAVEN-WAHBA(1979) GENERALIZED CROSS VALIDATION(1979) -GCV=  0.14436E-01
 HANNAN AND QUINN(1979) CRITERION -HQ=  0.15005E-01
 RICE (1984) CRITERION-RICE=  0.17046E-01
 SHIBATA (1981) CRITERION-SHIBATA=  0.11653E-01
 SCHWARTZ (1978) CRITERION-SC=  0.19766E-01
 AKAIKE (1974)INFORMATION CRITERION-AIC=  0.13089E-01

                      ANALYSIS OF VARIANCE - FROM MEAN
                    SS            DF           MS                 F
REGRESSION      0.71859           8.       0.89823E-01          8.657
ERROR           0.23864          23.       0.10376E-01
TOTAL           0.95723          31.       0.30878E-01

                      ANALYSIS OF VARIANCE - FROM ZERO
                    SS            DF           MS                 F
REGRESSION       1516.5           9.        168.50           16240.082
ERROR           0.23864          23.       0.10376E-01
TOTAL            1516.8          32.        47.399
```

```
VARIABLE    ESTIMATED   STANDARD    T-RATIO     PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT    ERROR      23 DF       CORR.  COEFFICIENT  AT MEANS

LPK         0.39319     0.16413      2.3956      0.4469  0.60555      0.41909
LPSA        0.17676     0.11411      1.5490      0.3073  0.21143      0.16434
LPT         0.12745     0.13671     0.93225      0.1908  0.15814      0.13137
LQS        -0.15660     0.66891E-01 -2.3412     -0.4387 -0.35877     -0.22102
LY          0.17937     0.36199     0.49549      0.1028  0.13169      0.22133
D1          0.44018E-01 0.62690E-01 0.70216      0.1449  0.11020      0.15989E-02
D2          0.10089     0.54833E-01  1.8399      0.3582  0.25258      0.36646E-02
D3          0.93931E-01 0.58822E-01  1.5969      0.3159  0.23517      0.34119E-02
CONSTANT     1.9011      1.9034     0.99879      0.2039  0.00000E+00  0.27622

DURBIN-WATSON = 1.2644    VON NEUMANN RATIO = 1.3051    RHO =  0.32895
RESIDUAL SUM = -0.45242E-14  RESIDUAL VARIANCE =  0.10376E-01
SUM OF ABSOLUTE ERRORS=   2.3224
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.7507
RUNS TEST:    11 RUNS,    14 POSITIVE,    18 NEGATIVE, NORMAL STATISTIC =   -2.1005
```

```
|_OLS LPSA LPK LPS LPT LQSA LY D1 D2 D3 /ANOVA RSTAT

REQUIRED MEMORY IS PAR=    11 CURRENT PAR=  273
OLS ESTIMATION
      32 OBSERVATIONS     DEPENDENT VARIABLE = LPSA
...NOTE..SAMPLE RANGE SET TO:    1,   32

 R-SQUARE =   0.4477     R-SQUARE ADJUSTED =   0.2556
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.32890E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.18136
SUM OF SQUARED ERRORS-SSE=  0.75647
MEAN OF DEPENDENT VARIABLE =   6.3989
LOG OF THE LIKELIHOOD FUNCTION =  14.5113

MODEL SELECTION TESTS - SEE JUDGE ET.AL.(1985, P.242)
 AKAIKE (1969) FINAL PREDICTION ERROR- FPE =   0.42140E-01
   (FPE ALSO KNOWN AS AMEMIYA PREDICTION CRITERION -PC)
 AKAIKE (1973) INFORMATION CRITERION- LOG AIC =  -3.1823
 SCHWARZ(1978) CRITERION-LOG SC =  -2.7701
MODEL SELECTION TESTS - SEE RAMANATHAN(1989,P.166)
 CRAVEN-WAHBA(1979) GENERALIZED CROSS VALIDATION(1979) -GCV=  0.45760E-01
 HANNAN AND QUINN(1979) CRITERION -HQ=  0.47564E-01
 RICE (1984) CRITERION-RICE=  0.54033E-01
 SHIBATA (1981) CRITERION-SHIBATA=  0.36937E-01
 SCHWARTZ (1978) CRITERION-SC=  0.62656E-01
 AKAIKE (1974)INFORMATION CRITERION-AIC=  0.41489E-01

                    ANALYSIS OF VARIANCE - FROM MEAN
                     SS            DF           MS                F
REGRESSION       0.61319           8.       0.76649E-01          2.330
ERROR            0.75647          23.       0.32890E-01
TOTAL             1.3697          31.       0.44182E-01

                    ANALYSIS OF VARIANCE - FROM ZERO
                     SS            DF           MS                F
REGRESSION        1310.9           9.        145.66           4428.570
ERROR            0.75647          23.       0.32890E-01
TOTAL             1311.7          32.        40.989
```

```
VARIABLE    ESTIMATED   STANDARD   T-RATIO     PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT   ERROR      23 DF       CORR.  COEFFICIENT  AT MEANS

LPK        0.38904     0.31633      1.2298      0.2484  0.50090     0.44601
LPS        0.39070     0.32497      1.2023      0.2432  0.32662     0.42023
LPT       -0.28648E-01 0.25952     -0.11039    -0.0230 -0.29717E-01 -0.31762E-01
LQSA       0.72904E-02 0.76923E-01  0.94775E-01 0.0198  0.18522E-01  0.93388E-02
LY        -0.32787     0.60999     -0.53751    -0.1114 -0.20124     -0.43515
D1         0.13512     0.10919      1.2374      0.2498  0.28280      0.52789E-02
D2         0.77405E-01 0.11118      0.69623     0.1437  0.16201      0.30241E-02
D3         0.65045E-01 0.10753      0.60490     0.1251  0.13614      0.25412E-02
CONSTANT    3.7145      3.4942      1.0631      0.2164  0.00000E+00  0.58049
DURBIN-WATSON = 1.6796     VON NEUMANN RATIO = 1.7338     RHO =  0.10618
RESIDUAL SUM = -0.19873E-13  RESIDUAL VARIANCE =  0.32890E-01
SUM OF ABSOLUTE ERRORS=   3.8996
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.4477
RUNS TEST:   15 RUNS,   19 POSITIVE,   13 NEGATIVE, NORMAL STATISTIC =   -0.5361
```

```
|_OLS LPT LPK LPS LPSA LQT LY D1 D2 D3 / ANOVA RSTAT

REQUIRED MEMORY IS PAR=   11 CURRENT PAR=  273
OLS ESTIMATION
      32 OBSERVATIONS     DEPENDENT VARIABLE = LPT
...NOTE..SAMPLE RANGE SET TO:    1,   32

 R-SQUARE =   0.6309     R-SQUARE ADJUSTED =   0.5025
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.23650E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.15379
SUM OF SQUARED ERRORS-SSE=  0.54396
MEAN OF DEPENDENT VARIABLE =   7.0946
LOG OF THE LIKELIHOOD FUNCTION =  19.7879

MODEL SELECTION TESTS - SEE JUDGE ET.AL.(1985, P.242)
 AKAIKE (1969) FINAL PREDICTION ERROR- FPE =   0.30302E-01
   (FPE ALSO KNOWN AS AMEMIYA PREDICTION CRITERION -PC)
 AKAIKE (1973) INFORMATION CRITERION- LOG AIC =  -3.5121
 SCHWARZ(1978) CRITERION-LOG SC =  -3.0999
MODEL SELECTION TESTS - SEE RAMANATHAN(1989,P.166)
 CRAVEN-WAHBA(1979) GENERALIZED CROSS VALIDATION(1979) -GCV=  0.32905E-01
 HANNAN AND QUINN(1979) CRITERION -HQ=  0.34202E-01
 RICE (1984) CRITERION-RICE=  0.38854E-01
 SHIBATA (1981) CRITERION-SHIBATA=  0.26560E-01
 SCHWARTZ (1978) CRITERION-SC=  0.45054E-01
 AKAIKE (1974)INFORMATION CRITERION-AIC=  0.29834E-01

                    ANALYSIS OF VARIANCE - FROM MEAN
                     SS          DF          MS               F
REGRESSION        0.92986         8.      0.11623           4.915
ERROR             0.54396        23.      0.23650E-01
TOTAL              1.4738        31.      0.47542E-01

                    ANALYSIS OF VARIANCE - FROM ZERO
                     SS          DF          MS               F
REGRESSION         1611.6         9.       179.06         7571.332
ERROR             0.54396        23.      0.23650E-01
TOTAL              1612.1        32.       50.379
```

```
VARIABLE    ESTIMATED   STANDARD   T-RATIO     PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT   ERROR      23 DF       CORR.  COEFFICIENT  AT MEANS

LPK        0.34745E-01 0.27934     0.12438     0.0259  0.43126E-01  0.35928E-01
LPS        0.20046     0.28060     0.71440     0.1473  0.16155      0.19447
LPSA      -0.10034E-01 0.18128    -0.55349E-01-0.0115 -0.96727E-02 -0.90500E-02
LQT       -0.10867E-01 0.89442E-01 -0.12149    -0.0253 -0.23995E-01 -0.12750E-01
LY          1.0140     0.46629      2.1746     0.4130  0.59998       1.2138
D1         0.17405     0.91402E-01  1.9042     0.3690  0.35117      0.61331E-02
D2         0.39773E-01 0.92840E-01 0.42841     0.0890  0.80250E-01  0.14015E-02
D3         0.37392E-01 0.96368E-01 0.38801     0.0806  0.75445E-01  0.13176E-02
CONSTANT  -3.0598       2.9447     -1.0391    -0.2118  0.00000E+00 -0.43129

DURBIN-WATSON = 1.3499    VON NEUMANN RATIO = 1.3935    RHO =  0.27839
RESIDUAL SUM =  0.59536E-13  RESIDUAL VARIANCE =  0.23650E-01
SUM OF ABSOLUTE ERRORS=   3.2965
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.6309
RUNS TEST:   14 RUNS,    15 POSITIVE,    17 NEGATIVE, NORMAL STATISTIC =   -1.0600
|_STOP
```

Appendix Table 16 Results of the 2SLS Regressions of Demand Equations

```
|_2SLS LPK LPS LPSA LPT LQK LY D1 D2 D3 (LQK LQS LQSA LQT LY D1 D2 D3)/DN RSTAT
 TWO STAGE LEAST SQUARES - DEPENDENT VARIABLE = LPK
  8 EXOGENOUS VARIABLES
  4 POSSIBLE ENDOGENOUS VARIABLES
       32 OBSERVATIONS
DN OPTION IN EFFECT - DIVISOR IS N

 R-SQUARE =   0.6227     R-SQUARE ADJUSTED =   0.4915
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.26769E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.16361
SUM OF SQUARED ERRORS-SSE=  0.85660
MEAN OF DEPENDENT VARIABLE =   7.3360


                               ASYMPTOTIC
VARIABLE    ESTIMATED   STANDARD   T-RATIO     PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT   ERROR    --------      CORR.  COEFFICIENT  AT MEANS

LPS      -0.25766     0.84552     -0.30474    -0.0634 -0.16730     -0.24173
LPSA      0.94952     0.89915      1.0560      0.2150  0.73748      0.82823
LPT       0.64128     0.75911      0.84479     0.1735  0.51667      0.62017
LQK      -0.21638     0.18432     -1.1739     -0.2378 -0.27802     -0.28547
LY        0.60443      1.1016      0.54866     0.1137  0.28814      0.69972
D1       -0.22091     0.26980     -0.81881    -0.1683 -0.35912     -0.75283E-02
D2       -0.13436     0.11877     -1.1313     -0.2296 -0.21842     -0.45788E-02
D3       -0.54891E-01 0.11522     -0.47642    -0.0989 -0.89231E-01 -0.18706E-02
CONSTANT  -4.4525      3.7146     -1.1987     -0.2425  0.00000E+00 -0.60694

DURBIN-WATSON = 2.2989    VON NEUMANN RATIO = 2.3731    RHO = -0.17474
RESIDUAL SUM = -0.47962E-13  RESIDUAL VARIANCE =  0.26769E-01
SUM OF ABSOLUTE ERRORS=   4.3426
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.7120
RUNS TEST:   17 RUNS,    14 POSITIVE,    18 NEGATIVE, NORMAL STATISTIC =     0.0913
```

```
|_2SLS LPS LPK LPSA LPT LQS LY D1 D2 D3 (LQK LQS LQSA LQT LY D1 D2 D3)/DN RSTAT
 TWO STAGE LEAST SQUARES - DEPENDENT VARIABLE = LPS
  8 EXOGENOUS VARIABLES
  4 POSSIBLE ENDOGENOUS VARIABLES
       32 OBSERVATIONS
DN OPTION IN EFFECT - DIVISOR IS N

 R-SQUARE =  -0.0626     R-SQUARE ADJUSTED =  -0.4321
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.31785E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.17828
SUM OF SQUARED ERRORS-SSE=   1.0171
MEAN OF DEPENDENT VARIABLE =   6.8826


                             ASYMPTOTIC
VARIABLE    ESTIMATED   STANDARD   T-RATIO    PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT    ERROR   --------      CORR.  COEFFICIENT  AT MEANS

LPK       0.36957     0.75813      0.48748     0.1011  0.56918      0.39392
LPSA      0.92909      1.3154      0.70632     0.1457   1.1114      0.86380
LPT       0.70644     0.66027       1.0699     0.2177  0.87657      0.72820
LQS      -0.19013     0.13975      -1.3606    -0.2729 -0.43557     -0.26833
LY        -1.0010      1.1576     -0.86470    -0.1774 -0.73492      -1.2352
D1       -0.23941     0.38465     -0.62241    -0.1287 -0.59939     -0.86963E-02
D2        0.10203E-01 0.19961      0.51117E-01 0.0107  0.25545E-01  0.37062E-03
D3        0.27848E-01 0.14408      0.19328     0.0403  0.69720E-01  0.10115E-02
CONSTANT   3.6126      5.9432      0.60786     0.1257  0.00000E+00  0.52490

DURBIN-WATSON = 2.0837    VON NEUMANN RATIO = 2.1509    RHO = -0.06748
RESIDUAL SUM =  0.34639E-13  RESIDUAL VARIANCE =  0.31785E-01
SUM OF ABSOLUTE ERRORS=   4.8240
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.5067
RUNS TEST:   15 RUNS,   16 POSITIVE,   16 NEGATIVE, NORMAL STATISTIC =   -0.7188
```

```
|_2SLS LPSA LPK LPS LPT LQSA LY D1 D2 D3 (LQK LQS LQSA LQT LY D1 D2 D3)/DN RSTAT
 TWO STAGE LEAST SQUARES - DEPENDENT VARIABLE = LPSA
  8 EXOGENOUS VARIABLES
  4 POSSIBLE ENDOGENOUS VARIABLES
       32 OBSERVATIONS
DN OPTION IN EFFECT - DIVISOR IS N

 R-SQUARE =   0.1287     R-SQUARE ADJUSTED =  -0.1743
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.37293E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.19311
SUM OF SQUARED ERRORS-SSE=   1.1934
MEAN OF DEPENDENT VARIABLE =   6.3989


                                  ASYMPTOTIC
VARIABLE    ESTIMATED   STANDARD   T-RATIO     PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT    ERROR    --------      CORR.  COEFFICIENT  AT MEANS

LPK      -0.10292      1.0764     -0.95616E-01-0.0199 -0.13251      -0.11799
LPS       0.43653     0.96410      0.45278      0.0940  0.36493       0.46952
LPT      -0.79290     0.64816     -1.2233      -0.2472 -0.82249      -0.87909
LQSA      0.92733E-01 0.11113      0.83444      0.1714  0.23560       0.11879
LY         1.4863      1.8945      0.78455      0.1614  0.91227        1.9726
D1        0.29582     0.13929       2.1237      0.4049  0.61916       0.11558E-01
D2        0.24893E-01 0.19868      0.12529      0.0261  0.52101E-01   0.97255E-03
D3        0.20498E-01 0.14198      0.14437      0.0301  0.42902E-01   0.80082E-03
CONSTANT -3.6934      10.543      -0.35031     -0.0729  0.00000E+00 -0.57719

DURBIN-WATSON = 2.0841    VON NEUMANN RATIO = 2.1513    RHO = -0.05532
RESIDUAL SUM =  0.16875E-13  RESIDUAL VARIANCE =  0.37293E-01
SUM OF ABSOLUTE ERRORS=   5.2539
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.2039
RUNS TEST:   17 RUNS,   17 POSITIVE,   15 NEGATIVE, NORMAL STATISTIC =    0.0226
```

```
|_2SLS LPT LPK LPS LPSA LQT LY D1 D2 D3 (LQK LQS LQSA LQT LY D1 D2 D3)/DN RSTAT
 TWO STAGE LEAST SQUARES - DEPENDENT VARIABLE = LPT
  8 EXOGENOUS VARIABLES
  4 POSSIBLE ENDOGENOUS VARIABLES
       32 OBSERVATIONS
DN OPTION IN EFFECT - DIVISOR IS N

 R-SQUARE =  -4.1758     R-SQUARE ADJUSTED =  -5.9761
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.23838
STANDARD ERROR OF THE ESTIMATE-SIGMA =  0.48824
SUM OF SQUARED ERRORS-SSE=   7.6282
MEAN OF DEPENDENT VARIABLE =   7.0946


                               ASYMPTOTIC
VARIABLE    ESTIMATED   STANDARD   T-RATIO     PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT    ERROR    --------      CORR.  COEFFICIENT  AT MEANS

LPK          1.8522      3.8964     0.47537     0.0986   2.2990        1.9153
LPS        -0.30469      2.2436    -0.13580    -0.0283 -0.24555      -0.29558
LPSA        -2.9342      3.4642    -0.84703    -0.1739  -2.8287       -2.6465
LQT         0.27779     0.47314     0.58713     0.1215  0.61342       0.32594
LY          0.42328      3.3320     0.12704     0.0265  0.25045       0.50669
D1          0.82904     0.88356     0.93829     0.1920   1.6727       0.29214E-01
D2          0.33409     0.61153     0.54633     0.1132  0.67410       0.11773E-01
D3          0.12926     0.34403     0.37571     0.0781  0.26080       0.45547E-02
CONSTANT     8.1495      26.804     0.30404     0.0633  0.00000E+00    1.1487

DURBIN-WATSON = 1.8957    VON NEUMANN RATIO = 1.9569    RHO =  0.04119
RESIDUAL SUM =  0.13856E-12  RESIDUAL VARIANCE =  0.23838
SUM OF ABSOLUTE ERRORS=   12.805
R-SQUARE BETWEEN OBSERVED AND PREDICTED = 0.0591
RUNS TEST:   11 RUNS,    14 POSITIVE,    18 NEGATIVE, NORMAL STATISTIC =   -2.1005
|_STOP
```

Appendix Table 17 Results of the Seemingly Unrelated Regression of the Dynamic of Effort Equations

```
|_SYSTEM 3/ ITER=50 PITER=0
|_OLS GCEF GNPR
|_OLS PSCEF PSNPR
|_OLS TRCEF TRNPR

MULTIVARIATE REGRESSION--    3 EQUATIONS
  3 RIGHT-HAND SIDE VARIABLES IN SYSTEM
MAX ITERATIONS =       50        CONVERGENCE TOLERANCE =   0.10000E-02
       22 OBSERVATIONS

ITERATION    0 SIGMA
   5297.8
   10638.      0.11449E+06
  -54322.     -0.18450E+06  0.10266E+07

BREUSCH-PAGAN LM TEST FOR DIAGONAL COVARIANCE MATRIX
   CHI-SQUARE =    22.412     WITH    3 DEGREES OF FREEDOM

ITERATION    1 SIGMA INVERSE
  0.41423E-03
 -0.44623E-05  0.12343E-04
  0.21116E-04  0.19821E-05  0.24476E-05

ITERATION    5 SIGMA INVERSE
  0.45990E-03
 -0.65768E-05  0.12634E-04
  0.24261E-04  0.19437E-05  0.26546E-05

ITERATION    5 SIGMA
   5395.7
   11715.      0.11464E+06
  -57888.     -0.19100E+06  0.10456E+07

SYSTEM R-SQUARE =  0.7275 ... CHI-SQUARE =   28.606     WITH   3 D.F.
LOG OF LIKELIHOOD FUNCTION =  -454.793
LIKELIHOOD RATIO TEST OF DIAGONAL COVARIANCE MATRIX =   27.145     WITH   3 D.F.

VARIABLE       COEFFICIENT   ST.ERROR       T-RATIO
GNPR        0.43062E-02   0.11225E-02     3.8362
PSNPR       0.36546E-01   0.96997E-02     3.7678
TRNPR       0.62710E-01   0.21783E-01     2.8788
```

```
 EQUATION  1 OF  3 EQUATIONS
DEPENDENT VARIABLE = GCEF                22 OBSERVATIONS

 R-SQUARE =   0.3145
VARIANCE OF THE ESTIMATE-SIGMA**2 =   5935.2
STANDARD ERROR OF THE ESTIMATE-SIGMA =   77.040
SUM OF SQUARED ERRORS-SSE=  0.11870E+06
MEAN OF DEPENDENT VARIABLE =   29.973
LOG OF THE LIKELIHOOD FUNCTION = -454.793


VARIABLE    ESTIMATED   STANDARD   T-RATIO    PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT    ERROR      20 DF      CORR.  COEFFICIENT  AT MEANS

GNPR      0.43062E-02 0.11225E-02   3.8362     0.6511  0.46025        2.0730
CONSTANT  -32.162      23.068      -1.3942    -0.2976  0.00000E+00  -1.0730

 EQUATION  2 OF  3 EQUATIONS
DEPENDENT VARIABLE = PSCEF               22 OBSERVATIONS

 R-SQUARE =   0.3533
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.12610E+06
STANDARD ERROR OF THE ESTIMATE-SIGMA =   355.11
SUM OF SQUARED ERRORS-SSE=  0.25220E+07
MEAN OF DEPENDENT VARIABLE =  -299.62
LOG OF THE LIKELIHOOD FUNCTION = -454.793


VARIABLE    ESTIMATED   STANDARD   T-RATIO    PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT    ERROR      20 DF      CORR.  COEFFICIENT  AT MEANS

PSNPR     0.36546E-01 0.96997E-02   3.7678     0.6443  0.56615      -0.31855
CONSTANT  -395.06      79.835      -4.9485    -0.7419  0.00000E+00   1.3186

 EQUATION  3 OF  3 EQUATIONS
DEPENDENT VARIABLE = TRCEF               22 OBSERVATIONS

 R-SQUARE =   0.2077
VARIANCE OF THE ESTIMATE-SIGMA**2 =  0.11501E+07
STANDARD ERROR OF THE ESTIMATE-SIGMA =   1072.4
SUM OF SQUARED ERRORS-SSE=  0.23003E+08
MEAN OF DEPENDENT VARIABLE =   156.55
LOG OF THE LIKELIHOOD FUNCTION = -454.793


VARIABLE    ESTIMATED   STANDARD   T-RATIO    PARTIAL STANDARDIZED ELASTICITY
  NAME     COEFFICIENT    ERROR      20 DF      CORR.  COEFFICIENT  AT MEANS

TRNPR     0.62710E-01 0.21783E-01   2.8788     0.5413  0.35143        4.6319
CONSTANT  -568.57      340.18      -1.6714    -0.3501  0.00000E+00  -3.6319
|_STOP
```