MANAGEMENT OF THE SEYCHELLES ARTISANAL FISHERY

by

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ABSTRACT

The Seychelles artisanal fishery has two sectors: a large number of boats exploit the inshore fish resources, and a smaller number of large vessels target the relatively lightly exploited offshore resources. Continued high levels of fishing effort inshore have given rise to concern over the status of the fish resources there and the socio-economic welfare of inshore fishers. Previous fiscal incentives in the form of soft loans were intended to help fishers purchase larger vessels and relocate fishing effort further offshore, but to date this has met with limited success.

In this study, the status of the inshore resources are re-evaluated, and constraints on relocating fishing effort faced by different socio-economic groups of fishers were examined. Field sampling, techniques from rapid rural appraisal and formal socio-economic surveys were used to collect quantitative biological, technical and economic information for each fishery sector, as well as information on the decision processes of different socio-economic groups. This was used to develop a unique bio-socio-economic model of the artisanal fishery, which allowed the likely outcomes of alternative management strategies to be evaluated.

Continuation of existing policy was predicted to put further pressure on the inshore stocks. Access restrictions, involving both vessel and fisher licence schemes, were found to provide the greatest opportunity for sustainable biological and economic recovery.

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1 INTRODUCTION

The Seychelles artisanal fishery has two sectors: a large number of boats exploit the fish resources close to areas of settlement around the main granitic islands of Mahé, Praslin and La Digue, and a smaller number of large boats target relatively lighted exploited resources offshore.

Continued high levels of exploitation within the inshore region have given rise to concern over the status of the fish resources there and the socio-economic welfare of inshore fishers.

In 1992, a review of the fisheries legislation in Seychelles, Flewwelling *et al.* (1992) recognised that the current level of fishing pressure being conducted within the inshore region was placing 'unacceptable' pressure on stocks in this area. In addition, they stated that 'if fishing is continued in this area at this level, it will neither be cost effective nor sustainable and will not allow for stock re-building' (p.15).

They also argued that the 'continuation of the status quo cannot last too far into the future. The pressures on stocks brought on by the increasing effort around the granitic islands, the introduction of non-traditional fishing technology and the current minimal surveillance and compliance efforts directed towards local fishing will require decisions in the near future to ensure sustainability.' (p.20).

As part of an ongoing development strategy, the government has attempted to relocate the high level of fishing effort within the inshore region to the lightly exploited demersal resources offshore. In an attempt to achieve this, fiscal incentives in the form of soft loans were intended to help fishers purchase large boats to fish offshore. To date these have met with limited success.

In response, Mees *et al.* (1998) undertook an inshore management strategy for Seychelles to identify, among other things, policies that would lead to the recovery of the stocks within the inshore region. The socio-economic welfare of fishers is also essential to monitor if new policies used to relocate fishing effort offshore are to remain equitable.

1.1 OBJECTIVES OF RESEARCH

The overall objective of this study is to evaluate the performance of alternative management options that will lead to the recovery and long-term sustainability of the inshore fish stocks. In doing so, the constraints faced by different socio-economic groups of fishers to purchase large boats and relocate fishing effort must also be identified.

In particular, the study aims to:

- Re-assess the biological status of the inshore fish stocks;
- Identify different socio-economic groups within the artisanal fishery;
- Describe the major decision-making processes of fishers within each socio-economic group;
- Develop a unique bio-socio-economic simulation model of the artisanal fishery;
- Use the model to predict the likely outcomes of alternative management options;
- Evaluate the success of each management option to promote the recovery and long-term sustainability of the inshore fish stocks;

This study was undertaken in parallel with Mees *et al.* (1998) and provided quantitative information relating to a recent socio-economic survey of the Seychelles fishing community (see Chapter 2, this study; Annex 1, Section 8, Mees *et al.*, 1998).

An outline of the chapter now follows. Section 1.2 gives a profile of the geography and climate within Seychelles, in additional to a brief summary of its' history and recent politics. An overview of the Seychelles artisanal fishery is presented in Section 1.3. The development of the fisheries sector is described in context with government policy objectives and legislation. Details of the fleet structure and technology are also described in addition to the current status of the resource base.

Section 1.4 describes the specifications of the bio-socio-economic model. A short review of the biological, bio-economic, and bio-socio-economic models available for fisheries assessment is described first before giving further details of the model structure and data requirements. Finally, Section 1.5 provides an outline to the thesis.

1.2 PROFILE OF SEYCHELLES

1.2.1 Geography & Climate

The Seychelles Exclusive Economic Zone (EEZ), situated between 5° and 10°S and 45° and 56°E in the Western Indian Ocean encompasses 1,374,000 km^2. Only 4% of this area is less than 200 m in depth, consisting of a plateau and various banks.

The Seychelles archipelago consists of 116 widely scattered granite and coralline islands covering a total area of just 455 km^2. The main granitic islands of Mahé, Praslin and La Digue are centred on a shallow plateau. It is upon these islands that the majority of the 77,000 population live (Anon., 1994). The capital of Seychelles is Victoria, located along the north-east coast of Mahé.

Seychelles is equatorial, but lies outside the cyclone zone. The region has two seasons defined by the south-east trade winds between May and the end of September. During this period, strong winds can average around 12 knots, often restricting fishing activities. After a transition period of unsettled weather, the islands then experience the north-west monsoon from mid-November to March. This period is also characterised by a period of light, but variable winds and frequent calm seas. The air temperature varies little throughout the year. Mean daily minimum ranges between 24-25°C; maximum 27-30°C.

1.2.2 History and Politics

The Seychelles was not inhabited until the 17th century, although the islands were probably occupied at various times by shipwrecked sailors and pirates. Although Portuguese and British explorers charted the area, but the French were the first to claim the islands in 1754. At the end of the 18th century the British gained an interest in the islands, finally taking them over in 1814. It was not until 1903 that the Seychelles became a crown colony, administered directly from London.

To encourage economic reforms, two political parties were formed in 1964. France-Albert René founded the Seychelles People's United Party (SPUP), whereas James Mancham led the new Seychelles Democratic Party (SDP). A coalition of the two parties in 1975 helped

give them independence from the UK a year later.

Shortly after independence, a coup took place in 1977 and René took control. Following a number of elections within single party politics, René was to be elected President in 1979, 1984 and again in 1989. During the 1990s, Seychelles began to see political reforms. In 1991, René legalised opposition parties which brought the Seychelles back into multi-party politics. During the first democratic elections in 1993, René heading the Seychelles People's Progressive Front (SPPF), was re-elected as President. More recently, René has once again been re-elected in March 1998.

1.3 Overview of the artisanal fishery

The Seychelles artisanal fishery has been subject to numerous reviews (Lablache & Moussac, 1987; Mees, 1996; Mees *et al.*, 1998). Therefore, this section attempts to synthesize the relevant information to provide a background to the research.

1.3.1 Development of the fisheries sector

To appreciate the management issues now raised in the artisanal fishery, it is also important to understand the historical development of the fishery.

Historical background

Until the 1950s, traditional wooden pirogues were the only fishing boats available to target fish resources situated close to areas of settlement. Without an engine, fishers used small paddles or a wooden punt to manoeuvre the boat in shallow waters. Towards the end of the decade, much larger undecked wooden vessels of clinker construction began to appear in the fishery. With only a single large sail and a compass for navigation, these traditional 'whaler' vessels were the first to exploit the relatively shallow and productive waters upon the Mahé Plateau. Without modern technology, triangulation of fixed landmarks and simple depth measurements were used as a common technique to relocate good fishing grounds. As a result, large boats seldom went out of sight of land (Tocos pers. comm., 1999).

By the mid 1960s, the first inboard powered whalers were fitted with a 2 cylinder engine, enabling further exploration of the Mahé Plateau. During this period, many fishing grounds were established on the banks around the periphery of the Plateau.

It was not until 1974, shortly after the opening of the Seychelles International Airport, that much larger schooner vessels with 4 cylinder inboard engines began operating. The airport had made it possible to export fresh fish to Reunion and Europe. At this stage, three main companies and a score of private entrepreneurs made up a total fleet of 40 schooners (Michaud, 1990).

In 1981, under the recently formed socialist state, the government created the Fisheries Development Company (FIDECO), and acquired the schooners belonging to the private companies. All export of fish was now carried out by the parastatal Fish Export Company. It was also during the early 1980s that small fibre-glass skiffs with an outboard engine began to appear in numbers within the artisanal fishery. In 1984, the Seychelles Fishing Authority was created by the government, and soon afterwards transferred management of the schooner fleet to SFA, but the government retained overall ownership.

Towards the end of the 1980s state ownership of the schooner fleet was disbanded, transferring the ex-FIDECO vessels back into the private sector by a series of hire-purchase agreements. The remaining 10 boats were repaired and sold back to fishers at approximately 50% of their estimated value. Soft loans were also made more widely available from the DBS to promote vessels capable of exploiting more distant resources (Nageon, 1986).

Unfortunately, even with the low level of initial capital required and favourable terms of repayment, the majority of ex-FIDECO schooners had been re-possessed by 1989 and resold by tender. Reasons given to explain this disappointing result include poor returns on the investment and the lack of management skills required to operate a large boat. A number of options to improve the fishery performance were given, including: fish price changes; removal of subsidies on fuel, engines and spare parts; introduction of new technologies such as echo sounders and electric reels;

establishment of cooperative fleet management; and finally a return to entrepreneurial management (Michaud, 1990).

However, the government policy to progressively transform the artisanal fishery and commercialise the operations of the demersal fishery on more distant fishing grounds had appeared to be successful. But closer scrutiny of the data revealed that the majority of large boats purchased over the past decade had been of the less suitable whaler category (see Figure 1.1). As stated by Mees *et al.* (1998):

'Whalers are less comfortable than other designs and safety of fishermen and quality of fish are also compromised compared to other designs. The potential for fishing outer island groups is not realised by the increases in this category of vessel.'

The purchase of whalers also indicated that a high level of fishing pressure remained within the inshore region. Although the number of small pirogues have substantially declined since 1985, the fishing power of small outboard boats have remained relatively constant. Biological assessments made on the status of the demersal fishery indicated that the inshore region was now under considerable fishing pressure, while the more distant offshore demersal resources were comparatively lightly exploited (Mees, 1992a; Mees, 1993; Mees, 1996). The increased demand for larger outboard engines may also provide anecdotal evidence that fishers are required to move further offshore to continue fishing operations (Mees *et al.*, 1998).

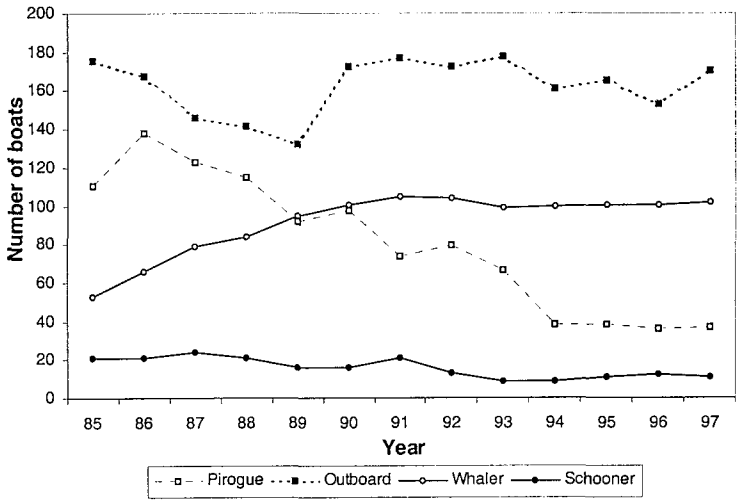


Figure 1.1 Average number of commercial fishing boats operating per month over the period 1985 to 1997 (SFA technical reports, 1986-98).

More recently, the government has continued to promote the offshore fishing grounds, by encouraging entrepreneurs to purchase large semi-industrial vessels. Between 1991 and 1993 an unsuccessful number of mothership-dory fishing ventures were undertaken to exploit the more distant demersal resources offshore (see Mees, 1991,1992; Grandcourt, 1995).

More recently, a fleet of long-line vessels capable of exploiting large pelagic resources within and outside the Seychelles EEZ have been promoted (Hastings, 1995). The small number of vessels, however, has yet to prove successful.

In summary, the initial government polices used to address part of the development issues within the fisheries sector have now also become management concerns.

1.3.2 Fleet Structure and Technology

The fleet structure of the artisanal fishery is well described in the literature, particularly by Mees (1989a) and Payet (1996a). The semi-industrial fishery has recently been described by Hastings (1995). These details have been partly reproduced to provide an overview of the structure and technology available to both the artisanal and semi-industrial fisheries. Combined, these form the *domestic* fishery of the Seychelles.

Fishing vessels

There are many types of fishing vessel operating within the domestic fishery. For assessment purposes, each vessel is classified according to their fishing power and pattern of use (see SFA, 1998). SFA currently monitor the artisanal fishery under the Catch Assessment Survey (CAS; see Lablache & Carrera, 1984), which classifies any vessel used three or more times in a week as full-time, and part-time otherwise.
The total number of each vessel type by geographic area is regularly monitored and published on a monthly basis within SFA internal reports. Over the past 10 years there has been a significant decline in the total number of boats operating within the artisanal fishery (Payet, 1996a). In spite of this overall decline, the number of traditional whaler-class fishing vessels have initially increased to reach a plateau in 1991 (see Figure 1.1). Many of these large boat types are known to exploit the inshore

region, which is likely to have a negative impact on the status of the resource.

Following the successful introduction of a number of semi-industrial vessels, recent observations suggest that the number of boats still in operation has declined by 16% (Payet, 1996a). A brief description of each boat type classified within the domestic fishery is given in Table 1.1.

Table 1.1 Description of boat types operating within the Seychelles domestic fishery.

Boat type	Description
On Foot	Although not strictly a boat-type, fishers can target marine resources from the shore using the snorkel, harpoon and fish trap.
Pirogues	A traditional wooden fishing boat (5-7 m) used with paddles or a punt. For statistical purposes, any fishing boat equipped with an outboard engine ≤ 15 Hp is classified as a pirogue.
Outboards	This category describes all fishing boat types equipped with an outboard motor >15 Hp. The majority of this category consists of a small fibre-glass hull (approximately 5 m), known as a Mini Mahé, although new designs are becoming available (approximately 8 m). Some boats have started to use removable ice boxes.
Whalers	A traditional wooden fishing boat of clinker construction is partially decked and has an inboard motor. Since their introduction, modifications have been made to the basic design, including complete decking, sails, small cabins and ice boxes. A number of alternative inboard vessels are also classified as a 'whaler', including the lekonomie, lavenir and nouvo lavenir.
Schooner	A traditional wooden, fully decked fishing boat (10-13 m), equipped with a three or more cylinder diesel engine. It's large ice box capacity (2-3 tonnes), general comfort and sea worthiness make it an ideal boat to undertake long fishing trips up to ten days duration. Echo-sounders and GPS units are now found on a number of vessels. A much larger vessel design, the La Digue is also classified as a schooner.
Semi-industrial (SI)	There are a number of boats in excess of 12 m operating within the semi-industrial fishery. These include three multi-purpose 'Cygnus' vessels and five vessels designed for specifically for long-lining.

Gear types

There are a large number of gear types used within the Seychelles domestic fishery, including harpoons, fish traps, hook and line, gill nets and beach seine. The following

description applies to the most common gear types in use.

Fish Traps

Fish traps are of a distinctive arrowhead design. They are made of a bamboo mesh with a minimum mesh size of 4 cm in diameter. There are presently three types in common use, although since 1984 fish traps have been differentiated into two categories for statistical purposes: active and static.

- The active trap (casier la vole) is a light trap is used mainly by fishers on foot, and is set around fringing reefs where rabbitfish (*Siganus* spp.) and other reef fish are relatively abundant. They are usually baited with seaweed and left to soak for short periods only before recovery.

- There are two types of static trap; the casier peser, and casier dormi. Both traps are set for up to 24 hrs. The former is a more robust trap design than the casier la vole (active) and is generally used by fishers without boats. Casier dormi traps are generally set in deeper water further offshore.

Handline

Each fisher operates a single monofilament hand line containing 4-8 hooks per line. Each hook is baited with small pelagic fish (e.g. Indian mackerel or bonito). In 1986 electric reels were introduced to increase the volume of catch on board larger vessels.

Long-line

Long lines have recently been introduced to target large pelagic species such as swordfish, marlin and tuna within Seychelles EEZ. The gear is always baited and set for approximately 24 hours. Specialized machinery and skilled personnel restrict availability of this gear category.

Boat-gear categories

The association between each boat and gear can be viewed as a simple matrix (see Table 1.2). This table simplifies the number of categories, combining the traditional whaler, lekonomie, lavenir, nouvo lavenir as whaler and traditional schooner and La Digue vessels as schooner.

Table 1.2 Common boat-gear categories operating within the domestic fishery.

	Foot	Pirogue	Outboard	Whaler	Schooner	SI
Snorkel	✓	✓	✓	-	-	-
Harpoon	✓	✓	✓	-	-	-
Static trap	✓	✓	✓	✓	-	-
Active trap	-	✓	✓	-	-	-
Handline & trap	-	✓	✓	-	-	-
Handline	-	✓	✓	✓	✓	-
Hoop net	-	-	-	-	✓	-
Bottom-Set gill net	-	✓	✓	✓	✓	-
Encircling gill net	-	✓	✓	-	-	-
Beach Seine	-	✓	✓	-	-	-
Long-lines	-	✓	✓	-	-	-
Drop-lines	-	-	-	-	-	✓
	-	-	-	-	✓	✓

SI *Semi-industrial*

The information displayed within the Table 1.2 above is static and cannot demonstrate the dynamic nature of interactions occurring within the fishery. For example, fishers who operate more than one gear category can potentially engage in several fisheries throughout the year. No information exists on the total number of gear categories owned by each fisher, and hence the potential diversity of resources they exploit.

1.3.3 Fishing Locations

For resource assessments, the banks and plateau have been stratified into a number of fishing sectors (Figure 1.2). Each fishing sector has been constructed for statistical and

analytical purposes only. They do not attempt to describe the boundaries of discrete fish stocks or those regions frequented by fishers. It should be noted however, that due to the territorial nature of many reef and demersal species, adult emigration and immigration may be low. Hence, the distribution of fish stocks are likely to remain mutually exclusive between fishing locations (i.e. demersal resources exploited within the inshore fishery may remain distinct from those exploited upon the offshore banks and outer islands).

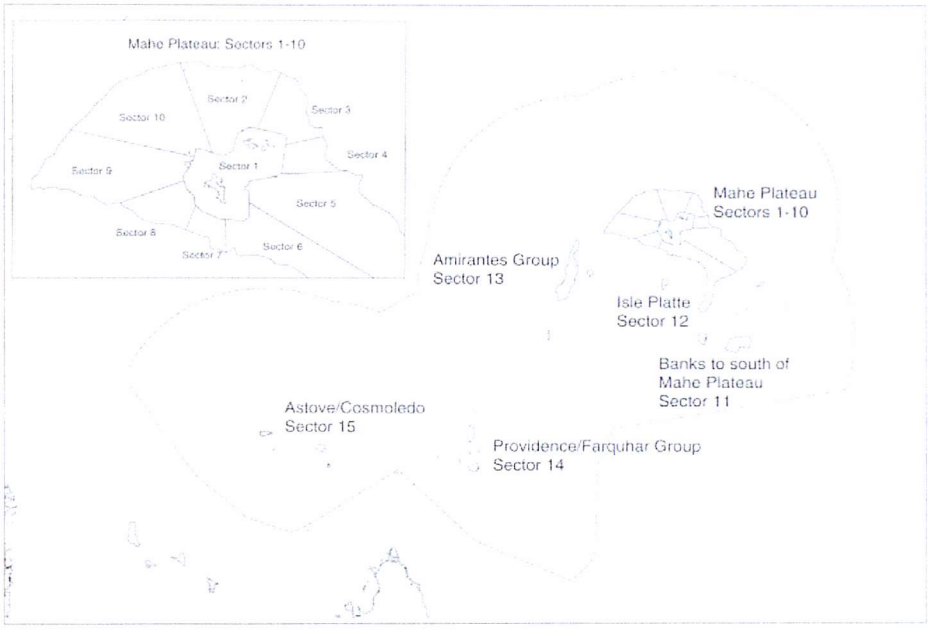


Figure 1.2 The Seychelles Exclusive Economic Zone, showing the Mahé Plateau and associated banks (after Lablache & Cararra, 1984). Insert displays statistical fishing sectors upon the Mahé Plateau.

Fishing grounds can be identified within three major regions; inshore reef and inshore waters and offshore fishing banks and outer islands. Both inshore regions relate to fisheries Sector 1, whereas the offshore banks and outer islands are classified within fisheries Sectors 2 - 15.

1.3.4 Fisheries policy

The current fisheries management policy has met with limited success to encourage artisanal fishers to purchase larger boats and therefore relocate fishing effort offshore. This section details the current management policies used within the domestic fishery.

Major objectives

Government of Seychelles fisheries policy and legislation has been cited in numerous works including Christy (1985), Boullé (1995); Grandcourt (1996) Mees (1996) and Mees *et al.* (1998). The legal framework and institutional setup associated with monitoring, control and surveillance have also been addressed in a revision of the Seychelles fisheries legislation (Flewwelling *et al.*, 1992).

Sectoral planning, originally through the National Development Plans (NDP) of the Seychelles have now been replaced by the Public Sector Investment Programme (PSIP). The most recent document, however, that clearly outlines a number of major objectives relevant to the domestic fishery is the National Development Plan 1990-1994 (Anon., 1990). These were:

- To enhance the fisheries sector's contribution to nutrition;
- The creation of the maximum amount of work opportunities;
- The maximization of foreign exchange earnings;
- The creation of optimum linkages with other sectors;
- The insurance of stable development in the industry;
- The conservation of marine resources in order to ensure the long term viability of the industry.

It is common for Seychelles National Policy objectives to conflict. For example the social objectives of creating employment opportunities conflict with the objectives of sustainable resource use. As reported by Mees *et al.* (1998), the conservation and long-term sustainability of resources should remain the highest priority, or else all other potential benefits will fail.

The Development Plan emphasizes the government strategy to progressively transform the artisanal fishery. The Plan also indicates that whilst opportunities for subsistence and recreational fishers must remain, operations of the demersal fishery must become fully commercialised, with larger and well-equipped vessels capable of exploiting more distant fishing grounds.

To promote purchase of larger boats, a policy to restrict the number of loans disbursed for small boats with outboard engines has been introduced through the Development Bank of Seychelles (DBS). This strategy aims to reduce the level of new fishing effort entering the fisheries within the inshore region.

Incentive schemes

To promote the re-distribution of fishing effort and increase the level of catches from offshore demersal resources, the government has introduced a number of incentive schemes. These include: the promotion of new vessel designs, provision of credit, establishment of credit schemes, management and technical services, technology development and fisheries extension, and the development of new fisheries (Anon., 1989). These strategies were promoted through a number of projects, including a fleet replacement programme, fishing boat construction, schooner fleet management, promotion of demersal fishing in outer islands, development of fisheries technology, and various infrastructure development projects.

These projects have led to the introduction of a number of new vessel designs, but their widespread uptake has not been observed within the fishery. Indeed, the majority of large boat purchases have been focussed on the traditional whaler-class which are capable of exploiting the inshore region.

Young Enterprise Scheme (YES)

In addition to the incentive programmes developed as part of the National Development Plan, there are a number of alternative schemes available to fishers. One of the most important of these is the Young Enterprise Scheme (YES).

The development of this initiative came from outside the fisheries sector under the auspices of the Full Employment Scheme. The scheme is available to the unemployed, young school leavers and groups of individuals aiming to set up a viable new business in any productive sector (e.g. fisheries). It has two main objectives:

- To assist and help people with initiative who have viable ideas to develop these projects;
- Fulfil their ambitions and contribute to the community at large through the medium of self-employment and therefore create jobs for others (SIDEC, 1996).

It has been noted that the scheme is operating contrary to the objectives of the National Development Plan. In addition, the scheme goes further to provide financial incentives to purchase small fibre-glass boats (Mini-Mahé) to enter the fisheries within the inshore region which has already been identified as fully or locally over-exploited. There is concern that the scheme has been abused and that loan recovery has been poor (Mees *et al.*, 1998). It has also been reported that young people taking advantage of the scheme often had little or no fishing skills or experience.

Development soft loans

Fishers are also entitled to apply for a soft loan from the Development Bank of Seychelles (DBS). The DBS grant loans between SR 25,000* and SR 6 million (Nageon, 1986). From 1991, loans were granted at an annual interest rate of 9% for loans up to SR50,000 and at 12% for over SR50,000 (Marguerite, 1992). These interest rates are favourable in comparison to the commercial bank rate of approximately 15 to 16% (Michaud, 1990). Unlike the YES, the DBS requires a form of collateral or a guarantor, in addition to a sizeable deposit (25-40% of capital sum).

The DBS is currently being used within the fisheries sector to acquire the capital necessary to purchase large boats, whereas the YES initiative is used to purchase small boats. It is therefore a paradox that under the current management regime, greater financial incentives are given to increase the level of fishing pressure where it is least required.

Fuel voucher scheme

Introduced in June 1991, the fuel voucher scheme was setup to help reduce the operational costs associated with fishing activities, increasing the financial incentives to local fishers (Marguerite, 1992). This is administered by the Ministry of Finance

* Exchange rate: £1.00 is equivalent to SR8.00

and Communications through the SFA. Fishers with a licenced boat are entitled to a rebate of one rupee for every litre of fuel (benzine or diesel). From an analysis of the results, it has been shown that the scheme can save between 15-20% on fuel costs (Marguerite, 1996).

1.3.5 Fisheries legislation

Within Seychelles, it is the overall responsibility of the government to regulate and enforce management policies. In 1992, the legal framework was reviewed to identify areas for improvement and/or modification (Flewwelling *et al.* 1992).

The principal legal framework pertaining to the fisheries sector is detailed in the Fisheries Act (1986), the Fisheries Regulations (1987) and subsequent amendments, the Licencing Act (1986) and the Licencing (Fisheries) regulations (1987).

Within the 1986 Fisheries Act (Anon., 1986), a number of regulations are used to ban detrimental fishing activities such as trawling and spear-fishing. Additional regulations are also in place to control the size of gear used.

Although licences are currently required for all local fishing vessels (SR100 plus SR25 administration fee) they were introduced with the intention of obtaining a more accurate picture of the fishery and also with the possibility of being using licences for regulatory purposes (Michaud, 1990). Additional licences are currently required for the use of large nets and capture of lobsters, turtles, shells and coral.

Licences can be suspended or cancelled in the event of violations, or if necessary for management purposes. Although the Seychelles Fishing Authority (SFA) are responsible for ensuring a compliance within the fishery, only the Seychelles Licencing Authority (SLA) can cancel a licence upon conviction of an offence.

In practice, both Flewwelling *et al.* (1992) and Mees *et al.* (1998), highlight the lack of resources and trained personnel which inhibit local patrols and enforcement. This has led to only a small number of cases actually brought to court.

1.3.6 Resource Base

The large numbers of boats operating within the inshore region have given rise to concern over the status of the inshore fish stocks (Grandcourt, 1996). This section provides an outline of the resources currently exploited by different fishing categories within each major fishing location (inshore reef; inshore waters; offshore).

Total catches by boat-gear category

The domestic fishery is currently exploited by a wide range of different boat-gear categories (cf. Table 1.2). The relative importance of each category can be gauged by their level of total annual catches (Table 1.3).

Table 1.3 Total annual catches (tonnes) retained by different boat-gear categories within the domestic fishery during 1997 (SFA, 1997).

	Gear type					
Boat type	Trap	Handline	Trap & Handline	Gill nets	Beach seine	Long-line*
Pirogues	25	5	3	2	2	-
Outboard	207	572	101	31	-	-
Whaler	3	2,177	-	-	-	-
Schooner	-	296	-	-	-	-
SI	-	-	-	-	-	49
Total	235	3,050	104	33	2	49

*Data obtained from 1995 (SFA annual report) for catches of long-line vessels only.

From catch data, handlines-only are by far the most important gear category utilised within the domestic fishery. This is followed by traps-only and, traps and handlines. Nets (gill net and beach seine) and long-line are both comparatively unimportant with respect to the other three gear categories.

Inshore Fisheries

The inshore region (fisheries Sector 1) is the most heavily exploited fishing location within the Seychelles domestic fishery. A wide range of fishing categories exploit an area of just 4,544 km^2 within 10 nmiles of the main granitic islands in water depths ranging from 0-75 m. Within this depth range, a number of opportunities exist to exploit the resources upon the plateau, including demersal and semi-pelagic. In general, this area is dominated by small boat activities, although larger vessels (schooners) are known to utilise the resources, particularly during bad weather (e.g. south-east monsoon).

Reef Fishery

A small fishery exists around the fringing reefs of the three main granitic islands in water depths ranging from 0-35 m. Within this depth range, an area of 577 km^2 is currently exploited from a potential total reef area of 2,000 km^2 (FAO/IOP, 1979). A number of different species are targeted by fishers on foot or within small boats, including octopus, lobster and several species of reef fish (mainly rabbitfish) (Table 1.4).

Table 1.4 Total catches (tonnes) by major species for the 1997 trap fishery (Mahé, Praslin and La Digue).

Species	Static Trap	Active Trap	Total	MSY*
Rabbitfish (*Siganus* spp.)	250.4	47.2	297.6	-
Other trap species	76.8	2.8	79.6	-
Other reef species	10.4	2.8	13.2	-
Total	337.6	52.8	390.4	600

Source: SFA technical report, 1997

* Lablache *et al.* (1988)

A preliminary assessment of reef fish taken from the inshore trap fishery was made by Lablache *et al.* (1988) using catch and effort data from on foot, pirogues, outboards and whalers. Using a Fox production model, an estimate of the maximum sustainable yield was obtained (600 tonnes). This would initially suggest that the reef fishery is

currently under-exploited. However, high catches in excess of MSY were recorded during the 1980s, which may have reduced the level of stock biomass.

The status of the inshore reef was re-assessed in Appendix 1.1, using the Schaefer production model. A revised lower estimate of MSY (474 tonnes), and the status of the stock biomass indicated that the inshore reef fishery is currently fully-exploited.

Demersal fishery

Inshore demersal resources are exploited by a number of vessels using baited hook and lines. The majority of vessels operate within 10 nmiles of the main granitic islands. More recently, fishers have been encouraged to operate further offshore, particularly around the banks and surrounding islands of the plateau where higher catch rates are obtainable. The demersal fishery has been described in detail by Mees (1996).

The total demersal annual catches within the inshore region (Sector 1), have been estimated by boat-type in Table 1.5.

Table 1.5 Total demersal annual catches (tonnes) in Sector 1 by boat type (adapted from Mees, 1996).

Boat type	89	90	91	92	93	94	MSY
Small boats	267	202	215	215	247	229	-
Whaler	225	391	305	308	357	185	-
Schooner	76	68	27	29	16	11	-
Total	568	661	547	552	620	425	458

The whaler handline fishery removes the largest biomass of the inshore demersal fishery. Despite this high fishing pressure, an assessment of the status of the inshore whaler hand line fishery provided no evidence of depletion for the period 1989 to 1994 (Mees, 1996).

These results should be viewed with caution. High fishing pressure was observed during the sampling period (1989-94) and present catch rates and species composition may reflect only a temporary equilibrium. Data prior to the assessment were

unavailable, during which depletion and species composition changes could have occurred (Mees, 1996). Furthermore, much of the biological data pertaining to the inshore fishery was collected from schooner vessels, predominantly on the offshore banks and periphery of the Mahé Plateau. Thus important biological information may reflect only lightly exploited areas. Observed fluctuations in the data set may be due, in part, to the quality and quantity of data available. For example, only the traditional whaler had sufficient catch and effort data available for assessment purposes.

Outer Plateau and Islands Fisheries

An offshore demersal fishery also occurs on a number of fishing banks upon the Mahé Plateau and outer islands (fishing Sectors 2 to 10, Figure 1.2). These are currently exploited by fishers on large boats with hook and lines (whaler and schooners).

Demersal fishery

A number of production estimates have been derived for the demersal resources of the Seychelles. These were initially based either on the swept area method applied to trawl surveys or through application of length cohort analysis to a representative sample (Birkett, 1979; Marchal *et al.*, 1981; Tarbit 1980).

Mees (1996) has since revised estimates of the total biomass and MSY of commercially important demersal species available to the hand line fishery (see Table 4, p.23; Mees, 1996). These update all previous estimates undertaken by Mees (1992), using the most recent data on bank area (see Table 1.6). These data however, exclude estimates for the trawlable grounds.

Table 1.6 Resources available to the offshore demersal fishery.

Location	Total Biomass (tonnes)	MSY (tonnes)	Reference
Mahé Plateau	42,000	-	Birkett, 1979
Mahé Plateau	75,000	-	Marchal *et al.* 1981
Mahé Plateau	80,000	-	Tarbit, 1980
Mahé Plateau	42,260	5,650	Mees, 1996

The results of the resource assessments show that the offshore region (Sectors2 to 15) have the potential for a substantial demersal fishery. The estimated total annual catches (tonnes) from the offshore demersal fishery are given in Table 1.7.

Table 1.7 Total annual catches (tonnes) from the offshore demersal fishery (adapted from Mees, 1996).

Year	Catch (tonnes)
85	395
86	719
87	803
88	660
89	725
90	993
91	1,454
92	1,134
93	867
94	937

The level of total annual catches (tonnes) for the offshore demersal fishery indicate that the fishery is only lightly exploited, retaining only approx. 20% of the potential sustainable yield.

Semi-pelagic fisheries

Semi-pelagic species, such as carangids (*Carangoides* spp.) are caught mainly within

the shallow waters of the Mahé Plateau. Mees (1996) attempted a preliminary assessment of the semi-pelagic fishery for carangue (*C.gymnostethus*) targeted by the whaler handline fishery. The results showed that significant fluctuations in catch rates with a general trend indicating depletion of the resource between 1989-94. Because this is a highly mobile species, it cannot be assumed that it is exclusive to fisheries Sector 1. Therefore the assumptions of depletion assessment models may be violated for this species.

The total annual catches (tonnes) from the semi-pelagic fishery are given in Table 1.8.

Table 1.8 Total annual catches (tonnes) from the semi-pelagic fishery (adapted from Mees *et al.*, 1998).

Year	Catch (tonnes)	
	Small boats	Whaler
88	353	1,651
89	396	1,335
90	466	1,900
91	380	1,502
92	460	1,743
93	328	1,519
94	279	978
95	470	1,031
96	468	1,077

The whaler boat type takes the majority of semi-pelagic catches, although Mees *et al.*, (1998) suggest that towards the end of the 1989s, this boat category increasingly targeted demersal resources. This could not be shown from the catch records.

Summary

The status of the inshore resources remain a key management issue. A brief summary of the status of all fisheries are described below;

- **Inshore reef fishery**

  The reef fishery is currently fully-exploited. Although present catches levels are below the re-estimated MSY (see Appendix 1.1), the status of the stock biomass is below that required to maximise sustainable catches.

- **Inshore demersal fishery**

  The inshore demersal fishery is fully- and possibly locally over-exploited. Catch levels have remained above MSY, with whalers removing the highest proportion of biomass.

- **Offshore demersal fishery**

  The status of the offshore demersal fishery is lightly exploited. Both whalers and schooners target demersal resources on the peripheral banks of the Mahé Plateau and outer islands.

- **Semi-pelagic fishery**

  The status of this resource remains unknown. Whalers are responsible for removing the highest proportion of biomass mainly from the inshore region (fisheries Sector 1).

1.3.7 Market Attributes

Knowledge of the price of fish is essential if the economic performance of a number of alternative management strategies is to be evaluated. At present, two markets are available for the sale of fish: domestic market and fish centres.

The fisheries sector has recently undergone a number of economic changes. The Seychelles Marketing Board (SMB) was originally owned by the State and controlled the sale and export of all Seychelles food products. This included the Divisions of Fisheries, Agriculture, and, Materials and Feed. Since the introduction of multi-party politics in 1993, the new democratic state began to sell-off many parts of SMB to private investors. At present, only the Division of Materials and Feed remains under state control.

The Fisheries Division operated 11 fish centres around the islands of Mahé, Praslin and

La Digue where fishermen were guaranteed to sell their catch, but at a fixed price. All fish centres have now been sold to private investors, the largest purchased by Oceana Fisheries Ltd., Victoria (Oceana).

Since the removal of a state monopoly there has been a notable decline in the volume fish purchased by the Oceana fish centre. This is probably due, in part, to an increase in other markets now available to fishers.

The purchase of fish by Oceana fish centre also shows a strong seasonal component directly related to climatic conditions. The seasonal abundance of fish can be observed directly through monthly catch statistics (see for example SFA, 1998). Seasonal effects are also shown in the monthly purchases from Oceana fish centre. The average monthly fish purchases have been plotted for 1992-97 in Figure 1.3.

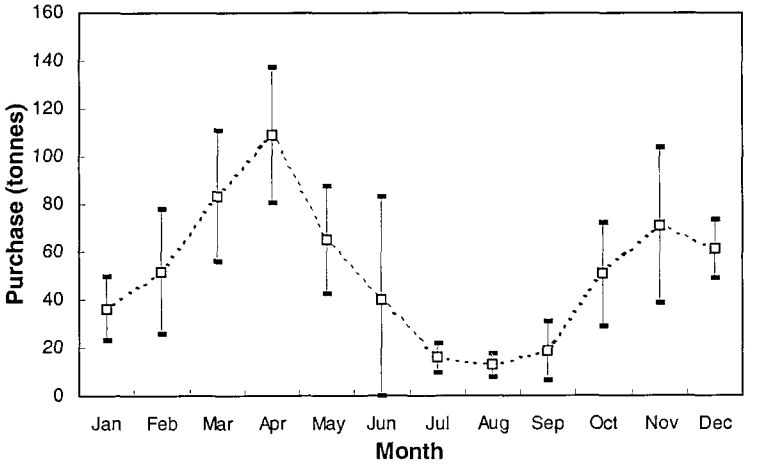


Figure 1.3 Average monthly fish purchases (tonnes) by fish centre between 1992-97. Vertical bars represent ±1 standard deviation.

The volume of catches returned in the low season may be governed by several factors, including; poor visibility (catchability), seasonal migration of species, and reduced number of fishers at sea. The seasonal nature of the fishery dominates market prices and the ability of fishers to re-pay outstanding debts.

Fish Prices

Since 1993, the policy of selling fish at a guaranteed fixed-price has been abolished in

favour of a free market. Fishers have now been given the opportunity to sell their catch to a private fish centre or directly on the domestic market.

Fish Centre

Oceana fish centre (former SMB) retain a rigid price structure. This system has become more flexible with the introduction of memos (Tirant pers. comm., 1997). Fish prices, advertised 'until further notice', may be temporary altered by price increases if the company has an increase in demand. These small fluctuations reflect not only the seasonal pattern of the fishery, but may also describe other local or international market demands.

Oceana has two price grades (A and B) which reflect the quality of the fish received. In addition, a bonus is given to all fishers on contract with the centre. This value is added to either price grade to obtain the total value per kg. Table A1.1 (Appendix 1.2) provides a guide to the potential value of different species caught within the domestic fishery.

Oceana are somewhat able to control supplies in the market by freezing and storing a volume of fish and fish products for sale during the low fishing season. This may depress what would otherwise be a buoyant fish market.

It should be noted that within the current price structure, a premium is paid for the most popular plate-sized fish less than 1 kg (e.g. bourgeois and job gris). Unfortunately, this practice encourages both recruitment and growth overfishing, and maintains a high level of fishing pressure upon the most valuable stocks. These stocks are also the most valuable for the export market.

Domestic market

Fish may be sold direct to the public where is has been landed (on the beach/roadside), or the catch may be taken to one of many local domestic markets.

Unless fish are considerably large (> 5kg), fishers generally sell reef (e.g. rabbitfish)

and demersal (e.g. snappers/emperors) fish tied together in packets. Each packet has a fixed value, although the weight may fluctuate.

As part of the SFA catch assessment survey (SFA, 1998), samples of fish packets are weighed, and the price per packet recorded. Unfortunately, this data are not available directly from SFA annual statistical reports. A sample of the average monthly fish prices (SR/kg) for trap fish (*Siganid* spp.), have been analysed for the period July 1996 to June 1997. The results are presented in Figure 1.4.

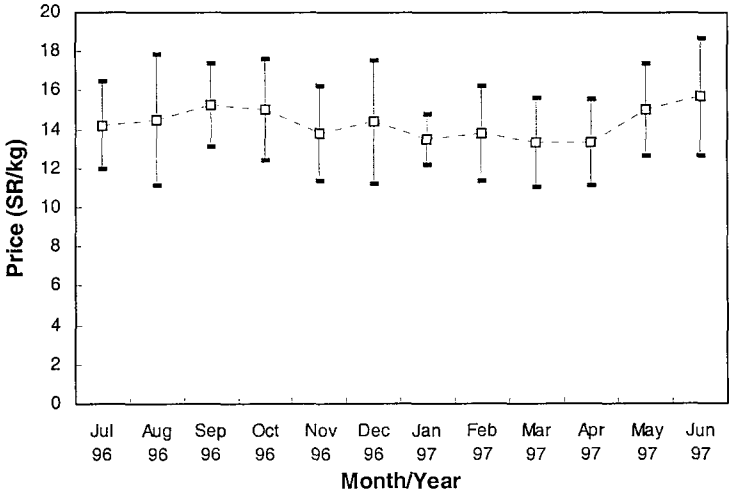


Figure 1.4 Average monthly fish price (SR/kg) for trap fish (*Siganid* spp.) over the period July 1996 to June 1997. Vertical bars represent ±1 standard deviation.

The average price for trap fish is relatively constant throughout the year at 14.2 SR/kg. Marginally lower prices are be observed during the peak fishing season (Nov. - Apr.).

1.4 Model Specification

To achieve the overall objectives of the study, a model is required that can be used to evaluate alternative management strategies within a complex tropical fisheries system. The principal aim of the model is to ensure the recovery and long-term sustainability of the inshore resources. Without the biological security and sustainable long-term catches, all other benefits from the fishery become diminished.

There are, of course, a number of additional economic and socio-economic policies that can also be addressed. In the National Plan, the government of Seychelles indicated that policies providing a more equitable distribution of income should be developed (Anon., 1990). Furthermore, the level of employment within the fisheries sector may also be considered an important management issue (Mees, 1990b).

It is common in fisheries policy that biological, economic and socio-economic objectives conflict with each other. For example, higher employment levels may lead to a decline in fisher income levels. It is not the objective of this study, however, to provide an optimal management solution. Rather, it has previously been highlighted that inshore fish stocks are already heavily exploited (see Section 1.3.6), and that the recovery of these inshore stocks should take priority. The simulation model can be used to assess the likely effects of suitable policies on different economic and socio-economic objectives.

There are a large number of models available to assess the biological status of the stock and to evaluate the potential effects of alternative management policies. Section 4.1.1 provides an overview of the type of models available in fisheries management, with emphasis on those which may be applicable to the current study. The specifications of the model to be used in this study are then described in full within Section 4.1.2.

Finally, given a description of the model, the type and quantity of data required are given in Section 4.1.3.

1.4.1 Fisheries assessment models

Biological

In many tropical countries the models used tend to be quite simple due to the lack of data available. This is usually because of the spatial and biological diversity of resources, the complexity of the fishery and the limited capacity for data collection and analysis (Appledorn, 1996).

The simplest models available to assess the biological status of a resource are comparative harvests and approximate yields. These compare potential yields from

related fisheries. If a fishery has no catch-effort data available to perform a comparison, then the MSY can be used from a comparative fishery with the same habitat. Potential yields of fish stocks have been reviewed by Russ (1995).

Similar to comparative harvest models, approximate yield models are available to estimate the potential yield where catch and effort data are lacking (see Gulland, 1983; Beddington & Cooke, 1983). These methods can only provide a rough estimate of the relative size of the potential yield. These simple models are of limited use to evaluate management options because they are unable to predict future outcomes.

If catch and effort data are available, however, the most common methods used to estimate the productivity of a resource are production models. These have been reviewed by Spare *et al.* (1989). There are now many variants of the production model which was first proposed by Schaefer (1954; Pella & Tomlinson, 1969; Fox, 1970). As they stand, these models only describe the current or historical pattern of exploitation. Without suitable modification, they cannot in themselves be used to predict catches. This is an important requirement of evaluating the impact of different management options on the status of the resource. One particular advantage of these models, however, is that only require a small number of input parameters.

The production model has also undergone various modifications for use in multi-species assessments. Ralston & Polovina (1982), aggregated species into groups to analyse the multi-species deep-sea handline fishery in Hawaii. The potential MSY was obtained by adding all groups together. Kirkwood (1982) was able to show, however, that multi-species MSY will be less than the sum of the single species MSYs. Since they require a number of difficult assumptions, and have a number of data requirements, multi-species production models have limited application.

If more information is available on the biological status of the resource, dynamic pool models (yield-per-recruit) can be used to assess the status of the stock. In brief, these simulate the growth, recruitment and mortality of fish stocks to predict yield (see Beverton & Holt, 1954). Yield-per-recruit models have the potential to provide more appropriate management advice, but at a greater cost. The data requirements for these models (e.g. growth, natural and fishing mortality) is often beyond that

available for most developing countries. In turn, the assumption of constant recruitment is generally flawed.

Age-structured models have become one of the most widely used in temperate industrial fisheries. Chávez (1996), used an age-structured dynamic pool model to assess the optimum harvesting strategy on a small-scale fishery in Mexico. By using the model to predict yields, he was able to investigate a number of management options, including altering the level of fishing mortality until optimum yields were obtained.

More commonly, single species cohort analysis, or VPA, is used to estimate the size of each cohort in each previous year as a result of growth and total mortality (see Pope, 1972). This was later extended into a multi-species cohort analysis integrating the traditional VPA with predator-prey relationships (Sparre, 1991). However, where catch-at-age data are difficult to obtain, length-cohort-analysis has been developed by Jones (1974).

Bio-economic

Obviously, the fishery system is not controlled exclusively by biological factors. Rather, it is the revenue generated from fishing activities that partly controls how much fishing effort is exerted. Integrated methods of biological and economic assessment have been included in the development of bio-economic modelling.

Much theoretical analysis has been given to estimate what is known as the Maximum Economic Yield (MEY), and the optimal bio-economic analysis of fisheries (see Clark 1985, 1990). There are many examples of bio-economic models which all attempt to optimise the level of harvest from single-species (e.g. Placenti *et al.*, 1992) or multi-species fisheries (e.g. Padilla and Copes, 1994).

It has been recognised that fisheries policy often conflicts with other management objectives. For example, maximising the net revenue from the fishery may require a reduction in the level of employment. To this end, bio-economic theory has been extended to optimise multiple objectives within the fishery system. There are many

examples of models which attempt to optimise multi-objectives. These include analyses for industrial single-species fisheries (Charles, 1995; Sylvia & Eníquez, 1994) and multi-species, multi-gear fisheries (Padilla & Copes, 1994).

In practice, estimation of MEY and multiple objectives are fraught with many problems associated with accurate data collection, which ultimately may be too difficult to obtain. Further to this, without limited access controls, the fishery will tend towards a bio-economic equilibrium, where any additional profit to be gained from the fishery will attract more fishing effort. Adoption of MEY policies are therefore often too difficult to implement by management agencies.

Bio-economic theory has also been extended to simulate the behaviour of fleet dynamics. Smith (1968) linked biological population dynamics with fishing effort to describe how fishers vary their levels of fishing effort over time in response to economic conditions.

There many examples of spatial models on fleet dynamics (Caddy, 1975; Durrenberger & Palsson, 1986; Kleiber & Edwards, 1988). Predicting vessel behaviour also enables future projections to be simulated. This can then be used to evaluate alternative management strategies (e.g. Christensen, 1997). It should be noted, however, that these models can lead to an 'optimal solution' if all skippers attempt to locate the highest fish abundance. Allen & M^{c}Glade (1986), have simulated the Nova Scotia groundfish fishery as a spatial multi-species model which does not assume a perfect transfer of information on catches.

All the bio-economic models described so far do not attempt to explicitly simulate the decision processes of socio-economic groups operating within the fishery. This is considered a key requirement, if the likely effects of alternative management options are to be fully evaluated within the fishery system (Opaluch & Bockstal, 1984).

Bio-socio-economic

The development of new fisheries policy requires that fisheries management consider a range of biological, economic and socio-economic objectives (Healy, 1984). It is also

likely that a better understanding of the labour dynamics is necessary for implementing efficient and equitable management policies (Terkla *et al.*, 1985; cited in Charles, 1995). Predicting the response of effort to economic incentives and to policies which affect these incentives, however, requires accurate modelling of fisher's behaviour at the micro level (Opaluch and Bockstal, 1984).

An assessment of the fishery system is complex, none more so than a tropical artisanal fishery. This requires the development of an integrated framework which combines the quantitative approach to bio-economic modelling with socio-economic studies (Charles, 1995). This approach to modelling therefore requires a multi-disciplinary analysis (Sivasubramaniam, 1993).

Although there is much qualitative socio-economic information available on fisheries systems (see review by Charles, 1988), this is not mirrored by the number of quantitative studies. A number of empirical studies have, however, been conducted. For example, Panayotou & Panayotou (1986) studied labour dynamics of fishers and fishing communities in the Thailand fisheries.

There are several models available to simulate human dynamics within the fishery. Both fleet dynamics (previously described) and labour dynamics have been used to simulate different levels of fishing behaviour. For example, the theoretical optimization of multiple objectives has been carried out by Charles (1989) using both fish and labour dynamics.

To date, the author is not aware of a bio-socio-economic modelling technique that incorporates both the decision-making processes of individual socio-economic groups within an artisanal fishery and an evaluation of alternative management options.

1.4.2 Outline of model structure

The principal aim of the model described in subsequent chapters of this thesis is to evaluate the likely outcomes of a number of alternative management options on different socio-economic groups identified within the artisanal fishery of Seychelles. This will lead, among other things, to the recovery and long-term sustainable use of the inshore fish

stocks and a more equitable distribution of income among artisanal fishers.

To achieve this aim, the model must include:

- Biological production to regenerate biomass;
- Economic information relating to the artisanal fisheries sector;
- Individual socio-economic groups with their own decision-making processes.

1.4.3 Data requirements

Much of the biological information required to develop a simple production model of the fishery is already available from secondary sources of information. In turn, quantitative information on the general technical attributes of the fishery are reported in a number of Seychelles technical reports (SFA, 1986-97) and catch assessment survey database (Lablache & Carrara, 1984).

There remains comparatively little information on the economic and financial details of the artisanal fishery. In addition, while socio-economic information is available to identify trends within the fishery, it does not permit the re-examination of socio-economic characteristics of individual fishers. There is currently no information on the technical and economic attributes of different socio-economic groups. Although technical and economic information exists within secondary sources, it must be linked to different socio-economic groups. Data that cannot easily be attributed to one or more group is therefore required.

The following summary indicates what information is required for the model.

Biological

- Input parameters for production model
  - Inshore reef
  - Inshore demersal
  - Offshore demersal

Technical

- Total number of boats and crew within each boat-gear category
- Annual number of fishing trips for each boat-gear category
- Average number of gear used by fishers within each boat-gear category

Economic

- Operating costs associated with each boat-gear category
- Fixed costs (incl. loans) associated with each boat-gear category
- Fish prices at different markets
- Government subsidies

Socio-economic

- Identification of distinct socio-economic groups
- Decision-making processes of fishers within each socio-economic group

1.5 Outline of thesis

In this chapter an original bio-socio-economic modelling approach has been proposed to evaluate a number of alternative management options which in turn should promote the recovery and long-term sustainable use of the inshore fish stocks.

In order to develop this model, a range of biological, technical, economic and socio-economic data are required. Although much of the biological and technical information is available through secondary sources, there is comparatively little quantitative data available for either economic or socio-economic attributes. A programme of data collection is therefore essential to obtain all the model data requirements.

Chapter 2 describes the methods used to conduct a formal survey on the Seychelles fishing community. This enables the identification of key socio-economic groups to be including within the bio-socio-economic model.

In Chapter 3 a series of informal interviews are described which identify key factors for fisher decision-making within each socio-economic group. The subsequent range of

decision options available to fishers within each socio-economic group are also described. Combined, the decision-making processes of each socio-economic group are used to describe the socio-economic attributes of the artisanal fishery.

An overview of the development of the bio-socio-economic model is given in Chapter 4. This chapter also describes explicitly both biological and economic sub-modules of the model.

Chapter 5 examines the decision-making processes of each socio-economic group identified within Chapter 2. These are developed into a socio-economic sub-module which defines the labour dynamics controlling the actions of fishers to changes in the fishery.

In Chapter 6, the ability of the model developed during previous chapters to replicate historical data from the artisanal fishery is examined. Good agreement between historical and predicted trends would increase the level of confidence placed in the key processes operating within the model.

The bio-socio-economic model is used to evaluate the performance of alternative management options in Chapter 7. The relative success of each management option is ranked based their ability to achieve management objectives. Based on this study, the most appropriate management options for the Seychelles artisanal fishery are discussed.

Finally Chapter 8 summarises the work described in this thesis. The contribution of the bio-socio-economic model to Seychelles artisanal fisheries management is discussed and future research arising from these studies is suggested.

2 IDENTIFICATION OF SOCIO-ECONOMIC GROUPS WITHIN THE ARTISANAL FISHERY

2.1 INTRODUCTION

Chapter 1 highlighted the concern expressed over the status of the Seychelles inshore resources and the limited success of current government financial incentives to relocate fishing effort offshore.

This study aims to evaluate a range of alternative management options which aim to allow the inshore fish stocks to recover to a sustainable level. This will be examined using a bio-socio-economic model of the artisanal fishery. The model will simulate the decision-making processes of fishers to help predict their likely behaviour under each management policy.

The aim of this chapter is to collect quantitative information on different characteristics of artisanal fishers such that a number of socio-economic groups can be identified. In order to collect this data, a formal survey of the Seychelles fishing community was conducted. The development of a questionnaire for this purpose also allowed additional information to be collected on both the technical and economic attributes of the fishery.

The chapter is organised as follows. Section 2.2 describes in detail the formal sampling strategy employed to collect quantitative information on different attributes of the artisanal fishery. Section 2.3 compares and contrasts the results of the formal survey with those from a previous study, to identify socio-economic trends. These trends are used in conjunction with other key fisher characteristics to identify a number of distinct socio-economic groups in Section 2.4. Due to the subjective nature of the method used to classify fishers into different socio-economic groups, discriminant function analysis was also used to provide a more robust group classification technique. The interactions between each socio-economic groups are described.

2.2 FORMAL SURVEY OF SEYCHELLOIS FISHERS

A survey was undertaken of the artisanal fishing community by means of a formal questionnaire. It was not possible to conduct a complete census, and therefore a sample of the fishing community was taken from the three main granitic islands of Mahé, Praslin and La Digue. Combined, these three islands contain almost the entire population of Seychelles (Anon, 1997b).

A previous socio-economic survey of the Seychelles artisanal fishermen had been conducted in 1989 by Mees (1990). This 1989 survey was designed primarily to investigate the socio-economic status of crew members, skippers and boat owners with and without a boat loan. By updating this information, the new data can be compared with the 1989 survey to help identify a set of characteristics for a number of different socio-economic groups.

The following sections describe the development of the formal survey. First, a description of the survey design is given, followed by the construction of the sampling frame that was used within the survey. A sampling frame was necessary to select a sample of fishers from the total population of full-time commercial fishers. Finally, details of the formal questionnaire that was used in this part of the survey are given in detail.

2.2.1 Survey design

Ideally, an appropriate survey design should select a random group of respondents (fishers) from the population to be surveyed (artisanal fishing community). This usually required the construction of a sample frame, from which a group of respondents are randomly selected from the population via one of a number of techniques (see Cochran, 1977). Random selection of individuals ensures that each has an equal probability of being chosen. This is important if the sample is to remain unbiased. (Poate & Daplyn, 1993); (Casley & Lury, 1989).

The artisanal catch assessment survey undertaken by SFA uses a cluster sampling strategy (see Lablache & Carrara, 1984; SFA, 1997), whereas the previous 1989 socio-economic survey aimed to complete a census of all boat owner-operators and a sample of crew

members. Neither strategy could be used for the 1997 socio-economic survey due to a number of constraints.

A lack of reliable information on each member within the fishing community, including contact details, prevented a stratified random sample from selecting a pre-determined group of fishers. Furthermore, even if fishers could be identified on paper and selected for interview, much time and effort would be wasted in attempting to relocate the same individual in the field. This would notably reduce the overall sample size. Also, with only limited resources available, it was considered impossible to conduct a complete census of all boat owner-operators and a sample of crew members.

To ensure that sampling effort was evenly distributed among different groups or strata, a *quota sampling* design was adopted. This permitted enumerators to select a pre-determined number of respondents, thus eliminating a requirement for detailed information to be available on all fishers within the population.

Quota sampling ensures that adequate sample sizes are obtained from within each chosen group or strata (Stephan and McCarthy, 1958); (Cochran, 1977); (Bernard, 1994). However, quota sampling may not result in random selection within the strata. This may affect the extent to which the survey is fully represented of the total population (Cochran, 1977). In the 1997 survey, enumerators were asked to sample the first respondent that met their sampling criteria.

2.2.2 Quota Sample frame

The design of a quota sampling strategy required a number of steps. First, the total population of the fishing community was divided into a number of mutually exclusive and exhaustive sub-populations or strata, according to the characteristics of their fishing operations. Second, an estimate of the fraction of the total population contained in each stratum was then calculated. Finally, the total sample size was allocated among these strata in proportion to their estimated size. Enumerators were then given a fixed number or 'quota' of respondents to interview within each stratum.

Stratification

When strata are chosen appropriately, sample units (in this case individual fishers) within any one stratum are more homogeneous than in the total population. Stratification may also help reduce the overall sampling variability (Poate & Daplyn, 1993). The quota sampling frame used two stratifications: by boat-type and by geographic region.

Following an overview of the artisanal fishery in Chapter 1, the size and type of boat was found to determine to a great extent the type of operations each fisher is likely to undertake.

There is a wide range of different boat-types currently operating within the artisanal fishery. In order to reduce the number of categories, all inboard powered vessels with partial decking were grouped into a broad whaler class, as is done in the SFA annual statistics (see SFA, 1997). In total, six boat-type categories have been used. These are described in Table 2.1.

Table 2.1 Major boat-type categories within the artisanal fishery, in ascending order of fishing power.

Category	Description
On Foot	All fishers operating from the shoreline without access to a boat
Pirogue	A traditional wooden fishing vessel approximately 5-7 m long, originally carved out of local materials and used with paddles or like a punt. Today, category includes all fishing boats equipped with a 15 Hp (or less) outboard engine.
Outboard	Small fibre-glass boat equipped with an outboard engine greater than 15 Hp.
Whaler-class	A broad category incorporating both traditional and modern partially decked fishing boats with an inboard engine of 1 or more cylinders. Includes the whaler, lekonomie, lavenir and Nouvo lavenir vessels.
Schooner	A traditional fully decked fishing vessel, equipped with an inboard engine of 3 or more cylinders. For statistical purposes now includes more modern La Digue fishing boats.
Semi-industrial (S.I.)	Modern multi-purpose fishing vessel used for longlining and dropline activities.

In addition to stratifying the fisher population by boat-type, different sampling fractions for different geographic regions were also used. Stratification by major geographic region ensured that spatial variation within the total sample was accounted for. Seven geographic regions were used, similar to those used within the existing SFA catch assessment survey (Table 2.2). Each geographic region was identified by the location of landing sites surrounding the islands of Mahé, Praslin and La Digue (see Annex 3.1 in SFA, 1997).

Table 2.2 Geographic regions identified by fisher landing sites within Seychelles.

Geographic region	Description of landing sites within each strata	Landing site codes
1. NW Mahé	Baie Ternay to Fai de Liane	10 - 15
2. NE Mahé	La Retraite to Petit Paris	16 - 26
3. E Mahé	Cascade to Anse Forbans	27 - 36
4. W Mahé	Port Glaud to Takamaka	37 - 43
5. NE Praslin	Anse Boudin to Consolation	44 - 53
6. NW Praslin	Anse Takamaka to Anse Lazio	54 - 60
7. La Digue	La Passe to Anse la Reunion	61 - 63

Data source (SFA, 1997).

Estimation of the total fisher population size

Unfortunately, there is currently no reliable information available on the total number of full-time commercial fishers within the fisher population. This is partly due to the seasonal nature of the fishery, and partly due to the lack of a distinction between recreational and part-time fishers, and full-time commercial fishers. SFA have introduced a system of registering all full-time commercial fishers. Up to 1997, however, this list was known to be incomplete.

Instead, an estimate of the total number of commercial fishers within the fisher population was calculated based on the product of the number of boat-types per geographic region and the average number of fishers operating on board each boat. A proportion of these fishers within each sub-stratum can then be selected to obtain the required sampling quota.

The total number of boats in operation within each geographic area was obtained from two sources of information. The 1996 annual statistical report (SFA, 1997) provided a breakdown of the average number of full-time fishing boats in operation at each landing site by geographic area. The total number of boats could then be cross-checked against a 1996 boat survey (Payet, 1996). The latter also provided an estimate of the number of semi-industrial (S.I.) vessels, not otherwise documented within the SFA annual statistical report. The average numbers of fishers per boat-type were obtained using data collected from the 1989 socio-economic survey (Mees, 1990) and cross-checked with personal observations (Table 2.3).

Table 2.3 Average number of fishers per boat-type.

On Foot	Pirogue	Outboard	Whaler-class	Schooner	S.I.*
1	1.9	2.1	4.4	5.8	6

**(Payet 1996, personal communication).*

An estimate of the total number of fishers within each sub-stratum was calculated as the product of the average number of boat-types identified within each geographic region and the average number of fishers per boat-type. The aggregation of all fishers within each sub-stratum then provides an estimate of the total fisher population size.

The estimated numbers of fishers within each sub-stratum of the population are presented in Table 2.4. In total, 1062 full- and part-time fishers were estimated within the artisanal fishery in 1996. The proportion of fishers within each sub-stratum of the fisher population are shown in brackets.

Table 2.4 Estimated numbers of fishers within each sub-stratum of the total fisher population (proportion of total in brackets).

Geographic Region	Boat-type						
	On Foot	Pirogue	Outboard	Whaler-class	Schooner	S.I.	Total
NW Mahe	3.3	1.5	53.3	37.4	0	0	**96.0**
	(0.003)	(0.001)	(0.050)	(0.035)			**(0.090)**
NE Mahe	0	5.3	63.0	194.9	104.4	36.0	**403.6**
		(0.005)	(0.059)	(0.184)	(0.093)	(0.034)	**(0.380)**
E Mahe	3.9	12.5	72.5	67.8	0	0	**156.7**
	(0.004)	(0.012)	(0.068)	(0.064)			**(0.148)**
W Mahe	11.0	5.1	42.6	51.5	5.8	0	**116.0**
	(0.010)	(0.005)	(0.040)	(0.048)	(0.055)		**(0.109)**
NE Praslin	8.1	22.2	75.4	30.4	17.4	0	**153.5**
	(0.008)	(0.021)	(0.071)	(0.029)	(0.016)		**(0.145)**
NW Praslin	3.3	24.9	47.5	8.8	0	0	**84.5**
	(0.003)	(0.023)	(0.045)	(0.008)			**(0.080)**
La Digue	9.8	2.5	28.8	11.0	0	0	**52.1**
	(0.009)	(0.002)	(0.027)	(0.010)			**(0.050)**
Total	**39.4**	**74.0**	**383.1**	**401.8**	**127.6**	**36.0**	**1061.9**
	(0.037)	**(0.070)**	**(0.361)**	**(0.378)**	**(0.120)**	**(0.034)**	**(1.000)**

Sample size

The sample size for the survey must be decided at the planning stage, together with the sample design. The sample size to be used depended upon three main factors: the level of precision required in the estimates, the intrinsic level of variability of the characteristics to be estimated, and the sample design. To achieve a high level of precision, and hence a small sampling error, a large sample size is desirable. Similarly, if the characteristic to be measured is itself highly variable within the total population, a larger sample size is required. The type of sample design is known to produce different levels of precision for the same sample size. In general stratification tends to increase the level of precision, thus reducing the required sample size (Poate and Daplyn, 1993).

There is obviously a trade-off between the maximum number of samples required to

achieve the high levels of precision and accuracy, and the resources available to collect the data. With the resources available, it was assessed that approximately 20 percent of the total estimated fisher population or 212 fishers could be expected to be sampled within the 1997 survey.

To sample the total fisher population, a quota was calculated for each sub-stratum, based on a proportion of the total sample size. For example, if a total of 212 fishers were to be sampled within the survey, a quota of 14 fishers with an outboard boat-type would be sampled from east Mahe (i.e. 0.068 * 212). The number of fishers estimated within each sub-stratum were rounded to the nearest integer. The quota of fishers to be sampled within each sub-stratum are shown in Table A2.1, (Appendix 2.1).

Allocation of quotas amongst enumerators

It was not possible to allocate a fixed quota to each enumerator at the start of the survey. This was partly due to the fact that enumerators were not confined to a single geographic region, but moved between different regions while conducting the SFA catch assessment survey. Each enumerator was therefore given a target number of interviews to complete within each sub-stratum, and these updated on a regular basis.

Enumerators working within the same geographic region could therefore have different target values that would in total add up to the overall quota for that region. Regular meetings were held to update enumerators on the progress of the survey and ensure that they were not over-sampling or attempting to interview the same respondent. A computer spreadsheet was constructed specifically for this purpose.

2.2.3 Structured questionnaire

The quantitative survey of the fisher population had two principal aims. First, new data directly comparable with that collected during the 1989 socio-economic survey (Mees, 1990), allowed identification of a number of alternative socio-economic groups based on a different fisher characteristics. Secondly, additional information which had not previously been collected by Mees (1990), was necessary to develop a simulation model

of the artisanal fishery.

Questionnaire design

Obviously, the design of the questionnaire must ensure that sufficient data were collected to form the basis of further analyses. It is essential to consider throughout the design stage of the questionnaire, exactly how the information will be transferred between the respondent, the forms and finally the data processing and analysis (Poate and Daplyn, 1993).

It is also important not to ask too many questions. This reduced both the amount of time spent interviewing the respondents and analysing the data. The maximum time allocated per interview was one hour. Beyond this, it was believed that the attention span of the respondents and the quality of information would diminish. To optimise the number and form of questions, a period of field-testing was considered essential (see below).

The content and presentation of the survey were designed to be easy to follow and to be self-contained. Open-ended responses were avoided on the questionnaire form because they may be difficult to code and awkward to process. In comparison, closed responses are standardised and are easy to compare. With the exception of absolute categories where all responses are known (e.g. gender), each question allowed for an 'other' option. This was necessary for it was unlikely that the question would encompass all possibilities in the answers. This also made it clear which answers have been attempted or ignored. An example of such a question is given in Figure 2.1.

Q1. What type of work did your father do (tick box)?

Fisher	1. ___
Boat builder	2. ___
Fish trader	3. ___
Farmer	4. ___
Government employee	5. ___
Other: Specify _____	6.

Figure 2.1 Example of closed response categories within questionnaire form.

Ensuring an adequate number of alternative answers has the disadvantage of taking up a large volume of space on the questionnaire form. For example, the question given in Figure 2.1 has 6 response categories. However, too few alternative answers will lead to a poor response rate (e.g. categories are completed as 'other'), which limits the amount of useful information.

The questionnaire form was also designed with the subsequent data processing requirements in mind. The contents of the forms were therefore developed at the same time as the initial stages of a socio-economic database. Closed response categories were given a numeric value which was also used to code the response within the socio-economic database (e.g. Farmer: 4).

Questionnaire outline

To maximize the time available in the field, a preliminary outline of the questionnaire was designed prior to the main fieldwork period using three sources of secondary information: the 1989 socio-economic survey (Mees, 1990), the SFA 1997 annual statistical report (SFA, 1997), and the 1996 artisanal boat survey (Payet, 1996).

The questionnaire was divided into five sub-forms. This enabled the enumerator to cover a broad range of subjects quickly by moving to different sections within the questionnaire form, depending on the characteristics of the respondent. A summary of the contents of each sub-form is given in Table 2.5.

Table 2.5 Description of contents within each sub-form of the 1997 questionnaire.

Sub-form	Content
Personal Details (P1)	• Occupational mobility/training
	• Household composition and characteristics
	• House ownership
	• Ownership of consumer items
	• Ownership of fishing unit
Boat Form (B1)	• Boat details
	• Credit arrangements of fishing unit
	• Boat modifications
	• Seasonal boat activities
	• Cost, revenue and share system
	• Utilization of fishing effort
Gear Form (G1)	• Gear ownership and utilisation
	• Seasonal fishing location and activities
	• Seasonal catch information
	• Seasonal market attributes
Crew Members (CM1)	• Credit arrangements of fishing unit
	• Boat details
	• Share system
	• Seasonal catch information
General Questions (GE1)	• Participation and Management
	• History of fishery

The start of the questionnaire was designed to ask personal information. Sub-form 'P1' was answered by all respondents and was used to gain a general background of the fisher using relatively quick and straight-forward questioning. This was aimed to help relax the respondent before more technical questions were asked. Field-testing ensured that the personal questions did not raise sensitive issues within the fishing community. These may otherwise have caused a respondent to reject the entire questionnaire, leading to a loss of valuable information and rapport.

Fishers who were either a skipper (non boat owner) or a boat owner over the past 12 months were also asked a series of separate questions from the Boat Form (B1). These questions provided economic and technical information about the fishing unit. If these fishers owned or skippered more than one boat, an 'Additional Boat Form' was completed for each additional boat.

Furthermore, any fisher who owned, shared or hired any gear over the past 12 months was asked to complete questions within the Gear Form (G1). This provided both technical and economic information on the type of gear used.

Also any fisher who had been a crew member at any stage over the past 12 months was asked to complete a Crew Member Form (CM1). Finally, all respondents were required to answer questions within the General Questions (GE1) sub-form. This last form provided an opportunity for fishers to express some of their own opinions about the artisanal fishery.

The questionnaire was not designed for self-completion; rather it required the assistance of a trained enumerator. To aid enumerator training, a schematic diagram was constructed to illustrate the order of questions within each sub-form (Figure A2.1, Appendix 2.2).

Each respondent was given a unique serial number that associated them with the data collected on the questionnaire form. To keep these data confidential, all subsequent analyses of the fishery refer to this serial number and not the named individual, unless otherwise stated. A confidential record of the name and corresponding serial number was required to ensure that each enumerator did not attempt to re-interview the same individual, and to enable questionnaire forms to be re-traced to the respondent if verification of an answer was required.

Field-testing and translation

To maximise the time available for interviews, a draft questionnaire had previously been written in the UK and circulated at SFA upon arrival for comments before field-testing. This meant that the structure and content of each question was already well defined. However, an intensive period of field-testing was necessary to help identify questions which were too complicated or perhaps now irrelevant. A first draft of the questionnaire was field-tested with a single respondent. Following this, the form was subject to a number of amendments before undertaking the second interview. With each interview and subsequent review, the questionnaire evolved from the original first draft. After approximately seven or eight interviews, few amendments were

found necessary and it was decided to stop field-testing after ten interviews. This period of field-testing also provided an opportunity to develop the socio-economic database.

After this period of field-testing, the final English version of the questionnaire form was translated into Creole. Following translation of each sub-form, it was further tested to ensure that the correct meaning of the original question had been retained. A complete English version of the 1997 questionnaire is given in Appendix 2.3.

Enumerator selection and training

As described earlier, the questionnaire was not designed for self-completion. Rather, it required a team of trained enumerators to complete the survey forms on behalf of the respondent. A number of volunteers from the Seychelles Fishing Authority were selected for training. This had several advantages. First, individuals from the SFA already have a good background knowledge and experience of fishery which was invaluable when completing a detailed questionnaire. Secondly, SFA field staff are in regular contact with the fishing community as they conduct the catch assessment survey. This ensured that both good communication and rapport could be achieved relatively quickly. Finally, field staff had no regulatory role within the fishery. This allowed a strong element of trust and honesty, which should have increased both the quantity and quality of the of data collected.

There are also possible disadvantages of selecting enumerators so closely involved with the fishing community. For example, there is a danger that they may use their own prior knowledge to complete the form before the respondent has had time to fully answer the question. Also, enumerators may deliberately select respondents that they know are likely to co-operate. This will reduce the degree on randomness in the selection of respondents and may introduce an unknown level of bias into the results.

To avoid these problems, a selected team of 4 enumerators were trained on an individual basis. There were several elements to the training programme. First, each enumerator had to become familiar with the survey design and questionnaire forms. This part of the training also included general issues related to the aims of the survey

and sampling rationale. The content of the questionnaire was discussed in full, looking at each question in turn to explain the reason for their inclusion and the type of answer that may be expected. Mock answers were used during this stage to facilitate their understanding of the form completion.

Following the initial training period, enumerators were given a copy of the questionnaire to study. A few days later, each enumerator was approached during their routine catch assessment survey to discuss the questionnaire and any questions they may have concerning the form. They were then invited to observe an interview. Again following more discussion, the trainee enumerator was invited to undertake the next interview under supervision. Potential problems could then be discussed and resolved quickly.

When a number of successful interviews had been completed, the trainee was asked to undertake the next interview unsupervised. Only when the trainee enumerator felt confident enough to conduct their own interviews, were they given a number of questionnaire forms to complete. During this final training period, close monitoring was given to the returned questionnaire forms. Due to the unique serial number given to each respondent, forms could be returned to the enumerator and respondent in order to complete or verify an entry. The data were then entered within a socio-economic database.

2.2.4 Socio-economic database

Throughout the development stages of the questionnaire, much thought was given to the subsequent processing and analyses of the data. During this period, a relational database was developed with MS Access™, based on the content and format of each questionnaire sub-form.

Design and layout

Due to the large number of questions, the survey form had been divided into five smaller sub-forms. Five main database tables were therefore constructed, based on the information collected within each sub-form. Similar to the questionnaire, each

table required a unique serial number which linked together the data within each table.

Following the construction of each table and appropriate linkages, data forms were designed based on the structure of each table. This permitted an end-user to either browse or enter/edit data within the table. The data forms were designed to resemble the original questionnaire sub-forms as far as possible. This made the database more user-friendly and facilitated accurate data entry.

Method of coding

The questionnaire was designed around a series of closed-response categories within each sub-form. This coding strategy greatly simplified data processing. A separate look-up table of pre-determined response categories (numeric or text) was created with a pull-down menu for selecting the appropriate answer given within the sub-form.

The look-up tables within a data form also allowed automatic conversion of a textual response category (e.g. Married) in a pull-down menu into a numeric code (e.g. '2') within the table. The look-up tables were also made editable, to allow new uncoded 'other' categories to be entered (e.g. other: labourer). Using this method of coding, the majority of data within each table was numeric.

Data checking, entry and verification

During the course of the survey, questionnaire forms were checked as soon as possible after they had been completed. If a problem could not be resolved following discussion with the enumerator concerned, the appropriate sub-forms were retraced to the respondent via their unique serial number. Ambiguous or incorrect information would be very difficult to check during the latter data entry stages.

In addition to checking the completed questionnaire forms, as far as possible, the data were also entered into the database during the survey period. This enabled a closer scrutiny of the data and provided an opportunity to give feedback on the progress of

the survey to members at SFA. Data from the remaining survey forms were entered in the UK.

Finally, after all data had been entered, the database was itself checked for errors. Data within each table were systematically verified against the corresponding survey forms. Information collected from the survey had therefore been rigorously checked at both the collection and processing stages, thus ensuring a high quality of data for all subsequent analyses.

2.3 SOCIO-ECONOMIC CHARACTERISTICS WITHIN THE ARTISANAL FISHERY

Results from the 1997 survey can be used to identify socio-economic characteristics of crew members, skippers and boat owner-operators and to determine how these have changed since the previous 1989 survey.

The identification of historical socio-economic characteristics is essential in order to be able to evaluate whether the model can replicate them. This is discussed in detail in Chapter 6. Socio-economic characteristics observed within the survey data can also be used to identify a number of distinct socio-economic groups that can be simulated within the model.

The formal socio-economic survey conducted during 1997 produced a wealth of information on different attributes of the Seychelles fishing community. This section covers only those aspects directly relevant to the current research. The complete data are available in a separate technical report, prepared for the Seychelles Fishing Authority (Wakeford, In prep). These have been analysed and discussed in Wakeford (In prep). In addition to these reports, the data have also been included within an FAO technical co-operation project report to provide guidelines for an inshore management plan for Seychelles (Mees *et al.*, 1998).

The following sections first describe the system of classification used to enable comparisons *within* the current 1997 survey and *between* the 1997 and previous 1989 surveys. The type and quantity of results compared were constrained by the data

collected during the 1989 survey. A formal statistical comparison between each survey was also not possible due to the limitations of the 1997 sampling strategy.

The age and work experience of fishers within the artisanal fishery are then described to establish the age structure of the fishing community and identify trends. Fisher's age, coupled with work experience and boat-type, are also used to describe recruitment patterns into the fisheries sector.

The highest level of education and training attained by fishers are also compared within and between crew members, skippers and boat owner-operators. This is important to determine whether the level of education and/or training acts as a constraint to fishers purchasing a boat. The highest level of education attained by age class will also determine whether a recent government policy to improve the level of education has infiltrated into the fisheries sector. If not, the fisheries sector may be recruiting new fishers with few employment opportunities who may be unable to purchase and successfully operate a boat.

Finally, household composition and characteristics are also analysed. These were examined to determine the marital status, family attributes and relative wealth of crew members, skippers and boat owner-operators. Where relevant, comparisons between different socio-economic characteristics (e.g. age and education) were also given.

The level of association between crew members, skippers and boat owner-operators for different socio-economic characteristics within the 1997 survey were tested statistically using the chi-squared test on the raw data and not the percentage values used here for display purposes. A one-way analysis of variance was used to compare the mean values of selected socio-economic characteristics (e.g. not ordinal or dichotomous variables) between crew members, skippers and boat owner-operators.

2.3.1 Classification of fishers by survey strata

To enable a historical comparison between the 1989 and 1997 survey data, the 1997 survey results have been processed and displayed in a number of discrete fisher groups or strata, previously used by Mees (1990). Division of the 1997 survey data into the same pre-

determined strata was necessary because the raw data from the previous 1989 survey were not available for re-analysis.

Mees (1990) had previously structured the presentation of the 1989 results in a number of strata for analytical purposes to determine the socio-economic status of the artisanal fishers. No attempt was made in the report however, to group fishers with similar socio-economic characteristics, other than whether a boat owner-operator required a loan to purchase their vessel or not. In total, 4 mutually exclusive strata were identified by Mees (1990) within the fishing community;

1. Crew members
2. Skippers (non boat owner-operators)
3. Boat owner-operators who have taken a loan
4. Boat owner-operators who have not taken a loan

Crew members are fishers who neither own a boat or hold any responsibility for running the boat. Skippers also do not own a boat, but are responsible for controlling all fishing activities. Boat owner-operators are boat owners that have acquired a fishing vessel either with or without a loan. The 1989 survey excluded boat owners who were not actively fishing within the artisanal fishery (i.e. boat owner non-operator).

To enable comparisons between fishers who operate on board small and large boats, each stratum has been further sub-divided by boat-type to form a total of eight sub-strata. For simplicity, all outboard powered boat-types are classified as 'small' whereas all inboard powered vessels are classified as 'large'.

2.3.2 Fishers age and work experience

For more than a decade, concern has been expressed over the ageing of the workforce within the fishing community (Mees, 1990a). It was concluded from analyses of the 1989 survey data however, that the mean ages, although relatively high, were within the expected range for the normal working population (Mees, 1990b). Despite this, fishers have continued to voice their concern over the ageing of the fisheries sector workforce. Figure 2.2a illustrates the age structure of the artisanal fishery during 1989 in comparison

with the total working population during 1987 (Mees, 1990a). In addition, Figure 2.2b illustrates the most recent age structure of the artisanal fishery during 1997 in comparison with the most recent estimate of the total working population during 1994 (National Population and Housing Census; MISD, 1996).

a. b.

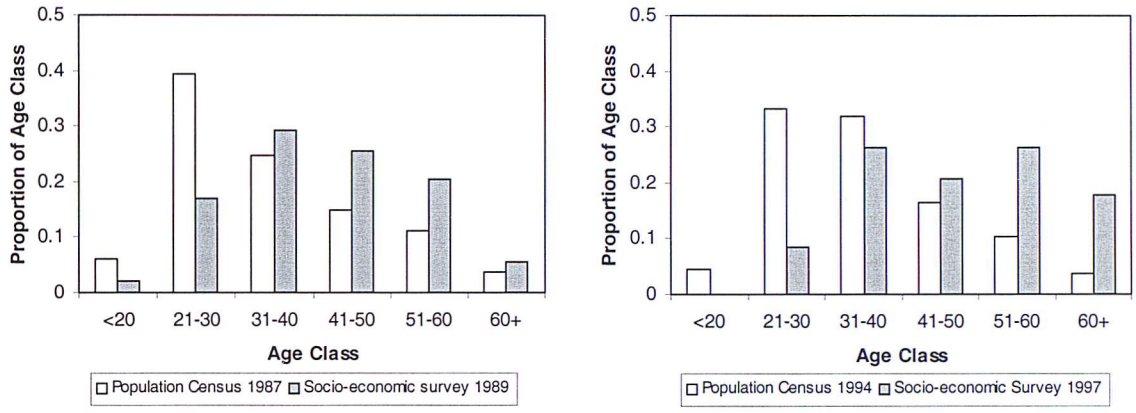


Figure 2.2 Age structure of the total working population (population census) and artisanal fishery (socio-economic survey) during a) 1987 and 1989, respectively and b) 1994 and 1997 respectively.

Figure 2.2b illustrates that the fishing community remains considerably older than that of the total working population. The level of association between the most recent frequency distributions was examined using the Kolmogorov-Smirnov test (see Appendix 2.4). This confirmed that the fishing community during 1997 was significantly older than the total working population during 1994 (Kolmogorov-Smirnov; $P<0.05$).

The median age of fishers sampled during 1997 was 44 years, whereas that of the total working population in 1994 was approximately 30. The National Population and Housing Census (MISD, 1996), has used median ages to confirm that the total population of Seychelles is also ageing.

To explore how recruitment patterns may have changed since 1989, a breakdown of the age structure of fishers within each sub-stratum is given in Table 2.6. On average the youngest fishers below 31 years of age are crew members. Crew members otherwise exhibit a wide range of age classes and they form the most heterogeneous group. Skippers are significantly older than crew members, particularly for larger boats (χ^2 test, $P<0.05$). Both skippers and boat owner-operators have a similar range of age classes,

although the latter group are marginally older, particularly for large boats. Finally, the age structure of owner-operators of small boats is significantly different to those of large boats (χ^2 test, $P<0.10$). This observed difference between the age structure of owner-operators may be due to the higher number of fishers with small boats below 41 years of age.

Table 2.6 Age structure of fishers (%) within different sub-strata of the 1997 survey.

Details	Crew member (%)		Skipper (%)		Boat owner-operator (%)			
					With loan		Without loan	
	Small	Large	Small	Large	Small	Large	Small	Large
	n = 17	*n = 21*	*n = 7*	*n = 10*	*n = 15*	*n = 9*	*n = 29*	*n = 10*
< 20 yrs	12	0	0	0	0	0	0	0
21-30 years	24	32	14	0	20	0	7	0
31-40 years	29	16	44	29	33	29	28	11
41-50 years	12	26	14	29	20	14	24	33
51-60 years	18	21	14	42	27	43	28	33
> 60 years	5	5	14	0	0	14	13	22

On average, the age structure of both crew members and skippers has not changed since the previous 1989 survey (cf. Table A2.3, Appendix 2.5). With the exception of crew members of small boats, the proportion of young fishers under the age of 21 has declined between the previous 1989 survey and 1997 survey. In part, this may be due to young fishers extending their level of education before they enter the fisheries sector. The highest level of fisher's education is described below.

In comparison to the 1989 survey, the proportion of owner-operators of large boats under the age of 31 has declined whereas those over the age of 60 has increased. This suggests that owner-operators of large boats are getting older, but also that there is a decrease in the number of fishers below the age of 31 purchasing large boats. In contrast, a greater proportion of owner-operators of small boats who are below the age of 31 are present in the 1997 survey than the previous 1989 survey. This would suggest that there is an increase in the number of owner-operators below the age of 31 purchasing small boats.

On average, crew members have the least full-time work experience (years) within the artisanal fishery (Table 2.7). In particular, crew members of small boats have

comparatively few fishers with over 20 years of experience. However, similar to their age classes, all crew members exhibit a broad range of experience and they form the most heterogenous group.

Skippers have an exceptionally high level of experience; no skipper has less than 10 years work experience in the fisheries sector. It is not surprising therefore, that skippers are significantly more experienced than crew members (χ^2 test, $P<0.05$).

Owner-operators of large boats have significantly more experience than those of small boats (χ^2 test; $P<0.05$). Interestingly however, there is a small proportion of all owner-operators with a loan that have considerably less experience (1-5 years) than the majority (16+ years).

Table 2.7 Number of years full-time work experience of fishers (%) within different sub-strata of the 1997 survey.

Details	Crew member (%)		Skipper (%)		Boat owner-operator (%)			
					With loan		Without loan	
	Small	Large	Small	Large	Small	Large	Small	Large
	n = 17	*n = 21*	*n = 7*	*n = 10*	*n = 15*	*n = 6*	*n = 23*	*n = 7*
< 1 year	18	11	0	0	0	0	0	0
1-5 years	29	21	0	0	9	20	17	0
6-10 years	6	5	0	0	0	0	13	0
11-15 years	12	11	29	0	18	0	4	0
16-20 years	12	5	14	14	27	20	13	17
> 20 yrs	23	47	57	86	46	60	53	83

In comparison to the 1989 survey, there is a greater proportion of young crew members in the 1997 survey with 5 years of work experience or less (cf. Table A2.4, Appendix 2.5). In contrast, no skippers with 10 years of work experience or less have entered the fisheries sector between the 1989 survey and 1997 survey. Similarly, there are fewer owner-operators with 10 years of experience or less within the 1997 survey than the previous 1989 survey.

In part, the pattern of boat purchase between the 1989 survey and 1997 survey is driven

by a combination of the age of fishers and their level of work experience. For example, a comparatively young fisher with little work experience is observed to purchase a small boat (with or without a loan), whereas on average, older and more experienced fishers purchase larger vessels.

Summary

- The fishing community is showing continued signs of an ageing workforce, with significantly fewer skippers (non-boat owners) less than 31 years old within the artisanal fishery.

- Crew members are the amongst the youngest group of fishers within the artisanal fishery, although overall they exhibit a heterogenous group with a broad range of both age classes and work experience. Interestingly however, between the 1989 survey and the 1997 survey, fewer crew members are observed below the age of 20.

- Skippers (non-boat owners) are a homogenous group of relatively old and more experienced fishers. Within the 1997 survey, skippers are significantly more experienced than crew members (χ^2 test, $P<0.05$). However, in comparison to the 1989 survey, the proportion of skippers 40 years of age and below has declined in the 1997 survey. This suggests that fewer skippers of younger age classes and/or experience have entered the artisanal fishery between 1989 and 1997.

- Owner-operators are on average older and more experienced than crew members. In comparison to the 1989 survey, there are fewer owner-operators who are 30 years of age and below in the 1997 survey. This suggests that fewer large boats were purchased by fishers 30 years of age and below between 1989 and 1997. In contrast, there has been an increase in the purchase of small boats by owner-operators of similar ages (30 years of age and below) between the 1989 survey and 1997 survey. Moreover, age structure and work experience of owner-operators of small boats within the 1997 survey is significantly different to those of large boats (χ^2 test, $P<0.10$).

2.3.3 Education and training

This section provides a description of the education and training of fishers within different sub-strata. The highest level of education attained by fishers within the 1997 survey is given in Table 2.8.

Crew members display a broad range of educational levels, similar to their range of age classes (cf. Table 2.6). The level of education attained by crew members however, is significantly different than either skippers or boat owner-operators (χ^2 test; $P<0.05$). In part, this may be expected, given the greater proportion of younger fishers amongst crew members.

Table 2.8 Highest level of education attained (%) by different sub-strata of the 1997 survey.

Details	Crew member (%)		Skipper (%)		Boat owner-operator (%)			
					With loan		Without loan	
	Small	Large	Small	Large	Small	Large	Small	Large
	n = 20	*n = 23*	*n = 7*	*n = 10*	*n = 15*	*n = 9*	*n = 29*	*n = 10*
None	5	10	0	0	7	11	8	10
Primary	25	29	43	60	27	56	41	70
Secondary	40	33	57	40	53	22	45	10
NYS	25	14	0	0	13	0	3	0
Polytechnic	5	10	0	0	0	11	3	0
Other	0	4	0	0	0	0	0	10

Younger fishers have recently undergone a more extensive programme of education than their predecessors, as more school leavers have been encouraged to enter advanced education such as the former National Youth Service (NYS) or Seychelles Polytechnic (MISD, 1996). The highest level of education attained by different ages is presented as a box-plot in Figure 2.3. This shows the range of ages given by fishers with a different level of education, the median and the inter-quartile range. The level of education is moderately correlated with the age of fishers (0.60; Spearman's rank correlation coefficient).

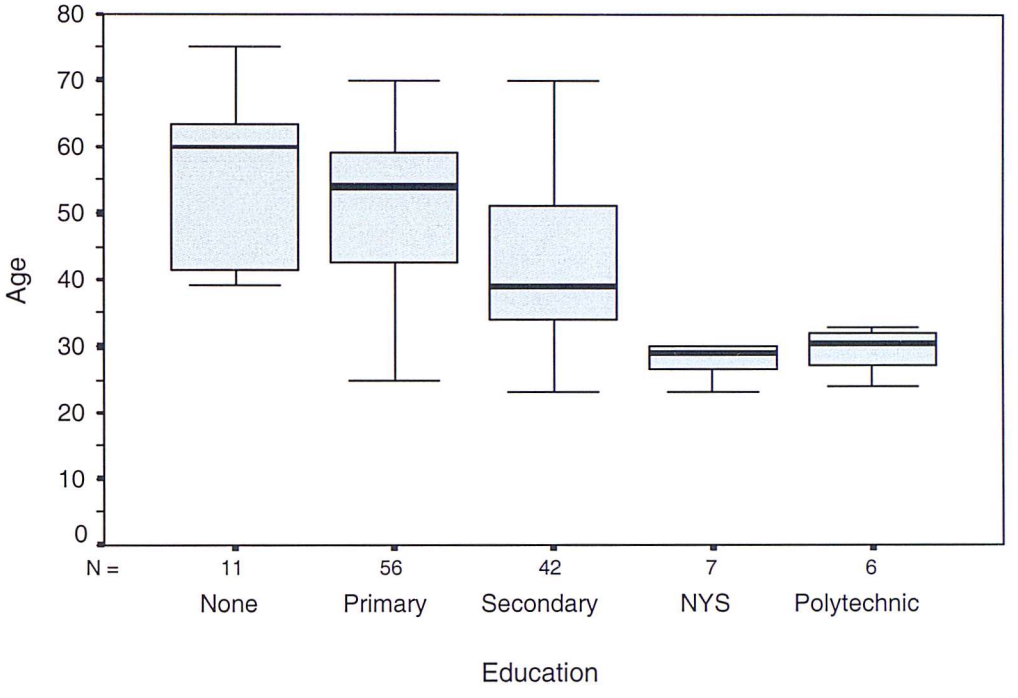


Figure 2.3 Box-plot to show the highest level of education attained by fishers of different ages.

In comparison to the 1989 survey, the results show that on average all crew members, skippers and owner-operators in the 1997 survey have gained a higher level of education (Table A 2.5, Appendix 2.5).

The highest level of education received by skippers reflect their age, and consequently have a relatively poor education. In contrast, only a minority of both crew members and boat owner-operators have little or no formal education. This minority of crew members and owner-operators however, may not have required a high level of education. If for example, fishing was a family tradition, young members could be trained by other members within the household. These fishers could then enter the fisheries sector with few or no qualifications but with good 'hands-on' experience. For others, it may simply reflect a profession that suited members with few academic qualifications.

The extent of family tradition within the artisanal fishery has been explored further by studying details of their father's occupation (Table 2.9).

Table 2.9 Details of father's occupation (%) for different sub-strata of the 1997 survey.

Details	Crew member (%)		Skipper (%)		Boat owner-operator (%)			
					With loan		Without loan	
	Small	Large	Small	Large	Small	Large	Small	Large
	n = 19	*n* = 23	*n* = 7	*n* = 10	*n* = 15	*n* = 9	*n* = 29	*n* = 9
Fisher	32	43	57	43	40	33	41	62
Boat Builder	0	5	0	0	0	0	0	0
Farmer	0	0	0	0	7	0	10	0
Govt. employee	16	14	0	14	7	14	3	13
Other work	52	38	43	43	46	56	46	25

Across all sub-strata at least one third of fishers had a father who was also a fisher. But only for skippers of small boats and boat owner-operators of large boats without a loan does this exceed 50%. A high proportion of all fishers had a father who undertook 'other work' (33-56%). With exception to owner-operators of large boats without a loan, fewer owner-operators had a father who was also a fisher in the 1989 survey (Table A2.6, Appendix 2.5). The results were otherwise comparatively similar between each survey.

To establish whether the father or other family member of a fisher was responsible for their training, details of where fishers learnt their fishing skills are presented in Table 2.10. The vast majority of fishers learnt how to fish either from their father or other fishers outside the family. However, a small group of fishers were also self-taught.

Of those fishers whose father was also a fisher, the majority were taught either directly by them or another family member. Surprisingly, more owner-operators of large boats with a loan were taught by their father than the actual number of fathers who were also commercial fishers. These fathers who taught their son or daughter to fish, even though they were not a commercial fisher themselves, may have gained their skills from undertaking recreational fishing.

Table 2.10 Where fishers learnt their fishing skills (%) for different sub-strata of the 1997 survey.

Details	Crew member (%)		Skipper (%)		Boat owner-operator (%)			
					With loan		Without loan	
	Small	Large	Small	Large	Small	Large	Small	Large
	n = 20	*n = 23*	*n = 7*	*n = 10*	*n = 15*	*n = 9*	*n = 29*	*n = 9*
Father/Family	25	33	29	14	40	86	21	50
Other fishers	60	57	42	72	53	0	62	25
Foreign vessel	0	0	0	0	0	0	0	0
Maritime study	0	0	0	0	0	0	1	0
Self taught	15	10	29	14	7	14	14	25

With exception to owner-operators of large boats with a loan, the observed sources of fisher's training have not changed notably since the previous 1989 survey (Table A2.7, Appendix 2.5).

Summary

- The level of education is correlated with the age of fishers. Crew members and owner-operators of small boats show a higher level of education.

- Crew members demonstrate a broad range in the levels of education. In comparison however, to either skippers or owner-operators of large vessels, crew members are on average the most highly educated of all fishers. The majority of crew members were taught their fishing skills from other fishers outside their family. However, all crew members who had a father who was also a fisher were taught either directly from their father or another family member.

- On average, skippers have gained a lower level of education than crew members. Although more skippers than crew members had a father who was also a fisher, unlike crew members, not all skippers were taught directly by their father or another family member. The majority of skippers therefore learnt their fishing skills from other fishers.

- On average, owner-operators of large vessels are the most poorly educated across all sub-strata. The majority of owner-operators of all large vessels have gained either a primary level of education or none. In contrast, the majority of owner-operators of all small boats have gained a secondary level of education or above. Owner-operators of large boats without a loan are more likely to have a father who was also a fisher. The majority of owner-operators with a father who was also a fisher were also taught by their father of another family member. In comparison to the 1989 survey, more owner-operators of large boats without a loan have a father who was also a fisher.

2.3.4 Household composition and characteristics

This section outlines the household composition and characteristics of the fishing community. First, a description of the household is given, enabling a comparison between the marital status, household size and the number of dependants for different sub-strata. Second, a description of the house ownership and rent payments is given to provide an indication of the living arrangements of different fisher groups. Finally, consumer items and cooking facilities are detailed. The latter has previously been identified as an indicator of poverty within the Seychelles (World Bank, 1996) and may provide an insight into the distribution of wealth within the fishing community.

The composition of a household is explored first by the marital status of each sub-strata (Table 2.11). Crew members on board small boats are more likely to be single than any other group. This is not unexpected, for this group also has the greatest proportion of young fishers (cf. Table 2.6). On average, crew members exhibit a broad range of age classes, and this is reflected by the proportion of married fishers, or those in a concubine relationship (non-married partner).

Skippers, being on average older, might be expected to be either married or have a concubine relationship. However, a notable group of older skippers operating large vessels were single at the time of the survey.

Owner-operators of large vessels without a loan, are most likely to be married. In comparison to the 1989 survey, the proportion of single owner-operators of small boats

with a loan has increased (Table A2.8, Appendix 2.5). This may be because of the number of young fishers purchasing small boats within the fisheries sector.

Table 2.11 Marital status of fishers within each sub-strata (%) of the 1997 survey.

Details	Crew member (%)		Skipper (%)		Boat owner-operator (%)			
					With loan		Without loan	
	Small	Large	Small	Large	Small	Large	Small	Large
	n = 20	*n = 23*	*n = 7*	*n = 10*	*n = 15*	*n = 9*	*n = 29*	*n = 10*
Married	20	33	14	29	33	29	41	66
Concubine	25	29	72	29	33	57	21	22
Single	55	38	14	42	33	17	38	11

The age and marital status of different sub-strata will to some extent determine the number of dependants they have. On average, all crew members have more dependants *under* the age of 18 than skippers, whereas all skippers have more dependants *over* the age of 18 than crew members (Table 2.12).

Table 2.12 Average number of dependants under and over 18 years of age, household size and dependancy ratio for each sub-strata of the 1997 survey.

	Crew member		Skipper		Boat owner-operator			
					With loan		Without loan	
Details	Small	Large	Small	Large	Small	Large	Small	Large
Dependants <18	1.7	1.75	1.00	0.89	1.14	1.88	2.50	1.90
Dependants >18	0.10	0.25	0.40	1.11	0.42	0.00	0.67	0.60
Household size	5.19	5.24	4.22	4.14	5.72	5.27	5.47	4.56

The results show that crew members have younger families than skippers who are themselves generally older. This can also be shown by household size. Skippers with older families are more likely to have children over 18 years of age who have left home, thereby reducing the average household size.

With exception to owner-operators of small boats with a loan, on average, owner-operators have more dependants under 18 years of age across all sub-strata. Furthermore, with exception to owner-operators of large boats with a loan, owner-operators have more dependants over 18 years of age than all crew members or skippers of small boats.

In comparison to the 1989 survey, on average, crew members in 1997 have fewer dependants, particularly over 18 years of age (cf. Table A2.9, Appendix 2.5). This contradicts the finding however, that crew members of small boats in 1997 have on average, larger household sizes than in 1989. The observed decline in the number of dependants and increase in household size, may both be explained by an increase in the proportion of young crew members in 1997 than 1989.

For example, a greater proportion of young crew members of small boats are single (cf. Table 2.11). It can be expected that single crew members of small boats would have fewer dependants than fishers who are in a concubine or married. In addition, a higher proportion of young, single crew members of small boats are expected to be still living at home with their parents or other family members (Table 2.14 below). Hence, younger crew members may be living with a number of relatives, thus increasing the average household size.

Similar to crew members of small boats, owner-operators of small boats with a loan have notably fewer dependants over 18 years but retain a similar size of household than in 1989. Owner-operators of large vessels however, clearly show that the family unit is getting progressively older; they are on average older with fewer dependants and a smaller size of household than in 1989.

The total number of dependants may not always reflect the number of children a fisher has got. For example, fishers within a concubine relationship may have additional dependants from their partner's previous relationship. Furthermore, fishers may be required to look after older members of their own family. The average number of children by the fisher, and those under 6 years of age, are presented for different sub-strata in Table 2.13.

The average age of fishers is correlated with the number of children (0.496; Pearson's correlation coefficient $P<0.05$), and so it is sensible to combine this with the previous information to obtain a more complete picture of the structure of the fishing community.

Table 2.13 Average number of children by the fisher and total below 6 years of age for different sub-strata of the 1997 survey.

	Crew member		Skipper		Boat owner-operator			
					With loan		Without loan	
Details	Small	Large	Small	Large	Small	Large	Small	Large
Mean	2.2	3.2	2.4	3.25	4.25	2.71	3.74	3.88
Total < 6 yrs	1.0	0.7	1.0	0.0	1.14	0.5	0.33	0.75

On average, there is a greater proportion of young and single fishers amongst crew members of small boats than in any other sub-strata (cf. Tables 2.6 and 2.11). This is reflected in the average number of children. In contrast, crew and owner-operators of large vessels contain a greater proportion of older members who subsequently have older families. Interestingly, owner-operators of small boats without a loan have fewer children and less below the age of 6 than other owner-operators.

Skippers of small boats are on average younger and within a concubine relationship than those of large boats who are more likely to be older and remained single. The results show that skippers of small boats also have younger families than those of large boats (Table 2.13).

Owner-operators requiring a loan have a greater number of dependants even though their household size is approximately the same (cf. Table 2.12). This may reduce the level of income available to purchase a boat outright without monthly repayments. The age and marital status of each sub-strata also relate to their current living arrangements and house ownership (Table 2.14).

Table 2.14 House ownership of different sub-strata (%) of the 1997 survey.

Details	Crew member (%)		Skipper (%)		Boat owner-operator (%)			
					With loan		Without loan	
	Small	Large	Small	Large	Small	Large	Small	Large
	n = 20	*n* = 23	*n* = 7	*n* = 10	*n* = 15	*n* = 9	*n* = 28	*n* = 10
Fisher himself	25	47	57	29	66	42	64	66
Parental home	75	33	29	29	20	29	32	0
Private landlord	0	10	14	29	7	0	0	11
Government	0	10	0	13	7	29	4	22

Young crew members of small boats are much more likely to be living at home with parents or another family member than those working on large boats (Table A2.11, Appendix 2.5). This provides young fishers greater security and use of more facilities, such as transport and other consumer items. Crew members of large vessels are more likely to own their property or rent from a private landlord or government, particularly if they were married (Table A2.8, Appendix 2.5).

It has been shown that, on average, crew members of small boats are younger than crew members of large boats (cf. Table 2.6). The type of living accommodation can also be compared to different ages of fishers by means of a box-plot (Figure 2.4). This shows the range of ages given by fishers living in different types of accommodation, the median and the inter-quartile range.

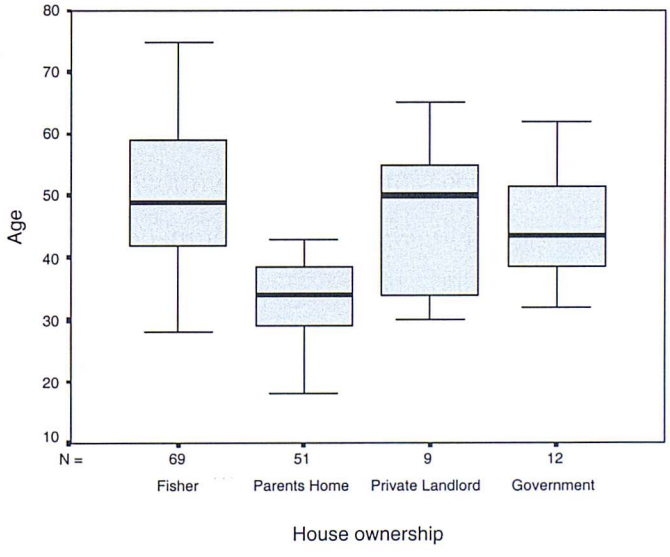


Figure 2.4 Box-plot to illustrate house ownership by fishers age.

The majority of skippers of small boats own their house, although a small proportion may still be living at home or with a family member. More skippers of large boats rent their accommodation from a private landlord or from the government than skippers of small boats. These skippers of large boats who rent their accommodation from the government are more likely to be younger than those who own their property (Figure 2.4).

The majority of owner-operators own their property. However, similar to skippers of large boats, all owner-operators who have chosen to rent newly-built accommodation from the government are more likely to be younger than those who have purchased their own house. Finally, a small proportion of owner-operators are still living at home with their parents or other family member. It may be deduced from Figure 2.4, that any owner-operators still living at home are relatively young.

Property ownership is not necessarily a good indicator of wealth, since many houses may be of poor build quality or under disrepair. The quality of housing described for different sub-strata living in the properties described above, is presented in Table 2.15. A total score (3 - 12) is given according to the quality of building materials used for the wall/floor/roof.

Table 2.15 Quality of housing for different sub-strata of the 1997 survey.

Details		Crew member (%)		Skipper (%)		Boat owner-operator (%)			
						With loan		Without loan	
		Small	Large	Small	Large	Small	Large	Small	Large
		n = 20	*n = 23*	*n = 7*	*n = 10*	*n = 15*	*n = 9*	*n = 28*	*n = 10*
Owner	3-6	0	0	0	10	0	0	0	0
	7-9	20	43	57	10	53	56	57	50
	10-12	5	4	0	0	13	0	7	20
Non-	3-6	0	0	0	0	0	0	0	0
owner	7-9	55	53	43	70	34	44	29	30
	10-12	20	0	0	10	0	0	7	0

The majority of fishers are found within average-built accommodation (quality scores 7 - 9). Surprisingly, a small proportion of skippers of large boats who own their property, are currently living in relatively poor quality housing (corrugated iron with concrete

floor). Further investigation of this group revealed that these fishers have also remained single and have few dependants (data not shown). In contrast, skippers of large boats living in newly constructed accommodation, such as government properties, have a good quality of housing. A minority of owner-operators also live in high quality private accommodation (cf. Table 2.14), but these are an exception to the majority of fishers.

Details of the rent or mortgage payments reflect the amount of disposable income fishers have available, and provide an indicator of the relative wealth of each sub-strata (Table 2.16).

Table 2.16 Rent/mortgage payments per month (SR *1,000).

	Crew member		Skipper		Boat owner-operator			
					With loan		Without loan	
Details	Small	Large	Small	Large	Small	Large	Small	Large
Mean (SR *1,000)	0.70	0.80	0.76	0.50	0.64	0.67	0.70	1.25
Max (SR *1,000)	0.70	1.30	1.00	0.70	1.00	0.83	1.30	2.0

Payments for accommodation vary across all sub-strata. Owner-operators of large vessels without a loan pay the highest mean value for accommodation (SR1,250 per month). This may reflect the fact that this group consists of mainly older fishers (cf. Table 2.6) in a stable relationship (cf. Table 2.11) with fewer dependants (cf. Table 2.12). Young fishers (e.g. crew members and owner-operators of small boats) who are still living at home were noted to pay a minimal family rent, which helped to reduce the average payment for these sub-strata.

The results show that skippers of large boats pay the least rent or mortgage payments (SR500 per month). This may reflect the poor build quality of the skippers own house. Cheaper building materials (i.e. iron sheeting), reduce the overall cost of the house construction and subsequent amount of any money borrowed. In addition, the majority of skippers of large boats are comparatively older than any other sub-strata (cf. Table 2.6), and may have finished paying for their mortgage in 1997.

It was noted earlier that cooking facilities can also provide an indicator of wealth within the Seychelles (Khan, 1996). Cooking facilities available to different sub-strata are given

in Table 2.17.

Table 2.17 Cooking facilities available (%) to different sub-strata of the 1997 survey (fishers can have more than one appliance).

Details	Crew member (%)		Skipper (%)		Boat owner-operator (%)			
					With loan		Without loan	
	Small	Large	Small	Large	Small	Large	Small	Large
	n = 20	*n* = 23	*n* = 7	*n* = 10	*n* = 15	*n* = 9	*n* = 28	*n* = 10
Gas	45	57	14	29	40	57	54	78
Electric	5	14	0	14	13	43	18	44
Kerosene	95	100	100	86	87	71	86	67

Almost all non-boat owner-operators have use of a kerosene stove. All skippers however, appear more reliant on kerosene as their primary source of cooking fuel than all crew members, who also have a high proportion of gas cookers. While most owner-operators have access to a kerosene stove, they are more likely than crew or skippers to use gas or electricity. Furthermore, owner-operators of large vessels (with or without a loan) were also more likely to use a gas or an electric cooker than owner-operators of small boats.

An additional indicator of wealth is the type of consumer items purchased by different sub-strata (Table 2.18). For example, all owner-operators are more likely than crew or skippers to own a car or pick-up.

Table 2.18 Consumer items either purchased or have access to by different sub-strata of the 1997 survey.

Details	Crew member (%)		Skipper (%)		Boat owner-operator (%)			
					With loan		Without loan	
	Small	Large	Small	Large	Small	Large	Small	Large
	n = 20	*n* = 23	*n* = 7	*n* = 10	*n* = 15	*n* = 9	*n* = 28	*n* = 10
Car/Pick-up	15*	5	0	0	7	22	11	10
Motorbike	5	0	0	0	0	0	0	0
TV	85	95	100	70	93	78	89	100
Video	55	76	57	50	67	33	86	80
Bicycle	5	10	14	0	13	0	7	0
Land Phone	50	62	71	40	47	44	68	80
Mobile phone	0	5	0	0	0	0	0	0

The majority of crew members of small boats that have indicated access to a vehicle (*) are actually referring to a family car, owned by another family member. Television and video have become more popular since 1989 across all sub-strata, although older members of the fishing community are less likely to have purchased or have access to a video.

Significantly fewer skippers of large boats have access to a land phone (χ^2, $P<0.05$), whereas the majority of all boat owner-operators without a loan own or have access to a land phone. Mobile phones are becoming more popular within Seychelles, although very few, if any fishers currently own such an item.

Summary

- The fishers who are most likely to be single are crew members of small boats. The broad range of age classes amongst crew members however, is also reflected by their range of marital status. Crew members have on average more dependants under the age of 18 years than skippers, who have more dependants over the age of 18. Typically, crew members have younger families than skippers, who are themselves generally older.

- In comparison to the 1989 survey, crew members have fewer dependants in 1997, particularly over 18 years of age. In addition, crew members of small boats in 1997 have on average, larger household sizes than in 1989. The observed decline in the number of dependants and increase in household size, was thought in part, to be due to an increase in the proportion of young and single crew members living at home in 1997 than 1989.

- Crew members who were still living at home, paid a nominal rent in comparison to other fishers who had purchased their property or rented from a private landlord or the government. This setup provided a relatively high standard of living at a low cost. Access to family transport was often available, in addition to a higher quality of cooking facilities (i.e. gas or electricity). Those crew members who were not currently living at home, had a slightly lower standard of living.

- Skippers are on average an older group of fishers who are more settled in a

concubine relationship or married. There is however, a notable group of skippers of large vessels that have decided to remain single. Skippers have older families and are more likely than crew members or owner-operators to have children over 18 years of age who have left home, thereby reducing the average household size.

- The majority of skippers of small boats purchased their own house, although a small proportion were found to be still living at home or with a family member in 1997. Skippers of large boats however, were are more likely to rent their accommodation from a private landlord or the government. Those older skippers who had purchased their own property were now living in the poorest quality of housing. These fishers were mainly single fishers who had few, if any, dependants.

- On average, skippers have a relatively low standard of living. They have no transport of their own, and the majority cook on kerosene stoves.

- Owner-operators of large boats are usually married or in a concubine relationship. It has been shown however, that the proportion of single owner-operators of small boats has increased notably since the 1989 survey. This was attributed to the higher number of younger fishers entering this sub-stratum.

- Owner-operators of small boats have on average the greatest number of dependants under the age of 18. Unlike crew members, however, owner-operators also have a relatively higher number of dependants over 18, which is reflected in their large household size.

- The majority of owner-operators have purchased their own property, although a small proportion of middle-aged fishers have rented their accommodation from the government or private landlord. Their quality of housing and general standard of living are the highest of all fishers. Owner-operators are more likely to have their own transport, and better cooking facilities.

2.3.5 Comparison between socio-economic characteristics of different sub-strata

Throughout the analysis of the 1997 survey results, a number of socio-economic characteristics have been identified within and between different sub-strata. These characteristics however, have often signalled that the existing sub-strata do not consist of distinct homogenous groups of fishers.

The similarity between existing sub-strata can be tested statistically. To increase sample sizes, small and large boat sub-strata have been combined for crew members, skippers and owner-operators with and without a loan. Socio-economic characteristics with continuous variables are compared by their mean values between each stratum (one-way analysis of variance, see Table 2.19). The level of association between each stratum with soco-economic characteristics displaying either nominal or ordinal variables are tested by a Spearman's rank correlation coefficient (Table 2.20). Both statistical analyses were undertaken within SPSS™ statistical computer package (SPSS, 1999).

Table 2.19 Mean values of demographic characteristics within different strata of the 1997 survey.

demographic characteristic	Crew	Skipper	Boat owner-operator			ANOVA
			With loan	No Loan	Total	p-value
n	*51*	*14*	*16*	*48*	*129*	
1. Age (yrs)	39.8	42.0	44.0	49.5	44.4	0.010*
2. Experience (yrs)	16.4	24.6	22.5	26.4	22.2	0.070
3. No. Children	1.8	2.1	3.1	3.4	2.6	0.026*
4. Total Dependants	1.0	1.2	1.8	1.1	1.2	0.308
5. Household size	5.2	4.2	4.9	5.5	5.1	0.364

*Mean values are significantly different between strata at 5% level.

If each stratum was to contain a relatively distinct homogenous group of fishers, one would expect that a number of the socio-economic characteristics would be significant. The results show in total five socio-economic characteristics that were measured within the 1997 survey were significant.

Table 2.20 Level of association of different socio-economic characteristics between strata of the 1997 survey using Spearman's rank correlation coefficient.

Socio-economic characteristic	Significance
6. Marital status	0.05*
7. Fathers Occupation	ns
8. Learn Skills	ns
9. Education	0.05*
10. House ownership	0.01*
11. House quality	ns
12. Car/pickup	ns
13. Phone	ns
14. Kerosene stove	ns
15. Gas cooker	ns
16. Electric cooker	ns

ns - result not significant

*Level of association between strata are significantly different at 5% level.

Age, Number of Children, Marital Status, Level of Education and **House Ownership** are all important in determining whether a fisher is classified as a crew member, skipper or owner-operator with or without a loan. It was previously mentioned that each stratum was originally developed to analyse the socio-economic status of fishers within the artisanal fishery and may not necessarily reflect particular socio-economic groups (see Section 2.3.1).

Following a brief discussion of the characteristics *within* each stratum, an attempt to re-classify fishers into alternative, more homogenous socio-economic groups will be made. The socio-economic characteristics of each group can then be re-tested to determine whether this has been successful.

2.4 IDENTIFICATION OF KEY SOCIO-ECONOMIC GROUPS

2.4.1 Re-classification of survey strata into socio-economic groups

Use of the eight sub-strata introduced in the previous 1989 survey, has been useful in establishing temporal changes in the socio-economic structure of the artisanal fishery

during 1997. The following sections describe in more detail the socio-economic characteristics of each sub-strata to identify a more homogenous socio-economic group of fishers within the artisanal fishery.

Crew members of large and small boats

The data collected for crew members suggest that fishers within this strata could belong to one or more socio-economic group:

- There is a group of young crew members who are more likely to be single and living at home with their family. In consequence these fishers have few, if any, dependants. Living with parents generally provides a higher standard of living, with quality housing, good cooking facilities and a range of household consumables. Young fishers can be well educated, although they have little or no fishing experience. Their father is not necessarily a fisher, and so many are required to learn their fishing skills from other fishers.

- A second group amongst crew members may be distinguished by their older ages. Older crew members are more likely to have settled down with a partner, and are either married or within a concubine relationship. This can also bring added responsibilities, such as children or other dependants. These fishers have an average standard of living, and may cook with basic facilities and have limited household consumables. They are unlikely to own any form of motorised transport.

- Finally, a small third group of fishers may be observed among crew members. These are older fishers who have remained single, and may be living alone or with a family member (e.g. brother). Similar to younger crew members, they are less likely to have children or any other dependants. Although they may own their own property, it is of average build quality with few household items (i.e. no video recorder or telephone). They would cook mainly on kerosene stoves and have no personal transport.

Skippers of large and small boats

Skippers (non-boat owners), were a more homogenous group than crew members and they are more likely to represent a single socio-economic group. Nevertheless, it is possible to distinguish two different groups amongst skippers.

- On average, skippers are older and more experienced than crew members. Due to their age, they have therefore gained a less formal education than other non-boat owners. The majority of skippers are either married or in a concubine relationship. These have more established family units, with older children or dependants than crew members. Although the majority of skippers with a family have purchased their own property, it is of average build quality, with the majority cooking on kerosene stoves. In general they do not have access to a telephone or personal transport.

- A small number of older skippers have decided to remain single, and may be living alone or with a family member. Typically, these fishers have little or no formal education. Similar to older, single crew members, they are have few, if any, children or other dependants. Although they may have purchased their own property, or inherited an old family house, it is usually of poor standard. This group therefore have little or no rent payments. This group also has few household items and cook on kerosene stoves. Similar to other skippers, they generally have not purchased or have access to a telephone or personal transport.

Boat owner-operators of large and small boats

Owner-operators are made up of those who have chosen to purchase a boat with a loan, and others who do not have a loan outstanding. These are specific decisions made by fishers and do not necessarily represent socio-economic groups. There is, however, a distinction between young boat owners and those which are more experienced.

- A relatively young group of boat owner-operators have purchased a small boat to use exclusively within the inshore region. These may or may not have been

purchased with the financial assistance of the government YES soft loan initiative. The majority of this group of young, relatively inexperienced boat owners are single, with few if any children or other dependants. Similar to young crew members, fishers of this group are more likely to be living at home with their parents. They are therefore more likely to have a high standard of living with minimal rent costs. Furthermore, their father was unlikely to have been a fisher and so they have had to learn from their own experience or from other members within the fishing community.

- In contrast, older and more experienced owner-operators are more capable of operating larger vessels than their younger counterparts. The majority of these fishers are married and have established family units. This group also exhibit the highest level of family tradition within the fisheries sector, with a high proportion of members who have been taught directly by their father. As a consequence, these fishers have gained the poorest level of education, but the greatest level of experience. Older members have also few children or other dependants remaining at home. They otherwise enjoy a relatively high standard of living. A high proportion of older boat owner-operators have purchased their own property or rent other accommodation. This group also exhibits a wide range of more expensive cooking facilities and has comparatively more household items. Finally, older owner-operators are also much more likely to own their own transport.

Based on the results described above, personal observations and informal interviews, an alternative set of groups has been proposed. These are labelled as socio-economic groups 1 - 5. Socio-economic groups 1 and 2 refer to boat owner-operators, whereas 3, 4 and 5 describe crew members and skippers.

Group 1 (small and large boats)

This category represents a group of relatively old boat owner-operators of both large and small boats. This group are relatively poorly educated, although they have the highest level of experience. Owner-operators of large vessels are more likely to have an element of family tradition, having been taught directly by their father. Members

of this group are generally married or in a concubine relationship. However, due to their age they have few dependants and an overall smaller household size. They have a good standard of living, with accommodation of high build-quality. The group also has a large number of consumer items, including gas or electric cookers and many have purchased their own transport.

Group 2 (small boats only)

In contrast to group 1, this category represents a group of relatively young, less experienced fishers. This group contains owner-operators of small boats only. The majority are single or in a concubine relationship, rarely married. All members of this group have insufficient experience and/or financial status to purchase a large offshore vessel. A proportion of this group have been reliant on the government YES soft loan initiative to purchase their boat. A relatively high proportion of this group are still living with parents or another family member. Those members who are in a concubine relationship or have become married are more likely to purchase their own property or rent from a private landlord or government.

Fishers who are still living at home have a relatively high standard of living, with access to good cooking facilities and use of a family car. In contrast, members who have decided to purchase or rent their own accommodation show an average standard of living (e.g. accommodation) although they may have fewer consumer items and no transport of their own.

Group 3 (small and large boats)

Older crew members who have gained a high level of experience are included within group 3. A large proportion of this group are skippers of either small or large boats. Due to their age, a relatively high number of this group are either married or in a concubine relationship. Members of this group are therefore likely to have an established family unit, with one or more dependant still living at home. They have an average standard of living, with many who have decided to purchase their own property. Their accommodation is of average build-quality although the majority still cook on kerosene stoves. Few, if any members of this group have purchased or have

access to transport.

Group 4 (small and large boats)

Members of this group are the youngest and least experienced of all fishers. The majority of this group are therefore crew of small boats only. They consist of new recruits who have recently finished their education and decided to enter the fisheries sector. The majority of this group are therefore single or in a concubine relationship, either still living at home with their parents or with another family member. Fishers who have decided to stay at home with their parents enjoy an above average standard of living (for fishers), with access to many facilities such as gas cookers and a family car.

Group 5 (small and large boats)

Older crew members who have remained single but have decided to live by themselves or possibly with another family member are classified within group 5. They have gained little or no formal education but have considerably more experience than group 4 fishers. Fishers that have remained single have few, if any, children or dependants. They also have a relatively poor standard of living. Fishers may have acquired their own property which is of relatively poor build-quality and comparatively little value. The majority cook on kerosene stoves and generally have few consumer items such as a television, video, telephone or car/pickup.

The experience gained by this group enable many of them to skipper a vessel with confidence. For a variety of reasons however, they have not purchased their own vessel.

2.4.2 Comparison between characteristics of each socio-economic group

Using the criteria of each socio-economic group outlined in the previous section, all fishers interviewed within the 1997 survey were assigned to one of the five groups 'by hand'. This subjective task was simplified by some of the constraints placed on group membership (e.g. boat owner-operator or crew member).

The socio-economic characteristics of each group are now compared. This will determine whether the subjective re-classification of fishers from the original 4 strata into the new 5 socio-economic groups has reduced the level of within-group variability. The results can then be compared with similar statistical tests performed on the original 4 strata (cf. Table 2.19 and Table 2.20).

Similar to Table 2.19, characteristics with continuous variables are compared by their mean values between each socio-economic group (one-way analysis of variance, see Table 2.21). The level of association between each soco-economic group with characteristics displaying either nominal or ordinal variables are tested by a Spearman's rank correlation coefficient (Table 2.22). Both statistical analyses were undertaken within SPSS™ statistical computer package (SPSS, 1999).

Table 2.21 Mean values of different characteristics within socio-economic groups.

Group	Mean value of socio-economic group						ANOVA
	1	2	3	4	5	Total	p-value
n	*63*	*11*	*38*	*21*	*10*	*143*	
1. Age (years)	50.30	33.27	45.37	28.10	47.80	44.13	*0.000
2. Experience (years)	27.44	10.82	23.16	7.95	26.20	21.90	*0.000
3. No. children	3.82	0.45	2.74	0.86	0.70	2.61	*0.000
4. Total dependants	1.46	0.55	1.34	0.76	0.70	1.19	0.147
5. Household size	4.89	7.82	5.00	5.48	3.50	5.17	*0.002

*Mean values are significantly different at 5% level.

The re-classification of fishers into 5 distinct socio-economic groups has immediately reduced the level of within-group variability of continuous variables. The division of fishers into one of five socio-economic groups has retained the importance of **Age** and the **Number of Children**, but now also includes both **Fisher's Experience** and the **Household Size**.

Similarly, the re-classification of fishers has also reduced the level of within-group variability of a greater number of nominal or ordinal socio-economic characteristics (Table 2.22). **Marital Status**, level of **Education**, and **House Ownership** were all still considered important characteristics in addition to access to a **Gas Cooker**.

Table 2.22 Level of association of different socio-economic characteristics between strata of the 1997 survey using Spearman's rank correlation coefficient.

Soco-economic characteristics	Significance
6. Marital status	*0.00
7. Fathers Occupation	ns
8. Learn Skills	ns
9. Education	*0.00
10. House ownership	*0.00
11. House quality	ns
12. Car/pickup	ns
13. Telephone	ns
14. Kerosene stove	ns
15. Gas cooker	*0.05
16. Electric cooker	ns

ns - result not significant

*Level of association between strata are significantly different at 5% level.

The re-classification of fishers into new socio-economic groups has considerably increased the level of within-group homogeneity. Division of fishers amongst the original 4 strata were only able to provide five socio-economic characteristics that were significantly different between all groups (cf. Tables 2.19 and 2.20). The present division of fishers into 5 socio-economic groups has led to an increase of 3 (8 in total) significantly different socio-economic characteristics within each group.

2.4.3 Interactions between socio-economic groups

Although fishers have been assigned to only one of five socio-economic groups, they do not remain mutually exclusive over time. For example, if a crew member or skipper purchases a boat, he will transfer from one group (crew members and skippers) to another (owner-operators). The following conceptual diagram illustrates the interaction between each socio-economic group described within the artisanal fishery for *small* boats (Figure 2.5). A separate diagram has been constructed to illustrate the interaction between each socio-economic group for *large* boats (Figure 2.6).

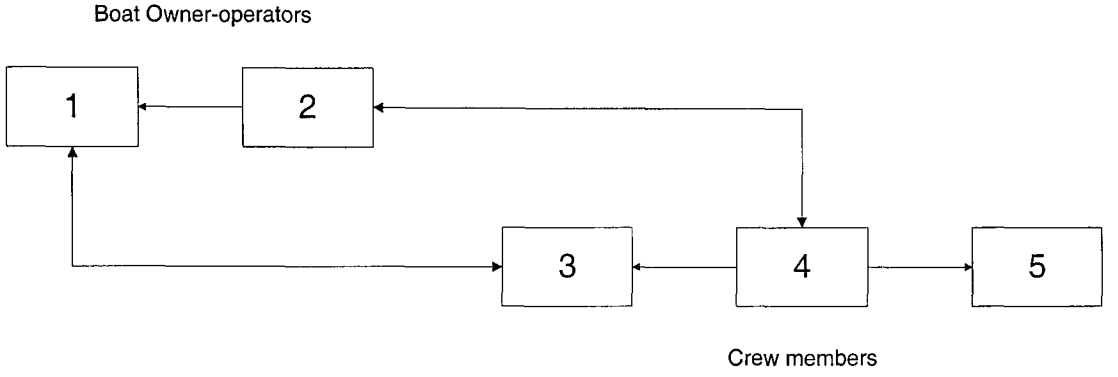


Figure 2.5 Conceptual diagram to illustrate the interaction between socio-economic groups 1 and 2 (boat owner-operators) and groups 3, 4 and 5 (crew members and skippers), for ***small*** boats identified within the artisanal fishery. The direction of the arrow represents possible movement of fishers between groups.

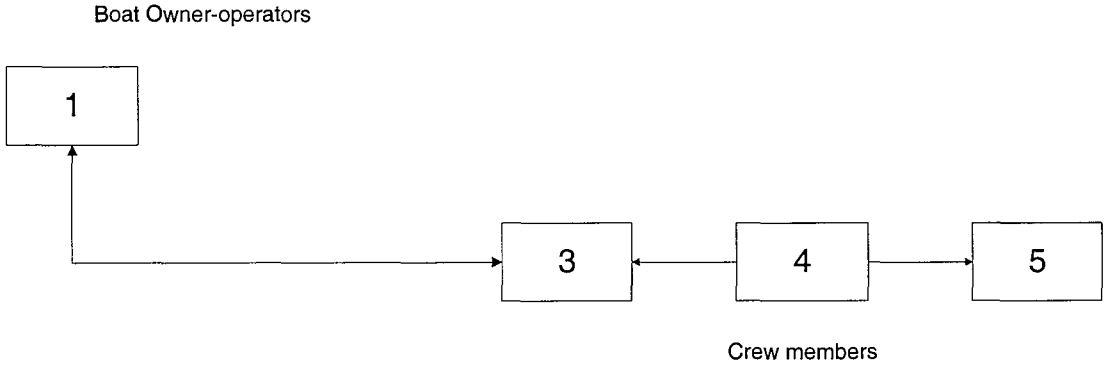


Figure 2.6 Conceptual diagram to illustrate the interaction between socio-economic groups 1 (boat owner-operators) and groups 3, 4 and 5 (crew members and skippers), for ***large*** boats identified within the artisanal fishery. The direction of the arrow represents possible movement of fishers between groups.

Socio-economic group 1 has been used to describe a group of older and more experienced boat owner-operators. They represent an important group of fishers within both small and large boat categories (Figures 2.5 and 2.6). If for any reason, fishers of socio-economic group 1 ever become a crew member, they have the opportunity to enter socio-economic group 3 of either large or small boats. Members of socio-economic group 3 have similar socio-economic characteristics to group 1, however for many reasons they have not purchased a boat.

Conversely, members of socio-economic group 2 are characterised by a group of young and relatively inexperienced owner-operators. Of course, over time members of this group are expected to gain more experience and transfer into socio-economic group 1. In the meantime however, members of this group are restricted to operating only small boats. They neither have the financial capital or level of experience required to purchase and successfully operate a large boat (group 2 is not represented in Figure 2.6).

If fishers within group 2 were ever to become a crew member, similar to group 1 fishers, they would enter a group of similar age and work experience. Group 2 owner-operators would therefore enter socio-economic group 4 as crew members of either a small or large boat.

Socio-economic group 3 consists of relatively old and experienced fishers who regularly skipper either a small or large boat. Under the right set of circumstances, some members of this group may have the opportunity to purchase a boat of their own. These fishers have gained a good level of experience and probably sufficient financial capital to purchase either a small or large boat.

Socio-economic group 4 has been used to describe crew members with relatively little experience. They represent new recruitment of young fishers into the fishery who have the greatest number of potential future options. Similar to group 2, over a period of time members of this group are expected to gain more experience and transfer between socio-economic groups. Unlike group 2 however, ageing members of group 4 may transfer between one of two socio-economic groups.

Group 4 fishers who were relatively poorly educated may remain single and/or move between partners in concubine relationships. They are not all committed to the fisheries sector, and may undertake a number of alternative employment opportunities. Ultimately this group have little family life and few dependents. To represent this transition, such members of group 4 move in time across into group 5 of either small or large boats. Alternatively, experienced group 4 members may remain committed to the fisheries sector, and over a longer period of time learn to skipper a vessel. These fishers move from group 4 into group 3 of either small or large vessels.

A small number of fishers from group 4 may also have the opportunity to purchase a boat of their own. It is this group for which the YES initiative has provided the most incentives for fishers to purchase small boats. If members of group 4 do purchase a vessel, their poor level of experience and lack of financial capital restricts their purchase to a small boat only. Members of group 4 who purchase a boat will therefore move from group 4 to group 2 small boats only.

Finally, socio-economic group 5 are characterised by a group of older, more experienced crew members who have remained single or stayed within one or more concubine relationships with few, if any dependants. For many reasons they have not purchased a boat and remain within the artisanal fishery as a crew member. There is therefore no path between groups 5 and 2 or 1.

2.4.4 Multi-variate analysis of socio-economic groups

In the previous section, fishers placed within the original four strata were subjectively re-classified into five socio-economic groups using characteristics observed within the artisanal fishery. This re-classification of fishers into new socio-economic groups has reduced the level of within-group heterogeneity. The actual process of re-classification however, was very subjective and a level of uncertainty remained over some of the classifications.

This section describes a multi-variate statistical technique to provide an unambiguous classification system of group membership. This approach, known as discriminant function analysis, is used to identify and establish the relative importance of a set of characteristics or variables that classify fishers in already known groups. This technique can also be extended to predict group membership of future fishers using a similar set of 'key' variables. This technique is used in Chapter 3, Section 3.3 to assign new fishers from informal interviews into each socio-economic group.

Prediction of group membership using discriminant analysis

Discriminant analysis creates a number of linear combinations (discriminant functions) of the independent variables, each weighted by a coefficient. These are

used as a basis to classify cases into groups. The discriminant function that correctly classifies the largest number of fishers in each group is selected as the optimum. In this research, discriminant analysis was used to produce discriminant functions of *survey* variables that correctly predicted the selected *socio-economic group* for the largest number of fishers.

The *i*th discriminant function is similar to a multiple-linear regression equation, and produces a score value (D_i), estimated for each case from the aggregation of a linear combination of independent variables (z), each weighted by a coefficient (d_i).

$$D_i = d_i + d_{i1}z_1 + d_{i2}z_2 + \ldots + d_{in}z_n.$$

The equation above describes the discriminant function for unstandardised data, as it includes a constant to adjust for the means. Values of d_i are then chosen to maximise differences between-groups relative to within-groups.

The discriminant function score for a single fisher is estimated by multiplying the raw data value (i.e. socio-economic characteristic) by its associated unstandardised discriminant function coefficient, adding the products over all survey variables, and adding a constant.

The analysis was conducted within a statistical computer package. Further details of the calculations used in discriminant function analysis can be found within the SPSS™ reference documentation (SPSS, 1999).

A mean value of D_i can be calculated for each group, known as a group centroid. This represents a reduction in the space of a group to a single dimension, or discriminant function. Group centroids can be plotted on a scatter diagram for each pair of discriminant functions to illustrate the spatial similarity between different socio-economic groups.

Data considerations

Discriminant function analysis imposes a number of statistical demands on the data

quality. Unequal sample sizes in groups do not pose any problems for within-group prediction. However for classification purposes, a decision is required on whether the sample size should influence the prior probabilities of assignment. In other words, should the probability that a fisher is assigned to a particular group also reflect the fact that the group is itself more (or less) probable in the sample? In general, the sample size of the smallest group should exceed the number of predictor variables. The current data set meets this requirement.

The analysis also assumes that the data have a multi-variate normal distribution and equality of within-group dispersion (homogeneity of variance-covariance). All data relating to dichotomous variables (e.g. communication and cooking facilities) were excluded from the analysis. If sample sizes are all equal or large (i.e. $n > 20$), then discriminant analysis is robust to the violation of homogeneity of variance-covariance. A statistical test, 'Box's M' (Tabacknick and Fiddell, 1996), showed that homogeneity could not be assumed in the data set (Appendix 2.6, Table A2.15). However, this test is regarded as over-sensitive to non-normality (Tabacknick and Fiddell, 1996).

Transformation of variables is a common method of dealing with heterogeneity of group dispersion. A square root transformation was used for variables showing average skewness. Of the ten socio-economic variables used, only 'number of children' required transformation.

Tabachnick and Fidell (1996, p.512) confirm that discriminant analysis is robust to departures from normality if this is caused by skewness rather than outliers. Discriminant analysis is highly sensitive to outliers. In the current data set, no fishers had any outliers.

Selection of socio-economic variables

With prior knowledge of whether a fisher is a crew member, skipper or boat owner-operator with or without a loan, a new socio-economic variable termed'strata' was used to reflect this information (values 1-4).

In addition to this new variable, the minimum number of socio-economic variables

were selected to reduce the amount of data collected from future surveys. This process of variable selection was assisted by a previous statistical analysis of within-group heterogeneity (see Tables 2.21 and 2.22). Using this information, six socio-economic variables were selected; age, marital status, level of education, number of children, household size, and house ownership.

Results of discriminant function analysis

The data set provided the calculation of four discriminant functions. However, not all functions carry the same value of information. An evaluation of the contribution of each function is given in Table 2.23.

Table 2.23 Estimation of eigenvalues and associated statistics for each discriminant function.

Function	Eigenvalue	% of variance explained	Cumulative % of variance explained	Canonical correlation
1	6.973	86.5	86.5	0.935
2	0.786	9.7	96.2	0.663
3	0.252	3.1	99.3	0.448
4	0.053	0.7	100.0	0.225

The eigenvalue is the ratio of the between-groups variability to within-groups variability. This shows that the first function is relatively 'good', whereas functions 2 and 3 have 'reasonable' values, and function 4 has little further information to be gained from the data. The canonical correlation is a measure of the degree of association between function scores and the groups.

In total, discriminant functions 1 and 2 account for 96.4% of the total between-groups variability. Application of the Wilks' Lambda test (Table 2.24), shows that both functions 1, 2 and 3 are significant whereas 4 is not significant (i.e. the observed variability could equally be attributed to sampling variability). Function 3 was dropped from further analyses because it did not provide much additional information that could be gained from functions 1 and 2 alone. Since function 4 was

not significant , it was also dropped from subsequent analyses.

Table 2.24 Wilks' Lambda test performed on each discriminant function.

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	0.053	387.08	28	0.000
2	0.425	113.04	18	0.000
3	0.758	36.50	10	0.000
4	0.949	6.86	4	0.144

Values for the average discriminant score for each group function (group centroids), have been estimated and plotted in Figure 2.7. Discriminant functions form the axes and the centroids of the groups are plotted along the axes.

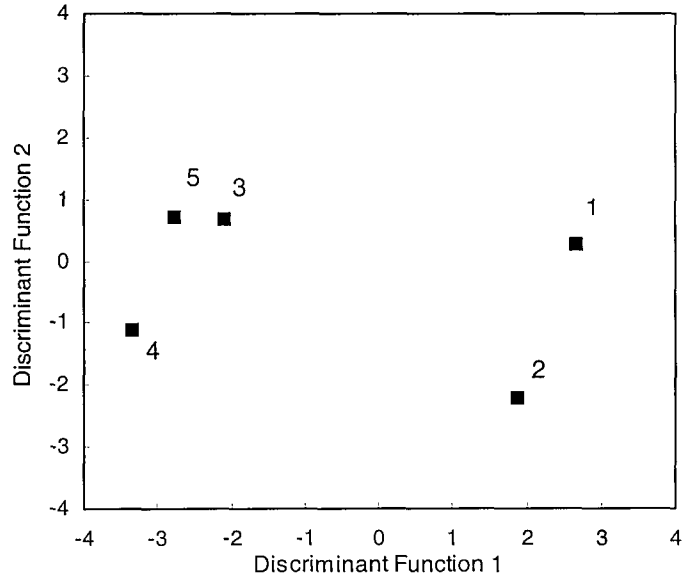


Figure 2.7 Centroids of five socio-economic groups on the two discriminant functions derived from the survey data.

The plot emphasizes the utility of both functions in separating the five groups. Using the selected variables, socio-economic groups 1 and 2 (owner-operators) are distinct from the remaining 3 groups (crew members and skippers). The analysis can also distinguish between groups 1 and 2 and group 4 from both groups 3 and 5. However, groups 3 and 5 are not very well distinguished.

The plot of each centroid illustrates how groups are separated by a discriminant function, but they do not provide any further information. The meaning of the function can be inferred from the pattern of correlations (loadings), between the function and the independent variables. A loading matrix for both discriminant functions is given in Table 2.25.

Table 2.25 Loading matrix for each discriminant function.

	Function	
	1	2
1. Strata	0.946*	-0.170
2. Age	0.174	0.741*
3. Education	-0.111	-0.410
4. Marital status	0.158	0.494
5. Number of children	-0.065	-0.308
6. Household size	0.21	-0.344
7. House ownership	-0.081	-0.031

For this data set, it can be seen that the first discriminant function correlates most highly with age class, whereas the second function correlates highly with marital status. Where there is more than one highly correlated variable, Tabachnick and Fidell (1996, p.540), have stated that 'consensus is lacking regarding how high correlations in the loading matrix must be to be interpreted'. They go on to say that 'by convention, correlations in excess of 0.33 (10% of variance) may be considered [for determining whether or not to interpret the variable as part of the discriminant function].'

The results of the centroid plot can now be fully interpreted. The first discriminant function is largely a measure of fisher's age class which separates both group 2 and 4 (young fishers) from the remaining groups (older fishers). The second discriminant function however, is highly correlated with martial status which separates groups 4 and 5 (single), from the other groups (concubine or married).

Evaluation of results

The success of discriminant function analysis in predicting group membership is summarised in Table 2.26. This table shows how fishers that were originally assigned within socio-economic groups 1-5, are classified using the discriminant functions. The optimal linear solution classified 85.6% of the fishers into the correct socio-economic group.

Table 2.26 Classification of group membership.

		Predicted Group Membership					
	Group	1	2	3	4	5	Total
Count	1	53	6	0	0	1	60
	2	2	9	0	0	1	12
	3	0	0	30	2	6	38
	4	0	0	1	19	1	21
	5	0	1	1	0	8	10
%	1	89.8	10.2	0.0	0.0	0.0	100.0
	2	18.2	81.5	0.0	0.0	0.0	100.0
	3	0.0	0.0	78.9	5.3	15.8	100.0
	4	0.0	0.0	4.8	90.5	4.8	100.0
	5	0.0	10.0	10.0	0.0	80.0	100.0

The high classification score (85.6%) indicates that the discriminant function analysis has performed well at grouping fishers into the correct socio-economic group. With exception to socio-economic group 5, the range or error in predicting group membership lies within between fishers of similar socio-economic status (e.g. boat owner-operators or crew members).

2.5 Summary

This chapter has described the methods used to conduct a formal survey of the Seychelles fishing community, with the assistance of the Seychelles Fishing Authority. The formal

survey has collected a large volume of quantitative data on different technical, economic and socio-economic attributes which are of direct relevance to the development of a bio-socio-economic model of the artisanal fishery.

A comparison of results with those from a former survey have identified a number of trends and characteristics which may be used to classify fishers into one of five socio-economic groups. Due to the subjectivity of classifying fishers into only a single group, a statistical analysis (discriminant function analysis) was undertaken. This developed a formal methodology to classify fishers into each of these socio-economic groups.

The socio-economic groups identified within this chapter are an essential prerequisite for the development of the bio-socio-economic model. A full description of how each group has been incorporated within the simulation model is given in Chapter 5.

The methods developed in this chapter to identify socio-economic groups can be extended to classify fishers surveyed in future studies into each group. This technique has been adopted in the next chapter to link information from informal interviews with those of the formal survey.

3 IDENTIFICATION OF FISHER OPTIONS (DECISION PROCESSES)

3.1 INTRODUCTION

Chapter 2 identified five socio-economic groups operating within the artisanal fishery from data collected during the 1997 formal survey. Although the characteristics of each group can now be used to develop a socio-economic framework within the simulation model (see Chapter 5), additional information is required to quantify the major decision rules governing their behaviour. These decision rules can then be incorporated within the model to simulate the labour dynamics of each socio-economic group within the artisanal fleet.

This chapter aims to identify the key factors that influence decision-making and the most important decision options undertaken by each socio-economic group identified within Chapter 2. This information was collected by a second survey conducted on artisanal fishers using informal interviews.

Section 3.2 briefly describes the identification and selection of sites within Seychelles to be used during the informal survey. The survey was conducted in 2 phases: a series of exploratory interviews were followed up by additional interviews to collect quantitative data on the decision-making processes of fishers within each socio-economic group. The overall research process is described in more detail in Section 3.3.

A brief outline of the fieldwork logistics and resource constraints are given in Section 3.4. The results of the exploratory research and subsequent interviews are presented in Section 3.5. Finally, a summary of the chapter is given in Section 3.6, which also provides further information on how the data are used in the remaining chapters.

3.2 SITE IDENTIFICATION AND SELECTION

The formal survey was conducted on all three main granitic islands of Mahé, Praslin and La Digue (see Section 2.2, Chapter 2). Due to limited time and resource constraints, it was not feasible to conduct the informal interviews on the islands of Praslin and La Digue. Instead, artisanal fishers were interviewed around the main landing sites of Mahé.

Landing sites were selected on a daily basis to coincide with the location of an SFA fieldworker undertaking the routine catch assessment monitoring programme. Interviews were continued until a representative sample (>20) of boat owner-operators and crew had been acquired from both small and large boats within the time available.

3.3 RESEARCH PROCESS

This section describes the sequence of events that were used to acquire quantitative data to describe the major decision rules governing the behaviour of each socio-economic group identified in Chapter 2. The process of data collection was undertaken in 2 phases.

3.3.1 Phase 1: Identification of key factors and decision options

An initial period of exploratory research was undertaken. Information was rapidly gathered using semi-structured interviews with the aim of:

- Identifying a number of *key factors* which may be responsible for controlling the behaviour of different socio-economic groups, and
- Identifying a series of the most important *decision options* available to fishers.

Clearly, decisions of individuals will be partly controlled by their socio-economic status. For example, crew members may wish to purchase boats, whereas boats owners may wish to replace or upgrade an existing boat.

Semi-structured interviews were conducted for both phases of the research process. Instead of developing a series of pre-determined questions, similar to those used in the 1997 formal survey, semi-structured interviews required a check list which was used to refer to a series of sub-topics. The check list, however, is designed to be flexible enough to allow questions to be asked relevant to the respondent. They also enable further questioning to probe for more detail.

3.3.2 Phase 2: Quantification of key factors and decision options available to each socio-economic group

Having identified the factors which triggered decisions and the options fishers faced in Phase 1, more focussed interviews were carried out in the second phase. These interviews, also semi-structured, were conducted with a total of 47 fishers taken from all sectors of the fishing community. In each interview, fishers were asked how they would respond in a variety of defined scenarios (based on the possibilities raised in Phase 1).

To be able to analyse their answers with respect to socio-economic status, these respondents had to be sorted into the socio-economic groups identified in Section 2.4, Chapter 2. This required the collection of key socio-economic attributes of each respondent. The method used to assign each fisher to a socio-economic group based on this information is described below. Other information was also collected on the technical attributes of each fisher, to determine which boat-gear category he was working on.

Classification of fishers into socio-economic groups

In Chapter 2, discriminant function analysis was used to identify artisanal fishers within five socio-economic groups using formal survey data. This was achieved using seven key socio-economic variables (see Section 2.4.4, Chapter 2). The analysis can now be used to assign artisanal fishers interviewed during the informal survey into these five socio-economic groups, based on a series of classification equations.

For each respondent, seven initial questions were asked relating to the seven key socio-economic variables. This provided quantitative data on each socio-economic variable required to classify fishers into one of the five socio-economic groups.

Five classification equations have been developed from the discriminant function analysis of the formal survey data, based on the seven socio-economic variables (see Table 3.1 below). Raw data for each fisher are substituted into each equation to calculate a classification score for each socio-economic group. The fisher is then assigned to the group which has the *highest* classification score.

In its simplest form, the classification equation for the jth group (j = 1, 2, ...n) is;

$$C_j = c_{j0} + c_{j1}X_1 + c_{j2}X_2 + \ldots c_{jn}X_n.$$

A score on the classification function for group j (C_j) is found by multiplying the raw data for each independent variable (X_n) by its associated classification function coefficient (c_j), and then aggregating over all independent variables before adding a constant (c_{j0}).

Classification function coefficients for each group were computed within SPSS™ (SPSS, 1999) (Table 3.1).

Table 3.1 Classification function coefficients developed from 1997 survey data to identify fishers from the 1999 informal survey into socio-economic groups.

	Classification function coefficients (c_j)				
Variable (X_n)	1	2	3	4	5
1. Strata	18.60	17.91	8.73	6.81	7.52
2. Age	0.92	0.78	0.86	0.70	0.96
3. Education	7.97	8.14	7.04	7.16	6.66
4. Marital status	7.98	8.85	7.41	8.11	9.16
5. Number of children	3.09	1.63	2.03	1.43	0.69
6. Household size	0.57	1.24	0.62	0.89	0.38
7. House ownership	2.51	2.33	3.14	2.46	2.86
(Constant)	-82.18	-78.73	-50.05	-43.00	-53.03

The variable 'strata' identifies the fisher into one of four groups: a boat owner-operator or crew member on either a small or large boat. The reader is referred back to Section 2.3 for further details of each socio-economic variable.

3.4 FIELDWORK LOGISTIC AND RESOURCE CONSTRAINTS

Data collected during the second survey (informal interviews) were conducted over a short time period between January and March, 1999. Time was considered the most

important constraint to the logistics of the survey.

Due to the informal nature of semi-structured interviews, additional enumerators could not be selected and trained to conduct interviews in the time available. This restricted the total number of surveys conducted and the subsequent quantity of survey data collected.

Careful planning was also required to ensure fishers within the offshore demersal fishery were available for interview. Schooner vessels operating within this fishery can spent up to 7-10 days at sea during good weather. Hence interviews needed to be tuned to coincide with the short periods of time these fishers spent on shore.

3.5 Results

A summary of the first phase of exploratory informal interviews is now given. These describe the range of key factors which control fishers' decision-making, and the subsequent decision options available to them (Section 3.5.1). These results provide a framework within which to present the quantitative results from the second phase of informal interviews.

Fishers interviewed within the second phase of the research process are first classified into one of five socio-economic groups (Section 3.5.2). The classification of fishers then enables the quantitative decision processes to be presented for each socio-economic group (Section 3.5.3).

3.5.1 Phase 1: Summary of key factors and decision options

Unsurprisingly, a variety of financial details were found to be the key factors responsible for fishers' decision-making. The results showed that fisher decision processes were triggered if they reached one of 3 financial levels:

1. **A minimum level of net income.** Equivalent to the opportunity cost of labour, this represents the lowest acceptable level of income fishers will except from the fishery to remain in the same boat-gear category. This was not a constant monetary value, but showed a range of values for different groups of fishers.

2. **A required increase to their current level of net income.** If a fisher's net income is already above their minimum acceptable level, they are not pressured into making financial decisions. However, an alternative employment opportunity within the fisheries sector may provide greater financial benefits than their current fishing activity. Fishers must therefore decide whether or not to switch to the new boat-gear category. The majority of fishers required a specific increase in their current level of income before they were to consider switching boat-gear categories.

3. **No profit.** If a fisher no longer generates a profit, he is technically operating at a subsistence level only. The results indicated that a minority of fishers may not be able to switch immediately to an alternative boat-gear category. For example, boat owner-operators may not have acquired the skills necessary to operate a new gear type.

These were the key processes used to discuss decision options with fishers from different sectors of the fishing community in the second phase of this research.

The decision options available to fishers at different financial levels were found to vary between their current status (boat owner-operator/crew) and boat-gear category. The complexity of their decision-making, however, can be greatly simplified. Opaluch & Bockstael (1984) identified three decision categories which can be used to define what action fishers take at different financial levels:

- Stay within the same boat-gear category,
- Leave the fisheries sector, or
- Switch to an alternative boat-gear category.

It was found that the most preferred option varied depending on the financial level concerned.

The results found that fishers who have indicated a preference to switch to an alternative boat-gear category were required to make a number of additional decision options. Because a proportion of crew members have the potential to become a boat owner-operator, they share a number of common decision options which relate to boat purchase and geographic fishing region. Further criteria on which they base their decisions are

shown in Table 3.2.

Table 3.2 Summary of information required to quantify the decision options available to fishers who consider switching boat-gear categories.

Attribute	Description
Economic	• Cost of boat/gear (transfer costs)
	• New or second hand boat
	• Credit arrangements
	• Alternatives to boat purchase
Technical	• Boat type preference
	• New or second hand boat
	• Crew availability
Socio-economic	• Status (owner-operator/crew)
	• Key socio-economic variables
	- Age
	- Education
	- Marital Status
	- Number of children
	- Household size
	- House ownership

3.5.2 Phase 2: Quantification of key factors and range of decision options

The initial exploratory phase of informal interviews identified a number of key financial factors that determine when fishers are likely to make a decision. This section describes the results of the second phase of informal interviews.

In order to present and analyse responses with respect to socio-economic status, it is necessary to present the results of the classification of respondents into the socio-economic groups (as discussed in the methods section).

This allows quantitative information on the key factors and decision options of fishers to

be linked to different socio-economic groups. This is essential to develop the socio-economic attributes within the simulation model.

Classification of fishers into socio-economic groups

At the start of the informal interviews, each respondent was asked a series of closed questions with specific response categories, to identify a set of socio-economic variables (X_n) which can be used to classify fishers into one of five socio-economic groups.

The following table illustrates a worked example of the process used to classify a fisher (owner-operator) into a single socio-economic group, using raw data (X_n) obtained from the second phase of informal interviews (Table 3.3).

Table 3.3 Classification of respondent (owner-operator) into one of five socio-economic groups.

		Owner-op.		Crew member/skipper		
Variable	(X_n)	1	2	3	4	5
1. Strata	4	74.40	71.64	34.92	27.22	30.09
2. Age	41	37.51	31.94	35.38	28.70	39.24
3. Education	2	15.94	16.28	14.09	14.32	13.31
4. Marital status	1	7.98	8.85	7.41	8.11	9.16
5. Number of children	1	3.09	1.63	2.03	1.43	0.69
6. Household size	4	2.28	4.96	2.46	3.56	1.51
7. House ownership	1	2.51	2.33	3.14	2.46	2.86
(Constant)		-82.18	-78.73	-50.05	-43.00	-53.03
Total Score (C_j)		61.7	58.9	49.3	42.8	44.0

The total classification scores for each group are given at the foot of Table 3.3. The socio-economic variables which characterise the fisher give rise to the highest score function in group 1 (61.7). This fisher is therefore assigned to this socio-economic group. This classification can be cross-checked by the fisher's own status within the fishery. In this example, the fisher is a boat owner-operator (1 or 2). Hence the

classification has been successful.

This process was repeated for each respondent within the informal survey (n = 47), to classify fishers into one of five socio-economic groups. The number of fishers classified within each group are summarised in Table 3.4. The classification system had been successful in placing all respondents into the correct strata (i.e. boat owner-operator/crew member).

Table 3.4 Number of fishers classified within each soco-economic group from the second phase of the informal interviews.

	Crew member		Owner-operator		
Group	Small	Large	Small	Large	Total
1	-	-	13	6	19
2	-	-	3	-	3
3	3	1	-	-	4
4	7	0	-	-	7
5	1	13	-	-	14
Total	11	14	16	6	47

Although the sample size was relatively small, these results show that the total survey coverage was relatively good. The potential low numbers of large boat owner-operators is partly due to the absence of fishers within socio-economic group 2.

Quantifying socio-economic group decisions

Having classified the respondents into socio-economic groups, it is now possible to analyse their responses with respect to socio-economic status. The following quantitative results are now presented by each socio-economic group and boat-gear category (where applicable).

Financial decision levels

Within the initial exploratory phase of informal interviews, three financial levels were

identified as key factors which determine when fishers are most likely to make an important decision within the artisanal fishery. This section now attempts to quantify these values for each socio-economic group.

Minimum acceptable level of net income

The minimum level of net income is equivalent to the minimum wage fishers within each socio-economic group are willing to receive from their fishing activities in order to remain within the same boat-gear category.

In general, it was very difficult to obtain explicit financial information from the artisanal fishers. Instead, an indirect line of questioning was required to describe monetary values in terms of the quantity of catch: fish packets (small boats) and tonnes (large boats). As a result, additional information on their daily operational costs, average number of crew and share system was also required. Based on this information, a series of calculations were used to estimate the minimum acceptable level of income for all fishers within each socio-economic group. These are presented in Tables A3.1 and A3.2 (Appendix 3). It should be noted that the minimum acceptable level of income could not be calculated for all respondents due to the lack of information or quality of data received.

The average minimum acceptable level of net income for each socio-economic group calculated from Tables A3.1 and A3.2 (Appendix 3) is presented in Table 3.5.

Table 3.5 Summary of the average minimum acceptable level of $\overset{\text{annual}}{\hat{}}$income (SR) for each socio-economic group within the artisanal fishery.

Socio-economic group	*n*	Average minimum level of net income (SR)	Std. Deviation
1	14	18,583	1,797
2	3	20,267	1,222
3	11	14,593	4,801
4	6	13,844	1,495
5	2	11,117	3,418

On average, socio-economic groups 1 and 2 (boat owner-operators) have a higher minimum acceptable level of net income than groups 3, 4 or 5 (crew members). This may be due to a number of factors, including the need to repay outstanding debts (e.g. boat loans), and/or additional family commitments.

The relatively high standard deviation values for crew members may reflect the low total sample size, but also may indicate that crew are not as dependant on the fishery for their income. For example, crew members are also able to take on seasonal employment (e.g. labouring), to boost their annual level of income.

Required increase in level of net income

If fishers are currently operating above their minimum acceptable level of net income (Table 3.5), the results from the exploratory research indicate that fishers require a financial incentive before they consider switching to an alternative boat-gear category. This difference would have to exceed their current level of net income before they would switch. The required level of income necessary before fishers consider switching between boat-gear categories has been calculated as a fixed percentage above their net income from their current boat-gear category. This was calculated from the reported additional level of catches required above their average daily catches.

The following table summarises the average required percentage increase in the level of net income for fishers to switch either to a small boat-gear category or to a large boat-gear category (Table 3.6). It should be noted that there are no fishers classified within socio-economic group 2 on large boats (cf. Section 2.4, Chapter 2).

* The results shown in Table 3.6 show that a small boat owner-operator would require a 50% increase in his annual net income before he considers switching to an alternative small boat-gear category. This increase reflects his reluctance to switch to an alternative small-boat category. The increase in annual net income levels is required to overcome numerous issues relating to switching gear types, including the temporary loss in net income whilst the fisher may have to acquire a new set of skills required to operate the new fishing gear.

The required percentage increase in annual net income values have been rounded to the nearest 10%. This definition of rounding reflects the fact that the majority of fishers found it difficult to make future economic predictions.

Table 3.6 Summary of the required percentage increase in the level of net income (SR) by fishers to switch small or large boat-gear categories.*

Socio-economic group	% Increase	
	Small	Large
1	50	50
2	50	-
3	50	100
4	50	100
5	50	100

This information also includes the percentage increase required to switch between boat-gear categories within the same boat type. It does not, however, include the additional costs associated with the new gear. For example, a trap-only small boat crew member will require a 50% increase in their level of net income before they consider switching to a handline-only small boat. Obviously, a small boat crew member will require a substantial financial incentive (100%) to transfer to a large boat.

Decision options

Having established the average financial levels at which fishers are likely to undertake a decision process, this section describes the proportion of fishers within each socio-economic group who either stay the same, leave the fisheries sector or decide to switch to an alternative boat-gear category.

A summary of the proportion of small boat fishers within socio-economic group 1 on small boats who decide to either stay the same, leave or switch boat-gear categories is given in Table 3.7.

Table 3.7 Proportion of decisions made by fishers on small boats within socio-economic group 1, at different financial levels (where financial level 1 = above the minimum acceptable level of net income; 2 = at or below their minimum acceptable level of net income; 3 = is no profit).

Financial level	Decisions made at different financial levels			Total
	Stay the same	Leave fishery	Switch	
1.	0.54	0.00	0.46	1.00
2.	0.62	0.00	0.36	1.00
3.	0.00	0.35	0.65	1.00

In the above example, 65% of fishers within this socio-economic group would switch to another boat-gear category at financial level 3, while 35% would leave.

It should be noted that Table 3.7 is a summary table of part of the results (i.e. fishers on small boats in socio-economic group 1). Further details of fisher decisions at different financial levels are described in detail within the socio-economic modelling chapter, Chapter 5.

Boat-type preference

One of the questions within the informal interviews examined the proportion of fishers who would prefer to remain in their current boat-type or who have no particular preference (i.e. ability to transfer). There are many reasons why fishers may show a preference to stay in their current boat-type, including level of experience and family commitments. The preference of boat-type can also be used to inform actions during boat purchases or movement of crew between boat-gear categories.

The following tables describe boat-type preferences of fishers within each socio-economic in small-boats (Table 3.8) and large boats (Table 3.9).

Table 3.8 Boat-type preference for fishers currently operating *on small boats* for different socio-economic groups.

Group	Stay	Transfer
1	7	6
2	3	-
3	2	1
4	5	2
5	1	0
Total	18	9

Table 3.9 Boat-type preference for fishers currently operating *on large boats* for different socio-economic groups.

Group	Transfer	Stay
1	1	5
2	-	-
3	0	1
4	0	0
5	7	6
Total	8	12

Details of boat purchase

Based on informal interview data, it was found that a number of common decision options were made by boat owner-operators and crew members concerning boat purchase arrangements. These related specifically to both the size and age of vessel, and credit arrangements.

Boat size and age preference

The choice of boat size and age preference was determined for all respondents. This ensured that potential boat owner-operators (i.e. fishers currently operating as crew members), would have the option to purchase a boat in the model. Boat size and age preferences for fishers within each socio-economic group are given in Table 3.10.

Table 3.10 Number of fishers that would prefer a new or second hand small or large boat.

Group	Small Boat		Large Boat	
	New	Sec. Hand	New	Sec. Hand
1	8	0	9	2
2	1	2	-	-
3	2	0	0	2
4	3	2	0	2
5	7	1	0	6
Total	21	5	9	12

The majority of fishers looking to purchase a small boat-type would consider a new boat, whereas a greater proportion of fisher purchasing a larger boat would be prepared to look at second hand boats. These are important financial decisions which may affect the ability of fishers to purchase a boat-type in the model. The latter can mainly be attributed to socio-economic groups 3, 4 and 5 (crew members).

Loan details

A high proportion of fishers stated that they would require a loan in order to purchase their preferred boat-type. The number of fishers within each socio-economic group requiring a loan are detailed in Table 3.11.

Table 3.11 Number of fishers that would require a loan to purchase their preferred boat type.

Group	Small Boat		Large Boat	
	Yes	No	Yes	No
1	4	4	9	2
2	3	0	-	-
3	1	1	2	0
4	4	1	2	0
5	7	1	6	0
Total	19	7	19	2

Further economic details concerning the current soft loan system have been collected from secondary sources of information, and are described in detail within the economic sub-module in Chapter 4.

It was perceived that some fishers who are required to make a decision because their net income has reached their minimum acceptable level may be unsuccessful in attaining their first goal. For example, if fishers were unable to afford to purchase their preferred *new* boat type, they may wish to consider a number of alternative options. These include purchasing a cheaper second hand boat, becoming a crew member for a short period of time, or leaving the fisheries sector altogether. The 'next best alternative' has been summarised for fishers within each socio-economic group. This is described for those who originally indicated a preference for small boat-types (3.12), or large boat-types (Table 3.13).

Table 3.12 Decisions made by potential *small* boat owner-operators who are unable to purchase a new boat.

Group	Leave	Second hand	Crew	Total
1	2	6	0	8
2	0	1	0	1
3	0	2	0	2
4	0	3	0	3
5	1	6	0	7
Total	4	17	0	21

Table 3.13 Decisions made by potential *large* boat owner-operators who are unable to purchase new boat.

Group	Leave	Second hand	Crew	Total
1	0	5	4	9
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
Total	0	5	4	9

On average, fishers would consider the purchase of a second hand boat before either leaving the fisheries sector or becoming a crew member (or remaining if already a crew member). It should be noted that no fishers who indicated a preference for a large boat would consider leaving the fisheries sector.

3.6 SUMMARY

This chapter has identified three financial levels which are key to controlling the major fisher decision-making processes within the Seychelles artisanal fishery. At each financial level, the range of decision options available to fishers within each socio-economic group have been simplified into those who wish to stay the same, leave the fisheries sector, or switch to an alternative boat-gear category. For the latter individuals, a more detailed quantitative analysis of their decision options was reported. This included an assessment

of the preferred region (inshore or offshore), the financial capability of fishers to purchase vessels (with or without a loan), and their vessel preference.

This quantitative analysis of fisher decision-making processes forms one of the cornerstones to the bio-socio-economic model. The methods used to incorporate this information into the model have been described within the socio-economic sub-module in Chapter 5.

4 DEVELOPMENT OF A BIO-SOCIO-ECONOMIC MODEL OF THE SEYCHELLES ARTISANAL FISHERY

4.1 INTRODUCTION

This chapter provides an introduction to the initial development of a simulation model that can be used to evaluate a set of outcomes from alternative management options within the Seychelles artisanal fishery.

To evaluate alternative management options that will help reduce the high level of fishing effort within the inshore region, the model must include elements of the fishery system sufficient to demonstrate each outcome, while retaining a level of simplicity to ensure the results can be fully interpreted. The simulation model describes the decision-making processes of fishers behaviour within the artisanal fishery in response to alternative management options. By understanding and modelling these processes in a deterministic manner, future outcomes from alternative strategies may be predicted.

This chapter describes in detail the biological processes and technical interaction within the artisanal fleet for each resource. Financial and economic details are given for each socio-economic group. The more complex decision-making processes of each socio-economic group are described within a separate chapter (Chapter 5).

An outline of the chapter is now given. An overview of the model is described in Section 4.2. This illustrates how the complexities of the artisanal fishery system have been simplified into a finite number of *key components* while maintaining the overall model resolution and balance. A time step, used to synchronise the interaction between different events occurring within the system model, is also given.

A brief description of the type of alternative management options available to model are given in Section 4.3. It is important to consider the number and type of alternative strategies available at the beginning of the modelling process. A number of performance measures used to describe the outcome of alternative management options are introduced in section 4.4.

A brief outline of the simulation model is given in section 4.5. This section describes in detail how the model is constructed around a set of biological, technical and socio-economic attributes.

An estimation of the initial level of fishing effort within each socio-economic group within all boat-gear categories is determined in Section 4.6. A full description of the biological sub-module within the simulation model is given in Section 4.7. This section includes both a description and parameterisation of each stock biomass, estimated total catch and an index of abundance for each boat-gear category. Section 4.8 describes the economic sub-module, providing details of the costs and revenues for each boat-gear category. A brief summary of the chapter is given in Section 4.9. This highlights the important input parameters required in the following chapter (Chapter 5) to simulate the decision-making processes of each socio-economic group.

4.2 Overview of the model

The format of the simulation model was constructed within an MS Excel™ spreadsheet (MS Excel, 1997). This approach was selected to increase the transparency of the fishery system and provide a suitable medium to output relevant graphics. The model however, was written in MS Visual Basic for Applications™ which ran 'behind' the spreadsheet (MS Visual Basic, 1997). This facilitated more complicated program routines that were not otherwise possible in the spreadsheet.

The model describes the artisanal fishery in terms of a whole system, relying on many different aspects or components relating to the biological, technical, economic and socio-economic attributes. Due to the complexity of the interactions within the system, the model was kept deterministic so that output from alternative management options could be fully interpreted.

The following sections describe the important components of the artisanal fishery system dynamics. The level of resolution or detail applied to each component is then discussed. Finally, a time step is selected to synchronise each component within the system model.

4.2.1 A simplification of the artisanal fishery: model components

An overview of the artisanal fishery (Section 1.3.2, Chapter 1), demonstrated the wide variety of boat-gear categories capable of exploiting a complex multi-species assemblage. To develop a model of the fishery which can be used to evaluate alternative management options, a number of simplifications were necessary. These reduced the number of interactions between fishers and boat-gear categories that were not relevant to the original aims of the study. Combined, an overview of the artisanal fishery (Chapter 1) and the results of each the socio-economic survey (Chapter 2) were paramount in identifying which attributes of the fishery should be included.

To determine the success of reducing the level of fishing effort within the inshore region, it was important to model both small inshore boats and larger vessels capable of exploiting resources further offshore. In a review of the artisanal fishery, it was demonstrated that the largest proportion of fishing effort occurred within the inshore region (fisheries Sector 1). This region is currently exploited by both small and large whaler-type boat categories (SFA, 1998; Mees, 1996).

The relationships between boat size, gear and fishing location are summarised in the following schematic diagram (Figure 4.1). A brief description of the major fisheries identified within each region are given below.

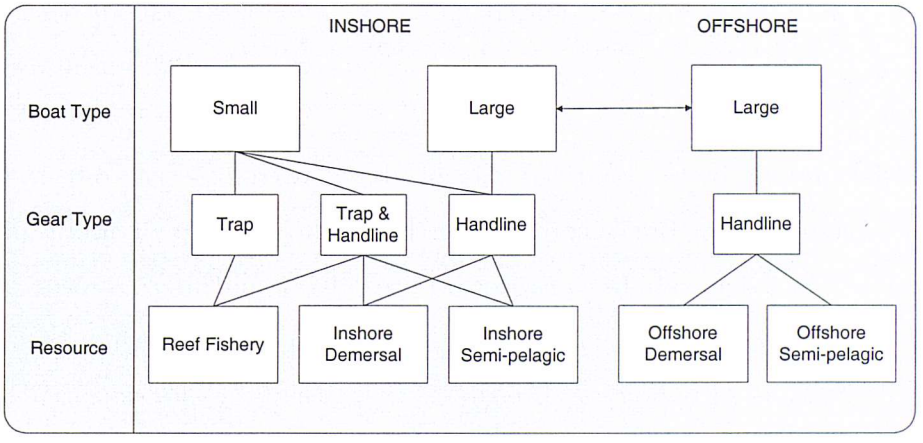


Figure 4.1 Schematic diagram to illustrate a simplification of artisanal fishery system. Small boats operate exclusively within the inshore region whereas larger whaler class vessels continue to make between 50 - 80% of their fishing trips within the inshore region (dotted line).

Inshore fisheries

Inshore fishers operate numerous gear types which target a range of inshore species. However, the greatest source of local employment and domestic fish supply is gained from inshore reef, demersal and semi-pelagic resources (SFA, 1998).

There are a wide variety of small boats operating within the inshore region. These comprise mainly of 16 to 21 foot fibre-glass skiffs with outboard engines, known locally as Mini-Mahé. However, new boat designs are beginning to emerge fitted with a removable ice box and have larger outboard engines which make them capable of exploiting resources further offshore (Nageon pers. comm., 1997). Although larger outboard vessels can fish further offshore during good weather, in practice this activity is rarely known to occur. It is assumed that all outboard powered vessels operate exclusively within the inshore region (fisheries Sector 1). These boats have been modelled as a single homogenous group with similar fishing power.

The majority of new small boats entering the fishery are now produced from a fibre-glass. However, this was not always so, and there still exists a limited number of traditional wooden pirogues. These are much smaller craft, which are only capable of fishing within the near shore zone. An overview of the artisanal fishery illustrated that pirogues once played a more important active role in the inshore sector (see Section 1.1.3, Chapter 1). Excluding this boat type from the model would therefore eliminate an important historical level of fishing effort applied to the inshore resource base. Since the model only simulates the purchase of more modern outboard vessels, it is important to incorporate the historical catch made by pirogue fishers.

It has been noted that a large proportion (50 - 80%) of trips undertaken by inboard-powered whaler-class vessels remain within the inshore region (see Mees, 1996; Art_fish database, SFA, 1997). This complicates the model in that inshore demersal and inshore semi-pelagic resources are retained by handline fishers using both small and large vessels. A range of different size vessels are currently described within the whaler category. However, it has been shown that smaller inboard powered vessels (e.g. 1 - 2 cylinder, lekonomie), operate almost exclusively within the inshore region, whereas larger inboard powered vessels (3 - 4 cylinder, traditional whaler/lavenir),

undertake more trips further offshore. The remaining number of trips undertaken by large vessels, including schooners, takes place on the peripheral banks of the Mahé Plateau and associated outer islands.

Offshore fisheries

As a consequence of reducing the level of fishing effort within the inshore region, a number of fishers may be relocated to the offshore fisheries. There are two sectors to the offshore fishery. An artisanal offshore handline fishery operates around the peripheral banks of the Mahé Plateau and associated outer islands, whereas a semi-industrial long-line fishery targets swordfish within the entire Seychelles EEZ. Although local fishers have moved into the latter fishery, either as experienced skippers or young motivated crew members, additional boat entry is constrained by the high capital costs associated with this activity (Michaud, 1990).

By far the greatest potential for relocating fishing effort away from the inshore region lies with the lightly exploited offshore handline fleet. In providing incentives to relocate fishers on board large vessels, precautions must be taken to prevent this effort returning to exploit the inshore region.

4.2.2 Model resolution and balance

The resolution of the model refers to the level of detail captured in different components of the system. In part, this is determined by the amount of information available to model the system, and the overall objectives.

To maintain a level of balance within the model requires a similar scale of resolution within each component. This is not always possible. If insufficient data are available, uncertainties in these results make conclusions from other more complex components less meaningful. For example, the resolution of the socio-economic component can be described at different scales. An attempt to model the decision-making processes of each and every fisher is one example. This very high resolution approach would be too detailed to simulate realistically. This would also make the model unbalanced in comparison to the biological component (i.e. *individual* fish or species cannot be

modelled).

In contrast, a set of decisions made by all members within a single boat-gear category have a very poor resolution, since this would not distinguish between crew members and boat owner-operators. Using data from the results in Chapter 3, different socio-economic groups identified within each boat-gear category provide a suitable compromise to model the socio-economic attributes of the system.

4.2.3 System time step

A time step represents a single iteration within the model. It is used to synchronise the interactions between and within each component. In general, these may reflect changes that occur over a period of days, months or even years.

The Seychelles has two distinct monsoon periods, lasting between 4 - 6 months (see Section 1.2.1, Chapter 1). Seasonal weather patterns also determine the level of catch made within the artisanal fleet (see Section 1.3.7, Chapter 1; Mees, 1996, p.123). Initially, this evidence suggests that a time step of one season (approx. 6 months), is sufficient to model the fishery. However, the seasonal component is cyclical, which enables catch information to be averaged over an entire year. This is important, since many sources of secondary data are only available on an annual basis. It was decided to match a time step equivalent to one year in the model.

4.3 ALTERNATIVE MANAGEMENT OPTIONS

At the start of the modelling process, it is important to identify the type of alternative management options that can be used. This keeps the development of the model tightly focussed on the original aims, and enables the construction of a set of performance measures to evaluate the relative success of each strategy.

From the results of the socio-economic survey (Section 2.3, Chapter 2), it was concluded that the artisanal fishery continued to lack a strong element of family tradition. Although options for co-management should be further explored, alternative management options are currently limited to a number of 'input' controls (e.g. gear restrictions) or 'output'

controls (e.g. volume of fish landed) (Francis & Shotton, 1997). In this way, the government retains overall responsibility for regulating patterns of resource use.

A number of input controls are suggested following a review of the artisanal fishery (Chapter 1), to help regulate the level of fishing effort within the inshore region. It is almost impossible to implement output controls within a multi-species context. For example, restricting the quantity of fish landed via Total Allowable Catches (TACs) operating within a multi-species fishery could lead to high levels of discarding or high-grading to ensure the most profitable fish are landed, leading to further resource depletion (Gulland, 1982).

Three forms of input control are considered in this study. In brief, these reflect changes to the current soft loan scheme, and restrictions on both access and gear within the inshore region. Area restrictions placed on small non-fished regions or 'no-take reserves', cannot be considered here due to the poor quality and quantity of spatial data available. A brief description of each input control used on the model is now given.

4.3.1 Soft loan system

The government YES initiative has been shown from the results of the socio-economic survey (Appendix 2.7), to be instrumental in providing financial incentives in the form of soft loans, to young fishers entering the heavily exploited inshore region. The YES initiative is therefore used as an important input control to *decrease* the level of fishing effort within the inshore region (e.g. increase interest rates, reduce term of repayment etc.). In contrast, the DBS can be manipulated to *increase* the level of financial incentive to purchase large offshore vessels (e.g. reduce interest rates, increase term of repayment). Manipulation of the DBS loan scheme must be carefully regulated in conjunction with access restrictions to prevent large vessels remaining within the inshore region (see below).

The compulsory boat insurance required for all loan agreements has been shown to substantially increase monthly loan repayments, especially for large vessels (Mees *et al.*, 1998). Insurance rates cannot directly be manipulated by the government, since all transactions are administered within the private sector. However, the overall effect of

reducing insurance premiums is to lower monthly repayments. This can also be simulated by other means within the model. For example, reducing the monthly interest rate or increasing the term of repayment both have the same overall effect of reducing monthly repayments.

It is unnecessary to replicate all input management controls. By recording the outcome of either reducing interest rates *or* increasing the term of repayment, decision-makers can decide how the strategy is finally implemented. For example, it may be more convenient to reduce interest rates than increase the term of repayment. These issues are discussed in more detail in Chapter 7.

4.3.2 Gear restrictions

The level of fishing effort within the inshore region may also be reduced by placing restrictions on gear size and/or the number of gear used. These restrictions are by far the most difficult to regulate and enforce.

The majority of handline fishers use only a single monofilament line, although hook size and the number of hooks attached per line are variable (Wakeford, 2000). Although the selection of hook size can determine the size of the fish retained (Betrand, 1988; Ralston, 1990), this management option is both difficult to regulate and is less appropriate within a multi-species fishery.

In contrast, fish traps are more conspicuous and provide a better means of gear regulation. Both an *increase* in the size of mesh and a *reduction* on the total number of traps used per fisher could be seen as methods of gear restriction. Although changes in trap mesh size have been shown to bring about a number of long-term benefits to both fish populations and fishers (Gobert, 1998; Ribochaud *et al.*,, 1999; Sary *et al.*, 1997), they are also more complicated to model than reducing the number of traps per fisher. Since both forms of gear restriction result in an immediate reduction in the level of fishing effort, the number of gear used per fisher has been used. Both the CAS (Lablache & Cararra, 1984; SFA, 1998) and the most recent socio-economic survey indicate approximately 5 traps are used per fisher.

4.3.3 Boat restrictions

Restrictions on access physically constrain the number of vessels participating within the inshore region. Currently two options exist; restrict access of *all* traditional whaler-type vessels within the inshore region, and/or introduce a strict licence scheme, similar to that used for the seasonal lobster fishery (see Domingue, 1996).

Currently in 1998, a nominal boat licence fee is charged (SR125) to have the fishing vessel registered at the Seychelles Licensing Authority. This is fixed charge to cover the administration costs, but could be increased to approximately SR5,000 to reflect the expected increase in benefits from a closed fishery. This value has been selected for illustrative purposes only. Further research would be required to develop an appropriate licensing agreement for local fishers.

4.4 Performance measures

The statistics used to evaluate the performance of alternative management options are known as performance measures. A wide variety of performance measures have been used in the literature (e.g. Punt, 1995), which reflect the objectives of the managers in the fishery in question and their attitude to risk. According to Francis and Shotton (1997), there are three criteria that should be considered when choosing a performance measure.

"First, it should be readily intelligible to managers and stakeholders to interpret. Second, a performance measure should show contrast between alternative management options, and third, it must be related to the management objectives."

In selecting an appropriate set of performance measures, it is worth revising the overall management objective of the study. First and foremost, the biological status of the inshore resources must be conserved in order to maintain sustainability of the fisheries sector. This suggests that a biological indicator related to the stock biomass is essential. Secondly, catch levels should be stable in order to maintain supplies of fish to both the domestic and foreign export markets. The domestic market provides a cheap source of high quality protein to the local community whereas the foreign export market provides an important source of foreign exchange earnings.

To measure the relative success of reducing the level of fishing effort within the inshore region, the level of capital investment within both inshore and offshore sectors can be measured. This reflects the number of active commercial boats operating within each boat-gear category, for example. A 'good' result would indicate a decline in the number of boats operating within the inshore region.

Furthermore, the level of fishing effort can be gauged by the number of active fishers operating within each boat-gear category. This also has other important implications relating to the overall level of employment within the fisheries sector. Closely associated with the level of employment, a measure of social welfare and equity can be gauged from the distribution of income levels between different socio-economic groups. Further details of each performance measure is given in Section 7.3, Chapter 7.

4.5 OUTLINE OF BIO-SOCIO-ECONOMIC MODEL

This section describes how each of the components described above are fully integrated to develop a simulation model of the artisanal fishery. The model is first used to simulate a period of historical fishing between 1986 - 1998 (i.e. *yr - 12 to yr*). The model is then projected forward 30 years (i.e. *yr + 1 to yr + 30*) to evaluate different outcomes from alternative management options.

At the start of the first year (*yr - 12*), a set of parameters values are used to simulate the historical pattern of resource use, based on a number of previous management options. A historical level of fishing effort is initially set by inserting a given number of fishers into different socio-economic groups within each boat-gear category.

This initial level of fishing effort is then applied to the starting stock biomass of each resource base to yield a total catch for each boat-gear category at the end of the first year. The technical interaction between different fishing units (boat-gear categories) and the resource base (stock biomass) are described in detail as a series of routines within the *Biological sub-module.*

The total catch from each boat-gear category is sold to generate a gross revenue for the fishing unit. The operational costs are then subtracted from the gross revenue to realise

a total net revenue (or profit). A standard 'share' system is then utilised to divide the net revenue between fishers to provide each socio-economic group an annual level of income for each category. The economic and financial calculations for each socio-economic group within each category are described in detail as a series of routines within the *Economic sub-module.*

Changes occurring within the model are driven by the availability of the resource to generate different levels of income. Based on the annual level of income for each socio-economic group within each category, fishers undertake a series of decision-making processes to determine what action they will undertake for the start of following year. For example, crew members may wish to purchase boats, transfer to a more profitable category, or simply leave the fisheries sector. At the end of the first year, the number of fishers within each category are then used as starting values for the level of fishing effort at the start of the second year (*yr - 11*). The technical interaction between socio-economic groups within each category are described in detail as a series of routines within the *Socio-economic sub-module.*

This sequence of events continues until the model reaches the end of 1998 (year *0*). After the model has run to simulate the first 13 historical years (*yr - 12 to yr*), a group of new parameters are inserted into the model to simulate alternative management options. The model then continues, projecting forward a total of 30 years. The new management options are selected at the very beginning of the run (i.e. *yr - 12*), and are 'switched on' during the projection period. This action is seamless, and does not require the model to be stopped at any stage. Running alternative management options therefore generates similar historical records before each projection period.

Of course, previous management options can also be used during the projection period to simulate the outcome if 'no alternative action' was undertaken (i.e. fishery left at status quo). This scenario acts as an important control, and provides a benchmark for all other management options. Finally, at the end of each simulation run, a set of performance measures are used to evaluate the relative success of each management option.

Outputs from the model are compared with a set of historical data collected from secondary sources of information in Chapter 6. In additional to the historical analysis,

the original management options are retained to project future output from the fishery under similar conditions. The response of taking no further management action has been evaluated using a set of performance measures. This scenario is used as a control or benchmark, upon which other alternative management options can be compared. A complete analysis of alternative management options is given in Chapter 7.

The following schematic diagram summarises the sequence of key information used within each module of the simulation model (Figure 4.2).

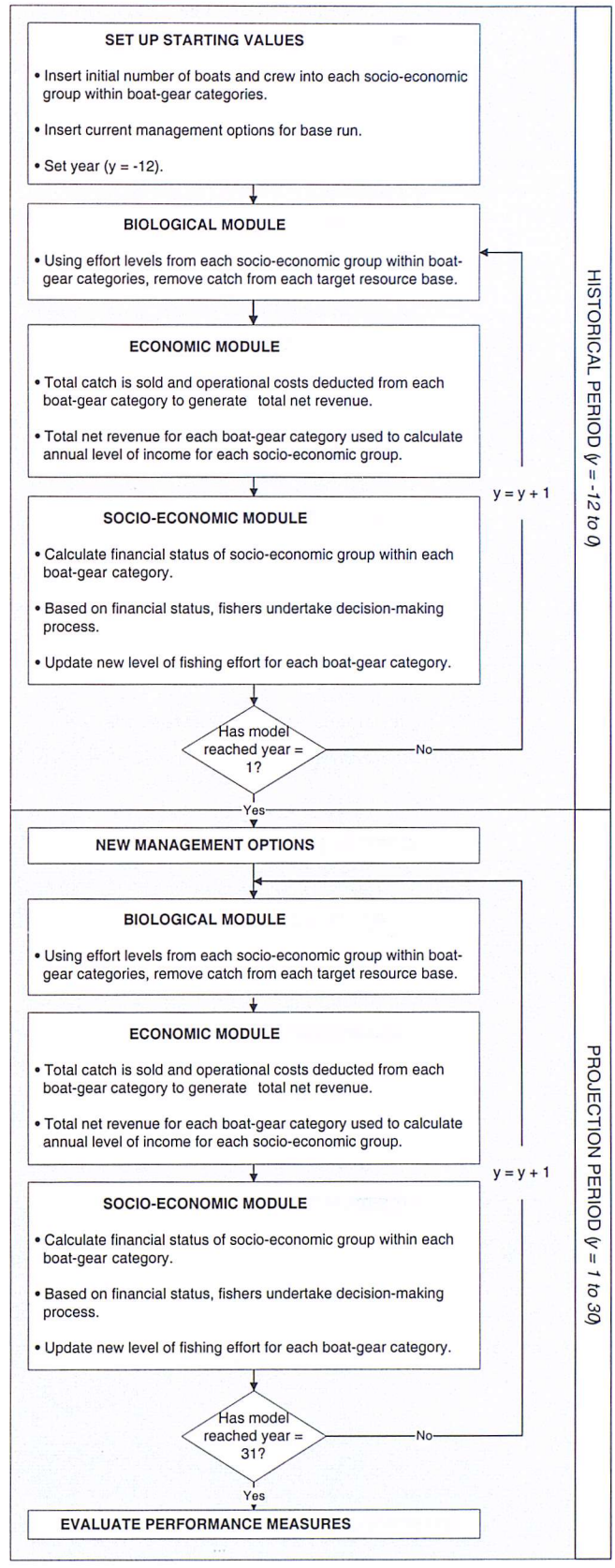


Figure 4.2 Schematic diagram to illustrate sequence of key information used within each module to generate historical and projected output within the simulation model.

4.6 ESTIMATION OF INITIAL LEVEL OF FISHING EFFORT

Within the model, the first simulated level of fishing effort is estimated from historical data. Following this, the dynamic model is then capable of simulating all subsequent levels of fishing effort, based on these values. The initial simulated level of fishing effort is calculated from the original number of fishers within each boat-gear category.

The total number of fishers within each boat-gear category at the start of the simulation period (i.e. *yr - 12*), was estimated from the original number of boats in operation and the average number of crew members on board each vessel. The number of commercial fishers starting within each socio-economic group could then calculated from a ratio obtained from the results of the 1997 survey. It is assumed that the ratio of fishers within each socio-economic group has not notably changed since the start of the simulation period.

4.6.1 Boat owner-operators

From the results of the 1997 socio-economic survey, only a small proportion of boat owners (approximately 2%) were not actively fishing within the sector. However, the number of non-boat owning skippers actively fishing was substantially greater (approximately 16% of all respondents), indicating that the actual number of boat owners not participating within the fishery may be considerably higher than the proportion of non active boat owners . To simplify the model, it was assumed that all boats operating within the artisanal fishery are controlled by boat owner-operators (i.e. boat owner also participating within the fishery). The proportion of boat owner-operators within each socio-economic group for each boat type was estimated from survey data and are presented in Table 4.1.

Table 4.1 Proportion of boat owner-operators within each socio-economic group for each boat type.

Socio-economic group	Small Boats	Large Boat
1	0.77	1.00
2	0.23	0.00

Source; 1997 socio-economic survey

No owner-operators from socio-economic group 2 are present within the large boat category. The total number of boats in operation at the start of the simulation model were obtained from secondary sources of information, and are presented in Table 4.2.

Table 4.2 Average number of commercial fishing boats in operation for each boat-gear category in 1986.

Small Boats			Large Boat Handlines	
Trap	Handlines	Trap & Handlines	Inshore	Offshore
28	77	33	28	33

Source; SFA, 1998

Mees (1996) estimated that approximately 70% of all fishing trips undertaken by whaler-class vessels were made within the inshore region (fishing sector 1). In contrast, larger schooner vessels operate almost exclusively within the offshore region. It was assumed therefore that the total number of large vessels operating within the inshore region was 70% of the total number of whaler-class boats, whereas the remaining 30% fished further offshore with the total number of schooner vessels.

With information on both the number of boats within each boat-gear category and the proportion of fishers within each socio-economic group, the total number of owner-operators within each socio-economic group can now be calculated. It is assumed that the proportion of fishers within each socio-economic group, estimated from data collected during the 1997 socio-economic survey, has not changed since 1986. The average number of boat owner-operators to be inserted within each socio-economic group and boat-gear category at the start of the simulation are given in Table 4.3.

Table 4.3 Estimated total number of boat owner-operators within each socio-economic group and boat-gear category at the start of the simulation.

Socio-economic	Small Boats			Large Boat Handlines	
group	Trap	Handlines	Trap & Handlines	Inshore	Offshore
1	22	59	25	28	33
2	6	18	8	0	0

4.6.2 Crew members

The average number of crew members at the start of the simulation can be estimated by combining information on the total number of boats in operation with the expected number of crew per boat. Results from the 1997 socio-economic survey provide a preliminary estimate of the average number of crew working on board different boat-gear categories. A further estimate of the average number of fishers (incl. boat owner-operators) per boat type was also given by Mees (1990). However, the most accurate estimate of the average number of fishers per boat-gear category can be obtained from the CAS (Art_Fish database SFA, 1998). These are presented in Table 4.4.

Table 4.4 Average number of fishers (incl. standard deviation), for each boat-gear category during 1986.

Boat type	Gear type	Average	Std. Deviation
Small	Trap	1.94	0.56
	Handlines	2.14	0.53
	Trap & Handlines	2.09	0.62
Large Handline	Inshore	5.59	2.01
	Offshore	5.13	1.16

Source; Art_Fish database SFA, 1998

The average number of fishers operating on board *small boats* during 1986 within the inshore region was approximately 2. This indicates that normally one boat owner-operator worked alongside an additional crew member. *Large vessels* were observed to take on more crew, between 5 and 6 fishers per boat, (i.e. between 4 and 5 crew members, excluding the owner-operator. The total number of crew members (excl. owner-op), within each boat-gear category at the start of the simulation can now be estimated from the total number of boats and the average number of crew (Table 4.5).

Table 4.5 Estimated total number of crew per boat-gear category during 1986.

Boat type	Gear type	Average
Small	Trap	39
	Handlines	78
	Trap & Handlines	44
Large Handline	Inshore	129
	Offshore	136

Finally, the total number of crew per socio-economic group within each boat-gear category can be estimated from the total number of crew (Table 4.5) and the proportion of fishers within each socio-economic group. Similar to boat owner-operators, the proportion of crew members within each socio-economic group have been estimated from ratios taken from the 1997 survey (Taken 4.6).

Table 4.6 Proportion of crew members within socio-economic groups 3, 4 and 5 for each boat-gear category.

Socio-economic group	Small Boats	Large Boat
3	0.46	0.62
4	0.36	0.26
5	0.18	0.12

The proportions of each socio-economic group (3, 4 and 5) have been adjusted for inshore and offshore boat-gear categories. The number of crew within each socio-economic group can then be distributed amongst boat-gear categories, as shown in Table 4.7.

Table 4.7 Estimated total number of crew members within socio-economic groups 3, 4 and 5 for each boat-gear category.

Socio-economic	Small Boats			Large Boat handline	
group	Trap	Handlines	Trap & Handlines	Inshore	Offshore
3	12	40	16	80	84
4	9	31	13	33	35
5	4	15	6	15	16

The estimated number of owner-operators (Table 4.3), and crew (Table 4.7), within each socio-economic group for each boat-gear category can now be inserted as the initial starting values within the biological module of the simulation model.

4.7 BIOLOGICAL MODULE

The biological module represents the regeneration of stock biomass between each year and the technical interaction between the resource and artisanal fleet to generate a level of catch for each boat-gear category. The numbers of fishers within each boat-gear category at the start of the model (described above) are important to simulate the first level of catches from each stock.

The biological module has 3 distinct sub-modules. First, the biological processes associated with the regeneration of stock biomass are detailed. Secondly, catches made by each boat-gear category are estimated from the respective target stock biomass. Finally, an index of abundance was calculated to monitor the status of the fishery and compare with historical data. A brief summary of each sub-module is given in Figure 4.3. This provides information on the type of input parameters required for each sub-module and a description of the expected output.

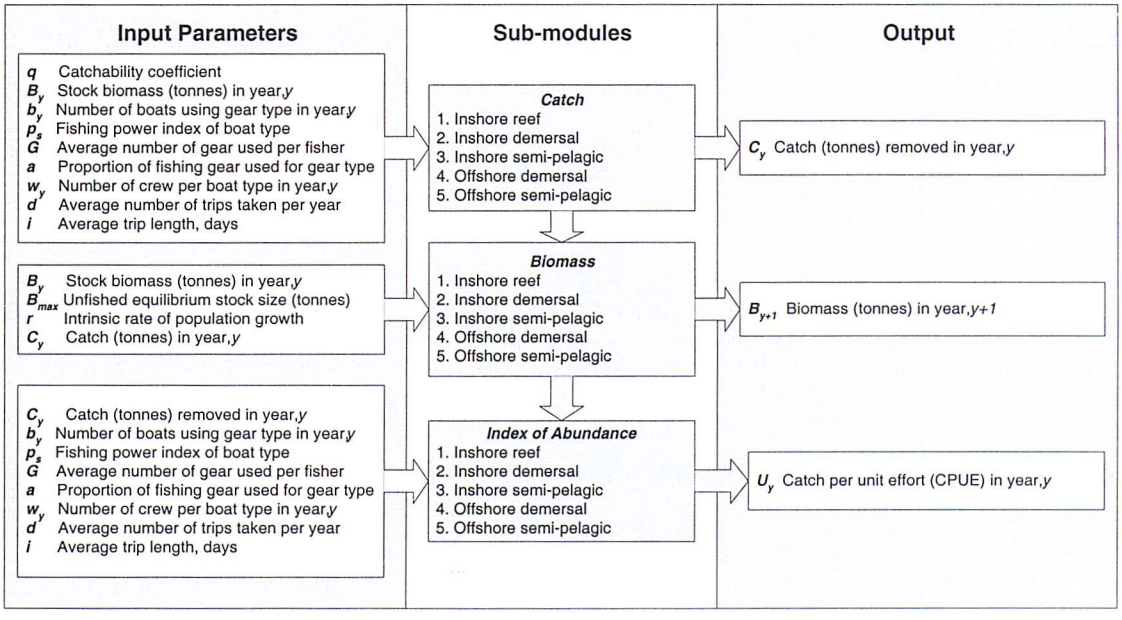


Figure 4.3 Summary of input parameters required by each sub-module and expected output from the biological module.

4.7.1 Biomass

The production of stock biomass is fundamental to the structure of the model. Not only does this drive the model between successive years, but equally important, it provides an opportunity to monitor the status of each resource in response to alternative management options.

In common with many tropical fisheries, both a lack of detailed biological information and relatively poor catch data prohibits the use of full age-structured models (Gulland, 1982). Since it would also be difficult, if not impossible, to regulate the fishery on a single species basis, the entire catch was considered as a single stock biomass consisting of species with similar attributes. A simple biomass dynamics model was used to characterise the relationship between the stock biomass and potential production.

Although a number of alternative relationships are available, a simple difference equation of the Schaefer form (1954), has been used (see Hilborn & Walters, 1976 and Hilborn & Walters, 1992).

$$B_{yr+1} = B_{yr} + rB_{yr} \cdot \left(1 - \frac{B_{yr}}{B_{\max}}\right) \qquad \text{Equation 4.1}$$

B_{yr} Stock biomass (tonnes) in year, yr

B_{yr+1} Stock biomass (tonnes) in year, $yr + 1$

B_{max} Unfished equilibrium stock size (tonnes)

r Intrinsic rate of population growth

There are numerous marine resources available to fishers within the Seychelles (see earlier overview of artisanal fishery, Chapter 1). However, these have been reduced to a number of key resources which have been used to gauge the relative success of each alternative management option. These are described in the following section.

Inshore Resources

Three inshore resources have been modelled explicitly; reef, demersal and semi-pelagic. The complexity of the multi-species reef fishery has been greatly simplified.

The biomass dynamic model (Equation 4.1), has been used to simulate the production of biomass to cover a wide range of species (e.g. octopus and rabbitfish). It has been assumed that the rate of production is the same for all species. In other words, values used to parameterise the biomass dynamic model represent an average for all reef species. In part, this assumption may be validated by the dominance of a single family (Signidae) in the inshore catch (86.5% by weight (SFA, 1998)). To assist the parameterisation of the inshore reef biomass, a preliminary stock assessment of the inshore trap fishery was conducted (see Appendix 1.1).

Production of inshore demersal resources have also been simulated using the biomass dynamic model (Equation 4.1). Unlike the reef fishery, there are many species that make up the total biomass of the catch (SFA, 1998). The fishery is very complex, and high levels of exploitation may result in changes to the multi-species assemblage (cf. Mees, 1996a; Jennings *et al.*, 1995; Jennings *et al.*, 1996). Fishers can further complicate matters by switching target species. Without this information, it too must be assumed that parameter values selected for the biomass dynamic model represent an average for all species. It is acknowledged that changes to the assemblage may result in different characteristics and productivity of the resource.

Due to the lack of information on both the pattern of distribution and abundance of inshore semi-pelagic resources, the total available stock biomass (B_{yr}) could not be estimated. Instead, the historical level of semi-pelagic catches from each boat-gear category were added to their total catch (see below). In this way, no biological information was required concerning the status or abundance of the resource.

In addition to the production model parameters in Equation 4.1, an initial stock biomass (B_{start}), was required at the beginning of the model to simulate the first stock biomass (B_{yr}) for each resource. Biological information gained from a review of the status of the artisanal fishery in Chapter 1, was used to parameterise the model. A summary of different parameter values for both inshore reef and demersal resources is given in Table 4.8.

Table 4.8 Summary table to indicate input parameter values for biomass sub-module for both inshore reef and demersal resources (fishery sector 1).

Parameter	Reef	Demersal†
B_{start}	1,070 tonnes	3,300 tonnes
B_{max}	1,826 tonnes	6,400 tonnes
r	1.04	0.48
B_{MSY}	474 tonnes	766 tonnes

†*Demersal information adapted from Mees (1996)*

The biological parameters used for the inshore reef fishery were updated from a re-assessment of the stock using information from the Seychelles trap fishery (see Appendix 1.1). The current estimate of potential yield (474 tonnes/year), stands considerably lower than a previous value for the region (600 tonnes/year; Lablache *et al.*, 1988). Lablache *et al.*, (1988) used existing catch data from 1979 - 86 to infer that the trap fishery was already fully exploited during this period. If however, the actual potential yield now stands closer to 474 tonnes/year, then the high level of catches acquired before the start of the model (i.e. 1986), suggest that the fishery was already fully- or even over-exploited. The reef stock biomass used at the start of the model (B_{start}), has therefore been chosen to reflect this historical level of exploitation (i.e. biomass has been reduced to the maximum rate of exploitation, or B_{MSY}).

Estimates of the total available inshore demersal stock biomass and yield were initially obtained from a description of the demersal biomass and potential yield from each fishing ground (see Mees 1996, p.23). Combined, this data was used to provide a preliminary estimate of the intrinsic population growth rate (r), for inshore demersal resources using parameters from the Schaefer production model (i.e. $r = (4*C_{MSY})/B_{max}$). When however, these parameter estimates were used in conjunction with historical inshore demersal catches, it was found that the stock collapsed (see Appendix 4.5). This implies that either the unfished equilibrium stock biomass (B_{max}) is too low and/or the intrinsic rate of population growth (r) is too low. In the model, r was kept the same value as it was very similar to the intrinsic rate of population growth for the offshore demersal resource. A new estimate of B_{max} was therefore required.

In relation to the traditional whaler handline fishery operating within the inshore region, Mees (1996, p.41) stated that '[up to 1994] no depletion or obvious multi-species effects were observed to occur despite the high fishing pressure.' He goes on to state that, 'it may be the case that present species composition and catch rates represent an *equilibrium* achieved at such high levels of pressure' (emphasis added). This infers that the inshore demersal resource was fully exploited during this period, and therefore catch rates may reflect an approximate estimate of MSY.

The total inshore demersal catch between 1986 - 94 was estimated at 766 tonnes/year (Appendix 4.5). If this figure is now used as an approximate value for C_{MSY}, a new B_{max} estimate can be acquired given the value of r (B_{max} = approx. 6,400 tonnes). It follows that the stock biomass should also have reached the maximum rate of exploitation, equivalent to $B_{max}/2$. Hence, B_{start} can be estimated from the value of B_{max} (B_{start} = approx. 3,200 tonnes).

Offshore Resources

Two resources have been simulated within the offshore region; demersal and semi-pelagic. There is currently no evidence to suggest that either offshore resource is connected to their inshore counterparts. It is therefore assumed that both populations are distinct and have been modelled separately.

Simulation of the offshore demersal resource has used the Schaefer biomass dynamic model (Equation 4.1) to simulate the production of offshore resources. The demersal parameter values however, are different to the inshore parameters, reflecting the difference in location and total available biomass. These have been estimated from secondary sources of data, and are presented in Table 4.9.

Table 4.9 Summary table to indicate input parameter values for biomass sub-module for the offshore demersal resource.

Parameter	Demersal
B_{start}	40,000 tonnes
B_{max}	42,260 tonnes†
r	0.52
B_{MSY}	5,649 tonnes†

† *Estimates obtained from Mees (1996b, p.23)*

The intrinsic rate of population growth (r) has been estimated using a similar approach to that of the inshore demersal resource (i.e. Schaefer production coefficients).

Similar to the problems associated with the inshore semi-pelagic resource, the total available stock biomass (B_{yr}) could not be estimated. Instead, the historical level of offshore semi-pelagic catches were added to their overall total catch (see below). In this way, no biological information was required concerning the status or abundance of the resource.

Having established the production of three major resources exploited within the artisanal fishery (excluding semi-pelagic), it is now possible to estimate the level of catches retained by each boat-gear category.

4.7.2 Total catch

It is assumed that the catch is proportional to both the stock size and fishing effort. The rate of catch retained by each boat-gear category can be determined based on the following simple catch equation (Hilborn & Walters, 1992):

$$C_y = q \cdot B_y \cdot E_y \qquad \text{Equation 4.2}$$

C_{yr} Catch (tonnes) removed from stock biomass as a rate in year, yr

q Catchability coefficient of gear type

B_{yr} Stock biomass (tonnes) in year, yr

E_{yr} Fishing effort exerted in year, yr

Total catches within the inshore region are made principally by two gear types: trap fishers who target reef fish and handline fishers who target both demersal and semi-pelagic resources. A small number of fishers also utilise both gear categories to retain a mixture of all three resource types.

As it has been noted earlier, a considerable number of trips are made by whaler-class vessels within the inshore region (approximately 70% of all trips). These vessels use handlines to exploit the inshore demersal resources in this region. It is therefore important to consider these catches being taken from the inshore demersal resource, even though they are taken by what is classified as a 'large' vessel. Within the model, catches acquired further offshore are made exclusively by handlines. Similar to the inshore fishery, handline fishers can target both demersal and semi-pelagic resources.

Clearly it is important to quantify the level of fishing effort exerted by each boat-gear category within each region. This enables both the catch and effort of the mixed gear category and large vessels to be apportioned to the correct resource in each region. The average catchability coefficient (q) for different gear types within each region is given in Table 4.10.

Table 4.10 Average catchability coefficients (q), for each major gear type within the simulation model.

	Small Boat		Large Boat Handline	
Parameter	Trap	Handline	Inshore	Offshore
q	0.0000047	0.0000035	0.00000587	0.0000011

The average catchability coefficient (q) of each gear type was estimated by re-arranging the catch equation (Equation 4.2):

$$q = \frac{C_{yr}}{\left(B_{yr}E_{yr}\right)}$$

Both historical catch records (C_{yr}) and fishing effort (E_{yr}; see below) were already available from secondary sources of information for each boat-gear category between 1986 - 97 (SFA Annual Statistics, 1987-98), whereas annual *estimates* of stock biomass (B_{yr}) had to be

regenerated using Equation 4.1 and existing catch data. Combined, this information produced an annual estimate of the catchability coefficient between 1986 - 97. These values were then averaged to provide a single estimate for each gear type. Full details are given in Appendix 4.6.

Finally, to prevent large catches eliminating the total stock biomass, a check is first made to ensure the stock remains above 5% of the unfished equilibrium stock size (B_{max}), after the catch is removed. This minimum stock biomass (B_{min}), is an arbitrary figure based on the lowest expected biomass available to fishers. If the potential catches in any year exceed the available stock biomass (i.e. $C_{yr} > (B_{yr} - B_{min})$), the total level of catches are reduced to equal the maximum available. This total available biomass is then redistributed between boat-gear categories based on a proportion of the fishing effort exerted by each boat-gear category. An example of these calculations are presented in Table 4.11.

Table 4.11 Redistribution of inshore demersal catch if potential catch (C_{yr}) exceeds the available stock biomass ($B_{yr} - B_{min}$). Where B_{max} is 6,500 tonnes; B_{min} is 325 tonnes (5%); and the current biomass (B_{yr}) is 500 tonnes. [Available stock biomass = (500 - 325 = 175 tonnes)].

Boat type	Gear type	Effort: Man Days	Effort: Proportion	Catch (tonnes)	Catch adj. (tonnes)
Small boat	Handlines only	30,000	0.35	100	61
	Trap & Handlines	5,0000	0.06	25	11
Large boat	Inshore handlines	50,000	0.59	175	103
	Totals:	85,000	1.00	300	175

In consequence, this check on the minimum available biomass was not important, since economic decisions would prevent the exploitation of a stock at this extreme level.

Fishing Effort

The level of fishing effort exerted on a stock each year (E_{yr}), is specific to each boat-gear category. This is due to the size or fishing power index of each vessel, the

number and type of gear, and the duration of its use. The total fishing effort per boat-gear category is the product of one unit of fishing effort and the number of vessels operating in this category. The following generic equation describes the fishing effort exerted by each boat-gear category.

$$E_y = \left(p_s \cdot G\alpha \cdot \left(1 + \varpi_y\right) \cdot d_{ys} \cdot i_s \cdot h \right) \cdot b_y \qquad \text{Equation 4.3}$$

E_{yr} Fishing effort exerted in year, *yr*

G Average number of gear used per fisher

a Proportion of fishing gear used for gear type

ϖ_{yr} Number of crew per boat in year, *yr*

$d_{yr,s}$ Average number of trips taken per year (*yr*) and by boat type, *s*

i_s Average trip length, days for boat type, *s*

h Proportion of fishing effort exerted within each fishing region

b_{yr} Average number of boats using specified gear type in year, *yr*

The average number of gear used *(G)*, is a constant and describes the number of traps or handlines used per fisher. Although the majority of handline fishers operate a single monofilament line, they are capable of using more than one hook per handline. It is assumed that all fishers use the same number of hooks per line. In contrast, the number of traps used per fisher is variable (current study and Art_Fish database; SFA, 1997). The average number of gear used by trap fishers and handline fishers is given in Table 4.12.

Table 4.12 Average number of gear used (*G*) by fishers using only traps or handlines.

Gear type	Average	Std. Deviation
Trap	4.7	2.9
Inshore handline	1.0	0.0
Offshore handline	1.0	0.0

The socio-economic survey and other secondary sources of data (CAS; SFA, 1998; Mees, 1996), indicate that fishers using both gear categories exert lower levels of fishing effort on each target resource than fishers who only utilise a single gear type shown in Table 4.12 above. In other words, a fisher using both traps and handlines

use less traps and spend less time handlining than a single trap or handline fisher.

The reduction in fishing effort can be measured as a proportion of the average number of gear used by fishers using only traps or handlines (a). The proportion is a constant and is estimated from i) the average number of traps used by fishers within the mixed gear category, and ii) the relative fishing power exerted by handlines used by fishers within the mixed gear category (Table 4.13).

Table 4.13 Average number of gear used (G) by fishers within mixed gear category and proportion of fishing effort (a).

Gear type	Average	Proportion (a)
Trap	2.4	0.51
Inshore handline	0.77*	0.77

**see Mees (1996, p.123)*

The average number of crew per boat-gear category (ϖ_y), is variable and is determined each year by the number of crew and owner-operators remaining within each category. However, at the start of the simulation the average number of crew per boat-gear category (ϖ_{start}), is determined by secondary sources of data (see Table 4.4, Section 4.6).

Large vessels operating further offshore are likely to undertake longer fishing ventures but have fewer trips per year than small boats. The average trip length per boat type (i_s), is a constant and has been estimated for both small and large vessels from secondary sources of data (Table 4.14).

Table 4.14 Average trip length per boat type (i_s).

	Average trip length, days (i_s)
Small: inshore	≤1.00
Large: inshore	1.24
Large: offshore	4.48

Source; Art_Fish database, SFA, 1998

Clearly it can be seen that trips undertaken within the inshore region (fishing sector 1), are single day trips. The average number of days per trip is extended for larger vessels which exploit regions further offshore.

The number of trips per year (d_{yr}), are described for both large and small vessels. Small vessels undertake day trips within the inshore region, together with a proportion of large fishing vessels. However, the number of fishing trips undertaken each year can be variable, and may be controlled in part by seasonal climatic conditions. The historical number of fishing trips may be estimated from secondary sources of data using Equation 5.4 below;

$$d_y = \left(\frac{L_y}{\varpi_y . b_y . i_s} \right) \qquad \text{Equation 4.4}$$

L_{yr} Total number of Man days for boat-gear category in year, *yr*

ϖ_{yr} Number of crew per boat in year, *yr*

b_{yr} Average number of boats using specified gear type in year, *yr*

i_s Average trip length per boat type, *s*

The total number of trips taken per year have been calculated for each small boat-gear category and are presented within Appendix 4.1. The number of trips undertaken by large vessels is slightly more complicated due to the proportion of vessels operating within each fishing region. The total number of trips taken per year for large boats operating inshore and offshore and are presented within Appendix 4.2.

The proportion of fishing effort undertaken by different boat-gear categories within each region have been estimated (h). Principally this controls the level of fishing effort exerted by large vessels within both inshore and offshore regions. During the historical period (*yr - 12* to *yr*), an average of 70% of all fishing trips were undertaken within the inshore region.

Finally, the actual number of vessels operating each year within different boat-gear categories (b_y), contribute to the overall level of fishing effort. These have previously been described in Table 4.2 above.

Biomass update

After the level of catches have been estimated for each boat-gear category, the stock biomass must be updated to provide the new level of biomass at the start of the following year. This is shown in the following equation:

$$B_{yr+1} = B_{yr+1} - C_{yr}. \qquad \text{Equation 4.5}$$

In the equation above, B_{yr+1} represents the stock biomass in the following year.

4.7.3 Index of abundance (catch per unit of effort)

An index of abundance in each year (U_y), is estimated from the annual catch (C_y), and respective level of fishing effort (E_y), for each boat-gear category. These can be used to provide information on the current status of the stock biomass, but have been simulated within the model to enable a comparison with secondary sources of data.

$$U_y = \frac{C_y}{E_y} \qquad \text{Equation 4.6}$$

The reef fishery considers the catch in terms of the number of traps used. Hence the weight per trap (i.e. kg/trap), is used throughout as a measure of catch per unit of fishing effort (cpue). Strictly, this measure may lead to sources of bias, since it does not include the actual soak times of the trap which may vary considerably. However, calculation of cpue values have been kept similar to those of the CAS to facilitate a comparison between the raw data and output from the simulation model.

Both small and large vessels operating handlines monitor the catch in terms of the number of working man days (i.e. kg/man day). Hence, if a fisher can work more than a single handline, catch rates will increase even though the number of fishers remain constant. Estimates for large vessel catch and effort are a combination of both inshore and offshore demersal resources. Hence, if poor catches are made within the inshore region, they could be 'masked' by good offshore catches.

4.8 ECONOMIC MODULE

Having established the levels of catches made by different boat-gear categories, values are passed onto the economic module to calculate the level of income for different each category. A brief summary of each sub-module within the economic module is given in Figure 4.4. This provides information on the type of input parameters required for each sub-module and a description of the expected output. Output from each sub-module may be re-used within the sub-module and / or brought forward as key input for the next socio-economic module.

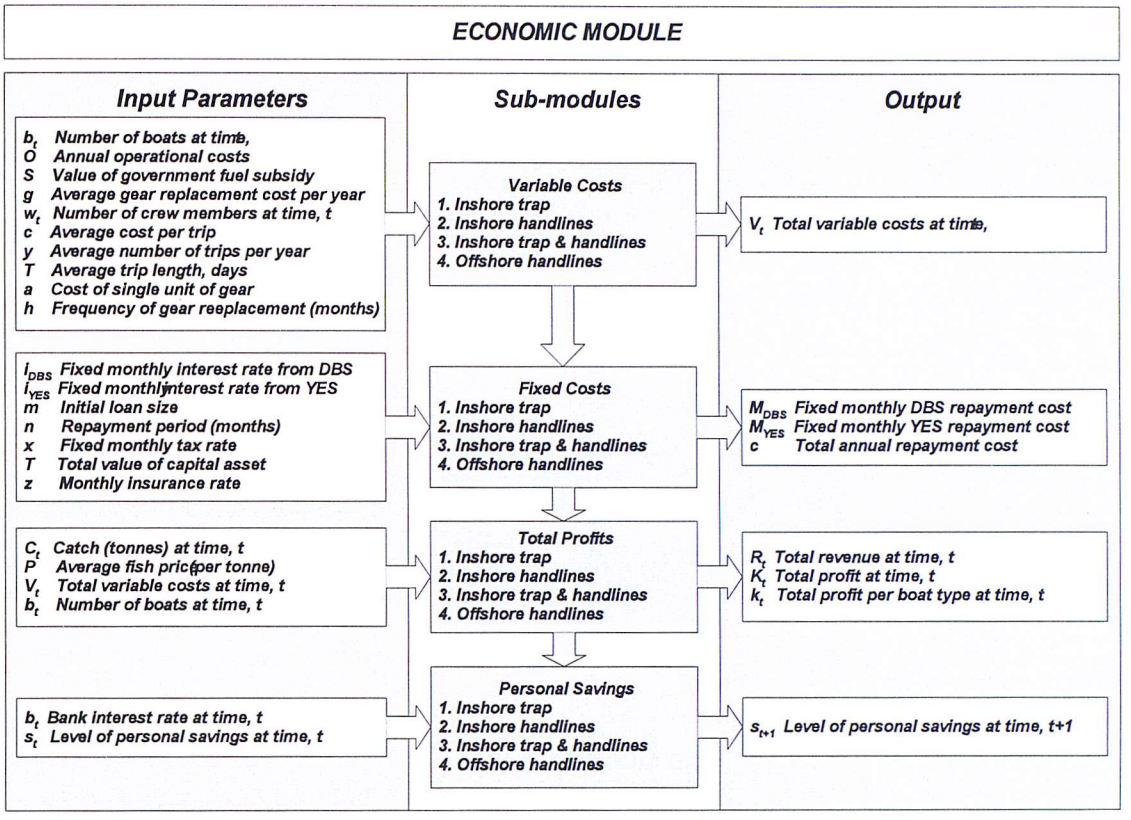


Figure 4.4 Summary of input parameters required within each sub-module of the economic module, together with the expected level of output from each.

First, the harvested biomass is 'sold' at a unit price to realise a total revenue from the fishery. Following this, total costs are calculated from both variable and fixed costs. The total costs are then subtracted from the total gross revenue to yield the net economic rent or net revenue for each fishery.

The net revenue is later divided between each vessel operating within the fishery to generate a total profit per vessel. Finally, the profit per vessel is shared out between the boat owner and other crew members to provide them with an annual level of income. The following sections describe in more detail how these steps are simulated within the model.

4.8.1 Total costs

Total costs include all the expenses incurred by the boat owner over a given period of time. Total costs are divided into variable and fixed costs.

Variable costs

Variable costs are those associated with the day to day running of fishing activities. Expenses incurred for items such as fuel, lubricants, bait, ice, transport and food are calculated on a per trip basis. Other components of variable costs include those associated with the repair and maintenance of vessels and replacement of gear. These are calculated over a one year period.

Variable costs also change according to the number and type of gear used and the size and efficiency of the fishing vessel. The total variable cost for a boat-gear category is the product of the overall number of fishing vessels and the variable cost per fishing unit. The following generic equation describes total variable costs (V_y) associated with all vessels participating in a single boat-gear category over a period of one year.

$$V_y = b_y.\left(\left(O - S_{ys}\right) + g.\left(1 + \varpi_{yr}\right)\right) \qquad \text{Equation 4.7}$$

b_y Average number of boats using specified gear type in year, y

O_y Annual operational costs, including fuel and other consumables

$S_{y,s}$ Value of government fuel subsidy in year, y, for boat type, s

g Average annual cost to replace/maintain gear

ϖ_y Number of crew per boat in year, y

Operational costs

The average numbers of boats within a boat-gear category (b_y), have already been established within Section 4.6. However, the annual operational costs (O_y) depend on the average cost per trip and the total number of trips undertaken in a single year (see Equation 4.8).

$$O_y = \left(c.d_y.i_s\right) + l \qquad \text{Equation 4.8}$$

c Average cost per day, including fuel and consumables

d_y Average number of trips taken per year, y

i_s Average trip length (days) for boat type, s

l Licence fee payment per year

The average daily operating costs (SR) are set as a constant for each boat-gear category (see Table 4.15). Small boat trap fishers have the lowest costs per day, since the majority of traps are situated close to shore and remain unbaited (Payet pers. comm., 1997). The few traps that are baited are done so using local resources such as sea urchins or seaweed. Fuel costs are also kept to a minimum due the short distance from shore and the amount of time spent actively fishing. Traps are usually hauled and reset twice a day to coincide with tidal movements and local markets (Nageon pers. comm., 1997).

Table 4.15 Average cost per day (SR) for each boat-gear category (c).

Small Boat			Large Boat	
Trap	Handline	Trap & Handline	Inshore	Offshore
300	450	300	750	1,250

Small boat fishers using handlines have comparatively high daily costs. These are mainly associated with the high cost of using bait and additional fuel to move between alternative fishing grounds. Fishers using both traps and handlines are able to reduce their daily costs by using part of their initial catch from each trap as bait, and for this purpose fishers often haul their traps first. At the end of the day, fishers will often return to haul their traps a second time before heading for shore.

Large boats have by far the highest daily costs. These mainly reflect the size of the vessel and engine size, but also the number of crew on board. The average cost per day will vary according to the fishing location. Of course, large vessels undertaking day trips within the inshore region (fisheries Sector 1), will have less costs than a trip lasting 4 or more days. It has been assumed that the *daily* cost of running a large vessel is the same whether they undertake a single day trip or cover several days at sea.

Finally, a small licence fee is payable for each commercial fishing boat (l). This nominal charge (SR125 + tax), covers the administration costs and ensures each boat is registered. Additional licence schemes have been used to regulate the level of fishing effort (e.g. lobster fishery). However, there are no additional licence payments

required for any boat-gear category within the model.

Government fuel subsidy

As part of a recent government policy to provide financial incentives to local fishers, a fuel voucher scheme was introduced in June 1991. The scheme is administered by the Ministry of Finance and Communication with the collaboration of the Seychelles Fishing Authority (Marguerite, 1992).

The scheme enables registered full-time boat owners to collect a rebate on the price of engine fuel (SR 1.00 on every litre of fuel they purchase). Vessel owners are expected to make a saving of between 15 to 20 percent on the cost of fuel. Since its introduction, the increase in quantity of fuel consumed has been attributed both to a higher number of vessels benefiting from the scheme and an increase in the number of vouchers used to purchase fuel by existing vessel owners (Marguerite, 1995).

Not all registered full-time boat owners took immediate advantage of the scheme in 1991 (Marguerite, 1995). Instead, the number of vessels using the scheme has gradually increased each year. To simplify the model, it has been assumed that *all* boat owner-operators immediately took up a proportion of the fuel subsidy value from 1991. However, an estimate of the expected level of benefit *per vessel* from the fuel voucher scheme has been calculated for outboard and inboard powered vessels between 1991 -97.

Marguerite (1995), provides an indication of the expected level of benefit per boat type from the fuel voucher scheme between 1994 and the first 9 months of 1995. The level of benefit in 1995 was first raised from 9 months to a full year. This provides an average saving per boat type (outboard and inboard powered) over a two year period (Table 4.16).

Table 4.16 Indication of the expected benefit per boat (SR) during 1994 and 1995.

Vessel type	1994 (SR)	1995* (Sr)	1995 adj. (SR)	% Increase
Schooner	7,505	7,540	10,053	34
Traditional whaler	5,398	5,431	7,241	34
Lavenir	5,113	5,391	7,188	41
Lekonomie	3,234	3,264	4,352	35
Mini-Mahé	4,127	4,520	6,027	46
Average large	5,313	5,407	7,209	36
Average small	4,127	4,520	6,027	46

Source; Marguerite (1995)

** Data for 9 months only.*

The observed percentage increases in the average level of savings per boat type between 1994 and 1995 were 36% for inboard powered and 46% for outboard powered. In the model, these high rates of increase were used to back calculate the original level of savings made between 1991 and 1993, and project future levels of saving until the value reached approximately 15% of the total operational costs. Operational costs were used since there is no information available on the actual quantity of fuel consumed per vessel. The results are presented in Appendix 4.7.

Gear replacement costs

The annual cost associated with replacing gear (g) depends on the unit price of the gear and the number of times the gear needs to be replaced in a single year:

$$g = m.G.\left(\frac{12}{h}\right) \qquad \text{Equation 4.9}$$

m Average cost of unit of gear (SR)

G Average number of gear used per fisher

h Average life-span of gear (months)

The average cost of a unit of fishing gear is similar whether a fisher has decided to replace it[1] or purchase it all from new to enter the fishery. For example, additional costs associated with the accessories of trap fishing (e.g. buoys, weights etc.), are often minimised by improvising from local materials (e.g. damaged floats/rocks). The estimated average cost of a unit of fishing gear is given in Table 4.17.

Table 4.17 Average cost of a unit of fishing gear (m).

Gear type	Cost (SR)
Trap	550
Handline	250

Source; Current study, Mees et al. (1998)

The average cost of a unit of handline gear is approximately half that of a single trap. However, the overall cost to the fisher is based on the quantity of gear used and the number of times the is replaced in a year. The average number of gear used per fisher (G), is important to establish both the total level of effort exerted by each boat-gear category and the cost associated with this level of effort. The average number of gear used per fisher has previously been estimated within Section 4.7.2, Table 4.13. The frequency of each gear replacement is given in Table 4.18.

Table 4.18 Average life-span of gear (h).

Gear type	Life-span (months)
Trap	3.0
Handline	1.0

Source; current study and Mees et al. (1998)

Units of handline gear are replaced more frequently than traps. Trap fishers however, are required to replace more gear units per year than fishers using handlines only. In total, trap fishers have higher gear replacement costs (approx. SR11,000 per fisher/year) than handliners (approx. SR3,0000 per fisher/year). Of course, the *total* replacement cost for each boat-gear category is dependent on the total number of

[1] Fishers may wish to replace old or damaged gear, or have to replace stolen traps.

active fishers per boat.

Fixed costs

Fixed costs are independent of the level of activity by each fishing unit, as they are costs resulting directly from the ownership of both a boat and fishing gears. Fixed costs include capital and interest payments, insurance, depreciation, and payment of any licence fees.

Fixed costs associated with obtaining capital to purchase a vessel may relate to a single one-off payment or regular monthly repayments in the form of a loan. The decision process undertaken by fishers to purchase a vessel are complex, and are described in detail within the socio-economic module in Chapter 5. This section describes the fixed costs associated with the purchase of a vessel.

By far the simplest means of acquiring a vessel is to purchase it outright with a single payment, using the fishers' own capital, possibly supplemented by financial contributions from friends and family. The fixed cost of this investment depends on the current market value of the boat. This can be determined by a number of factors including the age, overall condition and size of the vessel. The market value for each boat category is assumed to be constant across all years. An estimate of the market value of new and second hand vessels were determined from the socio-economic survey.

For many fishers, however, the only means of purchasing and maintaining a vessel is to obtain a loan. There are several lending institutions within Seychelles, although the Development Bank of Seychelles (DBS) and the government initiated Young Enterprise Scheme (YES), together grant the largest number and value of loans disbursed in the fisheries sector (DBS, 1997; SIDEC, 1998).

Until 1996, DBS had disbursed the largest number of loans for both size categories of fishing vessel (i.e. 'small' and 'large'). However, with the introduction of the YES initiative during 1996, this position changed. Although not strictly a government policy, the DBS now issues loans greater than SR50,000, suitable for large offshore

vessels, whereas the YES deals almost exclusively with small boats costing SR50,000 and under. As previously described in Chapter 1 , the YES initiative provides interest free loans, whereas DBS have continued to grant loans with a fixed rate of interest depending on loan size.

Within the model, it is important to take account of the different interest rates applying for different boat sizes. It has been assumed that until 1996, DBS handled *all* loan applications. Thus a lower rate of interest was available for small boats (approx. 8%), than larger offshore type vessels (10-12%). Since 1996 however, it is assumed that *all* small boat loan applications are covered by YES interest free loans.

There are many steps involved in obtaining a loan, and this can take several months to complete. The loan system has been described by Nageon, (1986). In order to secure a loan, fishers may have to provide a guarantee or other collateral. In addition to this, fishers can only expect to borrow up to 70 to 85% of the total capital asset value. This requires an initial deposit; something which many fishers find themselves unable to obtain. Each loan application is then passed to SFA for approval. This enables partial control over the quantity and power of vessels operating within the fishery. If the loan application is accepted and the fisher decides to proceed, a monthly repayment schedule is then organised, based on the current rate of interest and their ability to repay. This includes both tax and insurance contributions. A grace period of up to one year may be granted on the first repayment.

Within the model, a number of simplifications have been made to the loan process. First, a fixed percentage of the total capital asset value has been assumed as a suitable deposit for both lending institutions. Secondly, the repayment schedule has been fixed, based on the average repayment for a given size of loan. Although repayments are usually made each month, the model has been given a time step of one year. The first repayment is therefore an annual amount equal to the sum of 12 monthly installments, paid at the end of the same year. For simplicity, no grace period has been granted on the first repayment. Both tax and insurance rates are assumed constant. Loans are disbursed at the end of the year so that additional boats are ready to enter at the start of the following year.

The repayment value is calculated based on the 1998 (*yr*) rate of interest, tax and insurance and the total number of months over which repayment must be made. The calculation is complicated by monthly compound interest payments which must be summed over the total repayment period. This is shown in Equation 4.10.

$$C_{DBS} = i.\left(\frac{M(1+i)^n}{1-(1+i)^n}\right) \qquad \text{Equation 4.10}$$

C_{DBS} Fixed monthly repayment cost to DBS

i Fixed monthly interest rate

M Initial loan size

n Repayment period, (months)

Where no interest payments are required (i.e. all YES loans), the above equation can be simplified to estimate the fixed monthly repayment cost (C_{YES}). This is shown in Equation 4.11.

$$C_{YES} = \frac{M_t}{n} \qquad \text{Equation 4.11}$$

Each monthly repayment (C_{DBS} *or* C_{YES}) must also include both a tax and insurance payment. These are included in Equation 4.12.

$$c = 12.(C.(1+x)) + (T.r) \qquad \text{Equation 4.12}$$

c Total annual repayment cost

C Fixed monthly repayment cost (DBS or YES)

x Monthly tax rate

T Total value of capital asset

r Monthly insurance rate

The total capital asset values of each boat type (SR), have been estimated from the socio-economic survey, and are given in Table 4.19.

Table 4.19 Total capital asset value of each boat type (SR).

	Small (SR)	Large (SR)
New	50,000	140,000
Secondhand	15,000	75,000

The estimated cost of a new or secondhand large vessel is a weighted average from the total number of whaler-class and schooner vessels in operation and their associated purchase cost.

It is important to keep track of the number of fishers who have a loan outstanding in any one year for two reasons: first, boat owners with a loan outstanding have additional costs over those with no loans, by having to make a separate fixed repayment from their level of income, and second, fishers with a loan outstanding are restricted from switching between boat-gear categories or leaving the fishery. In the model, boat owners with and without a loan are kept separate for each socio-economic group.

Fishers with a loan outstanding are tracked within a table constructed in MS Excel™ (see Table 4.20). This example illustrates that 4 fishers (i.e. #) who bought a loan in yr -11 (1989) were still 'active' until the beginning of 1992. The table can simulate a maximum repayment schedule of 15 years .

As already noted, each boat purchased with a loan requires the payment of an additional insurance premium. This sum is calculated based on the total capital asset value, and paid on an annual basis until the loan is repaid. The boat owner must then decide whether to continue with the insurance payments after this period. Results of the socio-economic survey have indicated that up to 25% of the repayment costs are due to the insurance premium on the total capital invested. It is unusual that fishers continue to pay insurance after the repayment period. No insurance premium has been added to the fixed costs of fishers who do not have a loan.

Table 4.20 Loan repayment table to monitor the total number of fishers with a loan outstanding in any one year.

Yr	#	Term of Repayment (years)															Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
-12	0	0															0
-11	4	4	0														4
-10	3	3	4	0													7
-9	5	5	3	4	0												12
-8	7	7	5	3	0	0											15
-7	3	3	7	5	0	0	0										15
-6	1	1	3	7	0	0	0	0									11
-5	4	4	1	3	0	0	0	0	0								8
-4	3	3	4	1	0	0	0	0	0	0							8
-3	5	5	3	4	0	0	0	0	0	0	0						12
-2	11	11	5	3	0	0	0	0	0	0	0	0					19
-1	23	23	11	5	0	0	0	0	0	0	0	0	0				39
0	21	21	23	11	0	0	0	0	0	0	0	0	0	0			55
1	14	14	21	23	0	0	0	0	0	0	0	0	0	0	0		58
2	6	6	14	21	0	0	0	0	0	0	0	0	0	0	0	0	41

Depreciation and rate of inflation

The percentage change in the annual retail price index between 1986 and 1997 is relatively small, and fluctuates each year (see Appendix 4.7). This indicates that the rate of inflation is very small and has therefore been ignored in the model. This has greatly simplified the model and enables a focus on the decision-making processes of each socio-economic group.

4.8.2 Total net revenue

The total net revenue or profit for each boat-gear category was estimated from the gross revenue generated from the catch minus the variable costs, described earlier in Section 4.8.1. The total gross revenue (R_y) for each boat-gear category was estimated using Equation 4.13.

$$R_y = C_y . P \qquad \text{Equation 4.13}$$

C_y Total catch (tonnes) by boat-gear category in year, y

P Average fish price (SR/tonne)

The total catch appropriated to each boat-gear category (C_y) were determined within Section 4.7.2 of the Biological module. Catches from different boat-gear categories targeting similar resources (e.g. inshore reef, demersal or semi-pelagic) were previously aggregated to update the status of the stock biomass at the end of year. In this section, catches from each boat-gear category are retained in order to generate a total gross revenue for each fishing unit.

Fish price

In the model, the average price of fish (P) is kept constant for each resource type. The majority of fish are either sold on the domestic market or at fish centres (Tirant pers. comm., 1997). In general, all small boats supply fish to the domestic market whereas large vessels sell their catch to either the domestic market or fish centres. Schooners are most likely to sell to fish centres, whereas a greater proportion of whaler-type vessels are likely to supply the domestic market. Within the model, it has been assumed that *all* vessels operating within the inshore region (fishing sector 1), supply the domestic market, whereas *all* large vessels operating further offshore sell to fish centres.

The average price of fish sold on the domestic market has been obtained from the CAS between 1996 - 97, and fish centres from Oceana Fisheries Pty Ltd. (Oceana) between 1986 - 97. The average fish price for each resource on the domestic market are presented in Figure 4.5 and at fish centres in Figure 4.6.

It can be seen that the domestic market exhibits a seasonal component in the pricing of fish (SR/kg). During the south-east trade winds from the end of May to October, the average wind speed (12 knots) frequently restricts fishing activities (Michaud, 1990; Mees, 1996b). Although the selling price of fish remains constant (approx. 50 SR/packet) during this period, the number of fish (i.e. weight of the packet) is

considerably less.

Fish prices also fluctuate between months due the supply and market demand for the product. Most fishers attempt to land their daily catch either during the morning or mid to late afternoon, when the greatest volume of passing trade is available (i.e. commuters passing to and from the workplace).

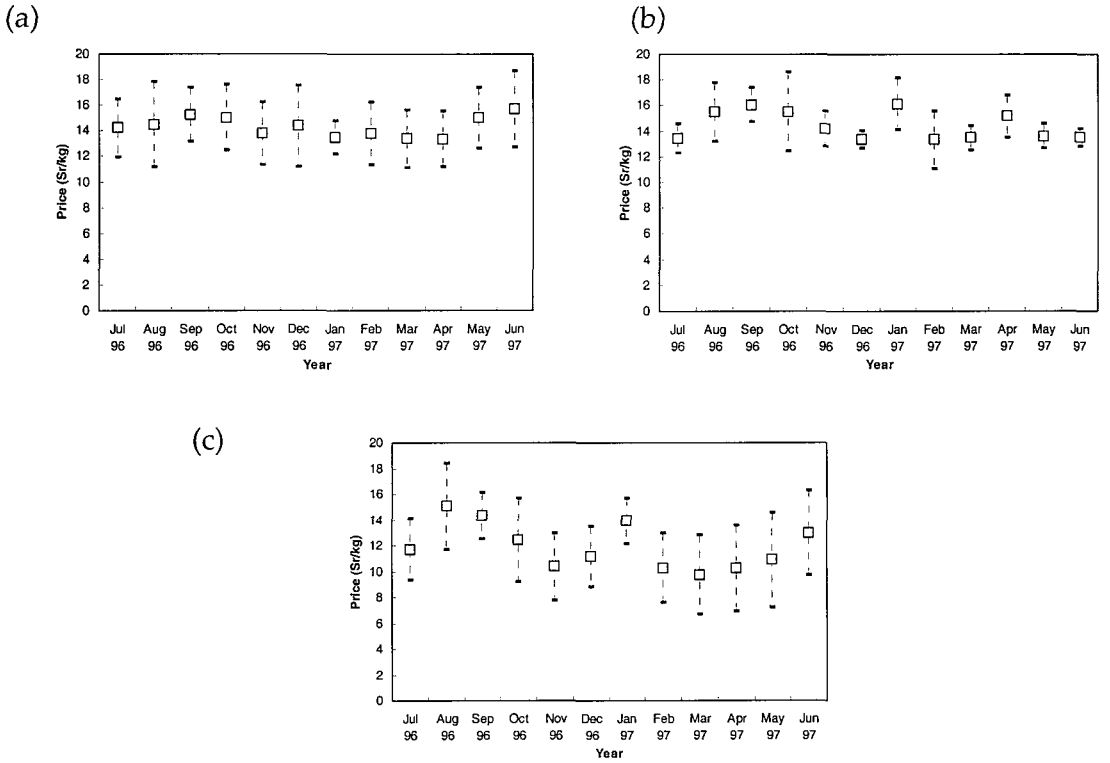


Figure 4.5 Average fish price (± standard deviation), for the *domestic market* between July 96 - June 97; (a) demersal, (b) reef, (c) semi-pelagic.

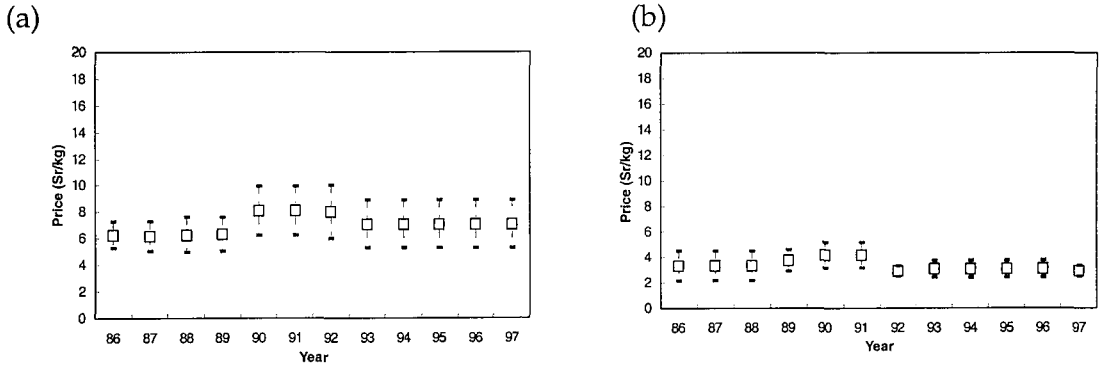


Figure 4.6 Average fish price, SR/kg (± standard deviation), for the *fish centre* during 1993 - 97; (a) demersal, and (b) semi-pelagic.

In contrast, the raw data acquired from Oceana fish centre displayed no sign of seasonal patterns. In part, this may be due to the control of world export markets. However, temporary increases in the price of fish may be given for certain species, particularly if local supply is poor and export demand remains high. Under these circumstances, a temporary seasonal pattern may occur for only a few target species.

The average fish price given by Oceana is considerably less than that obtained on the domestic market (approx. 50 - 60% less). Many vessel owners sign a contract with Oceana to supply fish in exchange for a quantity of ice. However, the temptation to supply part or all of the catch to the domestic market remains very high.

At Oceana the average price of both demersal and semi-pelagic fish have remained relatively constant over the past decade (Figure 4.6). Although the average price did jump at the start of the 1990s, it has since remained relatively constant. A brief analysis of this data (1986 - 97) illustrates that the overall increase in price (demersal *and* semi-pelagic) is in line with inflation (approx. 1% annually; Anon, 1997c).

The average fish prices (SR/kg) during 1997 for each resource sold at either the domestic market or fish centre are presented in Table 4.21.

Table 4.21 Average fish price (SR/kg) during 1997 for domestic market and fish centre.

	Domestic market†		Fish Centre‡	
Reef	Demersal	Semi-pelagic	Demersal	Semi-pelagic
15.4	14.4	12.0	7.1	3.4

Source; †(CAS, SFA, 1997), (Mees et al., 1998); ‡(Tirant, pers. comm., 1997)

With the information provided on the average fish price (SR/kg) for each resource type, the data were raised to produce a market value per tonne. Following this, the total net revenue or profit (U_y) was estimated from the total gross revenue (R_y) and total variable costs (V_y) for each boat-gear category (Equation 4.14).

$$U_y = R_y - V_y \qquad \text{Equation 4.14}$$

The total profit generated for each boat-gear category is used to drive the decision-making processes of fishers. However, although the total profit indicates how well the fishery may be operating, it does not provide useful financial information to fishers. To calculate the annual level of income a fisher is likely to receive, the total profit was first divided among the number of boats, and then further divided between the number of crew using a share system.

In any year (y), the profit per boat (u_y) for each boat-gear category is calculated from the total profit (U_y) and the number of boats within the category (b_y), (Equation 4.15).

$$u_y = \frac{U_y}{b_y} \qquad \text{Equation 4.15}$$

4.8.3 Share system

The actual level of income or wage each fisher receives (k_y) is determined by the share system. For the model, it is important to know how the earnings from each boat-gear category are distributed between each fishing unit. In general, the net earnings from the catch are distributed either in money or in kind (fish) according to an agreement between the owner of the fishing boat and the crew.

The most common share system operating within the Seychelles artisanal fisheries, is to share the remaining income between the boat owner and the crew, after deduction of operational costs.

In most cases revenue is divided into three equal shares (present study; Mees, 1990; Mees *et al.*, 1998). The boat owner receives one share, and the remaining two shares are divided equally between the crew members. If the boat owner also happens to be a crew member, he also receives an additional share. Within the 1997 socio-economic survey less than 3% of respondents were only boat owners, and approximately 12% skippers only. In general, non-fishing boat owners represented wealthy entrepreneurs that also had other business opportunities. Due to the relatively low importance of non-fishing boat owners it is assumed in the model that all boat owners are also crew members. All boat owner-operators therefore receive an additional share of the income (see Equation 4.16).

Estimation of the annual level of income for crew members (k_y) for each boat-gear category is given in Equation 4.17.

Boat owner-operators

$$k_y = \left(\frac{u_y}{3}\right) + \left(\frac{(2u_y/3)}{(1+\varpi_y)}\right) \qquad \text{Equation 4.16}$$

Crew members

$$k_y = \left(\frac{(2u_y/3)}{(1+\varpi_y)}\right) \qquad \text{Equation 4.17}$$

Here u_y is the annual profit per boat-gear category, and ϖ_y is the number of crew operating per boat within each category. The annual levels of income generated from each boat-gear category are held in a single table within the model and updated each year (Table 4.22).

Table 4.22 Annual level of income (k_y, SR), generated from each boat-gear category after deduction of operating costs and share system.

	Small Boat			Large boat handlines	
	Trap	Handline	Trap & Handline	Inshore	Offshore
Owner-operator	28,877	22,125	17,845	38,571	18,431
Crew member	15,845	11,472	10,813	15,222	11,254

Following the estimation of the annual level of income fishers can begin to decide what activity they may wish to undertake in the following year. Based on the level of income and assuming good communication and transfer of information, fishers are able to plan and make decisions for the start of the following year. Details of the decision-making processes have been modelled explicitly in a separate socio-economic module (see Chapter 5).

4.8.4 Personal savings

As noted earlier, a number of fishers are able to purchase vessels without the need of a loan. This suggests that they may have other sources of income, collateral from friends

or family, or personal savings. The socio-economic survey indicated that many such fishers do participate in a variety of alternative employment opportunities[2], and they may also have gained additional capital from friends and family to purchase a vessel.

Within the model, additional sources of income have been simplified into a single personal savings sub-module. Any individual profit remaining after the deduction of living costs is added to their personal savings account. These savings can accrue each year until they reach a level such that a single boat purchase may be possible. A fixed annual rate of interest (net of inflation) is applied to any savings in profit.

Within the model, if the net income from a boat-gear category is unable to cover the living costs of a socio-economic group (see below), the short-fall may be obtained from their personal savings account. If the personal savings account were ever to fall into the red, the resulting balance is not required to pay any interest. It is assumed that the majority of fishers would be able to borrow sufficient money from friends or family, rather than paying for an overdraft facility at the bank.

Living costs

Living costs have been estimated from the most recent Seychelles household expenditure survey (Khan, 1994). However, the data did not allow the segregation of costs by socio-economic group. Instead, the average household expenditure was presented for different household sizes. An approximation of the household costs were then estimated from the average household size identified for all boat owner-operators (socio-economic groups 1 and 2) and crew members (socio-economic groups 3, 4 and 5). These were rounded up to the nearest SR1,000 (Table 4.23).

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[2] A small proportion of boat owners have other business interests, whereas crew labour is flexible and permits some members to undertake additional part-time, casual or seasonal employment.

Table 4.23 Average living costs associated with each socio-economic group estimated from 1984 household expenditure survey.

	Living costs (SR)
Owner-operator	12,000
Crew member	10,000

4.8.5 Potential profits

Decisions to enter (or leave) a particular boat-gear category are based on the annual level of net income each fisher receives within each socio-economic group. If however no boats are present in a boat-gear category, there is no opportunity to calculate the expected annual net income. Without this, fishers will have no financial information upon which to base their decisions. Under these circumstances, a 'potential profit' is estimated. This hypothetical value estimates the expected wage an owner-operator and crew operating within the boat-gear category are likely to receive if they were to enter. This calculation is based on an average number of crew operating a single boat without a loan.

4.8.6 Government subsidies and licence revenue

There are a number of government subsidies available to Seychellois fishers. These relate to both a fuel voucher and soft loan scheme and have already been described. To provide some measure of the total cost to government of each alternative management option, the total cost of each subsidy is recorded each year for different strategies.

The total fuel voucher cost is relatively straight forward to calculate since it is assumed that each boat type utilises the maximum annual benefit to be gained from the scheme. The soft loan scheme, however, requires an additional set of calculations based on the current rate of commercial bank interest. The total government subsidy is the difference in value between the cost of a loan at the commercial bank rate and that of the government soft loan. The government can target the development of different economic sectors according to the level of subsidy. For example, the government could use the subsidy given to fishers via the soft loan scheme to create alternative employment opportunities outside the fisheries sector and provide suitable re-training.

The total value of government subsidy may be partly offset by the revenue from boat licence fees. In this way, the government can provide a number of financial incentives and disincentives in an attempt to control the level of fishing activity. For management purposes, the total revenue generated from boat licence fees is estimated for each boat-gear category.

4.9 SUMMARY

This chapter has described a number of important stages in the development of the bio-socio-economic model. It was first necessary to simplify the fishery system into a number of key boat-gear categories which are known to exploit the inshore reef, inshore demersal and offshore demersal resources.

The biological sub-module was used to generate total catches for each boat-gear category active within the three fisheries simulated. These total catches were then sold, after which the deduction of both operating and fixed costs generated a total net revenue for all fishers participating within the boat–gear category. Total profits were then divided between the number of boats within the category before issuing boat owner-operators and crew members a net income based on a share of the profits.

The individual level of net income for boat owner-operators (socio-economic groups 1 and 2) and crew members (socio-economic group 3, 4 and 5) form the basis of the decision-making processes of each socio-economic group within the socio-economic sub-module. These processes are described in the following chapter.

5 BIO-SOCIO-ECONOMIC MODEL: SOCIO-ECONOMIC MODULE

5.1 INTRODUCTION

This chapter completes a description of the bio-socio-economic simulation model of the Seychelles artisanal fishery. This section follows directly on from the economic module, where relevant output from the previous chapter is now brought forward with additional new information to realise a number of socio-economic attributes for each boat-gear category.

The results from Chapter 2 identified and described a set of attributes for five socio-economic groups within the artisanal fishery. These attributes were then used to predict future group membership for a series of informal interviews to obtain a set of decision-making processes for each group under alternative management options (Chapter 3). This chapter describes how these have been incorporated within the simulation model.

Section 5.2 provides a brief outline of the module, describing the input parameters required by successive sub-modules and the expected output.

Details of the labour and fleet dynamics are given in Section 5.3. This provides a description of which decision rule to apply in relation to their financial status, and the number of fishers eligible to undertake the decision process. A description of the decision rules used by both owner-operators and crew members are also given.

A description of boats purchases are given in Section 5.4. This provides information on how active boat-owners and crew members select and finance their choice of boat, with respect to its availability. A description of the crew ratio is given in Section 5.5. This describes in detail what decision processes are used if a boat-gear category has either below the minimum or above the maximum number of crew.

Each year a proportion of vessels are replaced. This may be due to disrepair or an opportunity to upgrade. The decision processes used in the model to simulate the replacement of vessels are described in Section 5.6.

* The behaviour of individuals or groups of individuals ('institutions') has been well documented within political and social theory, in particular in relation to the 'tragedy of the commons' dilemma in common-pool resources (e.g. Fricke, 1986; McCay, 1988; McCay & Acheson, 1996; McManus, 1996; Ostrom, 1996). More recently, research frameworks have been developed to help collect and organise qualitative information in an attempt to understand the behaviour and interaction between different groups or institutions within a complex system (e.g. Oakerson, 1992). These frameworks, however, cannot be used in predictive analytical models.

There are comparatively few quantitative studies that have been undertaken within fishing communities. Panayotou & Panayotou (1986), provided a detailed empirical analysis of the seasonal labour mobility in and out of a Thai fishing community. The study, however, was not used to help predict the outcome of future management scenarios on the status of the resource. There are now available an increasing number of assessment methods (e.g. Pido *et al.*, 1996; Pollnac, 1998) to analyse the fishery system which have evolved from rapid rural appraisal techniques (see Townsley, 1993; Chambers, 1995). Although data collected using these qualitative assessment techniques provide valuable information in order to understand many of the key decision-making arrangements within the fishery system, they offer little scope for predictive modelling.

Given this background, a number of authors have attempted to incorporate fishers' decision-making within the modelling process by assuming that fishers will always attempt to find means of maximising their annual net revenue from a variety of opportunities (Lane & Stephenson, 1988; Anderson, 1999). In practice it has been shown that different fishers will not all make the same set of decisions under similar financial circumstances (Opaluch & Bockstael, 1984).

In the present study, a major aim was to identify and establish the key issues that drive the decision-making processes within the Seychelles artisanal fishery. To achieve this, a period of exploratory research was conducted prior to the main data collection (Chapter 3). Although the results indicated that financial considerations were important, the research also identified a number of other important decision constraints (e.g. family commitments). A simulation model of the fishery system was designed to incorporate both the financial and social constraints on the decision-making processes of different socio-economic groups.

From the exploratory analyses it was found that the majority of decisions were financial-based. It was therefore decided to explicitly model the financial decision-making processes of different socio-economic groups, and then to incorporate a number of social 'constraints' on these economic-driven decisions. For example, a fisher may be able to afford the purchase of a boat to enter an alternative boat-gear category, however, they will have both size and age preferences of the type of vessel in additional to other limitations based on their level of experience, which will ultimately decide the final outcome of the decision. Within the model, these preferences have been simulated by a range of probabilities for each socio-economic group on board small and large boats.

Section 5.7 describes recruitment to each boat-gear category from members outside the fisheries sector. This provides additional information on what circumstances both owner-operators and crew members decide which boat-gear category to enter.

A review of each of the modules within the bio-socio-economic model and an overall summary of the chapter is given in Section 5.8.

5.2 Outline of Socio-economic module

This third module simulates the decision-making processes of each socio-economic group identified within the artisanal fishery. Each group are capable of making a unique set of decisions which lead to a number of alternative outcomes. These outcomes are directly related to their financial well-being, and the status of the fishery as a whole.*

This module is driven by the profits generated by each boat-gear category, and the subsequent decisions made by each socio-economic group within that category based on these profits. It is assumed that information is transferred between active fishers in different boat-gear categories regarding their current financial status. This 'perfect' information enables each group to make accurate judgements regarding alternative employment opportunities, both within and outside the fisheries sector. It is assumed that each socio-economic group reviews their current financial status at the end of the fishing season and will make a decision based on this.

5.3 Labour mobility and fleet dynamics

It is assumed that fishers decision-making processes are triggered by different levels of income generated solely from their fishing activities. Fishers within each socio-economic group are likely to make different decisions under varying levels of income. In the model, the annual level of net income has been used to determine the financial status of each socio-economic group. This value can be used to distinguish which set of decision rules to apply to each group. In brief, fishers have the choice of whether to stay in the same boat-gear category, switch to a more profitable boat-gear category or leave the fisheries sector altogether.

Fishers who decide to leave the fisheries sector enter a 'pool'. The pool represents a group of potential fishers that currently lie outside the fisheries sector. No distinction is made between pool members other than their socio-economic group. The pool therefore contains a eclectic group of potential fishers that may be looking for alternative business opportunities, undertaking some form of casual employment or are otherwise unemployed.

The proportion of fishers deciding to undertake each choice within a socio-economic group and boat-gear category, were determined from a series of informal interviews. The proportion values may however lead to a number of undesired effects. For example, if the majority of fishers within a single boat-gear category decide to switch to a more profitable boat-gear category, the sudden increase in fishing effort in the alternative category may reduce their future net income. In turn, this would result in many fishers deciding to switch back to their original boat-gear category during subsequent years. These fluctuations were not observed in the historical data set, which suggests that the number of fishers deciding to switch to an alternative boat-gear category or leave the fisheries sector in a single year are relatively few.

In the model, to reduce the number of fishers capable of moving each year, a proportion of the total number from each socio-economic group within each boat-gear category were nominated to undertake a decision rule.

The following sections first describe how the number of fishers within each socio-economic group and boat-gear category are nominated to undertake a decision rule. The decision rule applied to each group is then determined based on their financial status. Finally, a detailed description of each decision rule is given.

5.3.1 Nomination of fishers to undertake decision rules

In the model, the number of fishers moving each year are constrained to simulate the rate of change observed within the historical data set. Each year only a specified proportion of fishers from each socio-economic group within each boat-gear category are nominated to undertake one of the decision rules identified by their financial status. The remainder *stay* within their current socio-economic group and boat-gear category.

To identify the proportion of fishers from each socio-economic group within all boat-gear categories (i.e. 5 socio-economic groups x 5 boat-gear categories), a proportion function $p(x)$, was introduced (Equation 5.1):

$$p(x) = a\left(\left(\frac{e^{\frac{(-k-k_{\min})}{\varepsilon}} - e^{\frac{(k-k_{\min})}{\varepsilon}}}{2\left(e^{\frac{(k_{\min})}{\varepsilon}} - e^{\frac{(-k_{\min})}{\varepsilon}}\right)}\right) + 0.5\right) \qquad \text{Equation 5.1}$$

In this equation k is the current annual level of net income (SR) for the socio-economic group and k_{min} is the minimum acceptable level of net income (SR) of the group (see Table 5.1 below). ε is a constant and controls the shape of the curve for each socio-economic group. a is a constant which determines the overall proportion of fishers nominated from each socio-economic group within all boat-gear categories.

The number of fishers nominated each year is determined by the product of the total number of fishers within the socio-economic group within each boat-gear category and the proportion value, p. Hence, a higher proportion value and/or number of fishers in each group increases the overall number of fishers nominated. Moreover, since equation 5.1 is linked to the minimum acceptable level of net income of each socio-economic group, a less profitable boat-gear category results in more fishers being nominated within the group. In contrast, no fishers move if their current net income is twice their minimum acceptable level (i.e. 2.0 k_{min}) or above. This can be seen in Figure 5.1, where k_{min} is SR19,000.

In Figure 5.1 the constant a, restricts the maximum number of fishers nominated within a group to 20% or 0.2 of the total. Without this restriction, a high number of fishers would be capable of moving between boat-gear categories at low levels of net income. In the model, the value of a was manipulated until the number of fishers moving in each year matched the rate of change observed in the historical data set.

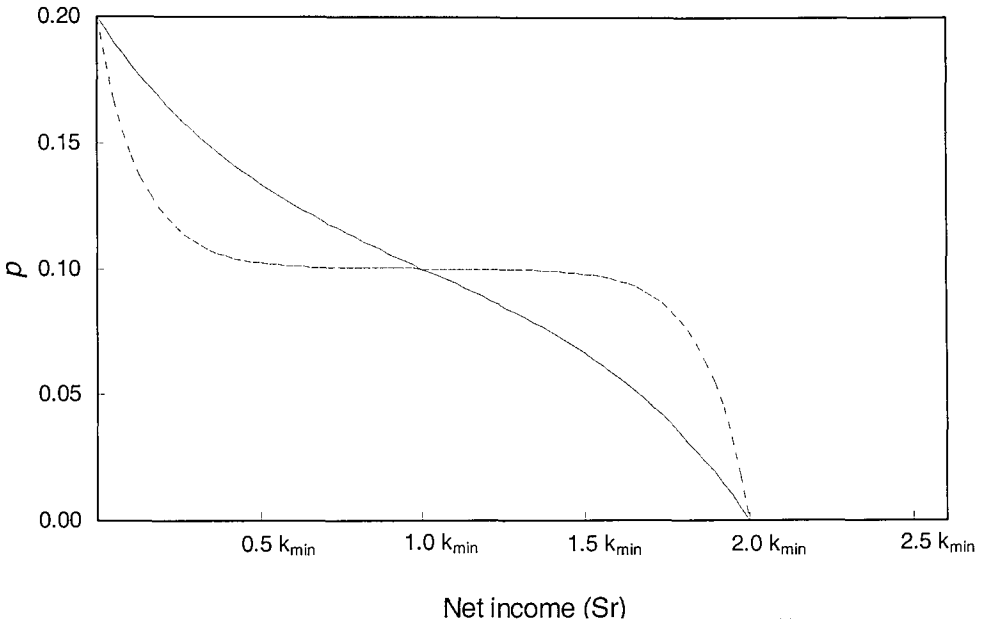


Figure 5.1 Proportion of fishers nominated (p) with respect to the level of annual net income (SR). The shape of the curve is determined by the value of ε. Illustrated are curves where $\varepsilon = 10{,}000$ (solid line) and 2,500 (dotted line), k_{min} = SR19,000 and $a = 0.2$. It should be noted that p is zero when k is at or above $2.0k_{min}$.*

Having identified the proportion of fishers moving from each socio-economic group within each boat-gear category, it is now important to determine which decision rule to apply.

5.3.2 Financial status

The decision rule applied to each socio-economic group within a boat-gear category is determined by their financial status. In turn, their financial status is governed by their current annual level of net income in relation to one of 2 threshold values:

i). The average *minimum acceptable level* of net income.
ii). The operating or *variable costs*.

The average minimum acceptable level of net income, is equivalent to the minimum wage each socio-economic group is willing to receive from their fishing activities in order to remain within a specific boat-gear category. In the model, it has been assumed that the average minimum acceptable level of income is a constant for each socio-economic group.

During informal interviews, data collected on the level of income from fishing activities were described by the quantity of catch: fish packets (small boats) or tonnes (large boats).

The minimum catch required to continue fishing (incl. variable costs) were recorded for each respondent. These were later converted into monetary values using the average fish price per packet or tonne.

Due to the small sample size ($n = 47$), an average minimum acceptable level of net income was estimated for all boat owner-operators (socio-economic groups 1 and 2) and all crew members (socio-economic groups 3, 4 and 5). These are presented in Table 5.1.

Table 5.1 Average minimum acceptable level of net income (SR) for each socio-economic group within the artisanal fishery.

Socio-economic group				
1	2	3	4	5
19,000	19,000	13,000	13,000	13,000

These minimum acceptable levels of net income are less than the national average (SR 28,572), for members working within this sector (Anon, 1997a). Information collected during informal interviews pointed to a variety of reasons why this may be so.

The average minimum acceptable level of net income estimated here is that based solely on fishing activities, whereas fishers may undertake additional employment outside the fisheries sector. Crew members in particular are more likely to undertake seasonal casual employment during periods of low income.

Furthermore, boat owner-operators who have a loan outstanding on their vessel have recently committed themselves to a number of years in the fishery. Unless they are able to sell their boat, they are effectively tied to the fishery. More experienced boat owner-operators have also seen the fishery fluctuate over a number of years, and would wait to see if it picks up again after years of lower than normal income. More importantly, the fishery has become a 'way of life' to many fishers. These fishers would be relatively unwilling to break away from the social niche they have forged within the fishing community. For others, the fishery also provides a valuable source of protein, which they

would otherwise have to purchase themselves.

The second threshold value is equal to the operating or variable costs of the boat-gear category. If the value of the catches are only sufficient to cover the operating costs, fishers within each socio-economic group of the boat-gear category receive no net income from their fishing activities. The annual variable costs can change each year due to the level of fishing effort.

Both threshold values are used to determine the financial status of a socio-economic group. There are three classes of financial status (1 - 3) described below.

Financial status 1

If the annual level of income for a socio-economic group is greater than the first threshold value, that group are given the financial status of 1.

Fishers within this group are under no pressure to move from their boat-gear category. If however, an alternative boat-gear category is generating more net revenue than their own, some fishers may consider switching to this more profitable category. The increased profits are assumed to compensate for any additional training required and/or transfer costs incurred in the move.

Financial status 2

If the net income is at or below their first threshold value (minimum acceptable level of net income) but above the second (variable costs) for one or more socio-economic group, that group are given the financial status of 2.

Nominated fishers within this socio-economic group must attempt to find alternative employment, either within or outside the fisheries sector. Fishers who have chosen to find employment within the fisheries sector do not require an expected percentage increase in annual net income (cf. Financial status 1). However, the net income from the new boat-gear category must exceed their minimum acceptable level. If not, unsuccessful fishers must leave the fisheries sector.

Financial status 3

Finally, if the net income is at or below their second threshold value (variable costs) for one or more socio-economic group, that group are given the financial status of 3. In theory, financial status 2 is the lowest income level at which the majority of fishers will remain in a boat-gear category. However, some fishers may not have an immediate alternative. Fishers reaching financial status 3 will be a mixture of those who previously wanted to switch or leave at financial status 2 but were unable to, and others who remained, expecting their circumstances to improve. Few fishers remain in an unprofitable category, unless they operate on a subsistence level only.

Similar to financial status 2, nominated fishers within this socio-economic group must attempt to find alternative employment. Fishers who have chosen to find employment within the fisheries sector do not require an expected percentage increase in annual net income (cf. Financial status 1). However, the net income from the new boat-gear category must exceed their minimum acceptable level. If not, unsuccessful fishers must leave the fisheries sector.

The decision-making criteria of each socio-economic group are likely to be different at each financial status. For example, more fishers are expected to leave a boat-gear category with financial status 3 than status 2. Hence a new set of decision rules is

triggered when the financial status of a socio-economic group changes. Having determined the financial status of each socio-economic group in relation to their financial thresholds, the following section details how the model determines what decision rule to apply.

5.3.3 Selection of decision rule

In the model, the decision rules that govern a socio-economic group are determined by their current and immediately previous financial status. These are recorded in a table similar to Table 5.2 below.

Table 5.2 Financial decision table for a each socio-economic group (1-5) within a single boat-gear category.

	Socio-economic group				
Time step	1	2	3	4	5
Current, (*yr*)	2	2	2	1	1
Previous (*yr - 1*)	2	2	2	2	1

The table above takes account of the fact that each socio-economic group within a single boat-gear category can hold a different financial status. In this example, socio-economic groups 1-3 remain at or below their minimum acceptable annual level of income (i.e. financial status 2), whereas the financial status of socio-economic group 4 has increased from 2 to 1. The annual level of income was acceptable for socio-economic group 5 in both years (i.e. financial status 1).

The magnitude of the change in financial status also influences the decision-making process of fishers and subsequent decision rules within the model. For example, a rapid decline in the financial status of a socio-economic group from 1 directly to 3 would invoke an alternative set of decision rules than if the same result was achieved over a longer time period (i.e. they passed through financial status 2 in at least one year). This 'direct' route from 1 to 3 requires an additional decision rule in the model. As a result, there are a total of *four* decision rules, based on three levels of financial status.

Within the model, the decision rule selected in the current year for each socio-economic group was specified using both the financial decision table above (Table 5.2), and a simple decision tree (see Figure 5.2 below).

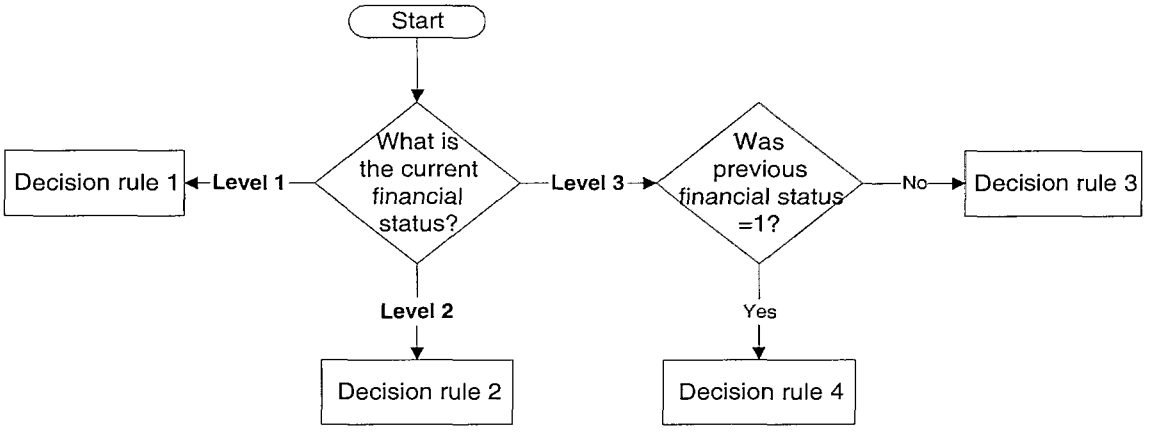


Figure 5.2 Decision tree used to establish which decision rule to apply to each socio-economic group, based on their current and previous financial status.

In summary, a group of fishers has now been nominated from each socio-economic group within all boat-gear categories. Their financial status (1, 2 or 3) has been determined, together with the appropriate decision rule (1 of 4) to apply. The following section describes in detail the decision rules applied to each group under different levels of financial status.

5.3.4 Decision rules

Depending on their financial status, one of four decision rules will now be applied to the nominated group of fishers within each socio-economic group and each boat-gear category. In essence, the overall structure of each decision rule is relatively similar. Therefore to avoid unnecessary replication of information, the generic structure of a decision rule will be described, providing details of how each changes according to the decision rule to be applied.

The following sections first describe the proportion of decisions made by nominated fishers within each socio-economic group and each boat-gear category. A description of the decision processes made by nominated fishers who have decided to try and switch

boat-gear categories is then given.

Decision proportions

In the model, all fishers who have been nominated to undertake a decision rule must now make a choice between one of three options;

i). Stay in the same boat-gear category, or
ii). Leave the fisheries sector altogether, or
iii). Switch boat-gear categories.

Within each nominated group, a proportion of fishers decide which option to undertake. For example, from a group of 20 fishers, 10 (0.50) may decide to stay; 6 (0.30) leave and 4 (0.20) change. These proportions have been estimated in advance from a series of informal interviews of fishers with different levels of financial status for each socio-economic group and boat category (small or large).

The proportion of nominated fishers who have decided to stay in the same boat-gear category, remain in the same category during the current year. As a result, they are available for making another set of decisions in the same boat-gear category in the following year. The proportion of nominated fishers who have decided to leave the fisheries sector altogether, are removed from the boat-gear category, along with any personal savings, and added to the relevant socio-economic group within the pool. The proportion of nominated fishers who have decided to 'switch' have chosen to enter a new boat-gear category. These are discussed in more detail below.

An example of the decision proportions made by small boat fishers within socio-economic group 1 at different levels of financial status are given in Table 5.3.

A complete set of decision tables by socio-economic group and boat type are presented in Appendix 5.1.

Table 5.3 Proportion of small boat fishers within socio-economic group 1 deciding to stay, leave or switch for each decision rule.

Decision Rule	Decision proportions			Total
	Stay the same	Leave	Switch	
1	0.54	0.00	0.46	1.00
2	0.64	0.00	0.36	1.00
3[a]	0.22	0.45	0.33	1.00
3[b]	0.00	0.20	0.80	1.00
4	0.00	0.35	0.65	1.00

[a] Decision proportion of fishers who originally decided to 'stay the same' during decision rule 2 (i.e. 0.64).

[b] Decision proportion of fishers who originally decided to 'switch' during decision rule 2 (i.e. 0.36).

If the third decision rule is selected (i.e. net income has declined from minimum acceptable level to variable costs), the proportion of fishers staying, leaving or switching must account for the decisions taken in the previous year.

For example, fishers who had decided to leave the fisheries sector in the previous year are no longer present in any boat-gear category and cannot have any influence on future decisions. However, the proportion of fishers that decided to stay in the same boat-gear category in the previous year under decision rule 2 can now make a further decision whether to stay, leave or switch (decision rule 3[a], Table 5.3). Similarly, fishers that originally decided to switch (and where unable to as a result of a subsequent decision rule), can also make a further decision whether to stay, leave or switch (decision rule 3[b], Table 5.3).

The outcome of decision rule 3 is the combination of proportions from both rules 2 and 3. This may be seen more clearly in the following diagram (Figure 5.3).

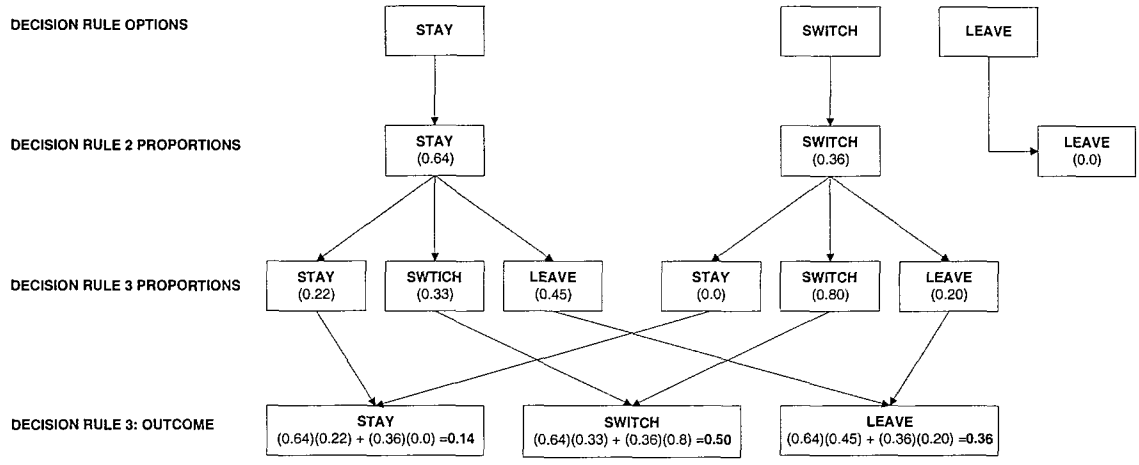


Figure 5.3 The proportion of fishers making each choice in decision rule 3 are dependent on the previous decision rule 2. Proportion of fishers that 'stay' and 'switch' in decision rule 2 are adjusted after fishers leaving.

The outcome of decision rule 3, is calculated from fishers decision to stay, leave or switch, given their previous decision to stay or switch under decision rule 2 in the previous year. Details of those fishers who have decided to try and switch to a new boat-gear category are now described in the next section.

Switching boat-gear categories

In the model, all nominated fishers who have chosen to try and switch boat-gear categories must first select which boat-gear category they wish to enter. Before they complete the move however, they must also pass a series of possible constraints or 'hurdles' to switching boat-gear categories (e.g. unable to acquire a boat loan etc.). The first of these constraints apply to the expected level of net income of the new boat-gear category. Following this, owner-operators must determine whether they can afford the cost of transferring between boat-gear categories.

Selection of boat-gear category

The proportion of nominated fishers who have decided to 'switch' have chosen to enter a new boat-gear category. From the results of the socio-economic survey, fishers indicated that they would not simply move into the most profitable fishery, but may

also have a number of other boat and gear type preferences. These decisions were based on a number of factors, including their level of experience and family commitments in addition to the safety and comfort of the vessel.

The preference of fishers within each socio-economic group and boat-gear category, to remain either within their current boat type or operate an alternative, are described by a fixed proportion value. For example, 60% of small boat owner-operators show a preference to continue fishing inshore on board small boats, whereas the remaining 40% had no objection to operating larger vessels, if they were able to acquire one. A boat type preference for each socio-economic group (boat owner-operators and crew members) is given in Table 5.4.

Table 5.4 Boat type preference table for boat owner-operators and crew members.

		Socio-economic group	New Boat type	
			Small	Large
Current Boat type	Small	Owner-operator	0.63	0.37
		Crew member	0.73	0.27
	Large	Owner-operator	0.17	0.83
		Crew member	0.50	0.50

The majority of fishers operating small boats within the inshore region have a preference to remain on board a small vessel. If they wanted to switch, these fishers would therefore attempt to switch gear-types to enter one of the remaining two small boat-gear categories. The remaining proportion of small boat fishers would otherwise attempt to join a large vessel (boat purchase or crew), operating either within the inshore region or further offshore.

All nominated fishers are then divided by their boat type preference. For example, of 100 nominated small boat trap-only crew members, 75 would attempt to switch to an alternative small boat category (handline-only or trap & handline), whereas the remaining 25 would attempt to switch to large boat (handline-only operating inshore or offshore). The number of fishers who eventually decide to enter each category is then determined by a proportion of the net income of each new category.

Proportion of net income of new boat-gear category

The proportion of net income of the new boat-gear category is used to determine how many of the nominated fishers select each category (based on their original boat type preference, see above). The results of the socio-economic survey indicated that some fishers also express a preference for gear type (e.g. some handline fishers do not wish to use traps). The historical data set also shows that new boat owner-operators are split between a number of boat-gear categories in a single year, and therefore may not be driven by the maximum available net income.

Using data from the example above, 75 small boat trap-only crew members would be looking to enter either the small boat handline-only or trap and handline categories. If for example, the net income from the handline-only category was SR25,000 and that of the handline & trap was SR20,000, 42 fishers (25/45 = 55%), would enter the handline-only and 33 fishers (20/45 = 45%) would enter the handline & trap category. Therefore a higher net income in one group attracts a higher proportion of fishers.

If however, the net income from one or more category was equal to or less the minimum acceptable level of net income of the nominated fishers (e.g. SR19,000 for socio-economic group 1), they would not consider this boat-gear category. For example, if handline and trap had a net income of only SR18,500, all 75 fishers would select the handline-only category.

Similar examples may be given for large vessels that operate either inshore or offshore. However, nominated fishers on board large vessels who state a preference for remaining on board a large vessel only have one other option. Thus, if this category has a net income above their minimum acceptable level, all nominated fishers to remain on board a large vessel select this category.

Required net income

In the model, nominated fishers will only consider moving to their new boat-gear category if the new level of net income is greater than an expected threshold value. This threshold value is specific to the decision rule used.

Nominated fishers who have a financial status of 1, will be undertaking decision rule 1. These fishers will only carry out this decision rule if the net income of the new boat-gear category exceeds their expected net income. This is calculated as a fixed percentage above the net income from their current boat-gear category. Four percentage values reflecting this required net income were initially obtained from the socio-economic survey for both owner-operators (socio-economic groups 1 and 2) and crew members (socio-economic groups 3, 4 and 5) operating on board small and large vessels (Table 5.5).

Table 5.5 Required percentage increase in annual net income required by each socio-economic group with financial status 1 before considering to switch boat-gear category.

Socio-economic groups	Move to Small boat (%)	Move to Large vessel (%)
1 and 2 (owner-operators)	50	50
3, 4 and 5 (crew members)	50	100

Nominated small boat fishers require a considerably higher net income to move to a large vessel, than their large vessel counterparts to switch to a small boat. If the net income generated from an alternative boat-gear category is below the required percentage increase, no fishers within the socio-economic group will move.

In contrast, nominated fishers who have an annual net income at or below their minimum acceptable level do not have the same level of expectation. Instead, nominated fishers will carry out their decision rule (2, 3 or 4), if the expected net income only exceeds their minimum acceptable level (i.e. greater than 100%), (see Table 5.6).

Table 5.6 Expected percentage increase in annual net income required by each socio-economic group with financial status 2 or below, before considering to switch boat-gear category.

Socio-economic groups	Move to Small boat (%)	Move to Large vessel (%)
1 and 2 (owner-operators)	>100	>100
3, 4 and 5 (crew members)	>100	>100

Unlike decision rule 1, nominated fishers undertaking decision rules 2 or below who wanted to switch boat-gear categories, but are unable to since the expected net income is equal to or less than their minimum acceptable level, are required to leave the fisheries sector.

Transfer costs

In the model, all nominated owner-operators (socio-economic groups 1 and 2) who have selected their alternative boat-gear category (which also exceeds their expected net income), must now calculate if they can actually afford the transfer costs associated with switching boat-gear categories.

To decide if a nominated owner-operator can afford to move, the sum of their current net income and any personal savings must exceed the cost of transferring. The costs associated with transferring between boat-gear categories can vary greatly. For example, a nominated owner-operator of a small boat using only traps may decide to relocate offshore and purchase a large vessel, or simply purchase an additional set of handlines. The cost associated with switching to a large vessel requires a significant capital investment, whereas that for purchasing an additional gear type is relatively insignificant. The cost of transferring between boat-gear categories is dependent on which category they originate from and switch to.

Transfer costs associated with switching between small boat-gear categories are relatively minor (i.e. only additional gear costs). Moreover, if the fisher already operates a percentage of the alternative gear category (e.g. trap *and* handlines), they

will only have to purchase the extra gear required in order to complete the switch in categories (e.g. additional traps *or* handlines).

If however, the nominated owner-operator requires the purchase of an alternative boat type (e.g. to fish offshore), they must embark on a new set of decision processes associated with boat purchase. It is assumed that the cost of new or additional gear is included in the overall cost of the new boat. Boat purchases are described in a separate section (see Section 5.4 below).

Finally, if the nominated owner-operator is successful in transferring between boat-gear categories (i.e. has funds to do so), they are added to the new category, along with any personal savings, minus the transfer costs. If however, they were unable to afford the transfer costs and were undertaking decision rule 2 or below, (i.e. net income at or below the minimum acceptable level), they are required to sell their existing boat and leave the fisheries sector. Nominated owner-operators of decision rule 1 are not removed from the fishery, but remain in their original boat-gear category.

In the model all nominated crew members (socio-economic groups 3, 4 and 5) are more flexible in their mobility since they only have to consider which is the most profitable boat-gear category to switch to. It is assumed that crew members do not have to purchase any gear in order to switch boat-gear categories.

If they have selected an alternative boat-gear category which also exceeds their expected net income, they are added to the new boat-gear category along with any personal savings.

If however, the alternative boat-gear category does not exceed their expected net income and they were undertaking decision rule 2 or below, they are required to leave the fisheries sector. Nominated crew members of decision rule 1 are not removed from the fishery, but remain in their original boat-gear category.

5.4 BOAT PURCHASE

In the model, boat purchases are considered outside the main decision rules (described above) because members of socio-economic group 5 are not eligible to purchase vessels. A separate group of crew members (socio-economic groups 3 and4) within each boat-gear category must therefore be nominated to make an additional set of decisions as to whether they purchase a boat or not. These represent a group of motivated fishers that have acquired both the necessarily skills and training to operate a boat (mainly skippers), and have the finance available.

This section also describes the purchase of vessels by existing boat owner-operators looking to switch to an alternative boat type. Boat purchases by owner-operators looking to replace an existing vessel and remaining in the same region, and pool members entering the fisheries sector for the first time are described under separate headings below.

The decision to purchase a vessel will depend on three inter-related factors that have been simplified in the model; boat type, finance, and availability. For example, the size of vessel chosen may depend on their personal experience as well as available finance. Moreover, the ability to secure a loan may also determine the age (i.e. new or second hand) as well as size of the boat. A large vessel also requires a minimum number of crew in order to operate successfully. If there are insufficient crew available, the purchase of larger vessels can be restricted. These issues are discussed in more detail within the Section 5.5 below.

5.4.1 Boat selection

Fishers who have been nominated to purchase a boat must first decide which size category they would like to purchase and operate. Small boat fishers may wish to purchase a large vessel, and vice-versa. These proportions have already been established for active boat owner-operators within the decision rules described above (Table 5.4). The boat type preference table is also used to determine which boat type socio-economic groups 3 and 4 would prefer to purchase. Under these circumstances, crew members utilise the active boat owner-operators boat type preferences. Nominated fishers within

socio-economic groups 3 and 4 are further divided between each boat-gear category based on a proportion of their profitability.

Having estimated the number of fishers looking to purchase a small or large boat, the age or quality of the vessel must be decided. The socio-economic survey indicated that some fishers would always prefer to purchase a new vessel over a second hand one, irrespective of their socio-economic group. These preferences have been simplified into a fixed proportion of new and second hand for each boat size, and are presented in Table 5.7.

Table 5.7 Boat size and age preference table for both owner-operators (socio-economic group 1 and 2) and crew members (socio-economic groups 3 and 4 only).

Socio-economic group	Small boat		Large boat	
	New	Second hand	New	Second hand
Owner-operator (1 and 2)	0.82	0.18	0.82	0.18
Crew member (3 and 4)	0.80	0.20	0.00	1.00

Socio-economic groups 3 and 4 prefer a second hand large boat to a new one. This preference may have been forced upon them due to the increased size of capital required to purchase a new vessel. However, before a second hand boat is purchased, they are subject to availability and must be checked. This may restrict the number of vessels entering the fishery (see Section 5.4.4 below).

5.4.2 Crew availability

The availability of crew members to successfully operate a large boat type will deter potential boat owner-operators from purchasing this vessel type. Large boat types require a minimum number of crew in order to operate (cf. Section 5.5.1 below).

In the model, this minimum threshold value acts as a constraint. If the number of crew available to purchase a large vessel is currently below the minimum number, no large vessels are purchased. Unsuccessful potential boat owner-operators with decision rule 1 remain in their original boat-gear category, whereas those with decision rule 2 and

below are required to leave the fishery, along with any personal savings and are added to the appropriate socio-economic group within the pool. In practice however, financial decisions will ultimately determine the lowest number of crew members present on board a large vessel.

There are is no minimum number of crew required to successfully operate a small boat type.

5.4.3 Boat finance

The size (large or small) and age (new or second hand) of the boat has been established, and it is necessary to outline how nominated fishers are able to finance their new venture. Some fishers may be able to afford the purchase of a vessel outright, whereas others may require financial assistance. Obviously these are related to the amount of capital required, and the wealth of the socio-economic group.

From the results of the socio-economic survey, a preference table was constructed to indicate the proportion of fishers who would require a loan to purchase their intended vessel (Table 5.8).

Table 5.8 Proportion of fishers that would require a loan to purchase their preferred vessel type.

Socio-economic group	Small boat		Large boat	
	Yes	No	Yes	No
Owner-operator (1 and 2)	0.64	0.36	0.81	0.19
Crew member (3 and 4)	0.80	0.20	1.00	0.00

Socio-economic groups 3 and 4 always require a loan in order to purchase a large boat. This can be linked to Table 5.7 to conclude that all crew members who wish to purchase a large boat can only afford to do so if they obtain a loan for a second hand vessel. The pattern of boat purchase can therefore be described by a series of constants, based on the preference and ability of nominated owner-operators and crew members to purchase a new/second hand boat with/without a loan.

Existing boat owner-operators that wish to switch to an alternative region and crew members purchasing their first boat, must first decide if the new venture is likely to be profitable after the deduction of the vessel payment. This may involve a single payment (outright purchase), or annual loan repayments over a number of years. It is assumed that no fisher would purchase a vessel if after the deduction of a vessel payment, their expected annual net income was at or less than their minimum acceptable level.

If the nominated owner-operators were unable to afford the new boat type and they were in decision rule 1, they would remain in their current boat-gear category. If however, they were in decision rule 2 or below, they would be required to sell their boat and leave the fisheries sector.

If a crew member from socio-economic group 3 or 4 is successful in purchasing a boat, they also change their socio-economic group. Young crew members from group 4 are added to socio-economic group 2, whereas older, more experienced fishers within group 3 are added to group 1. Their decision-making processes now reflect those of the new socio-economic group. If however, nominated crew members were unable to afford the boat, they would remain in their current boat-gear category. This is because boat purchase is an additional activity for socio-economic groups 3 and 4 which ultimately doesn't matter if they can't acquire a boat or not.

5.4.4 Secondhand boat availability

Nominated fishers who have decided to purchase a second hand vessel (see Table 5.7 above), must first check the availability of such a vessel. Only a finite pool of second hand boats is available for purchase. Once this pool is empty, no further purchases can be made until additional boats become available at the start of the following year as a result of boat replacements (see Section 5.6 below).

Where demand outstrips supply, the available second hand boats are divided between each socio-economic group within each boat-gear category, based on the level of demand from each group. For example, if 10 second hand boats were divided between 70 trap-only, 20 handline only and 10 trap and handline fishers, trap-only fishers would be guaranteed 7 boats, handline only fishers 2 boats, and trap and handline fishers only 1

boat.

If the remaining nominated active boat owner-operators were in decision rule 1, they would remain in their current boat-gear category. If however, they were in decision rule 2 or below, they would be required to sell their boat and leave the fisheries sector, along with any personal savings.

Any remaining nominated crew members would remain in their current boat-gear category. As described above, this is because boat purchase is an additional activity for socio-economic groups 3 and 4 which ultimately doesn't matter if they can't acquire a boat or not.

5.5 Crew ratios

Following the completion of the decision rules and boat purchase sub-routines described above, the crew ratios within each boat-gear category are checked. A crew ratio is defined as the number of crew members (excluding the owner-operator) per vessel within a boat-gear category. The ratio is an average value, calculated from the *total* number of crew members and owner-operators within a boat-gear category. The actual number of crew per vessel may therefore not represent a whole number, but a *ratio*.

It is important to keep track of these ratios since they help to regulate the number of crew members within a boat-gear category.

5.5.1 Minimum number of crew

In the model, a minimum number of crew is required to operate some boat types. While all small boats have the potential to operate with only a single fisher (the owner-operator), large vessels require at least 2 crew members and an owner-operator (i.e. crew ratio of 2.0). This minimum threshold value is used as a constraint, below which no further large vessels can enter the boat-gear category.

5.5.2 Maximum number of crew

In contrast, *all* boat types have a maximum number of crew physically able to operate on board the vessel. A small boat is capable of taking a maximum of five fishers, including the owner-operator. Therefore the maximum crew ratio for small boats is 4.0. On larger vessels this ratio can be increased to 7.0. If the crew ratio of a boat-gear category has reached its maximum threshold value, it too acts as a constraint and no further crew members can enter the fishery without the addition of another boat.

As a result of these constraints, following completion of the decision rules for each socio-economic group within a boat-gear category, crew ratios within each category are checked. If the ratio is above its given threshold, a series of additional decision-making processes are required by the crew members to remedy the situation. These have been summarised in a flow diagram (see Figure 5.4).

In the model, if the crew ratio is too high in one or more boat-gear categories, a proportion of crew members from socio-economic group 3 are first given the opportunity to purchase a vessel in the *same* boat-gear category. This would be expected to be a viable option since the fishery is both profitable (crew members are the first to leave an unprofitable fishery and the boat-gear category would therefore not have exceeded the maximum crew level) and there is an ample supply of crew members within the same category available to make the investment worthwhile. The resulting increase in overall boat numbers would decrease the crew ratio.

If however, crew members from socio-economic group 3 within the same boat-gear category are unable to purchase the number of boats required to reduce the crew ratio to below the maximum level, a proportion of the remaining crew members (socio-economic groups 3, 4 and 5) must decide whether to switch to an alternative boat-gear category, or leave the fisheries sector.

The number of crew required to leave the boat-gear category is updated following any boat purchases from socio-economic group 3. The number of crew nominated in each socio-economic group is then calculated based on a proportion of their abundance. An example of these calculations based on 5 crew members required to leave are presented

in Table 5.9.

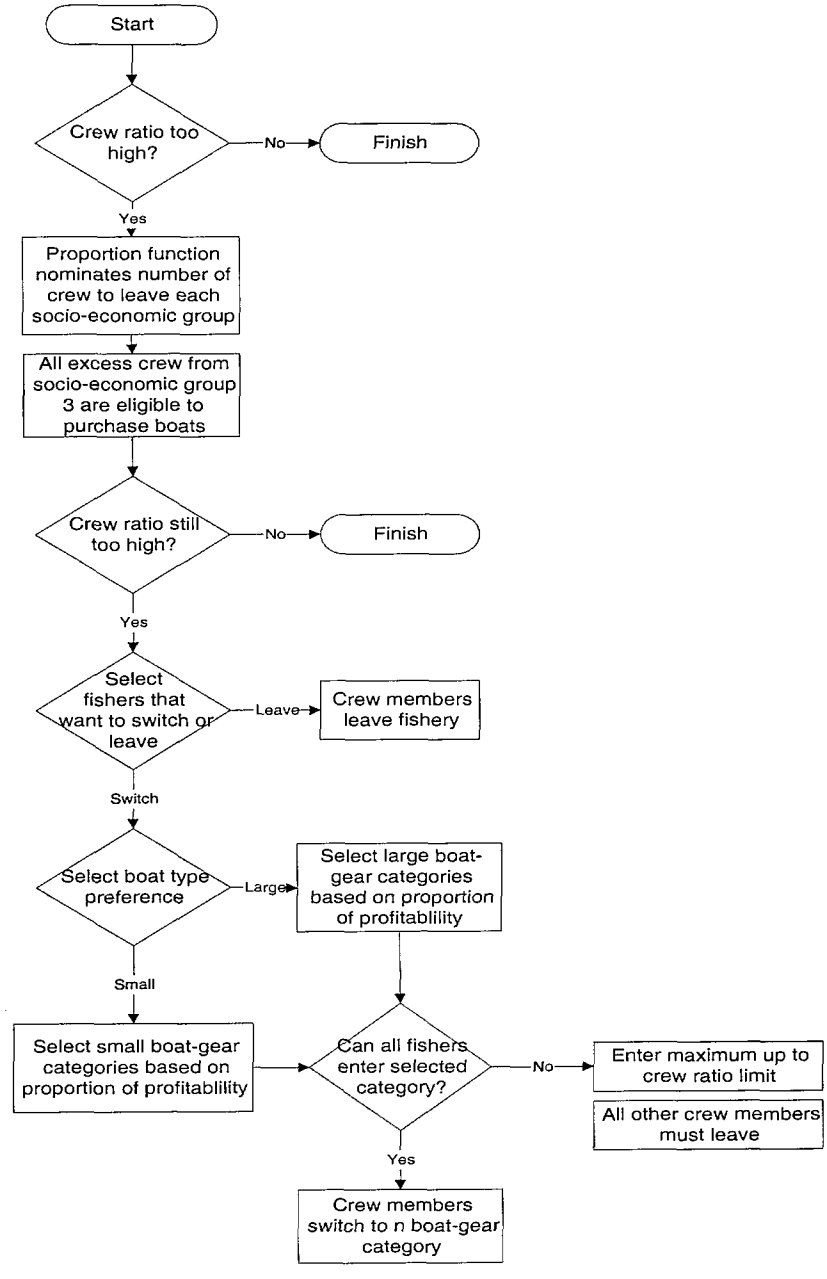


Figure 5.4 Decision rules used if excess crew are found operating within a boat-gear category.

Table 5.9 Calculation of the number of fishers nominated within each socio-economic group from a single boat-gear category based on a proportion of their abundance. A total of 5 fishers are required to switch or leave the category.

	Socio-economic group			
	3	4	5	Total
Number of fishers within group	30	10	10	50
Proportion of fishers within group	0.6	0.2	0.2	1.0
Number of fishers nominated	3	1	1	5

Within each nominated group, a further division is made between those fishers that wish to leave the fishery altogether, or attempt to switch to an alternative boat-gear category. These were determined in advance by a fixed proportion value based on a series of informal interviews. An example using data from Table 5.9 above is presented in Table 5.10.

Table 5.10 Proportion of nominated fishers within each socio-economic group from a single boat-gear category who decide to switch or leave the fisheries sector.

Socio-economic group	Fishers nominated	Switch (80%)	Leave (20%)
3	3	2	1
4	1	1	0
5	1	1	0
Total	5	4	1

Nominated crew members who have decided to leave the fisheries sector are removed from the boat-gear category along with any personal savings, and added to the appropriate socio-economic group within the pool. The remaining nominated crew members who have decided to try and switch boat-gear categories are further divided into those that wish to remain in their current boat type or move on board a new boat type.

Finally, nominated crew members from each socio-economic group on board each preferred boat type are dispersed between new boat-gear categories based on the

proportion of their potential annual net income. It is necessary to calculate however, whether these crew can actually enter the desired category. If the crew ratio is already at or above the maximum threshold value, the nominated crew members are unsuccessful in switching boat-gear categories and must leave the fisheries sector along with any personal savings,which are added to the appropriate socio-economic group within the pool. If however, there is sufficient room for only a proportion of those that wish to enter, the number within each nominated socio-economic group are selected based on the proportion of their abundance. All remaining unsuccessful nominated crew members must leave the fisheries sector along with any personal savings, and added to the appropriate socio-economic group within the pool.

5.6 BOAT REPLACEMENT

Each year a number of owner-operators decide to replace their current boat type. This may be either due to the poor condition of the vessel or an opportunity to upgrade. The total number of boat replacements may therefore fluctuate each year.

In the model, this creates a supply of second hand boats which enter a separate boat pool. Each year it is assumed that 10% of all boats replaced will enter the boat pool which then become available for purchase as second hand. In the model, the replacement of boats takes place *before* the decision rules and general boat purchase in order to provide a supply of second hand boats in the current year.

All boats purchased by owner-operators remain in their existing boat-gear category. For example, an owner-operator of a small boat will attempt to replace their existing vessel with a small boat. The following sections describe the decision rules used by owner-operators to replace their boat.

5.6.1 Number of boats replaced

The number of owner-operators wishing to replace their vessel is variable each year. No secondary sources of information are currently available on the actual number of fishers replacing their boats.

* In the model, it is assumed that the age structure of the artisanal fleet remains the same across time. This explains why secondhand boat replacement costs have been assumed constant over time.

It is assumed that small boats have a average life-span of 15 years. This represents approximately 7% of the total number of active small boats to be replaced each year. However, a number of boat owner-operators may also wish to renew their boat before it falls into disrepair. This suggests that the proportion of small boats replaced may be greater than 7% per annum. Loan incentives such as the YES initiative are also likely to increase the proportion of boats replaced.

Large vessels however, encompass a wide variety of boat categories (e.g. lekonomie, traditional whaler, schooner etc.), which all have different potential life-spans. For example a traditional whaler or schooner may have a life-span lasting anything up to 25 years with good maintenance. In contrast, a lekonomie is expected to have a similar life-span to that of a small fibre-glass boat (i.e. 15 years).*

The decision-making process used by owner-operators to replace their current vessel is complex. For example, if an owner-operator was thinking of replacing their boat, they would have to ensure that the new boat was going to be profitable. Due to fluctuations in their net income, some fishers may therefore wish to delay purchasing a replacement vessel. This implies that the proportion of boats replaced each year can also be substantially lower than their expected life-span (e.g. less than 7% per annum for small boats).

Older fishers on board a large vessel may wish to consider selling-up to purchase a small boat to use close to shore during their 'retirement', whereas younger fishers may wish to upgrade to a larger vessel, having gained the necessary experience and finance. In part, these processes have already been incorporated within the decision rules of the model, described earlier.

5.6.2 Boat replacement decisions

In the model, the decision process used by owner-operators required to replace their current boat type, is similar to that used for general boat purchases described earlier (see Section 5.4). However, the number of owner-operators nominated to replace their boat and the type of vessel to purchase is pre-determined.

The first decisions made by owner-operators replacing their current boat type are the age of the boat and the associated financial arrangements. These were previously described during the boat purchase routine. Re-applying data from these tables result in a fixed proportion of boat owner-operators within each socio-economic group who have decided to try and purchase a new or second hand boat (of the *same size* category), either with or without a loan.

The same decision rules as the boat purchase routine are then applied to each group. For example, checks on the availability of crew and second hand boats are made, in addition to the financial checks to decide if they can actually afford to purchase the boat (i.e. the net income after the deduction of vessel repayment costs is greater than their minimum acceptable level). If for any reason a replacement boat cannot be purchased, owner-operators must then make an alternative set of decisions.

Unlike the boat purchase routine, owner-operators who are unable to replace their current boat type are given a series of alternative options to try and stay in the fishery. These are necessary because fishers would normally only attempt to replace their boat if they thought they could actually afford to do so. In the model, a pre-determined proportion of owner-operators from each boat-gear category are required to replace their boats each year whether they are in profit or not.

The alternative set of options include whether or not to purchase the *same* boat type but of a *different* age and/or with *different* financial arrangements. Failing this, owner-operators may choose to remain in the fishery as a crew member, or leave altogether. These decisions vary according to their original boat replacement preference.

The decision process of an owner-operator who initially wanted to try and purchase a new boat *without* a loan are presented in Figure 5.5a and b. The decision process of an owner-operator who initially wanted to try and purchase a second hand boat *without* a loan are presented in Figure 5.5.

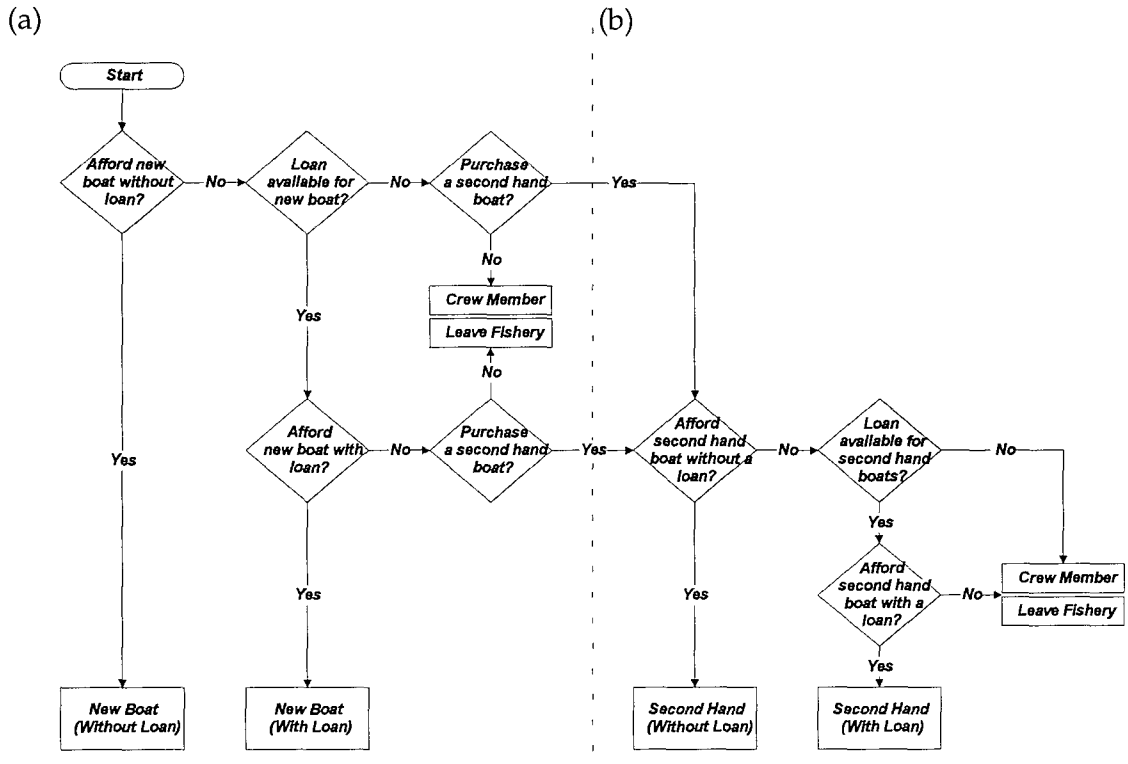


Figure 5.5 The decision process of an owner-operator who initially wanted to replace their current boat type with a new vessel, *without* a loan (a & b). Where b) is the decision process of an owner-operator who initially wanted to purchase a second hand boat, *without* a loan.

Unsuccessful owner-operators who initially wanted to purchase a new boat *without* a loan (first box, left hand side), will first attempt to purchase a new boat *with* a loan, before considering a second hand one. However, some members of this group may not wish to purchase a second hand boat, and would prefer to become a crew member for a short period or undertake alternative land-based employment. The proportion of owner-operators making each decision were obtained from informal interviews, and presented in Table 5.11 below.

Table 5.11 Preference table to indicate the proportion of unsuccessful owner-operators who will attempt to purchase a second hand boat, become a crew member or leave the fishery altogether.

Current boat type	Proportions of decisions made if no loan available		
	Leave	Second Hand	Crew
Small boat	0.2	0.8	0.0
Large boat	0.0	0.6	0.4

Unsuccessful owner-operators that have opted to replace their existing boat with a second hand one, must first check their availability. If there are sufficient second hand boats available, the owner-operator remains in their current boat-gear category. If however, there is a limited supply of second hand boats, and this fails to meet the demand, the available boats are divided between each socio-economic group as a proportion of their abundance. For example, if 20 second hand small boats were available, and socio-economic group 1 required 15 and group 2 required 10, then 12 boats (15/25 * 20) would be allocated to group 1 and 8 boats (10/25 *20), allocated to group 2. It is assumed that all remaining owner-operators unable to purchase a second hand boat become a crew member.

All former owner-operators that have selected to become a crew member are divided by their boat type preference. Potential small boat crew members are then partitioned between each boat-gear category, based on a proportion of their expected level of net income. However, before potential crew members are able to enter the chosen category, the maximum number of crew (or crew ratio), must be calculated for each socio-economic group. Overcrowding on board vessels was described earlier under crew ratios. If a boat-gear category is unable to take on all fishers within a socio-economic group (e.g. the maximum number of crew per boat has been reached), the remaining fishers must leave the fisheries sector and enter the pool.

The decision process of an owner-operator who initially wanted to try and purchase a new boat *with* a loan are presented in Figure 5.6 a and b. Similar to Figure 5.5 above, unsuccessful owner-operators who initially wanted to purchase a new boat *with* a loan would first attempt to try and purchase a new boat *without* a loan before considering a

second hand boat. In the model, the purchase of new boats *without* a loan may be automatically selected if the availability of loans are restricted as a result of an alternative management option.

The decision process of an owner-operator who initially wanted to try and purchase a second hand boat *with* a loan are also presented in Figure 5.6 b.

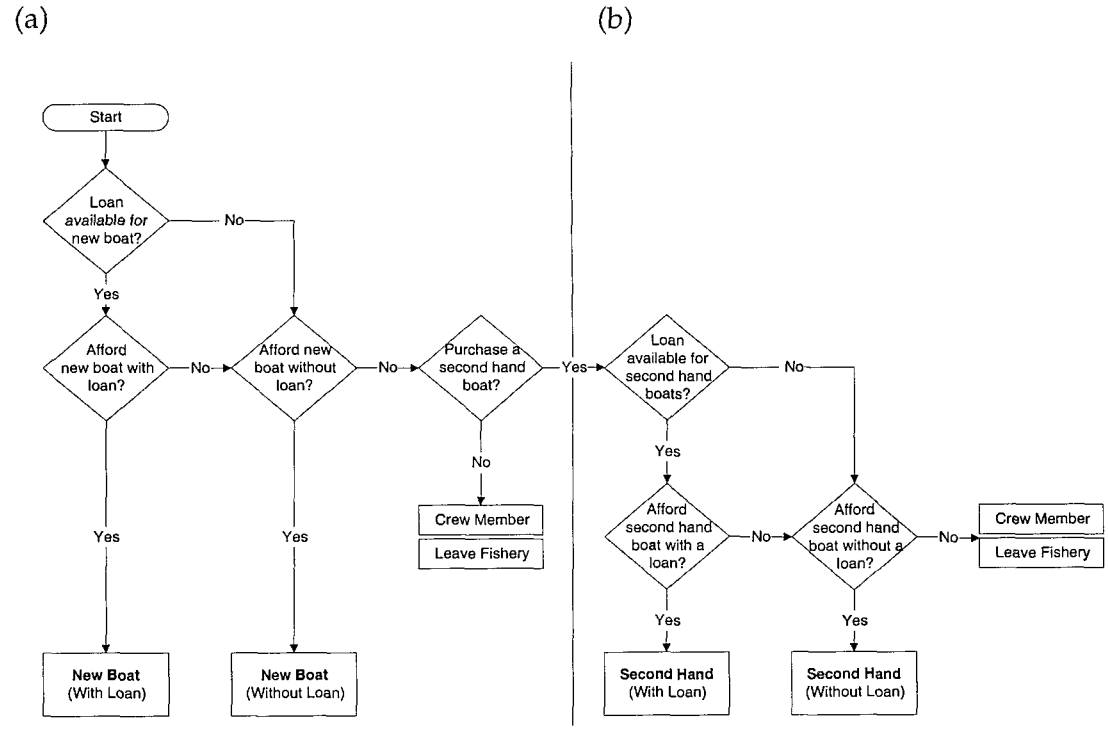


Figure 5.6 Decision process of an owner-operator attempting to replace an existing vessel with a new boat *with* a loan (a & b). Where (b) is the decision process of an owner-operator who initially wanted to purchase a second hand boat *with* a loan..

As previously described above, some members of this group may not wish to purchase a second hand boat, but would prefer to become a crew member for a short period of time or undertake alternative land-based employment. The proportion of owner-operators making each decision were presented in Table 5.11 above.

5.7 Recruitment to the fisheries sector from the pool

As previously introduced, the pool represents a group of potential fishers that currently

* In the model, it has been assumed that the age structure of the pool remains the same for the duration of the projections.

lie outside the fisheries sector. No distinction is made between pool members other than their socio-economic group. The pool therefore contains a mixed group of potential fishers that may be looking for alternative business opportunities, undertaking some form of casual employment or are otherwise unemployed.*

An advantage of utilising a pool is to enable the model to operate within a closed system. The closed system itself brings several advantages. First, it enables control over the number of fishers entering each boat-gear category. Historically, it has been shown that the number of new recruits into the fishery has fallen, and the fisheries sector is now showing signs of an ageing workforce. In part, this can be simulated in the model. As fishers leave the pool to enter the fisheries sector, the number remaining in the pool diminishes. Under these circumstances, fewer fishers become available to enter the fisheries sector.

A closed system also enables rates such as employment to be estimated. These can be calculated for each boat-gear category as a proportion of the total available workforce. For example, if the fisheries sector becomes more profitable, a higher proportion of the available workforce may be employed within the fisheries sector and vice versa. The level of employment is also used as a performance measure.

The pool consists of potential fishers from each socio-economic group (1-5). However, the decision rules within the pool entry do not permit crew members (socio-economic groups 3, 4 and 5) to purchase vessels or boat owners (socio-economic groups 1 and 2) to become crew.

Furthermore, the number of pool members entering the fishery may be constrained by the minimum or maximum number of crew permitted on board each boat-gear category. For example, potential owner-operators must determine if there are sufficient crew members available to make the investment worthwhile (i.e. above the minimum crew ratio), whereas potential crew members must determine if there are sufficient boats available (i.e. boats that have a crew ratio below the maximum level).

To simplify the model, it is assumed that no prior information is given to potential crew members on the number of additional boats entering from the pool. Similarly, the number

of owner-operators purchasing boats from the pool are assumed to have no prior information on the expected number of crew members entering the fishery. If potential crew members knew more boats were entering, the potential number of crew members could increase, and vice versa.

The decision processes used by 'pool' owner-operators and crew members are similar to decision rule 1 used to describe the labour mobility and fleet dynamics within section 5.3 above. However, because the pool does not distinguish between fishers within each boat-gear category (only socio-economic group) pool members must first decide which boat-gear category they would like to enter. The following sections describe the decision rules used by each socio-economic group to enter the fisheries sector from the pool.

5.7.1 Selection of boat-gear category

Pool members entering the fisheries sector must first decide which boat-gear category they would like to enter. It has previously been stated that active fishers would not simply move into the most profitable fishery, but may also have a number of other boat and gear type preferences. It is assumed that pool members also exhibit similar preferences. This table cannot be used directly because it assumes that pool members already belong to a boat type (small or large).

Table 5.12 Boat type preference table for pool members entering the fisheries sector.

Socio-economic group within pool	New Boat type	
	Small	Large
1 and 2 (owner-operators)	0.77	0.23
3 -5 (crew members)	0.80	0.20

It is assumed that the majority of pool members from socio-economic groups 1 and 2 decide to try and purchase a small boat type. Similarly, the majority of pool members from socio-economic groups 3, 4 and 5 also wish to try and enter a small boat type.

Within each selected boat type, pool members must make a further decision to choose

which boat-gear category they wish to enter. Similar to Boat Purchase (section 5.4), this is based on a proportion of net income from each boat-gear category.

Proportion of net income of new boat-gear category

The proportion of net income of the new boat-gear category is used to determine how many pool members from each socio-economic group select each category. As previously stated, the results of the socio-economic survey indicated that some active fishers also express a preference for gear type (e.g. some handline fishers do not wish to use traps). It is assumed that pool members also have similar gear type preferences.

Pool members who have decided to try and fish on board a small boat therefore have 3 boat-gear categories to choose between, whereas large boats have only 2. The following table provides an example of the proportion of net income used to determine the proportion of fishers who choose between each boat-gear category (see Table 5.13).

Table 5.13 Proportion of net income (from owner-operator) for each boat-gear category used to determine how many fishers choose between each gear type *within* each boat type.

Boat type	Gear type	Net income (Sr)	Proportion
	Trap only	35,000	0.39
Small	Trap and Handline	30,000	0.33
	Handline only	25,000	0.28
Large	Inshore handline	40,000	0.47
	Offshore handline	45,000	0.53

Pool members from each socio-economic group are therefore assigned to one of five boat-gear categories. For example, 77 of 100 pool members from socio-economic group 1 would have decided to try and purchase a small boat (cf. Table 5.11). Of these 77, 30 pool members would then choose to enter the trap-only, 25 trap and handline and therefore 22 pool members would choose to enter handline-only small boat-gear categories (Table 5.13).

Finally, the number of pool members actually nominated to enter their chosen boat-gear category is determined by the proportion function, p (see Equation 5.1). However, the average net income (SR28,572, k_{ave}), is used in place of the minimum acceptable level of net income (k_{min}) (see Equation A5.1). Hence if the chosen boat-gear category generates a net income in excess of $2.0k_{ave}$, no pool members will recruit to the boat-gear category.

5.7.2 Expected net income

Similar to the decision rules in labour mobility and fleet dynamics (Section 5.3), nominated fishers will only consider entering their chosen boat-gear category if the new level of net income is greater than an expected threshold value. This threshold value is calculated as a fixed percentage value above the average wage (k_{ave}), and applies to all socio-economic groups (1-5). These are presented in Table 5.14.

Table 5.14 Expected percentage increase in annual net income above the average wage (k_{ave}), required by each socio-economic group before considering to enter the chosen boat-gear category.

	Expected percentage increase in net income (%)	
Socio-economic groups	Small boat type	Large boat type
1 and 2 (owner-operators)	125	125
3, 4 and 5 (crew members)	125	125

The table shows that Pool members will only enter the fisheries sector, if the net income in their chosen boat-gear category exceeds 125%. This table can be linked to the modified proportion function, p (Equation A5.1), to conclude that pool members can only enter the fisheries sector if the net income from the chosen boat-gear category lies between 125 - 200% of the average net income (k_{ave}).

5.7.3 Transfer costs

Unlike general boat purchases (Section 5.4), there are no additional transfer costs associated with entering the fisheries sector from the pool. It is assumed that additional costs generated from acquiring new gear are included within the purchase costs of a boat.

5.7.4 Boat purchase

Unlike general boat purchases (Section 5.4) the purchase of boats are considered within the main decision rules of pool entry. This is because only socio-economic groups 1 and 2 are eligible to purchase boats from the pool.

The decision to purchase a vessel will depend on three inter-related factors that have been simplified in the model; boat type, finance, and availability. The size of boat however, has already been selected in an earlier routine (see Section 5.7.1 above). Only the age of the boat, finance and boat availability are left to determine. These issues have previously been described within boat purchase (see Section 5.4), and are also assumed to apply to members of the pool.

The size of vessel may also require a minimum number of crew in order to operate successfully. If there are insufficient crew available, the purchase of larger vessels can be restricted. These issues were discussed within Section 5.5 above.

Boat age and finance

Having already estimated the number of pool members looking to purchase a small or large boat, the age or quality of the vessel must be decided. The socio-economic survey indicated that some fishers would always prefer to purchase a new vessel over a second hand one, irrespective of their socio-economic group. These preferences have already been simplified into a fixed proportion of new and second hand for each boat size (see Table 5.11), and have been re-applied to the nominated pool members.

Having established the size (large or small) and age (new or second hand) of the boat, it is necessary to outline how nominated pool members are able to finance their new venture. Some fishers may be able to afford the purchase of a vessel outright, whereas others may require financial assistance. Obviously these are related to the amount of capital required, and the wealth of the socio-economic group. The proportion of fishers who would require a loan to purchase their intended vessel were also previously described for active fishers within Table 5.8. These preference values have been re-applied to the nominated pool members (socio-economic groups 1 and 2).

Crew availability

The availability of crew members to successfully operate a large boat type will deter potential boat owner-operators from purchasing this vessel type. Large boat types require a minimum number of crew in order to operate (cf. Section 5.5 above). If nominated pool members were unable to purchase a large vessel due to the size of the crew, they remain in the pool.

Second hand boat availability

Nominated pool members who have decided to purchase a second hand vessel (cf. Table 5.11 above), must first check the availability of such a vessel. Only a finite pool of second hand boats is available for purchase. Once this pool is empty, no further purchases can be made until additional boats become available at the start of the following year as a result of boat replacements (see Section 5.6 above). Similar to general boat purchases, where demand outstrips the supply of second hand boats, only a proportion of boats can be purchased based on a proportion of their abundance (cf. Section 5.4.4 above). Nominated pool members who were unable to purchase a second hand boat remain in the pool.

5.8 SUMMARY

The net level of income generated from the Economic sub-module for each socio-economic group (Chapter 4) has been used to form the basis of decision-making processes within the artisanal fishery.

Each year, the level of income determines the financial status of each socio-economic group within each boat-gear category. In turn, the financial status determines the range of decision options available to fishers within each group.

Decision rules have been modelled explicitly for each socio-economic group for large and small boats at different financial levels. Each rule governs the type of action fishers are likely to consider. Groups are not constrained to a single action; each group can make a variety of choices at a given financial level, rather than merely attempting to maximise income levels. Ultimately, however, a number of constraints may inhibit certain fishers from completing their chosen objective.

As a result of the decisions, fishermen may move between boat-gear categories. Therefore, at the end of each year the level of fishing effort is re-assessed for the following season.

The prediction of fisher behaviour can be used to evaluate the performance of a number

of alternative management options. Before this is attempted, however, the success of the model in replicating known historical trends is evaluated. Tuning of the bio-socio-economic model and testing its ability to mimic actual historical trends within the Seychelles artisanal fishery is described.

6 TUNING OF THE MODEL PARAMETER VALUES

6.1 INTRODUCTION

Chapters 4 and 5 described in detail the bio-socio-economic model of the Seychelles artisanal fishery. They also report the initial estimates of the many parameters, which have been obtained from analyses of both primary and secondary sources of information. The model is complex and it has a number of strongly interacting components. In addition, many of the initial parameter estimates have considerable uncertainties associated with them. In such circumstances, it is to be expected that when the parameters are varied within plausible ranges, a wide range of behaviours may result. Since the overall aim of this study is to evaluate the predicted performance of alternative policies, it is essential that this range of possible behaviours be narrowed down, and that to the extent possible, the model predictions are validated.

The aim of this chapter is to evaluate the ability of the model to replicate historical trends in biological, technical, economic and socio-economic attributes. If good agreement between historical and predicted trends can be demonstrated, then considerably more confidence can be placed in the way the key processes have been modelled, especially the influential socio-economic decision processes within the artisanal fishery. In turn, greater confidence can then be attached to model predictions of the outcome of future decisions.

Before final comparisons between simulated and historical trends were made, a process of 'tuning' of the parameters was undertaken. This involved iteratively making small changes in parameters selected for tuning, starting from the initial set of parameter estimates, with a view to improving the correspondence between simulated and historical trends. It should be noted that it was by no means certain that this process would actually achieve an acceptable correspondence between simulated and historical trends, since model predictions depend heavily on the decision process structurally incorporated in the model and these were largely unaffected by the tuning process.

Section 6.2 describes the selection of parameters and range of values used in tuning the model. A description of the methods used to tune the model is given in Section 6.3. Section 6.4 outlines the set of historical data series that were selected to represent key

biological, technical, economic and socio-economic attributes of the artisanal fishery and then examines the performance of the untuned and tuned models in replicating trends in each of the selected series. The final parameter values for the tuned model are described in Section 6.5. Finally, the overall performance of the model is reviewed in Section 6.6.

6.2 SELECTION OF PARAMETERS FOR TUNING

Given the large number of model parameters, it is clear that only a subset could be used for tuning purposes. As described in Chapter 4, the estimates of the biological parameters have been obtained from extensive analysis of biological and catch data, mainly in independent studies. Consequently, biological parameters were excluded from the tuning process.

To select the set of technical, economic and socio-economic parameters to be used to tune the model, two criteria were used. First, the set of parameters which had the greatest level of uncertainty after comparing the simulated and historical trends were identified. Second, from the initial set of parameters highlighted, the most influential parameters responsible for simulating the observed patterns were finally selected for further tuning.

The following sections describe which parameters have been selected for tuning, for each main attribute of the model. The initial values of the selected parameters used during the base run are given, together with a range of values to be used during the tuning process.

6.2.1 Technical attributes

The model includes several parameters which describe the technical attributes of the artisanal fishery. From the results of the base run, three of these were selected for tuning the model. These were the proportion of gear used by fishers (within a mixed boat-gear category), the number of days spent fishing each year, and the proportion of boats replaced each year.

Proportion of gear used by trap & handline fishers

Although the SFA catch assessment surveys provide much detailed information on

the number of traps and handlines used by fishers (Art_fish database, 1986-97), there exists a broad range in the number of traps used. This is due to the different numbers of traps used by fishers operating both traps and handlines. In contrast, there is good information regarding the relative fishing power of handlines by fishers operating both traps and handlines (see Table A1.1, Mees, 1996). Therefore only the proportion of traps was considered for tuning.

The average number of traps used per fisher operating with traps only was 4.70 (Art_Fish database, 1986 - 1997). In comparison, the average number of traps used per fisher operating both traps and handlines was 3.67, or 78% of traps only. Historical data from the catch assessment survey, however, show that fishers using both traps and handlines use a wide range of trap numbers. The observed maximum number of traps used by fishers operating both traps and handlines exceed the average used by fishers operating traps only. However, the average proportion of traps used by fishers operating both traps and handlines was not believed to exceed the average number used by trap-only fishers.

In the model, the number of traps used by fishers operating both traps and handlines is specified as a proportion of the number of traps used by fishers operating with traps only. The untuned parameter value used within the base run, and the observed range of values for tuning based on data from the catch assessment survey are given in Table 6.1.

Table 6.1 The proportion of traps used by fishers operating both traps and handlines in comparison to the numbers of traps used by trap-only fishers.

	Untuned	Range used for tuning
Proportion of traps used	0.78	0.2 - 1.0

Annual number of days spent fishing

In the model, the annual numbers of days spent fishing were estimated from secondary sources of information (SFA, 1987-1998). This parameter, which to a large extent controls the level of total annual catches, varied considerably between years.

The annual numbers of days spent fishing is calculated from the product of the numbers of trips per year and the average trip length (days). Trip length has been well documented in the catch assessment survey (Art_Fish database, 1986 - 1997), and has a comparatively small level of variation (Table 6.2).

Table 6.2 Average trip length (days) per trip length.

	Average trip length (days)	Std. Dev
Small inshore	≤1.00	0.050
Large inshore	1.24	0.026
Large offshore	4.48	1.350

The average numbers of fishing trips by large boats are less than any other boat-gear category (Table 6.3). This is because they have a longer trip length (Table 6.2). The average number of trips must therefore be multiplied by the average trip length (days) to obtain the total number of days at sea. However, since little variation is observed in trip length, only the number of trips was used for tuning the model. For tuning purposes, the number of days spent fishing each year were assumed to lie between 0 and 365.

Table 6.3 Estimated average numbers of fishing trips between 1986 and 1997 by different boat-gear categories used in the untuned model.

Year	Trap Only	Handline Only	Trap & Handline	Large Inshore	Large Offshore
86	160	149	164	126	35
87	139	113	108	140	39
88	148	106	103	132	37
89	141	94	149	94	26
90	84	69	82	108	30
91	124	72	98	98	27
92	143	78	117	80	22
93	123	84	96	91	25
94	108	105	83	87	24
95	113	90	75	103	28
96	110	103	72	124	34
97	70	94	41	102	28

Boat replacement

The frequency with which fishers replace their existing boats is, by itself, an important parameter in the simulation model. However, following the results of the base run, it was immediately apparent that boat replacement is also an important element in the purchase of boat loans. This was because the documented increase in the number of loans issued for the purchase of small boats was not matched by a corresponding increase in the number of vessels recorded in the commercial fishery statistics (cf. Figures 6.12 and 6.14). This is discussed in more detail in Section 6.6.

Unfortunately, little quantitative information is available on the frequency of boat replacement. Within the untuned model, it was assumed that all small boats were replaced after 15 years (with approximately 7% of all small boats being replaced per annum), whereas large boats were replaced after 25 years (with approximately 4% of all large boats being replaced per annum). The results of the base run showed that the numbers of boats purchased with a loan each year were highly variable (cf. Figures 6.15a). Consequently, to match the historical data, the annual rate of boat replacement

must have varied between years.

The range of values used to determine the proportion of boats replaced each year is partly controlled by the boat-type. On average, large boats are expected to be replaced less frequently than small boats. Since to the introduction of the government YES soft loan initiative in 1996 (SIDEC, 1996), an even higher proportion of existing small boat fishers are thought to be using the scheme to replace their ageing vessels. However, because the large boat category contains a wide range of different boat-types, it has been decided to keep the range in the proportion of fishers replacing small and large boats the same (0-25%).

Table 6.4 The percentage of boat owner-operators who replace their boat each year.

	Untuned		Range for tuning	
	Small	Large	Small	Large
Boat replacement (%)	7	4	0 - 25	0 - 25

6.2.2 Economic attributes

Following the results of the base run, only a single economic attribute was selected for tuning. This was the daily operating cost associated with each boat-gear category.

The untuned daily operating costs associated with each boat-gear category were obtained from the present study and a recent costs and earnings survey of artisanal fishers (Mees *et al.*, 1998). Results from the present study showed that the range of costs varied within and between boat-gear categories. These data have been used to set the upper and lower limits for tuning the model (see Table 6.5).

Table 6.5 Average daily operating costs for each boat-gear category.

Boat-gear category	Average daily operating cost (SR)	
	Untuned	Range for tuning
1. Trap only	300	100 - 600
2. Handlines only	445	100 - 600
3. Trap and handlines	300	100 - 600
4. Large inshore boat handlines	750	500 - 1,500
5. Large offshore boat handlines	1,250	500 - 1,500

6.2.3 Socio-economic attributes

Due to the limited quantitative socio-economic data, several socio-economic parameter values were regarded as having a high level of uncertainty. Two of these were selected for tuning the model: the expected percentage increase in profits required to switch to an alternative fishery, and the level of personal savings accrued each year.

Required percentage increase in profits

The required percentage increase in profits controls the financial level at which fishers decide to attempt to switch to an alternative, more profitable, boat-gear category. The higher the required percentage value, the higher the alternative net income must be before fishers consider this a viable option. These financial decisions are not used, however, by fishers who are currently receiving less than their minimum acceptable level of income. Under these circumstances, fishers base their decisions on a viable alternative option which only has to exceed their minimum acceptable level.

The required percentage increases in profits for boat owner-operators and crew members of large and small boats are shown in Table 6.6 During the 1997 socio-economic survey, the range of required percentage values were given between 0% - 200% above their estimated current level of net annual income. Obviously, higher values indicate that fishers are less willing to switch boat-gear categories.

Table 6.6 The percentage increases in the level of net income required by fishers within the artisanal fishery to switch to an alternative boat-gear category.

	Boat type	Untuned %	Range for tuning %
Crew members	Small	100	0 - 200
	Large	100	0 - 200
Owner-operators	Small	100	0 - 200
	Large	100	0 - 200

Information on the required percentage increase in the level of net income is also needed for pool members. For this category, however, the required percentage increase is based on the *average* level of income within the fisheries and agriculture sector (Anon, 1997a). These values control the financial level at which pool members decide to enter the fisheries sector. Without any additional information, the range of values for pool members has been kept the same as for fishers (Table 6.7).

Table 6.7 The percentage increases in the level of net income required by pool members before attempting to enter the artisanal fishery.

	Boat type	Untuned %	Range for tuning %
Crew members	Small	100	0 - 200
	Large	100	0 - 200
Owner-operators	Small	100	0 - 200
	Large	100	0 - 200

Personal savings

The level of personal savings describes the percentage of fisher's net income which is saved after the deduction of living costs. The level of personal savings determines whether fishers within each socio-economic group of different boat-gear categories can afford to take on a number of financial commitments, including boat purchase. Information is required on both the level of personal savings available to fishers at the start of the simulation and on the annual percentage of net income saved thereafter,

following the deduction of annual living costs.

In the base run, it was assumed that each socio-economic group had the equivalent of 10% of their minimum acceptable level of net income available as savings (Table 6.8). The minimum acceptable level of net income was used as a financial reference point, since this value was already known at the start of the simulation (cf. Table 4.5, Chapter 4).

For tuning purposes, it was assumed that the level personal savings available at the start of the simulation did not exceed their minimum acceptable level of net income. This maximum value is a largely arbitrary figure, and is set at a level which should enable some fishers to purchase a small boat outright, but would be insufficient to purchase a large boat without additional net income from the fishery.

Table 6.8 Initial savings as a percentage of the minimum acceptable level of net income at start of simulation by socio-economic group.

Socio-economic group	Untuned %	Range for tuning %
1	10	0 - 100
2	10	0 - 100
3	10	0 - 100
4	10	0 - 100
5	10	0 - 100

A proportion of the total net income, after the deduction of living costs, was saved each year the fisher made a profit. The untuned proportion of net income saved after the deduction of living costs was set at 10% for the base run (Table 6.9). For tuning, it was assumed that fishers were not able to save more than 100% of their current net annual income from the fishery.

Table 6.9 Proportion of net income saved each year, after the deduction of living costs, by socio-economic group.

Socio-economic group	Untuned %	Range for tuning %
1	10	0 - 100
2	10	0 - 100
3	10	0 - 100
4	10	0 - 100
5	10	0 - 100

6.3 METHODS USED TO TUNE THE MODEL PARAMETER VALUES

The previous section has outlined the ranges of values of parameters which were selected for tuning the model. This section now describes the methods used to carry out the tuning.

Tuning the simulation model was not achieved via a formal statistical analysis. Rather, it consisted of a series of iterative steps aimed at progressively improving the agreement between the simulated model output and the historical data.

Due to the complexity of the non-linear model, changing a single parameter value frequently affected more than one output variable. If changing a single parameter resulted in a better fit between simulated and historical data for one or more model attribute, but in a worse fit for another, changes were then made in other parameters known to counteract these unwanted side effects. For example, increasing the number of boats within a boat-gear category is likely to also increase the total level of catches by that boat-gear category. If the new level of total catch is too high, however, it may be reduced by then changing the average number of days spent fishing a year by the boat-gear category.

The following sequence of steps which resembles an amoebic iteration was used to tune the model. Each step involved making a number of small changes to parameters, which were reviewed before the next step in the tuning process was undertaken.

Step 1 First, the numbers of boats operating within each boat-gear category were considered. The numbers of boats within each category can be altered by changing the parameter values for several economic and socio-economic attributes. For example, reducing the daily operating costs of fishing activities (cf. Table 6.4), makes a boat-gear category more profitable, which in turn may increase the number of boats entering. If, however, these costs approach their minimum value within the specified range, the expected level of profits required to either switch to an alternative boat-gear category or enter the fisheries sector from the pool can also be lowered (cf. Tables 6.5 and 6.6).

Step 2 Next, after improving the numbers of boats within each boat-gear category, attention was then switched to the total level of catches. If these were also changing in the right direction, little or no manipulation of the parameter values was required. If, however, large changes had occurred to the catch levels and these were moving in the wrong direction, or they had overshot the targets, then other technical parameter values were used to re-adjust the total level of catches. For example, the proportion of traps used by fishers operating both traps and handlines could be adjusted in an appropriate direction.

Unless the levels of catches were very notably different between the simulated model output and the historical data in successive years, the parameter value controlling the number of days fishing per year was left unchanged until the final stages of fine tuning the model.

Step 3 Finally, after changes had been made to tune the number of boats and catch levels, the numbers of boat loans were then considered. The number of loans purchased was variable between successive years, but could be partly controlled by the proportion of boats replaced each year. If more loans had been purchased within a particular year than had been simulated by the model, the proportions of boats replaced in that year were increased.

Steps 1 to 3 were repeated, slowly adjusting each set of parameters a little at a time, until no further substantial improvement in agreement was observed between the simulated output and the historical data.

* Emphasis was placed particularly on matching patterns of the historical data, especially the peaks and troughs, rather than getting the averages correct in a range of biological, technical, economic and socio-economic attributes.

Minimizing the sum of squares or a log-likelihood function was not considered appropriate for several reasons. These included for example, that although a good fit may be possible with the historical data, the value of one or more parameters used to do this may fall outside what is considered a realistic range.

Multiple-criteria decision making, such as neural networks or expert systems (e.g. Cochran and Zeleny, 1977; Clímaco, 1997; Triantaphyllou & Sánchez, 1997; Bousquet *et al.*, 1994; Brans *et al.*, 1998) were not used due to the difficulty in assigning an appropriate level of weighting for each parameter. Furthermore, it was not certain whether these weighted values could converge to reach an optimum solution.

Given this background, it was decided to change different parameter values within a specified range; each result provided a new benchmark for comparison with actual historical data until a good match was found.

6.4 COMPARISON OF MODEL OUTPUT WITH HISTORICAL DATA

This section illustrates how well the model performed, based on a comparison with a selection of historical data. It is important to show that the simulation model can replicate historical data, for it will be used in the following chapter to project the fishery forwards over a number of years under the operation of a series of alternative management options. *

The model was used to simulate data between 1986 and 1997. This range of years was selected because it contained the majority of quantitative historical data that was available for comparison. The types of data compared, were chosen to represent a range of biological, technical, economic and socio-economic fishery attributes.

Historical data were available from a number of sources. Aspects of the biological and technical attributes were obtained from the SFA annual statistical reports (SFA, 1987-98) and the catch assessment survey (Art_Fish database, 1986-1997). Economic details concerning the number of boat loans disbursed by boat type were obtained directly from the DBS and SIDEC. Finally, socio-economic details concerning the number of fishers within each group and boat-gear category were estimated from the 1997 socio-economic survey. This is described in more detail in Section 6.4.4.

6.4.1 Biological attributes

There is much historical biological information available as a result of the SFA catch assessment surveys (see SFA, 1987-98). These provide a wealth of data from mid-1985 onwards. This section compares catch records, which combined with other technical attributes are important indicators of the status of the artisanal fishery. The historical catch information represents only that removed by specific boat-gear categories. For example, the model did not simulate explicitly catches retained by small pirogues, and therefore these catches have been removed from the comparative historical data.

Total catches are first compared by resource type. Specific catch details are then described for each boat-gear category.

Total catches by resource type

Total inshore reef catches by fishers in small boats (excluding pirogues) are shown in Figure 6.1. In comparison to the historical data (Figure 6.1a), simulated catches from the tuned model (Figure 6.1b), show a similar peak in catches during 1992 and decline in catches after 1993. In contrast, the simulated catch data from the untuned model (Figure 6.1c) show continued high levels of catches after 1993.

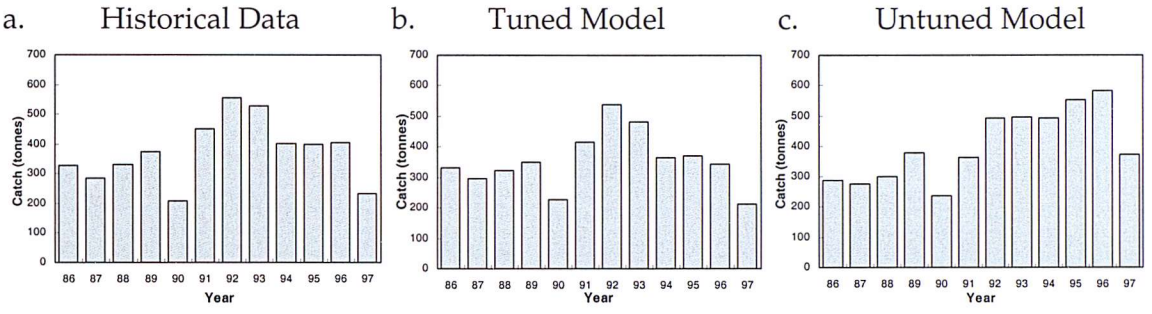


Figure 6.1 Total inshore reef catches (tonnes) by fishers operating in small boats, over the period 1986 to 1997: a) historical data, b) simulated tuned data and, c) simulated untuned data.

Next, the total inshore demersal catches by fishers in small boats (excluding pirogues), are given in Figure 6.2. On average, the total annual catches simulated from the untuned model (Figure 6.2c), are low in comparison to the historical inshore demersal catches (Figure 6.2a). Simulated output from the tuned model, however, has successfully increased the level of annual catches (Figure 6.2b), although the initial catches made between 1986 and 1989 are higher, and the observed peak in historical catches between 1991 and 1994 is less pronounced than the historical data.

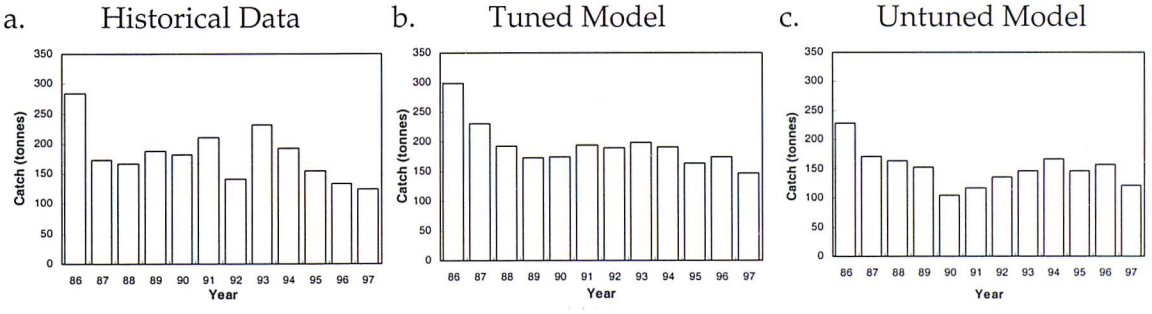


Figure 6.2 Total inshore demersal catches (tonnes) by fishers operating in small boats, over the period 1986 to 1997: a) historical data, b) simulated tuned data and, c) simulated untuned data.

The total inshore demersal catches taken by large inshore boats between 1986 and 1997 are given in Figure 6.3. Although on average, simulated total catches from the untuned model increase each year (Figure 6.3c), they do not show the same trends observed in the historical data (Figure 6.3a). Simulated catches from the tuned model (Figure 6.3b), have removed the increasing trend in the untuned catches, but catches from 1990 onwards are under-estimated.

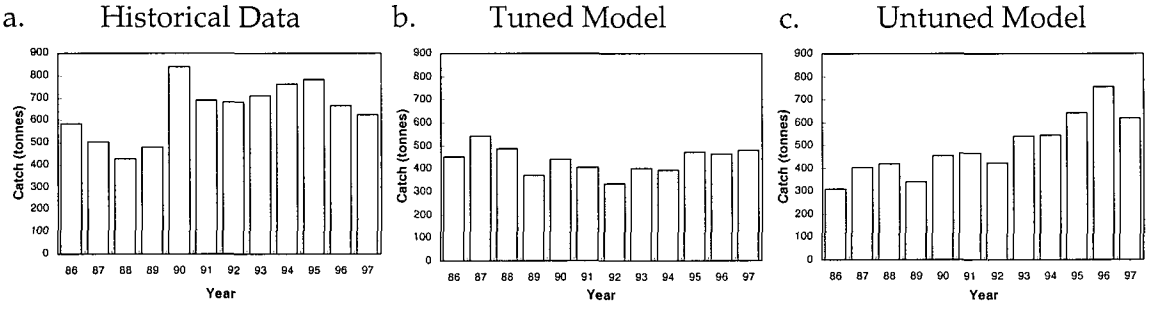


Figure 6.3 Total inshore demersal catches (tonnes) by fishers operating in large inshore boats, over the period 1986 to 1997: a) historical data, b) simulated tuned data and, c) simulated untuned data.

The total offshore demersal catches for large boats fishing offshore are given in Figure 6.4. The simulated catches for the untuned model (Figure 6.4c), are higher than the historical data (Figure 6.4a), particularly after 1991. On average, the historical total catches between 1986 and 1991 are higher than the those retained after 1991. In contrast, simulated output from the tuned model has successfully replicated the offshore demersal catches from the historical data (Figure 6.4b).

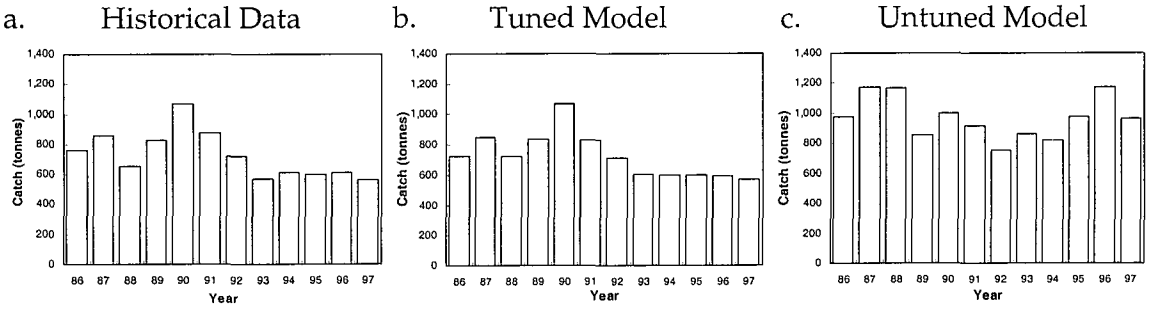


Figure 6.4 Total offshore demersal catches (tonnes) by fishers operating in large offshore boats, over the period 1986 to 1997: a) historical data, b) simulated tuned data and, c) simulated untuned data.

Although the historical total annual catches of semi-pelagic resources are used directly in the model, division of the catch between inshore and offshore regions is determined by the level of fishing effort simulated in the model. The total simulated inshore semi-pelagic catches are aggregated across all small and large boats fishing inshore. The historical total inshore semi-pelagic catches are given in Figure 6.5a.

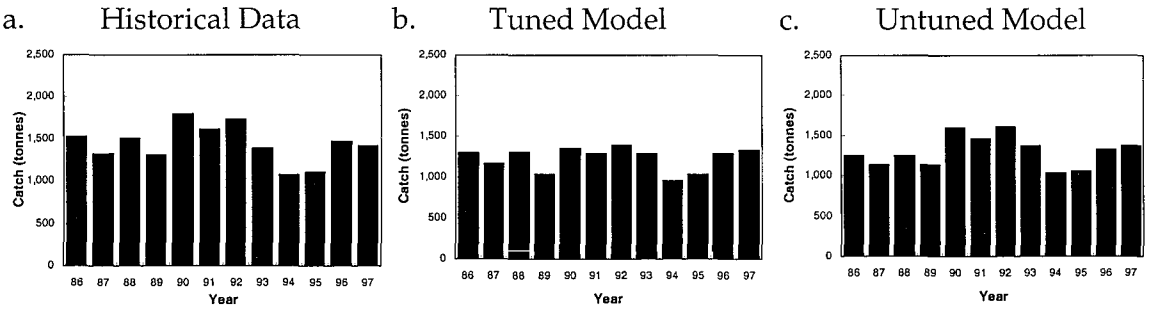


Figure 6.5 Total inshore semi-pelagic catches (tonnes) from all small boats and large inshore boats over the period 1986 to 1997: a) historical data, b) simulated tuned data and, c) simulated untuned data.

The distribution of simulated catches from both the tuned and untuned model are similar (Figures 6.5b and 6.5c). Both simulated results, however, under-estimate the level of catches between 1990 and 1992.

The total offshore semi-pelagic catches are given in Figure 6.6. The distribution of historical catches is similar to that observed within the inshore region, but the catches are considerably lower (Figure 6.6a). In comparison, simulated output from both the tuned and untuned model show similar catch distributions (Figure 6.6b and 6.6c). Both simulated results, however, have higher catch levels than the historical data, in particular after 1989. This result was not unexpected. Since the simulation model uses the historical data values, and the inshore semi-pelagic catches have been under-estimated, it follows that the offshore simulated catches must be over-estimated between 1990 and 1992.

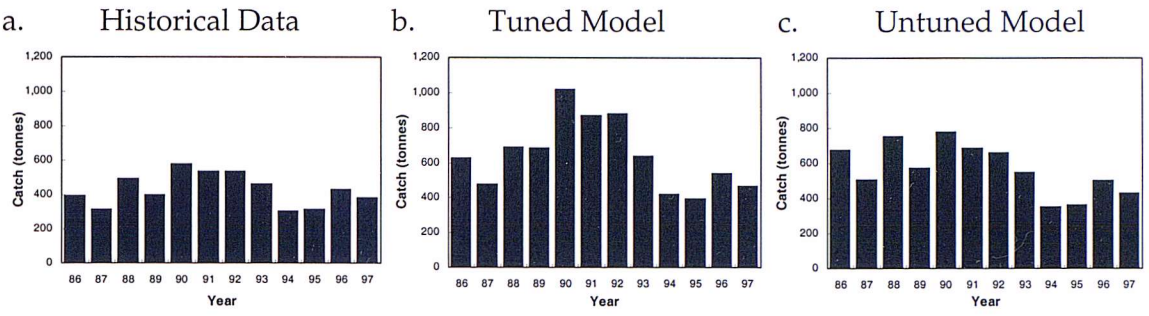


Figure 6.6 Total offshore semi-pelagic catches (tonnes), from all large offshore boats over the period 1986 to 1997: a) historical data, b) simulated tuned data and, c) simulated untuned data.

Total catches by boat-gear category

Total reef catches by fishers in small boats with traps-only, are given in Figure 6.7. Fishers operating with traps-only retain the highest reef catches. This is also seen in the range and distribution of historical and simulated total reef catches by all boat-gear categories (cf. Figure 6.1a-c). The tuned model results match the historical data very well, in contrast to the untuned model results.

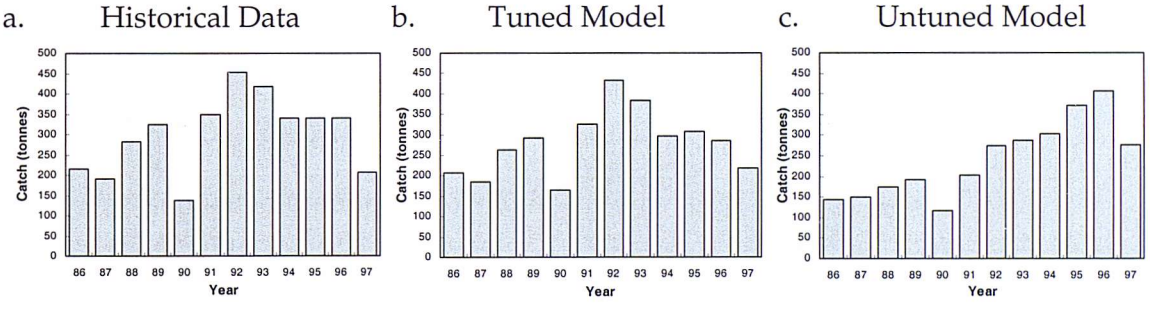


Figure 6.7 Total catch (tonnes) by trap only fishers operating in small boats over the period 1986 to 1997: a) historical data, b) simulated tuned data and, c) simulated untuned data.

Total annual catches by fishers in small boats with handlines only are given in Figure 6.8. The simulated inshore demersal catches from the tuned model (Figure 6.8b) are a little higher than those of the untuned model (Figure 6.8c), but otherwise they have successfully replicated the distribution of historical inshore demersal catches (Figure 6.8a).

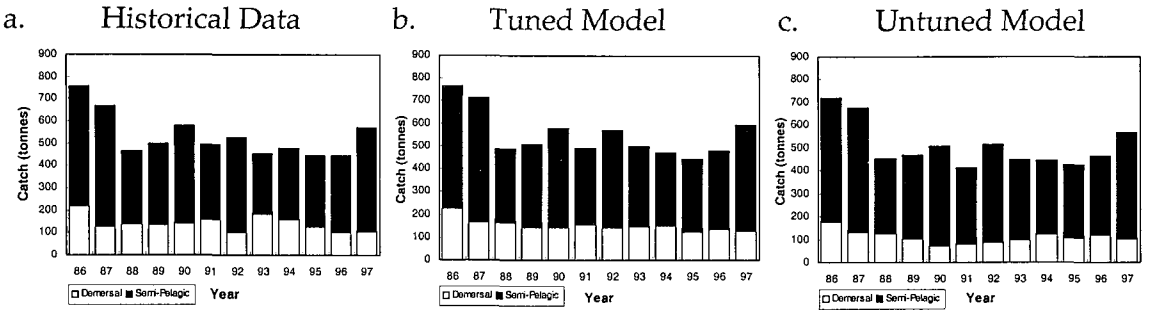


Figure 6.8 Total catch (tonnes) by handline-only fishers operating in small boats over the period 1986 to 1997: a) historical data, b) simulated tuned data and, c) simulated untuned data.

The total annual catches by fishers in large inshore boats with handlines-only, are given in Figure 6.9. Although the historical inshore demersal catches of large boats have previously been described (cf. Figure 6.3a), this comparison now includes the historical inshore semi-pelagic catches retained by fishers in large inshore boats.

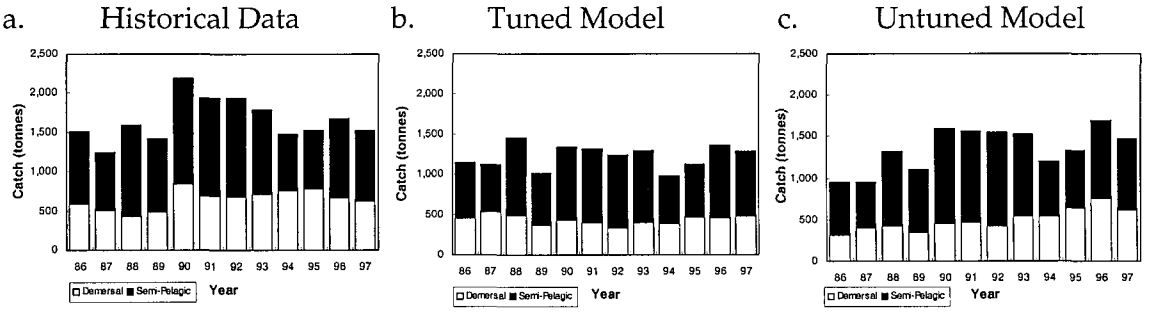


Figure 6.9 Total catch (tonnes) by handline-only fishers operating in large inshore boats over the period 1986 to 1997: a) historical data, b) simulated tuned data and, c) simulated untuned data.

On average, the simulated catches from the untuned model (Figure 6.9c), are greater than the tuned model (Figure 6.9b). The simulated output from both the tuned and untuned model poorly represent the distribution of historical data (Figure 6.9a). It has previously been shown that the simulated catches from the tuned model also under-estimate the levels of both inshore demersal and semi-pelagic catches (cf. Figures 6.3b and 6.3c).

The total annual catches by fishers in large offshore boats with handlines are given in Figure 6.10. Although the offshore demersal catches of large boats have previously been

described (cf. Figure 6.4), this comparison now includes offshore semi-pelagic catches. Although the simulated output from the tuned model (Figure 6.10b) has successfully managed to replicate the overall pattern of historical catches, the levels of semi-pelagic catches are higher between 1990 and 1992.

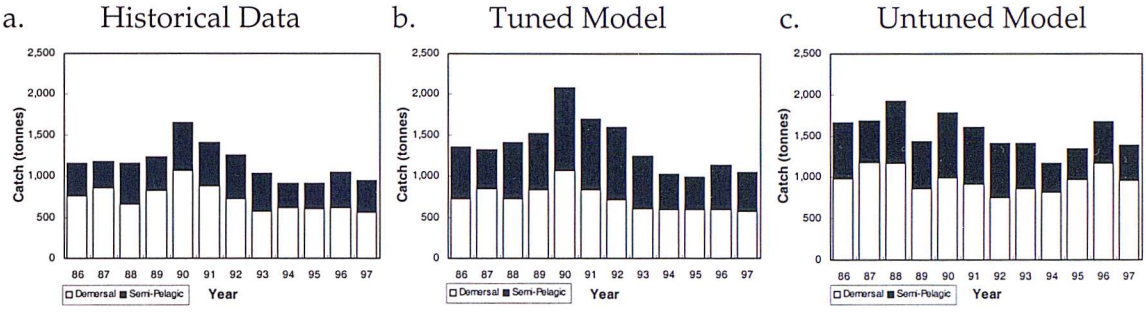


Figure 6.10 Total catch (tonnes) by handline-only fishers operating in large boats over the period 1986 to 1997: a) historical data, b) simulated untuned data and, c) simulated untuned data.

Finally, total catches made by trap and handline fishers in small boats are given in Figure 6.11. The results indicate that the majority of catches by fishers using both traps and handlines are taken from the reef. The simulated catches from the untuned model (Figure 6.11c) are notably higher than either the tuned model (Figure 6.11b) or historical data (Figure 6.11a). In comparison, simulated catches from the tuned model have successfully replicated the pattern of historical data .

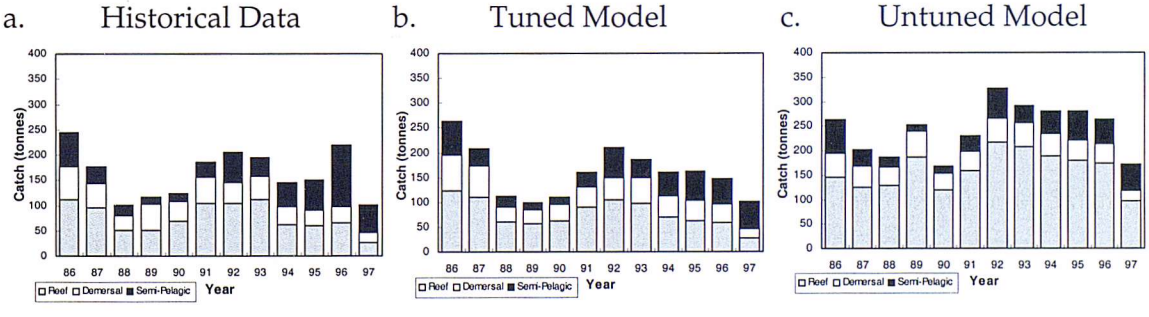


Figure 6.11 Total catch (tonnes) by trap and handline fishers operating in small boats over the period 1986 to 1997: a) historical data, b) simulated tuned data and, c) simulated untuned data.

6.4.2 Technical attributes

The majority of technical information has also been collected as part of the SFA catch assessment survey (see SFA technical reports 1987-98). The technical parameters selected for comparisons, were the number of boats and the number of associated crew members. This enables the historical numbers of fishers within each boat-gear category to be compared with output generated from the simulation model.

The actual numbers of boats within each boat-gear category are given in Figure 6.12. On average, the historical numbers of small boats with traps and handlines, handlines-only, and large offshore boats with handlines have remained relatively constant between 1986 and 1997 (Figure 6.12a). In contrast, small boats with traps-only, and large inshore boats with handlines, have increased in numbers since 1986, reaching a plateau in 1992.

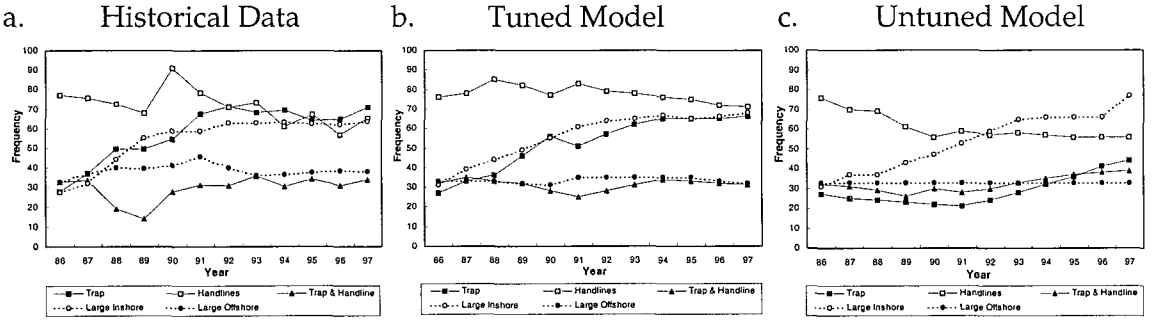


Figure 6.12 Total numbers of boats within each boat-gear category over the period 1986 to 1997: a) historical data, b) simulated tuned data and, c) simulated untuned data.

The simulated numbers of boats in operation from the untuned model are very different from the historical number (Figure 6.12c). Although the numbers of large inshore boats have been simulated to increase, small boats operating with traps-only did not shown the same pattern of increase. Instead, the number of boats operating with traps-only have a greater similarity to the number of boats operating with both traps and handlines.

In contrast, simulated output from the tuned model (Figure 6.12b) has replicated many of the features observed in the historical data (Figure 6.12a). There is, however, a notable decline in the historical number of small boats operating with both traps and handlines between 1987 and 1990 which has not been replicated within the results of the simulated

output of the tuned model.

In addition to the number of boats in operation, the total numbers of crew in each boat-gear category have been estimated (Figure 6.13). This highlights a number of interesting points. The observed changes in the number of boats within each small boat-gear category is matched by the number of crew members within each category. Furthermore, as the numbers of large inshore boats increased to reach a plateau in 1991, a similar increase in the number of crew was observed, but crew members immediately declined thereafter. Although a similar rise in crew members was observed for large offshore boats, they show an unexpected decline after 1991.

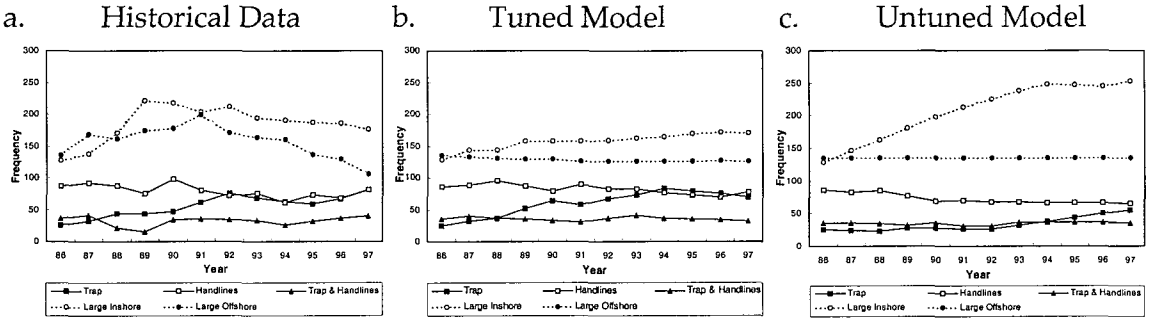


Figure 6.13 Total numbers of crew members within each boat-gear category over the period 1986 to 1997: a) historical data, b) simulated tuned data and, c) simulated untuned data.

The simulated numbers of crew from the untuned model (Figure 6.13c), showed a number of differences from the historical pattern. In particular, the simulated output showed a substantial increase in the number of crew in large inshore boats.

The simulated numbers of crew from the tuned model (Figure 6.13b) match the historical data well for handlines-only, traps-only and traps & handlines. However, they do not show a similar rise and fall in the number of crew members in large boats. Instead, the numbers of crew in large inshore boats increase steadily with the number of additional boats (cf. Figure 6.12b). Simulated crew members of large offshore boats remained relatively constant between 1986 and 1997.

6.4.3 Economic attributes

In contrast to both the biological and technical data, there exists relatively little in the way of economic data for the Seychelles artisanal fishery. The majority of these available economic data (e.g. costs and earnings) have been used directly to help parameterise the simulation model.

There is however, an important economic output from the model; the number of soft loans disbursed. The ability to simulate and monitor the number of soft loans is important because manipulation of the number of soft loans can be used as an alternative management option to help control the level of fishing effort within the inshore region.

The numbers of loans disbursed for large and small boats from the Development Bank of Seychelles (DBS) and the government YES soft loan initiative between 1986 and 1998 are given in Figure 6.14a. The distribution of soft loans is highly skewed. Although small peaks are observed in 1990 and 1993, a sudden large increase was observed during 1996, coinciding with the start of the government YES soft loan initiative. The number of loans disbursed for large boats remained relatively constant between 1990 and 1998.

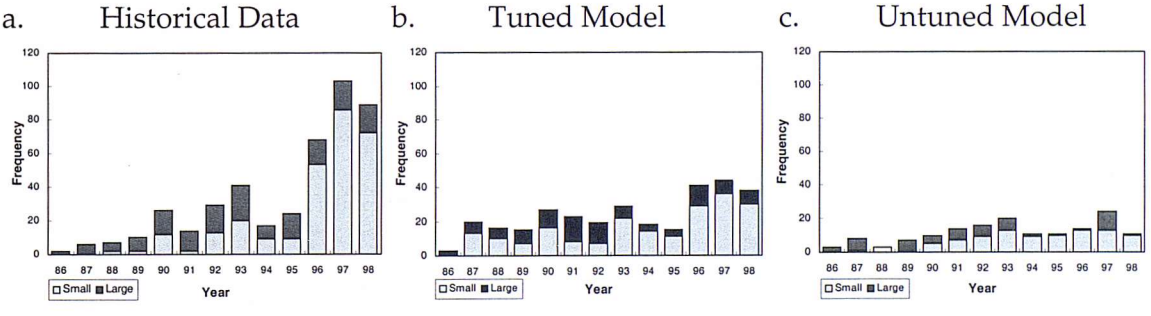


Figure 6.14 Total number of boat loans disbursed by boat-type over the period 1986 to 1998: a) historical data, b) simulated tuned data and, c) simulated untuned data.

The simulated data from the tuned model has been reasonably successful in replicating part of the historical distribution of loans disbursed (Figure 6.14b). Although a greater number of small boats was purchased between 1986 and 1989, the model has reproduced the peaks of 1990 and 1993, and the simulated number of small boat loans has increased from 1996 onwards. The tuned model has not, however, simulated the same order of

magnitude of small boat loans after the introduction of the YES initiative. In contrast, the simulated data from the untuned model does not show much resemblance to the historical data (Figure 6.14c).

6.4.4 Socio-economic attributes

There is little quantitative socio-economic information available regarding the Seychelles fisheries sector. In particular, data from the 1989 socio-economic survey of artisanal fishers did not allow identification of the proportion of fishers within each socio-economic group.

Without any additional information, the model was set up to simulate the number of fishers within each socio-economic group during 1986, using with same proportions of fishers within each group identified from the 1997 survey. Therefore, it has been assumed that the proportion of fishers within each socio-economic group has not changed substantially since 1986.

Given this assumption, the numbers of fishers within each socio-economic group and each different boat-gear category can then be estimated over the period 1986 to 1997. For example, the numbers of trap-only fishers within socio-economic group 1 were estimated from the proportion of fishers within group 1 and the historical number of trap boats in operation between 1986 and 1997 (Figure 6.15a). These are compared with simulated output from the tuned and untuned model (Figures 6.15b and 6.15c).

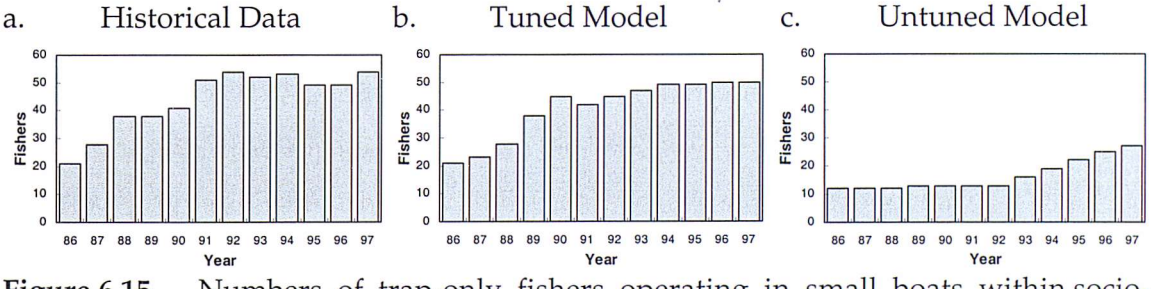


Figure 6.15 Numbers of trap-only fishers operating in small boats within socio-economic group 1 (owner-operators) over the period 1986 to 1997: a) estimated historical data b) simulated tuned data and, c) simulated untuned data.

The total numbers of fishers within each socio-economic group of different boat-gear categories for the estimated historical data and simulated tuned and untuned model are presented in Appendix 6.1. Generally, there is a good level of agreement between the number of simulated fishers for the tuned model within each socio-economic group and the estimated historical numbers.

6.5 TUNED PARAMETER VALUES

The previous sections have identified the parameter values which were used to tune the simulation model, and compared the results of the simulated output from the tuned and untuned model with actual historical data. This section describes how the selected parameter values have changed during the tuning process.

6.5.1 Technical attributes

Proportion of traps used by trap and handline fishers

Only the proportion of traps was selected for the trap and handline boat-gear category for tuning purposes. The proportion of traps used by fishers within the tuned model was decreased from 0.78 to 0.60 (Table 6.10). The most important effect of this action was to reduce the level of reef catches in the total catch of the trap and handline boat-gear category without reducing the total catch of inshore demersal fish (cf. Figure 6.11).

Table 6.10 The untuned proportion of traps used by fishers operating both traps and handlines during the base run, the observed range within the historical data and final tuned parameter value.

	Untuned	Tuned
Proportion of traps used	0.78	0.60

The proportion of traps used by trap and handline fishers within the tuned model (0.60) is equivalent to approximately 3 traps per fisher.

Number of days spent fishing per year

For tuning purposes, the range of the number of days spent fishing each year was assumed to be between 0 and 365. The results of the simulated output from the tuned model, however, show that the average number of days spent fishing remained similar to the output from the untuned model (Figure 6.16). Details of the average number of fishing trips per year from both the tuned and untuned model are given in Appendix 6.2.

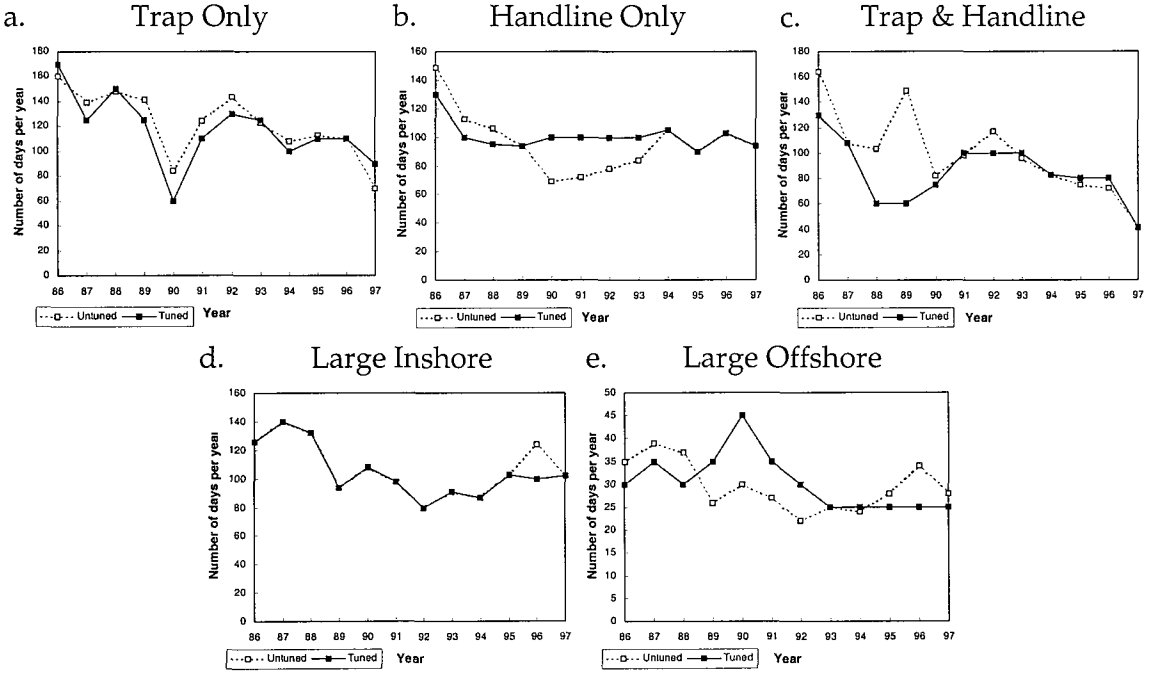


Figure 6.16 Average numbers of fishing trips per year from untuned simulation model (dashed line) and tuned simulation model (solid line) over the period 1986 to 1997. For fishers operating in small boats: a) trap-only b) handline-only c) trap and handline; for large boats d) inshore handline-only and, e) offshore handline-only.

Boat replacement

The annual percentages of boat replacements within the untuned model were constant, set at 7 percent for small boats and 4 percent for large boats. The numbers of annual boat replacements were expected to lie between 0 and 25 percent of the total

numbers of small and large boats (cf. Table 6.4). The final tuned percentages of annual boat replacements over the period 1986 to 1997 are given in Table 6.11.

Table 6.11 Tuned values used to estimate the annual percentage of boats replaced.

Year	86	87	88	89	90	91	92	93	94	95	96	97
Small	1	1	1	10	7	7	10	7	7	25	25	25
Large	2	2	15	15	15	15	15	15	15	15	15	15

Small boats show a large range of the annual percentages of boats replaced (1-25%). Although the simulated output for small boat loans from the tuned model is comparatively similar to the actual historical data between 1986 and 1997 (cf. Figure 6.15), the tuned model was unable to replicate the very high level of small boat loans observed between 1996 and 1998. Similar values could be obtained, however, if exceedingly high percentage values of annual boat replacement were used. However, these values (50-80%) are a considerable distance outside the specified range, and they were therefore not selected for the tuned model.

In comparison, large boats show a smaller range of the annual percentage of boats replaced. With exception to 1986 and 1987, annual percentage of large boat replacement is constant over the simulation period. This may reflect that larger boats are considerably more expensive to purchase, and require a longer period of financial planning.

6.5.2 Economic attributes

The average daily operating costs were adjusted for each boat-gear category (Table 6.12). The results of the tuned model show that the average daily operating costs for trap-only fishers (boat owner-operators), has reduced by 50% from the original untuned model. The effect of reducing the operating costs is to increase the profitability of the boat-gear category, such that the number of boats and crew increased over the period 1986 to 1994 (cf. Figure 6.13). Small or no changes were made to the operating costs for the remaining small boat-gear categories.

Table 6.12 Average daily operating costs observed for each boat-gear category.

Boat-gear category	Average operating cost per day (SR)	
	Untuned	Tuned
1. Trap-only	300	150
2. Handlines-only	445	460
3. Trap and handlines	300	300
4. Large inshore boat, handlines-only	750	1,000
5. Large offshore boat, handlines-only	1,250	750

The daily operating costs of both large boat-gear categories were almost completely reversed. The low operating costs for large inshore boats within the untuned model had substantially increased (+33%), whereas the costs associated with operating a large offshore vessel were observed to decrease (-40%). Further investigation of the operating costs reveal this may be due to the availability of obtaining ice. Ice is an expensive operating cost, but it is obtained free of charge for large offshore vessels on a contract with Oceana fish centre. This is discussed in more detail in Section 6.6.2.

6.5.3 Socio-economic attributes

Required percentage increase in profits

With the exception of crew members on large boats, the percentage increases in the required level of net annual income for fishers to switch to an alternative boat-gear category have decreased after tuning (Table 6.13).

Table 6.13 Required percentage increases in the level of net income for fishers within the artisanal fishery to switch to an alternative boat-gear category.

	Boat type	Untuned	Tuned
Crew members	Small	100	50
	Large	100	200
Owner-operators	Small	100	75
	Large	100	75

Crew members of small boats were more likely to switch to an alternative small boat-gear category (50%) than owner-operators (75%). In contrast, crew members of small boats required a very large increase in their expected level of net income before they considered switching to crew a large boat (200%).

A similar pattern was observed in the expected percentage increase in the level of net income available for pool members looking to enter the artisanal fishery (Table 6.14). With the exception of crew members of large boats, the expected percentage increase in the level of net income was less than that of fishers within the fisheries sector (125%).

Table 6.14 Required percentage increases in the level of net annual income for pool members who are looking to enter the artisanal fishery.

	Boat type	Untuned	Tuned
Crew members	Small	100	25
	Large	100	200
Owner-operators	Small	100	25
	Large	100	25

Personal savings

The initial savings as a percentage of the minimum acceptable level of net income at the start of the simulation increased after tuning (Table 6.15). An initial level of savings was required to ensure that fishers were capable of purchasing boats at the start of the simulation period. In the untuned model, however, the initial level of savings was set too low and therefore prohibited the purchase of large boats with a loan and prevented the observed increase in the number of large inshore boats during 1986 and 1992 (cf. Figure 6.12).

Table 6.15 Initial savings as percentage of net annual income at start of simulation by socio-economic group.

Socio-economic group	Untuned	Tuned
1	10	75
2	10	75
3	10	75
4	10	75
5	10	75

A proportion of the total net income, after the deduction of living costs, was also saved each year the fisher was in profit. Following tuning of the model, the annual proportion of net income saved was reduced from 10% to 5% for all socio-economic groups (Table 6.16). The reduction in annual savings provided a more realistic level of personal savings, which may control the ability of a fisher to purchase a boat.

Table 6.16 Proportion of net annual income saved each year, after the deduction of living costs, by socio-economic group.

Socio-economic group	Untuned	Tuned
1	10	5
2	10	5
3	10	5
4	10	5
5	10	5

If the proportion of net income saved each year remained at 10% or higher, all fishers became very rich. This unrealistic result also enabled fishers to live off their savings during periods of low income.

6.6 Discussion

This chapter has described the methods used to tune specific parameter values of the simulation model. The performance of the tuned model has then been tested by a visual comparison of the simulated model output with a selection of historical economic,

technical, economic and socio-economic attributes of the artisanal fishery.

In most cases, the results have shown that the tuned model is capable of simulating output which replicates a broad range of actual historical trends within the Seychelles artisanal fishery. The following sections describe in more detail the simulated output from the tuned model with respect to the biological, technical, economic and socio-economic attributes of the fishery.

6.6.1 Biological attributes

The tuned simulated model showed that it was successful at replicating the historical levels of catches retained by all small boat-gear categories, and the majority of large offshore boats. The most influential parameter used to tune the model for biological attributes was the annual numbers of fishing trips. Although the numbers of trips were originally estimated from secondary sources of data, a high level of uncertainty remains in these parameter values.

The annual numbers of fishing trips is an average taken across a wide range of fishers. For example, the soak time of different traps (2 - 48 hours), and the number of days per week spent fishing (3 - 7 days) are both highly variable between individual fishers. Climatic conditions are also known to effect the number days spent fishing per year.

The model was weakest at simulating the historical catches of large inshore boats. Increasing the annual numbers of fishing trips could have been used to boost the under-estimated simulated catches retained by large inshore boats between 1990 and 1992 (see Figure 6.3b). This action was not undertaken, however, because although the simulated number of large inshore boats were similar to the historical values (Figure 6.12b), it was found that the simulated numbers of crew members operating on large inshore boats had also been under-estimated between 1990 and 1992 (Figure 6.13b). This reduction in the expected number of crew members led to the observed decrease in the level of simulated total catches.

6.6.2 Technical attributes

Simulated output from the tuned model showed that it was also successful at replicating the numbers of boats in operation. Although several parameters are responsible for simulating the number of boats, it was found that the daily operational costs were most influential in fine-tuning the model.

Trap-only fishers in small boats have been given the lowest daily operating costs (Table 6.5). These costs, however, do not include those associated with replacing traps. Trap-only fishers are otherwise capable of minimising their costs by reducing the time spent at sea. Trap-only fishers usually undertake 1-2 trips per day in order to check and reset their traps. In contrast, handline fishers require bait, and they usually fish for longer periods, moving between different fishing grounds.

It is not surprising that large boats have the most expensive daily operational costs. It is interesting however, that after tuning, large inshore boats have higher operational costs than large offshore boats (cf. Table 6.5). In the model, all large offshore boats are assumed to have a contract to sell their catches directly to a fish centre. Although poor fish prices can reduce their total gross revenue, all contract boats are eligible to collect free ice from the fish centre (Tirant, Oceana Pty Ltd., pers. comm., 1998). This provides an important incentive which acts to reduce their overall operational costs.

In contrast, all large inshore boats within the model sell their catch directly to the domestic market. The increase in fish prices that this brings helps to maintain a higher total gross revenue from their fishing activities, but they are also required to pay for all consumables, including ice. The daily operating costs associated with large inshore boats may therefore be substantially greater than those for large offshore boats.

6.6.3 Economic attributes

The tuned simulation model was capable of replicating reasonably the number of small and large boat loans disbursed between 1989 and 1995. Prior to 1989, however, the model simulated a higher number of small boats purchased with a loan.

The historical data show that prior to 1989, the number of small boats contained a high proportion of pirogues. These small wooden boats are relatively cheap and may not

require a loan for their purchase. These have not been simulated within the model. A proportion of fishers may therefore have chosen to purchase pirogues without a loan, rather than a fibre-glass skiff with a loan.

The tuned proportions of boats required to be replaced each year were surprisingly high (cf. Table 6.3), particularly after 1995. Even with these high proportions, the simulated output from the tuned model was substantially smaller than the total number of boats purchased with loans between 1996 and 1998 (cf. Figure 6.13). This observed sudden increase in the number of small boat loans, has been attributed to the introduction of the government YES soft loan initiative, introduced in 1996.

It is significant, however, that although the numbers of small boat loans have increased vastly since 1995 (cf. Figure 6.15), the average historical numbers of fishing boats do not show the same pattern of increase over that period (cf. Figure 6.12). Small boats may be purchased with a loan for several reasons. First, in keeping with the objectives of the YES soft loan initiative, young entrepreneurs may set up and operate their own fishing operations, thereby reducing the level of unemployment among young Seychellois. Second, the scheme is also used by older, more experienced fishers who are looking to replace their existing ageing boats. Both these processes have been included explicitly within the simulation model.

There remains, however, an undocumented number of boats which have been purchased under the YES soft loan initiative that have not entered the commercial fishery. Informal interviews confirmed that a group of young fishers have used the YES initiative to purchase their own boat for 'recreational' purposes only. These have therefore not been recognised and recorded within the SFA catch assessment survey as additional commercial boats. Unfortunately, there is no quantitative information on the number of these vessels, which otherwise could be subtracted from the number of commercial small boat loans between 1996 and 1998.

It is believed that a maximum of 25% of the total number of small boats can be replaced in a single year. This suggests that between 1996 and 1998, approximately 150 small boats have been purchased by young Seychellois for recreational purposes only.

6.6.4 Socio-economic attributes

Assuming that the proportion of fishers within each socio-economic group has not changed substantially since 1986, the tuned model has been successful in replicating the expected numbers of fishers within each socio-economic group in the majority of cases.

The model was weakest, however, at simulating output for the historical numbers of crew members in large boats. This was first highlighted in the previous section after the tuned model had under-estimated the total level of catches made by large inshore boats between 1990 and 1992. Additional information specific to this group of fishers may be required.

The number of crew members in large boats can be partly controlled by the percentage increase in net annual income required to change boat-gear categories. It has been noted earlier in the results that this parameter value has been set very high in the tuned model (200%). This acts to constrain the number of fishers becoming a crew member in a large boat. For many crew on small boats, the prospect of spending several days at sea per trip, rather than a maximum of one, is not attractive.

6.6.5 Summary

This chapter has evaluated the performance of the model to match historical trends in the biological, technical, economic and socio-economic attributes of the Seychelles artisanal fishery. Before final comparisons between the simulated and historical trends were made, a process of tuning was undertaken. A description of the parameter values selected and the methods used to tune the model are also given.

The tuned model performed well at replicating the historical levels of catches retained by all small boat-gear categories, and the majority of offshore boats. The most influential parameter used to tune the biological attributes was the number of fishing trips per year.

The simulated output showed that the model was also successful at replicating the numbers of small and large boats in operation. Daily operating costs were found to be the most influential in tuning the number of boats in operation.

The number of loans disbursed over the period 1989-95 were reasonably well represented, although the model was unable to match the high level of small boat loans disbursed under the government YES initiative. A number of reasons were put forward to explain this observation, including that an undocumented number of small boats have been purchased under the scheme, but these have not yet entered the commercial fishery.

Having established that the model has performed well at matching the historical data, greater confidence can now be attached to model predictions of the outcomes of future scenarios management. An evaluation of alternative management policies is given in the next chapter.

7 AN EVALUATION OF ALTERNATIVE MANAGEMENT OPTIONS

7.1 INTRODUCTION

The bio-socio-economic model was described in Chapters 4 and 5. As described in Chapter 6, the model parameters were tuned by a selection of parameters. The performance of the model was also evaluated by its ability to replicate historical trends in the Seychelles fishery's biological, technical, economic and socio-economic attributes. The good agreement between historical and predicted trends achieved enables greater confidence to be placed in the way key processes have been modelled, in particular the socio-economic decision processes within the artisanal fishery. In turn, increased confidence can be placed on model predictions of the outcome of future decisions.

The current government policy to provide soft loans in order to promote the offshore demersal fishery and alleviate the high level of fishing effort exerted within the inshore region has to date met with little success (see Chapter 1). This chapter identifies a range of alternative management policies which could be imposed directly by the government. Due to lack of data, it was not possible to simulate either the spatial or seasonal movement of fishers within the artisanal fishery. Consequently, closed areas and/or seasons have been excluded from the evaluation.

The aim of this chapter is to use the model to predict future outcomes for the artisanal fishery under a series of alternative management policies. The performance of each management option is evaluated using a number of biological, economic and socio-economic performance measures. Finally, each management option is ranked in comparison to the current policy in place, based on a number of management criteria. These criteria examine whether inshore fish stocks recover to sustainable levels, and whether the distribution of employment and income are equitable.

Section 7.2 describes the selection of alternative management options from a range of input control methods. Details of the biological, technical, economic and socio-economic performance measures used to evaluate the performance each policy are described in Section 7.3. The outcome of each management option are then evaluated in terms of the overall objectives of the study (Section 7.4).

Section 7.5 outlines the methods used to rank each policy for a number of biological, economic and socio-economic attributes. The performance of each policy is then re-evaluated under a number of future scenarios in Section 7.6. Finally, the overall performance of each alternative management option is reviewed in Section 7.7.

7.2 ALTERNATIVE MANAGEMENT OPTIONS

Under the existing institutional management of the Seychelles artisanal fishery, the resource base within the inshore region has now become fully or over-exploited. In an attempt to help alleviate the high level of fishing pressure within the region, allowing the inshore stock to recover, a number of alternative management options have been put forward.

Only input control measures (e.g. restricting effort levels), have been used in the formulation of alternative management options (see Section 4.3, Chapter 4). Output controls, such as total allowable catches (TACs), are considered unsuitable within a multi-species fishery (Gulland, 1983). Also, although it is recognised that co-management may be used as a management tool, the present study has focussed solely on management options available to government.

In total, three forms of alternative management have been selected for evaluation. These consist of further manipulations to the current soft loan scheme and introducing gear and access restrictions within the inshore region. To provide a benchmark against which to compare the performance of the alternative options, the performance of the current management policy will also be examined.

When evaluating the performance of each alternative management option, it has been assumed that there is 100% compliance from the fishing community, and that there are no illegal fishing activities.

7.2.1 Loan system

Although most recent attempts to encourage fishers to purchase larger boats have met with limited success, results from informal interviews suggest that there is a high

proportion of fishers still interested in acquiring a loan. This suggests that additional loan options may help alleviate the level of fishing pressure within the inshore region. These loans aim to provide a number of financial incentives for fishers to purchase larger vessels capable of exploiting resources further offshore.

Manipulation of the loan system also requires minimal interaction between the management institution and the fishing community. On that basis it may be considered an attractive option over alternatives that require greater management intervention. A number of potential options are examined:

Reduction of interest rates for purchase of large boats

Existing repayment costs associated with large boats purchased with a loan lie beyond what many fishers can afford to pay. A reduction of the current interest rate would provide a financial incentive to purchase a large boat by reducing the total size of the capital sum required.

The first alternative policy investigated therefore involves a reduction in interest rates from 10% to 8% on loans suitable to purchase a large boat. A similar reduction in the monthly repayment could have been simulated by increasing the repayment period.

Increase interest rates for purchase of small boats

In contrast to providing financial incentives to purchase large boats, financial disincentives can be introduced to dissuade fishers from purchasing small boats. All YES soft loans which have been used by fishers to purchase small boats are interest-free. An obvious alternative management option is to increase the interest rate on loans used to purchase small boats. The interest rate for small loans have therefore been increased from 0% to 6%. The latter value is the highest level of interest currently paid for a loan of this size from a commercial bank.

Adjust both interest rates simultaneously

Adjustments to a single rate of interest which target either potential small or large boat owner-operators may, by itself, fail to provide sufficient incentives for fishers to move. Consequently, the management option combining both financial incentives and disincentives described above, is also investigated.

Restrict loan availability for purchase of small boats

A final option involves restricting all loans for the purchase of small boats. Effectively, this is equivalent to eliminating the YES soft loan initiative. This extreme action is expected to prevent any fishers who cannot afford to purchase a small boat without a loan from entering the inshore region as a boat owner-operator.

7.2.2 Gear restrictions

A more direct input control measure than that offered by the loan system is the imposition of gear restrictions.

In general, handline fishers use only a single mono-filament line. Reducing the level of fishing effort by handline fishers therefore requires a reduction in the actual number of fishers. Since the number of crew per small boat has remained stable over the period 1986 to 1997, and actually declined for large boats, the number of handlines may be controlled directly by restricting boat entry. This is described in a separate section below.

In the model, the number of traps deployed is determined by crew size. Hence, a larger number of crew will be able to use a higher number of traps. Imposing a maximum number of crew per boat therefore controls the maximum number of traps used.

Reduce number of traps used

Two alternative management options have been used to reduce the number of traps used per fisher. The first imposes a moderate 25% reduction in fishing effort, from an average of 4.7 traps per fisher to 3.5 traps per fisher. A second, more severe restriction

on trap fishing effort that is investigated imposes a 50% effort reduction to a maximum of 2.35 traps per fisher.

7.2.3 Boat restrictions

The total level of fishing effort can also be reduced by restricting the number of boats in operation within the inshore region. The number of boats may be controlled by introducing a fixed licence fee for different boat types, without placing any actual restrictions on the maximum number of boats. Alternatively, the number of boats may be physically constrained by introducing a limited licence scheme, without an increase in the nominal boat licence fee (SR125).

Licence fee

The introduction of a fixed licence fee for different boat types is expected to reduce the number of fishing boats within the inshore region. This is because not all current fishers are expected to be able to afford an increased annual licence fee.

Three alternative licence fee management options are investigated. The first introduces an initial licence fee of SR8,000 for all small boats. This fixed licence fee is equivalent to removing the total value of their annual fuel subsidy.

A substantial number of large boats are also known to operate within the inshore region (Mees, 1996). A second management option introduces an additional licence fee of SR13,000 for all large boats operating within the inshore region. Similar to the fixed licence fee introduced for small boats, this amount is equivalent to removing the total value of their annual fuel subsidy.

Finally, a third much higher licence fee is introduced for all inshore boats (small and large). A fixed annual licence fee of SR20,000 is considerably higher than either of the other management options and is expected to severely restrict the number of boats operating within the inshore region.

Limited access

The number of boats within the inshore region can also be physically controlled by introducing a limited licence scheme. The outcome of introducing four levels of boat access are investigated. These involve increasing levels of access restriction, which in turn are expected to be more difficult to implement.

The first option is to set the maximum number of boats within the inshore region at a level equivalent to the current level of fishing effort. This has the effect of restricting any additional fishing effort from entering the inshore region. If, however, a boat drops out of the inshore fishery, an additional boat may be given a licence to maintain the same number of boats. Within this scenario, it has been assumed that existing boats do not become more efficient, and consequently that there is no increase in fishing power. Furthermore, it is assumed that no additional boats are likely to enter the fishery upon the announcement of a licence scheme, which were not previously recorded in the statistics.

A second option reduces the maximum number of all inshore boats to 75% of their current level. A different method of achieving this is applied to small and large boats. In an attempt to facilitate the practical introduction of this management option, the numbers of small boats are permitted to decline gradually by preventing ageing boats to be replaced. Thus, as owner-operators of small boats leave the fishery, no additional small boats are permitted to enter. Similar to the previous option, new boats are allowed to enter the fishery, provided the total numbers stay below the permitted maximum. In contrast to small boats, due to their increased life-span, large boats they have the potential to remain in the fishery for much longer. For this reason, a proportion of owner-operators of large boats are immediately required to leave the inshore region.

A further reduction in the number of inshore boats (small and large) is also tested. By reducing the number of inshore boats to 50% of their current level, instead of 75%, a considerable number of fishers within the artisanal fishery will be affected. The same procedures are used to reduce the level of fishing effort as those described above to reduce the maximum number of boats to 75% of their current level.

From the initial base run and other secondary sources of data, it is known that large boats retain the highest catches within the inshore region (Mees, 1996). It also appears that owner-operators of small boats are less wealthy than those of large boats (present study; Mees *et al.*, 1998). As a result, the last option investigated places a greater restriction on large boats. This alternative management option therefore maintains the current level of fishing effort by small boats, but reduces the number of large inshore boats by 50%.

7.2.4 Mixture of alternative management options

During evaluations of the performance of each alternative management option described above, the simulation model predicted that after restricting boat access to the inshore region, many original boat owner-operators decided to become crew members. Although the number of boats had therefore reduced, the total level of fishing effort remained comparatively high.

To counteract this, a restriction on the number of boats *and* crew members was introduced as a final measure. Restricting the number of crew members was simulated within the model by reducing the maximum number of crew per boat. In total, the number of small boats were kept the same, although the maximum number of crew per boat was reduced from 5 to 3, and the number of large inshore boats were reduced to 50% of their current level.

7.2.5 Summary of alternative management options

The following table provides a summary of the alternative management options tested with the simulation model of the artisanal fishery (Table 7.1).

Table 7.1 List of alternative management options simulated within the model to help alleviate the high level of fishing pressure within the inshore region.

No.	Description
	Control
1.	• No restrictions placed on artisanal fishery
	Manipulation of current loan system
2.	• Reduce interest rate for large boats (from 10% to 8%)
3.	• Increase interest rate for small boats (from 0% to 6%)
4.	• Adjust interest rates for both small and large boats (as above)
5.	• Restrict loan availability for all small boats
	Gear restrictions
6.	• Reduce number of traps per fisher by 25% (4.7 to 3.5)
7.	• Reduce number of traps per fisher by 50% (4.7 to 2.35)
	Boat restrictions
8.	• SR8,000 licence fee for small boats only
9.	• SR8,000 licence fee for small boats and SR13,000 large boats
10.	• SR20,000 licence fee for all inshore boats
11.	• Maintain existing level of small and large boat numbers
12.	• Decrease all inshore boats by 25% of existing level
13.	• Decrease all inshore boats by 50% of existing level
14.	• Maintain existing small boats and decrease large inshore boats by 50%
15	• Maintain existing small boats and decrease large inshore boats by 50%, and, restrict total crew size of small boats from 5 to 3 fishers.

7.3 MANAGEMENT PERFORMANCE MEASURES

Chapter 4 first introduced a series of measures which can be used to evaluate the performance of alternative management options. These are now described in more detail.

7.3.1 Biological

It is important to quantify the level of risk to the resource associated with alternative management options. There have a been a wide variety of measures used for the assessment of stock biomass. The most common of these performance measures relate to the proportion of times that the stock biomass B falls below a threshold biomass B_{thr} $P(B<B_{thr})$. The literature demonstrates that many threshold values have been proposed, although $0.2B_0$ (Beddington and Cook,1983; where B_0 is virgin biomass), $0.5B_{MSY}$ (Getz *at al.* 1987; B_{MSY} is the biomass associated with the maximum sustainable yield), are regarded as the most popular (Francis and Shotton, 1997).

In this study, the level of stock biomass is assessed as a proportion of the simulated biomass at successive 5 year intervals to the level of biomass associated with the maximum sustainable yield ($B_{(yr)} / B_{MSY}$). If the ratio is less than 1.0, the stock is currently below that required to obtain the maximum estimated sustainable yield, and should be viewed with caution. If the ratio is above 1.0, the value indicates that the stock is relatively lightly or under-exploited.

In addition to stock biomass, the status of the fishery can be monitored through the level of total catch. The long term sustainability of the resource can be measured by the level of catches relative to maximum sustainable yield ($C_{(yr)}/C_{MSY}$). Cumulative relative catches over successive 5 years intervals have been assessed to determine which option provides the greatest catch level. However, catch levels must be interpreted in conjunction with the status of the stock. For example, relatively 'good' catches taken when the stock is below MSY level may place the stock in considerable danger of collapse.

7.3.2 Technical

The number of active boats within the fishery provides an indication of the level of capital investment within the fisheries sector. More importantly, it also provides a measure of the relative success of alternative management options in relocating fishing effort further offshore. In evaluating the performance of alternative management options, the aim is to reduce the number of fishers operating on board small and large boats within the inshore region.

The success in reducing fishing effort can be measured by the proportion of small boats remaining in the fishery at successive 5 year intervals, relative to the number at the start (i.e. $b_{(yr)}/b_{(1998)}$). If the ratio is 1.0 or above at the end of each projection period, the number of small boats has remained the same or increased. Ideally, this ratio should fall below 1.0, demonstrating that the number of boats operating within the inshore region has declined.

7.3.3 Economic

Management options involving soft loans and fuel vouchers effectively require government to subsidise the fishery. The greater the amount of incentives, the greater the amount of subsidy.

The government must also decide if the level of subsidy cannot be used better elsewhere within the economy. For example, subsidy funds could be used to improve employment opportunities outside the fisheries sector, thus raising fishers' opportunity cost of labour.

The total cumulative cost to government of the soft loan scheme over successive 5 year intervals is calculated from the difference in value between boats purchased under the development loan schemes and at the commercial bank rate.

The cost of the fuel voucher scheme is equivalent to the number of boats in operation. It is therefore assumed that each boat takes equal advantage of the scheme. The total cost to government is calculated as a cumulative total over successive 5 year intervals.

Total costs associated with the level of government subsidy can be balanced by setting higher boat licence fees. The revenue generated from higher licence fees assumes that each boat owner-operator complies with the new regulations.

The net value of the government subsidy is the cumulative total subsidy (soft loans and fuel voucher), minus the cumulative total licence revenue. This has been calculated over successive 5 year intervals up to a maximum of 30 years.

7.3.4 Socio-economic

Social well-being can be gauged on many different scales. However, for modelling purposes, a quantitative measure is essential. In this respect, a financial value has been used to approximate social well-being. This makes the assumption that an increase in the personal level of income will increase the level of social well-being.

Income per capita has been used to indicate social well-being for fisher groups (Charles, 1989). The average wage of workers in the fisheries and agriculture sector of the Seychelles during 1997 was approximately SR28,000 per year (MISD, 1997). The level of net income for fishers of different socio-economic groups within each boat-gear category has been calculated as a proportion of the average wage at 5 year intervals up to 30 years (i.e. $(I_{(yr)}/I_{(average)})-1$). If the level of net income is greater than the average wage, a positive value is returned. Conversely, a lower level of net income returns a negative value.

In addition to financial well-being, employment is also considered important in the literature (e.g. Charles, 1989; Healy, 1984). Employment within the fisheries sector, in conjunction with the level of boat purchase, can be used to indicate the relative success of alternative management options to relocate fishing effort away from the inshore region. Although the actual number of fishers is often used to as a measure of employment an employment rate as a function of the total available labour force has been used (cf. Charles, 1989).

In this study, the 'pool' represents both unemployed and 'potential' fishers otherwise currently employed. The proportions of fishers employed within each fishery ($L_{(yr)}$) at 5 year intervals up to a maximum of 30 years are measured as a ratio of the total available labour (L^*), the total number of fishers and non-fishers within the system. Hence, a proportion of the labour force is likely to remain outside the fisheries sector.

The proportions ($L_{(yr)}/L^*$) determine the total level of employment both within the fisheries sector and within each fishery. If an alternative management option has been successful in relocating fishing effort, the proportion of employment within the inshore fisheries should decline. Moreover, if appropriate incentives have been given, labour should remain within the fisheries sector, rather than moving to alternative employment

opportunities or unemployment.

7.4 AN EVALUATION OF THE SUCCESS OF ALTERNATIVE MANAGEMENT OPTIONS

The application of each alternative management option described in Section 7.2 has been simulated over a period of successive 5 year intervals up to 30 years into the future. This time period has been selected because, although decision-making processes of fishers may be subject to change over a shorter-term, a longer management period is required to ensure the biological recovery and sustainable exploitation of the inshore stocks. Furthermore, the success of the model in mimicking historical data suggests that decision-making processes have not changed substantially over the past 12 years.

To evaluate the relative success of each option, simulated output from the model must be directly compared with one another. This can be achieved using two methods. First, the outcome of each management option must be evaluated in terms of the overall study objectives and second, a comparative study can be used to rank those options that lead to the most successful outcome.

7.4.1 Biological performance measures

The status of inshore stocks is by far the most important attribute to consider when evaluating the performance of alternative management options. The overall aim of the study is to alleviate the high level of inshore fishing pressure and allow resources in the region to recover to an optimum level of exploitation (i.e. B_{MSY}). Obviously, failure to ensure this recovery constitutes poor performance for a management option. However, recovery to biomass levels well above B_{MSY}, thereby leaving the resource under-exploited, also constitutes poor performance in terms of this objective.

By far the most heavily exploited resource is the inshore demersal stock. The performance of each management option in terms of the status of this specific resource is given in Figure 7.1. It is surprising that some alternative management options can lead to a worse outcome than leaving the fishery under current management procedures. In particular, restricting the availability of loans for all small boats (management option 5), causes a substantial further decline in the stock.

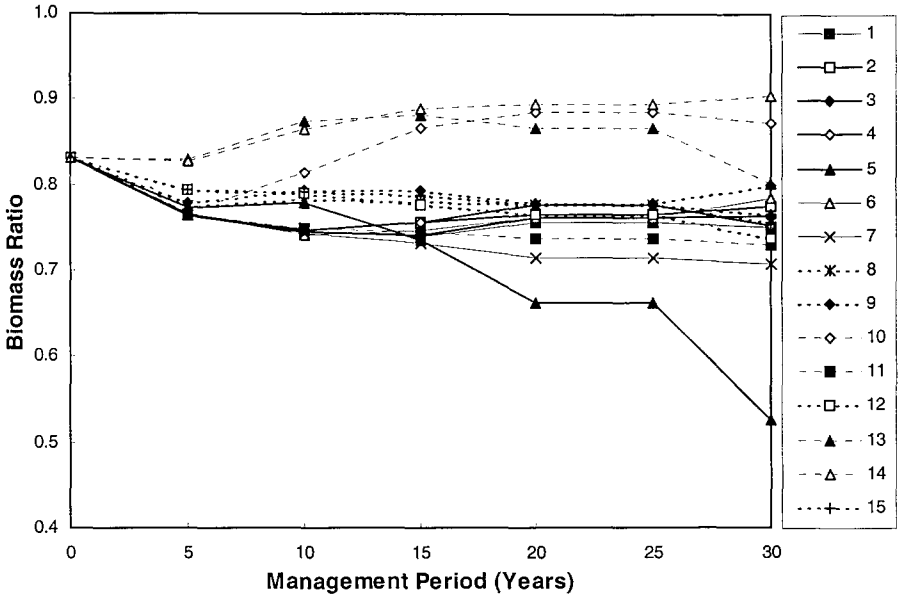


Figure 7.1 Estimated inshore demersal biomass ratio over a simulated period of 30 years for a range of alternative management options (1-15). Note y-axis does not start at zero.

Overall, only a few management options successfully led to an increase in the stock biomass. Unsurprisingly, these most effective measures are also the most draconian; introducing either a high licence fee (management option 10), or restricting boat access (management options 13 and 14).

The second most heavily exploited resource within the inshore region is that of the inshore reef. Biomass performance measures for each management option for the inshore reef resource are shown in Figure 7.2.

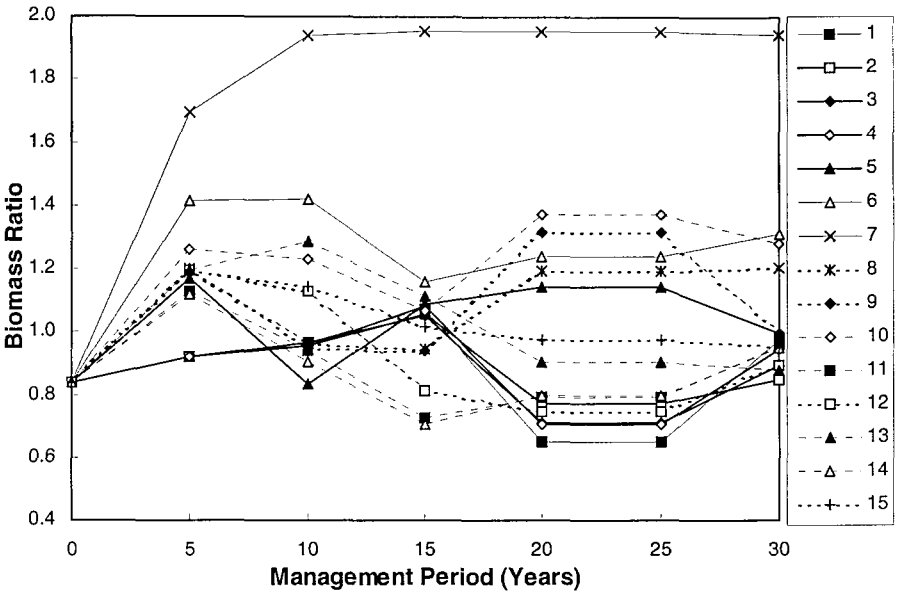


Figure 7.2 Estimated inshore reef biomass ratio over a simulated period of 30 years for a range of alternative management options (1-15). Note y-axis does not start at zero.

In contrast to the inshore demersal stock, the majority of management options enable the reef stock to recover. All the management options are therefore considered potentially suitable, although some are ranked higher than others. One of the management options, however has restricted the level of fishing effort to such an extent that the stock biomass returned to near the unexploited level (management option 7). Option 7 (reduction in the number of traps used) also led to a substantial decline in the level of catches (see Figure 7.3).

Estimated inshore reef catch ratio indicates that the majority of management options result in improved catches. New catch levels are just below that at maximum sustainable yield. This should enable the stock to continue to recover. With the exception of management option 7, options are considered to be performing adequately, although again some will be ranked higher than others.

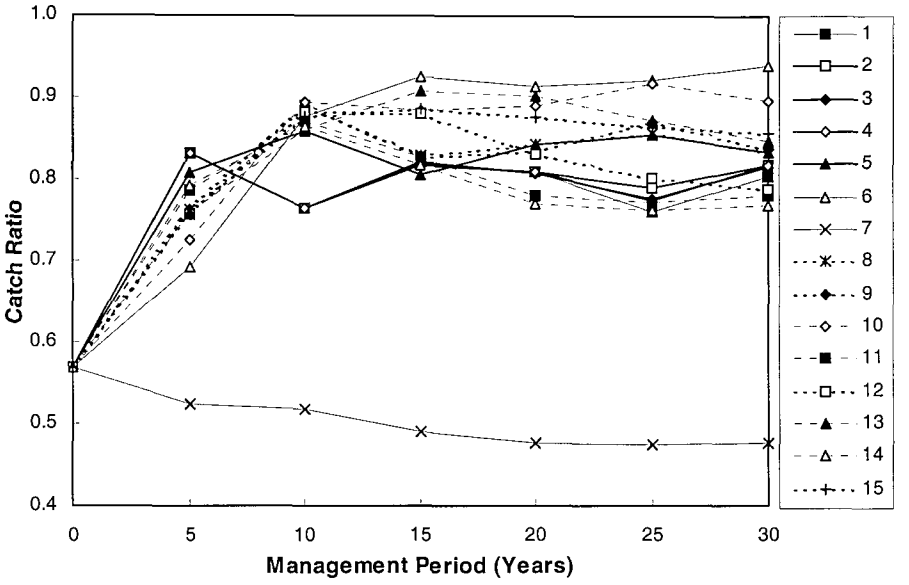


Figure 7.3 Estimated inshore reef catch ratio over a simulated period of 30 years for a range of alternative management options (1-15). Note y-axis does not start at zero.

The performance measures for the remaining technical, economic and socio-economic performance measures are included within Appendix 7.1.

7.5 RANKING OF SIMULATION RESULTS

The performance of alternative management options has been described by a series of performance measures. Management options have then been ranked according to how well their performance meets the management criteria described below.

7.5.1 Method of ranking

Management options were ranked in ascending order of their performance in matching a set of criteria for each model attribute. The management option which most closely met the specified criterion was assigned a rank of 1. This process was then repeated for all remaining options until all 15 had been ranked. Where 2 or more management options were equal, tied ranks were assigned to each. For example, if two management options were rated as joint 5th, a ranked score of 5.5 was assigned to each.

Criteria used to rank performance measures

The criteria upon which ranking was based were to a certain extent subjective and specific to each performance measure. Each criterion, however, aimed to measure a different aspect of the performance of different management options in their ability to ensure the long term recovery and optimal sustainable use of the inshore reef and demersal resources.

Biological attributes

- Over-exploited resources must show signs of recovery.
- Total catches from each resource should reach, but not exceed the maximum sustainable yield.

Economic attributes

- Income levels for inshore small boat owner-operators should stabilise or increase towards the national average for the sector.
- Very high income levels of large boats should decline, but should not fall below the national average.
- The lowest subsidy value implies the cheapest option for the government.

Socio-economic attributes

- Employment of all inshore boat owner-operators should see an overall decline. It is desirable, although not essential, to see an increase in the number of large offshore boat owner-operators.
- Employment of all inshore crew members should remain stable or show a decline. Increases are undesirable due to increased levels of fishing effort.
- Employment of offshore crew members should not decline. It is a bonus if the number of crew members in large offshore boats increases.

To complete the ranking exercise and facilitate comparison of results, all ranks were re-calibrated in relation to the rank of the first management option or 'control'. For each set

of ranks, the rank for each option was subtracted from the rank assigned to the control option. The re-calibrated rank of the control policy was therefore set at zero. The most successful options therefore had a high re-calibrated rank score, the least successful had a low score. A brief example for 5 hypothetical management options is given in Table 7.2.

Table 7.2 Example of re-calibration of ranked scores in comparison to management option 1 (control) for 5 management options.

Management Option	Initial Ranked Score	Re-calibrated Rank Score
1	4	0
2	5	-1
3	3	1
4	1	3
5	2	2

In this example, management option 4 is the most successful and has been assigned an initial rank score of 1. On re-calibration, it is ranked 3 higher than the control. Management option 2 is ranked below the control and has therefore been re-calibrated with a negative rank score (-1).

7.5.2 Biological attributes

Biological performance measures for both the inshore demersal and inshore reef resources have been described in Figures 7.1 and 7.2 above. The results for the offshore biomass have been excluded in all ranking exercises because they showed little or no fluctuation and the offshore resources remained lightly exploited (see Figure A7.1., Appendix 7.1). Total catches for the offshore region, however, have been included within the ranking process. Further details of the simulated output used for the biological ranking are given in Figures A7.1 & A7.2 (Appendix 7.1).

Summing re-calibrated rank scores for each of these biological performance measures resulted in the combined biological rankings shown in Figure 7.4.

The performance of management options varies considerably, as reflected in the wide

range of ranked scores. Given the biological criteria, management options 10, 13 and 14 have performed the best. Unsurprisingly, these attempt to reduce the greatest level of fishing effort.

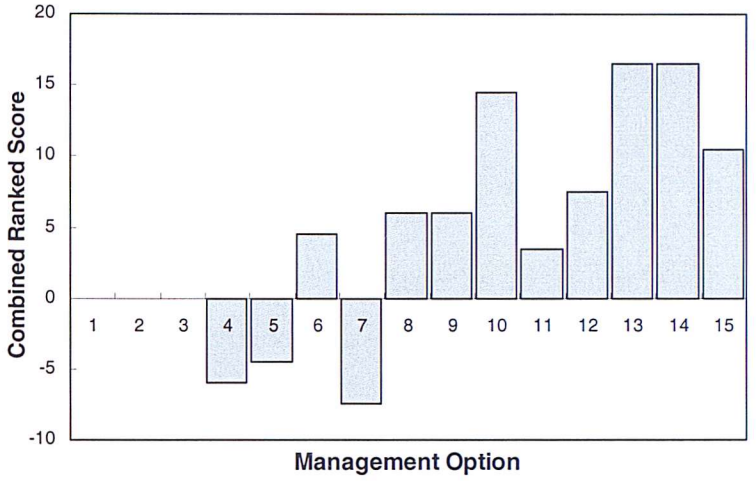


Figure 7.4 Re-calibrated ranked scores for biomass and total catches for each management option (1-15). Management option 1 has a rank score 0.

It is also necessary to identify which management options, if any, lead to a worse outcome than leaving the fishery at status quo. For the biological attributes, three alternative management options (4, 5 and 7) performed worse than the control. Management options 4 and 5 are both associated with changes to the loan system, while option 7 imposed severe gear restrictions.

7.5.3 Economic attributes

Two economic attributes were selected and ranked independently for each management option: total net income and total government subsidy.

The estimated net income ratio for owner-operators of each boat-gear category has been ranked from the simulated output shown in Figure A7.3 (Appendix 7.1). Results of the income ranking are shown in Figure 7.5. Ranking favoured those management options which increase the level of equity between fishers within the fishing community. The highest ranked options are those which lead to incomes closest to the national average for the fisheries and agricultural sector.

The results in Figure A7.3 (Appendix 7.1), show that restricting gear or boat access led to income levels far in excess of the national average (management options 3, 5, 9, 10 13 and 15). These options cannot be considered equitable since they enable a few fishers to become very rich. They were therefore assigned a low rank score. Management options which enabled the level of net annual income for fishers in small boats to remain stable or increase towards the national average were ranked highest (options 11, 12 and 14).

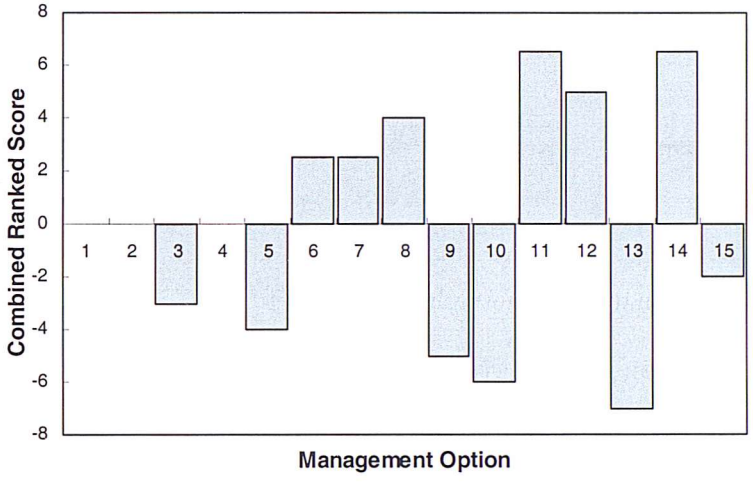


Figure 7.5 Re-calibrated ranked scores for level of net annual income for owner-operators of each boat-gear category under alternative management options (1-15). Management option 1 has rank score 0.

The total costs to the government associated with each management option are given in Figure A7.4 (Appendix 7.1). The cheapest option was given the highest ranked score. Figure 7.6 presents re-calibrated ranked scores summed across each boat-gear category.

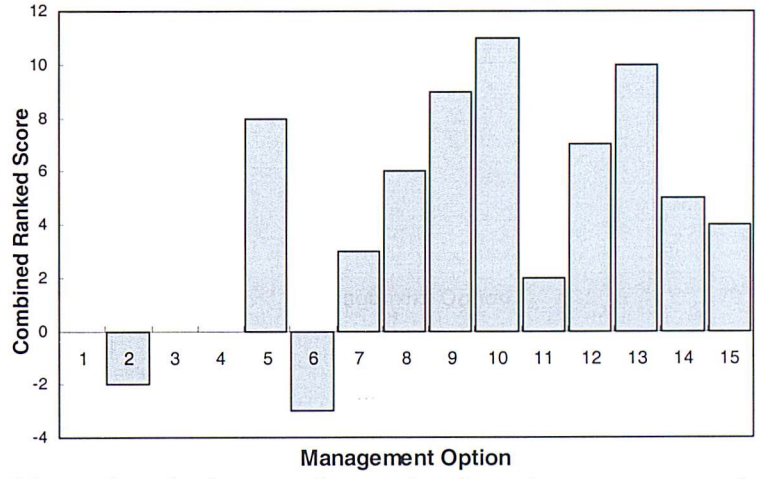


Figure 7.6 Re-calibrated ranked scores for total value of government subsidies for each management option (1-15). Management option 1 has rank score 0.

In general, management options that ranked highest in terms of subsidies were those introducing licence fees (8, 9 and 10) and those restricting boat access to the inshore region (11 to 15). Both types of management option scored well for different reasons. The introduction of licence fees primarily helps offset the total costs of the fuel subsidy and soft loan scheme. In addition, high licence fees may also deter some fishers from taking out a boat loan, which in turn reduces costs associated with the number of soft loans disbursed. Restricting boat access directly reduces both the number of boats purchased with a loan and consequently the level of fuel subsidy.

Imposing a loan restriction for all small boats (option 5) also performed notably better than the current management policy. Restricting loan availability reduces the costs associated with number of soft loans disbursed and therefore the total number of boats using the fuel voucher scheme.

In contrast, management options 2 and 6 performed worse than current management policy. A reduction in interest rates for large boats (option 2) had little or no impact on the fishery, but cost the government more in terms of soft loan subsidies. Imposing moderate trap restrictions (option 6), surprisingly increased the number of small boats within the trap fishery. Consequently, the level of government subsidy (soft loans and fuel voucher) increased in line with the number of new small boats.

7.5.4 Socio-economic attributes

The estimated number of owner-operators and crew members employed within the fisheries sector were estimated for each management option (Figures A7.5 and A7.6, Appendix 7.1). Based on the socio-economic management criteria described above, each management option was ranked on the total level of employment for both owner-operators and crew members within each boat-gear category (Figure 7.7).

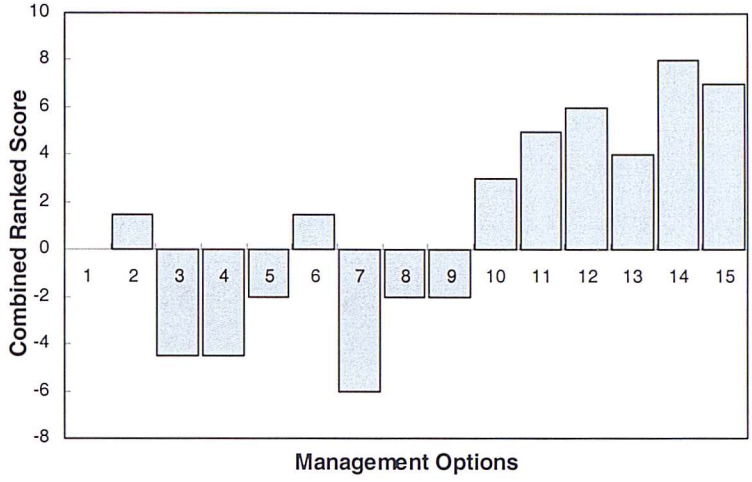


Figure 7.7 Re-calibrated ranked scores for the level of employment for both owner-operators and crew members within each boat-gear category for each management option (1-15). Management option 1 has rank score 0.

The ranked scores show that access restrictions were the only management options capable of reaching the target level of employment specified in the socio-economic criteria. Within the inshore region, the number of boat owner-operators must decrease in order to lower the level of fishing effort within the inshore region. This would not be sufficient, however, if many owner-operators then became inshore crew members. The level of employment for inshore crew members must therefore remain the same or decrease to gain a higher ranked score.

The most successful management option (14), reduced the level of boat owner-operators within the inshore region without increasing the number of crew members, in addition to increasing the number of large offshore boats and crew.

In comparison, management option 7 was ranked as the least successful. Although this option achieved a decrease in the number of inshore small boats, it surprisingly increased the number of large inshore boats and associated crew members. This also led to a further decrease in the inshore demersal resources (cf. Figure 7.1).

7.5.5 Total ranked scores

To gauge the overall performance of each management option, ranked scores were

aggregated over each attribute. This implicitly assumed that ranked scores from each attribute were of equal importance, and no additional weighting was applied to the results.

The total ranked scores for each management option are shown in Figure 7.8. From the results, each of the management options 6 and 8 to 15 differ from the control in terms of reducing the high level of fishing effort within the inshore region. It is necessary, however, also to analyse the contribution of various attributes to the total ranked score. As previously mentioned, the status of the inshore reef and inshore demersal resources are the primary concern.

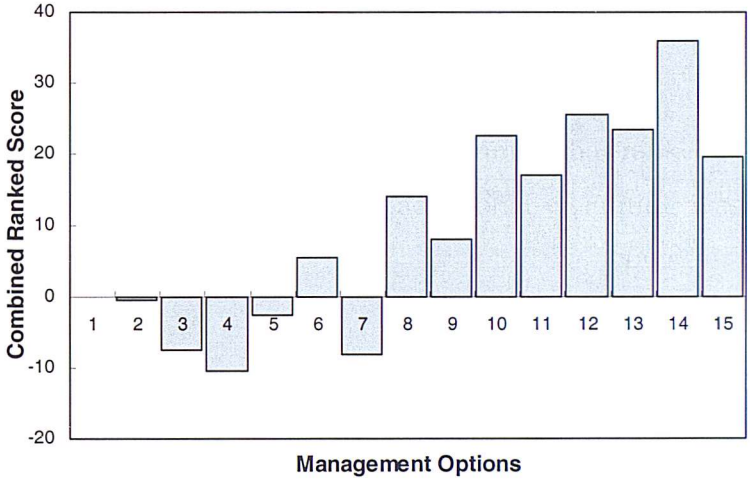


Figure 7.8 Re-calibrated total ranked scores over all performance measures for fishers within each boat-gear category for each management option (1-15). Management option 1 has rank score 0.

Management option 14 was ranked the most successful strategy in achieving the overall study aims. This option was also capable of increasing the inshore demersal stock biomass, without creating a small group of elite rich fishers (in contrast to option 13). Not only is option 14 most successful overall, it also scored highly on almost all of it's individual rankings.

Management options 11 and 12 also scored comparatively well. It should be noted, however, that they scored a high proportion of their ranks points from increasing the level of net income for inshore fishers. If further consideration of these management options were to be required, it would be necessary to reconsider the relative importance of their

contribution to alleviating the biological status of inshore resources.

Management options 8 to 10 (increase boat licence fees) generally performed much better than the current management policy. They each gave an overall improvement in the status of the inshore reef stock, and introduction of a licence fee obviously helped to reduce the level of government subsidy. They did not perform as well as management options 11 to 15, primarily because they enabled the level of fishing effort to increase on the inshore demersal stock, which consequently reduced net income levels.

Management options 3, 4, 5 and 7 performed worse than the current management policy (control option). These options failed to reduce the level of fishing effort on either the inshore reef or demersal resource, and as a direct result these stocks showed a further decline.

7.6 Evaluation of alternative management options under future scenarios

In the process of tuning the model, a sensitivity-type analysis was used to reduce the level of uncertainty in the most important parameters until observed trends matched the historical data as far as possible. The results of tuning a selection of parameter values (Chapter 6), showed that the model did particularly well in matching historical data. This gave greater confidence in the results described in Section 7.5, generated from future simulations of the model.

The model cannot however, be used for further sensitivity analysis without disrupting the historical trends established from the tuning process. Instead, a selection of parameters were investigated which were thought to change over time. New parameter values were now selected to reflect these changes *after* the historical period, so as to not alter the historical patterns.

7.6.1 Selection of future scenarios

A number of future scenarios (e.g. a sudden decline in stock biomass) were selected to model changes in the biological, economic and socio-economic parameters which were

* The values chosen in this section (±25%) are arbitrary and not estimates of the potential effects.

thought could change. Management options were then re-run under these new conditions in addition to management option 14, which was used as a benchmark.

Future scenarios were chosen from a range of biological, economic and socio-economic parameters which it was thought could change over the projected management period of the model.

Due to time constraints, not all alternative management options were re-run for each scenario. Instead, the effects of each scenario on a single management option (14) were examined. Following this, the future scenario identified as the most detrimental to the success of the examined management option was applied to all other management options (1-15). Results were examined to identify changes in the overall ranking of management options. to determine whether option 14 remains the most successful.

Biological

In 1998, the largest recorded world-wide coral bleaching event occurred. This damaged many shallow water coral reef ecosystems, including those of the Seychelles (Goreau *et al.*, 2000). The effects on the abundance of reef fish populations have yet to be established.

Examining the effect of a reduction in the biological status of the resource base can determine the possible effects of a variety of detrimental environmental impacts. In the model, two biological scenarios have been investigated: *

- 25% reduction in the abundance of all reef and demersal resources, and
- 25% reduction in the abundance of semi-pelagic species.

The first scenario addresses the concern expressed over the potential decline in reef and demersal resources as a result of the 1998 bleaching event.

The second scenario investigates the abundance of semi-pelagic resources within the Seychelles. Little or no information is known about their biology and distribution of abundance. The sensitivity of management options to changes in the original stock

biomass is therefore examined.

Economic

Owner-operators and crew of large offshore vessels have expressed concern over the poor level of remuneration they receive for the type of work they undertake. In the model, all large offshore boats sell their catch directly to Oceana fish centre, which generates a low revenue from poor fish prices. If fishers of large offshore boats were capable of selling their catch at a higher price, the offshore fishery may become more attractive. This is simulated in the model by increasing the price of demersal and semi-pelagic fish to their equivalent value on the domestic market.

- Increase offshore demersal fish price to equivalent domestic market value.

Socio-economic

The fisheries sector shows signs of an ageing workforce (cf. Chapter 2). This may decline further if young fishers cannot be attracted into the industry. In the model, the effects of reducing the number of available fishers was simulated by reducing the pool size by 25%.

Conversely, if other sectors of the economy were to experience high unemployment, the number of potential fishers within the pool may be expected to increase. To reflect this in the model, the number of fishers within the pool (for all socio-economic groups) has been increased by 25%. Changes to the national rate of employment may be expected to alter the minimum acceptable level of net income fishers are willing to receive (i.e. values may decrease). Without additional information and to simplify interpretation of the results, simultaneous changes to the minimum acceptable level of income have not been attempted.

- 25% decrease in the number of pool members, and
- 25% increase in the number of pool members.

A brief summary of the sequence of future scenarios are given in Table 7.3.

Table 7.3 Summary of future scenarios simulated for management option 14.

No.	Description
1.	Management option 14 (Control)
2.	Decrease in number of pool members (-25%)
3.	Increase in number of pool members (+25%)
4.	Increase fish prices for offshore fleet to match domestic market
5.	Decrease semi-pelagic stock biomass (-25%)
6.	Decrease both reef and demersal stock biomass (-25%)

7.6.2 Total ranked scores

Simulated model outputs for each performance measure and future scenario are given in Figures A7.7 to A7.10 (Appendix 7.2). Using the same management criteria for each performance measure used in the previous analysis (see Section 7.5.1), ranked scores have been calculated and are presented in Figure A7.13 (Appendix 7.3).

The aggregated ranked scores for each future scenario from each performance measure are given in Figure 7.9. With exception to scenario 2 (scenario 1 is the control), all have a negative impact on the success of management option 14 in promoting the sustainable recovery of inshore resources. By far the most detrimental scenario was a further reduction in the total biomass of both reef and demersal fish (Scenario 6, Figure 7.9).

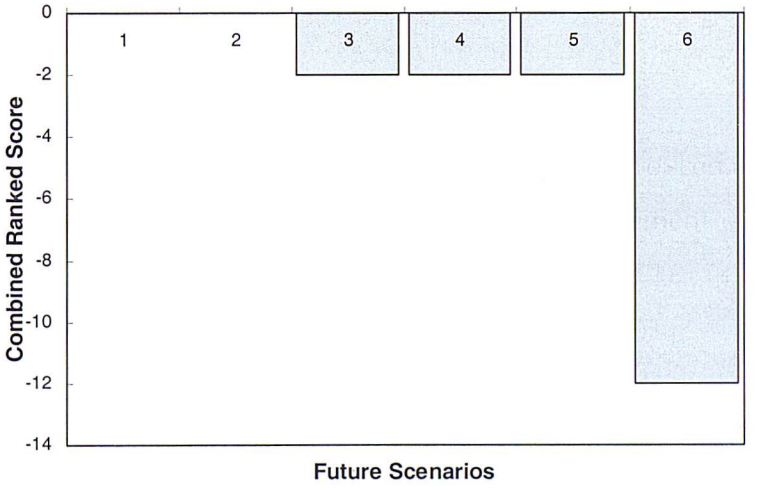


Figure 7.9 Re-calculated total ranked scores over all performance measures for fishers within each boat-gear category for each alternative scenario (1-6). Future scenario 1 has rank score 0.

7.6.3 Re-evaluation of alternative management options

A re-evaluation of all management options was undertaken to determine whether the previous best performing management option (option 14) remained the best option after a 25% reduction in both the reef and demersal stock biomass.

The simulated output for each management option for different performance measures are given in Figures A7.14 to A7.19 (Appendix 7.4). In addition to these, the ranked scores for each management for different performance measures are given in Figure A7.20 (Appendix A7.5). The following section describes the final results of total ranked scores.

Total ranked scores

As before, it was assumed that ranked scores from each attribute are of equal importance, and no additional weighting has been applied to results. The total ranked scores for each management option are shown in Figure 7.10.

It should be noted that after a 25% reduction in the stock biomass of both reef and demersal resources, the majority of management options performed much better than the current management policy (cf. Figure 7.8).

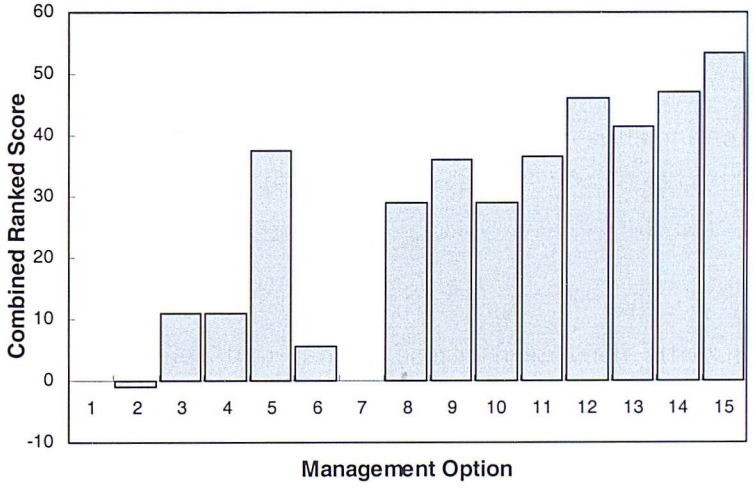


Figure 7.10 Re-calibrated total ranked scores over all performance measures for fishers within each boat-gear category for each management option (1-15) after 25% reduction in reef and demersal stock biomass. Management option 1 has rank score 0.

It is reassuring that management option 14 retained a high position, ranked second overall. The highest ranked management option, however, is now 15. This is equivalent to option 14, but imposed additional restrictions on the total number of crew members permitted to operate in small inshore boats (see Table 7.1).

Perhaps surprisingly, management option 5 now appears to do particularly well (cf. Figure 7.8). Previously, it had been ranked worse than the current management option. This results from a lower level of government subsidy and level of net income (Figure A7.20, Appendix 7.5). These observations reflect the fact that the inshore demersal stock would be in further decline and few, if any, fishers have entered the inshore region (Figures A7.14 & A7.18, Appendix 7.4).

7.7 Discussion

This chapter has identified a number of alternative management options in an attempt to improve the status of the inshore fish stocks and encourage fishers to relocate offshore. In order to evaluate the performance of each management option, a series of biological, economic and socio-economic performance measures were used. Each management option was ranked in comparison to the current management policy according to how well the option matched these management criteria. In brief, these criteria ensured that inshore fish stocks showed signs of a recovery towards sustainable levels, total catches were maintained, and the distribution of net income and employment were equitable.

Selected management options have used input control measures which are more suited to multi-species management. These have also made the government responsible for their monitoring, control and enforcement.

To minimise the potential difficulties associated with imposing regulations, the current loan system has been updated to provide a new series of financial incentives (and disincentives), to relocate fishing effort offshore. Following this, more severe management options are utilised to restrict the use of gear within the inshore region. Finally, boat restrictions (licence fee and limited access) are placed on boats operating within the inshore fisheries.

7.7.1 Loan system (Management options 2 to 5)

Soft loans have previously been used by the government to increase employment opportunities within the fisheries sector and to encourage fishers to purchase large boats capable of fishing demersal resources offshore. Although the existing policy has met with limited success, it is believed that more appropriate financial incentives and disincentives could facilitate a decrease in the high level of fishing effort within the inshore region and further promote the offshore fishery without government physical intervention.

If suitable changes to the soft loan system can reduce the high level of inshore fishing effort, it will also have proved successful at minimising both regulation and enforcement costs. Soft loans are also seen as benefits to fishers, which also prevents political confrontation and unpopularity.

Four management options (2 to 5), were used to simulate the performance of different loan scenarios. The results of the simulations, however, suggest that any further manipulation of the soft loan scheme under present conditions may actually be worse than leaving the fishery at status quo.

The first management option (option 2) provided cheaper loans to purchase a large boat capable of exploiting the offshore region, but had a negligible impact in comparison to the current policy on reducing the number of boat owner-operators and crew within the inshore region. Consequently the inshore demersal stock biomass failed to show any signs of recovery. Failure to increase the status of inshore stocks suppressed catch levels and the subsequent level of income generated. Overall, costs to the government were marginally higher than the current policy due to decreasing the interest rate for large boats purchased with a loan.

Management option 3 imposed a financial disincentive to purchase small boats with a loan by increasing the rate of interest. Similar to option 2, however, the change of interest rate failed to reduce the number of boat owner-operators and crew within the inshore region. Without a recovery of the inshore fish stocks, low catch rates were also maintained. An increase in the cost of purchasing a small boat with a loan led to a further reduction in the average level of income for small boat fishers. The total costs to

government, however, were less than the current management policy due to the increased cost of borrowing.

A third management option combined the financial incentives to purchase a large boat (option 2) with the disincentives to purchase a small boat (option 3). This policy, however, did little more than shuffle fishers between different boat-gear categories within the inshore region, and it encouraged additional crew members on large inshore boats.

Finally, management option 5 restricted all loans available for small boats. This was by far the most effective loan option for reducing the number of small boats operating within the inshore region. Despite this, however, it is surprisingly that the inshore reef and demersal stocks failed to show any sign of recovery. This is because without credit facilities, potential boat owner-operators instead became crew members or skippers on small boats. The actual level of fishing effort therefore remained relatively constant. The total cumulative costs to the government, however, was reduced since it no longer had to subsidise soft loans to the small boat sector, and consequently comparatively fewer boats claimed fuel subsidies.

Detailed examination of the simulation results showed that fishers tend to remain within the inshore region. This is because many have an overall preference to stay inshore, while others require a substantial increase in their level of net income before they consider moving further offshore.

7.7.2 Gear restrictions (Management options 6 and 7)

Two management options have been used to restrict the number of traps used to determine whether more severe management options are capable of achieving the desired level of inshore fishing effort.

The first gear restriction (management option 6), imposed a moderate decrease in the number of traps used per fisher (-25%). In general, this option performed better than the current management policy. Restricting the number of traps enabled the reef stock to make a brief recovery. However, without restricting the number of fishers operating in the fishery, the number of boat owner-operators using traps substantially increased.

Although this action helped to maintain the total catch levels, it also prevented higher levels of net income from the inshore fishery.

Due to the observed increase in the number of trap boats, and hence increase in the number of small boat loans and fuel subsidies, the cost to the government is greater than leaving the fishery at status quo.

A second, more dramatic decrease in the number of traps used per fisher (-50%), immediately caused the fishery to become unprofitable (management option 7). As a consequence, the number of boat owner-operators using traps declined substantially, allowing the reef stock to increase dramatically. Following this increase in reef stock biomass, the resource continued to be under-utilised.

The sudden decline in the trap fishery, however, forced many fishers to switch to the inshore demersal fishery as crew members on large boats. The majority of these fishers decided to remain in the inshore region, although the management option also led to an increase in the number of large offshore boats. The increased effort within the inshore region directed at the inshore demersal resource then led to a further decline in that resource. In combination, therefore, a reduction in the number of traps used per fisher by 50% performs considerably worse than leaving the fishery at status quo.

Placing restrictions on the use of different gears may be a difficult management option to enforce. In the past few years, a total ban has been made on the use of shark gill nets. The banning of this gear type, however, was not due to concern about the status of the shark resources, but rather to environmental concerns about the effect on the wider marine wildlife.

7.7.3 Boat restrictions

Boat restrictions are the most successful management options available in this study to improve the status of the inshore fish stocks. Two approaches were taken: licence fees and access restrictions (non-licence). This study, however, does not attempt to describe how the boat restrictions can be imposed. The introduction of licence fees and/or access restrictions is complicated, and must also address issues concerning the equitable

distribution of harvesting rights. Moreover, other considerations such as regulation and enforcement have not been included within the costs of the management option.

Licence fees (Management options 8 to 10)

The introduction of a fixed licence fee for an unlimited number of small boats proved successful in increasing the reef stock biomass while maintaining current inshore demersal stock biomass levels (management option 8). An increase in the level of reef biomass led to an increase in catches which ultimately without access restrictions provided financial incentives for additional trap boat owner-operators to enter the fishery. The initial financial benefits gained from the introduction of the licence fee were therefore dissipated between an increased number of inshore fishers. Not surprisingly, the increased level of inshore boat owner-operators led to an increase in licence fee revenue.

Extending licence fees to an unlimited number of large boats (management option 9) may at first appear to eliminate any financial incentives to purchase a large offshore boat. However, if the inshore demersal stock continued to decline, only the offshore demersal fishery will have sufficient available stock biomass to generate a profit.

The inshore reef stock biomass fluctuates over the projection period as initial high levels of catches attract additional fishing effort. The subsequent decline in boat owner-operators as a result of decreasing profit margins, is dissipated across the inshore region.

Finally, a substantial increase in licence fees was introduced for an unlimited number of inshore boats (small and large). This severe financial management option (option 10) reduced the level of fishing effort within the inshore region such that both inshore reef and demersal stocks showed signs of a recovery. The increase in biomass was also initially matched by higher catch levels.

The increase in the level of inshore catches generated a higher revenue, which in turn supported the number of boats capable of purchasing such a high licence fee.

The licence schemes proved successful, but may not all be particularly equitable. A licence fee for small boats only target the poorest fishers within the fishery. The introduction of licence fees are successful because they help to increase stock biomass, reduce the number of boats and therefore level of government subsidy, while at the same time increasing licence revenue and increasing fisher incomes. Closer inspection of the simulated data, however, show that the introduction of licence fees help to produce an elite group of rich fishers. In the model, the remaining fishers are pushed out of the fisheries sector into the pool.

Limited access (Management options 11 to 15)

The most effective means of improving the status of the inshore stocks is to physically restrict access to the inshore region. In total, five management options were selected to simulate different levels of access restriction to the inshore region.

The first management option (option 11), to restrict access prevented any further increase in the number of inshore boats. Even without additional boats entering the region, the status of the inshore reef and demersal stock biomass showed little sign of recovery. It is surprising therefore, that the inshore stocks showed small fluctuations in their biomass. Closer scrutiny revealed that the number of crew on board inshore boats also fluctuated. The restrictions placed on purchasing an inshore boat (small and large) have caused fishers to enter the inshore fishery as skippers or crew members. The option was also been partly successful in increasing the total number of large offshore boats.

Second, management option 12 restricted access by introducing a marginal reduction (-25%) in the total number of all inshore boats (small and large). This policy successfully stemmed further declines in the inshore resource base, which led to more stable total catches from the inshore region. The management option has also performed better than the current policy to increase the level of income for inshore fishers. Consequently, many skippers and crew members remained in the inshore region.

The management policy was also successful in relocating fishing effort to the offshore

region. Obviously, a proportion of owner-operators of large inshore boats relocated to the offshore region rather than leave the fisheries sector.

A third management option (option 13) to limit access was probably the most draconian of all alternative policies examined in this study. A reduction in the total number of inshore boats (small and large) by 50% enabled the inshore stocks to make a good recovery towards sustainable levels and provide high total catches for the limited number of inshore boats. The restriction of any further boats entering the inshore region therefore created an elite group of very rich fishers. Eventually, the number of crew members within the inshore region increase, acting to dissipate some of the high levels of income.

It is therefore unsurprising that this policy was also the most successful at relocating fishing effort offshore. This success, however, was undermined by the inequitable distribution of income within the fisheries sector. To address this issue, the policy used in management option 14 restricted the number of large inshore boats by 50%, but only prevented any further access for small boats.

The results of this policy show that the presence of large boats within the inshore region severely hamper the recovery of inshore fish stocks. By removing a large proportion of these, the subsequent recovery of inshore stocks yielded higher catches and greater financial returns to fishers on small boats.

It should be noted, however, that a high number of crew members also entered the inshore region without any access restrictions. Over the long term, this could undermine benefits gained by restricting the number of boats within this region. For example, limited boat access was introduced for the lobster fishery in 1983, but resulted in much higher crew numbers such that it almost eliminated any benefits to be gained from restricting boats access (Mees pers. comm., 2000). To investigate this further, the final management policy used in this study (option 15), restricted the number of crew members per small boat.

Restricting the total number of fishers (owner-operators and crew) on small boats illustrated similar inequity issues as the policy to restrict the number of all inshore

boats by 50% (management option 13). It should be noted, however, that although the level of income substantially increased for trap-fishers, it has also reached the approximate national average level of income for the remaining fishers.

In conclusion, the simulation results have shown that further manipulation of the soft loan system yield no additional benefits to the status of the inshore fish stocks, and may even cost the government more in subsidies.

Restrictions placed on the number of traps, have shown that trap-fishers move into the inshore demersal fishery, thus further exacerbating the inshore demersal situation. Severe gear restrictions, however, can lead to a dramatic underutilisation of the inshore reef resources.

Finally, access restrictions are shown to be the most effective management policies used in this study at alleviating the high level of fishing pressure within the inshore region, allowing the fish stocks to recover to sustainable levels. Severe limited access to the inshore region can lead to issues concerning the equitable distribution of income. It should be noted that the benefits to be gained from limiting access can also be reduced by increased numbers of crew members.

7.7.4 Conclusions

In conclusion, from this study it would appear that only the most draconian management policies are required to stop the further decline of the inshore fish stocks. Access restrictions are by far the most effective, but careful consideration must be given to the equitable distribution of harvesting rights. Furthermore, it has been shown that access restrictions should be tailored to different inshore fisheries. In this way, movement of labour between boat-categories cannot be used to undermine the overall management objectives. Within specific fisheries, fisher licences instead of boat licences may be more appropriate to limit the total level of fishing effort.

8 CONCLUSIONS AND SUMMARY

8.1 INTRODUCTION

The primary goal in fisheries management is to secure the long-term sustainability of the target resource base. Without this basic requirement all other potential benefits from the fishery are diminished. The biological status of the resource has therefore dominated the procedures used to provide pertinent management advice (see Spare *et al.*, 1991). The concept of maximising the total levels of catches from a sustainable resource (MSY) has become enshrined as one of the principal aims of all fisheries management.

More recently, however, fisheries economists have shown that the maximum economic rent (MER) is generated from catches below the MSY. This is an advantage since MSY is notoriously difficult to estimate without fishing past that point on the catch curve. Attempts to incorporate economic information in the data analysis have been made to encourage the exploitation of a resource in the most profitable manner. Indeed, the biological and economic aspects of a fishery can be considered as the main criteria behind fisheries management advice. However, theoretical models have often attempted to optimise a wide range of conflicting fishery attributes. For example, high employment within the fisheries sector can lead to short-term, unsustainable high catch levels.

It is fast becoming realised that socio-economic information plays an important role in redefining specific management criteria. Within many less developed countries, the potential high number of small-scale fishers within an artisanal fishery may present different management concerns than just maximising the potential revenue, such as maximising employment and a more equitable distribution of income. The challenge now facing fisheries management is concerned with how this additional socio-economic information can be incorporated within a decision-making process.

The Seychelles inshore reef and inshore demersal fish stocks have been shown to be over-exploited. Previous fiscal incentives in the form of soft loans were intended to help fishers purchase larger boats and relocate fishing effort offshore, but to date these havemetwith limited success. A number of alternative management policies are available, including additional loan schemes, gear and access restrictions.

To achieve these aims, this research has developed a bio-socio-economic model of the Seychelles artisanal fishery which simulates the behavioural response of different groups of fishers to changes in the fishery. As a result, the model is capable of evaluating the performance of a range of alternative management options. In this way, the merits of each policy can be described from a series of different outcomes which can be systematically ranked according to a set of specific management criteria. This approach facilitates a greater level of understanding of the processes occurring within the fishery, and the overall effects of alternative management policies on different socio-economic groups. As a result, the most equitable policies which are capable of long-term sustainability of the resource base can be identified.

This chapter summarises the studies described in this thesis and how they were combined in the development of a bio-socio-economic model to evaluate the performance of alternative management options (Section 8.2). The contributions to the field of tropical fisheries management arising from the work are then detailed (Section 8.3). Finally, a series of further studies arising directly from this work are suggested (Section 8.4).

8.2 SUMMARY

To successfully develop a bio-socio-economic model of the Seychelles artisanal fishery, a number of key data requirements were necessary. An initial period of exploratory research was undertaken, first to identify the data requirements for the model, and second to provide the relevant background information necessary to design and carry out a formal survey of the artisanal fishers. The formal survey was designed to obtain quantitative information on specific technical, economic and socio-economic attributes of the Seychelles artisanal fishery that were either unavailable or required updating from secondary sources of information.

A description of the formal survey, combined with a complete analysis of the results were given in Chapter 2. Results from both the formal survey and exploratory research were used to identify five socio-economic groups within the Seychelles artisanal fishery. These represented two groups of boat owner-operators, and three categories of crew members.

The initial selection of fishers into one of five groups was a subjective exercise, based on

a number of key socio-economic characteristics. These criteria were formulated on the results of informal interviews and personal observations. Due to the inherent level of variability in the results and the limited number of characteristics, a small number of fishers could not be assigned to a particular socio-economic group. Therefore, a statistical classification technique (discriminant function analysis) was used to sort fishers into each group. This statistical analysis reduced the number of variables required to classify fishers, and as a consequence, simplified the procedure for classifying additional fishers into existing socio-economic groups.

The formal questionnaire was not able to provide the level of detail required to model the decision-making processes of each socio-economic group. Instead, a series of informal interviews were conducted following the formal survey. In Chapter 3, the techniques adopted to collect information during the initial exploratory research and other informal interviews were described. The results of these informal interviews were presented. These data were later incorporated within the model described in Chapter 5. To ensure data pertaining to the decision-making processes of each fisher could be classified into a single socio-economic group, the informal interviews were required to obtain a set of 'key' variable information, identified from an analysis of the data from the previous survey.

Chapters 2 and 3 provided additional quantitative data necessary to develop the bio-socio-economic model of the fishery. An overview of this model was provided in Chapter 4. The model was constructed within MS Excel™, and written in MS Visual Basic™ for Applications. Chapter 4 also included a detailed description of the biological, technical and economic attributes of the model.

Chapter 5 was devoted to the analysis and parameterisation of the decision-making arrangements of the socio-economic groups identified in Chapter 3. In this way, the labour and fleet dynamics of the artisanal fishery were defined. The socio-economic attributes of the model were described separately in addition to the decision-making processes of each group.

In the model, the financial decisions and constraints facing fishers within each socio-economic group were developed in addition to other non-financial preferences, which in total were used to control the mobility of labour.

A selection of model parameters were based on those that were responsible for differences between the untuned model output and the historical data, *and* also had the highest level of uncertainty were 'tuned' in Chapter 6 to enable the performance of the model to be tested. This was achieved by comparing outputs from the model with actual historical biological, technical and socio-economic data from the fishery. The model performed particularly well at replicating both the level of total catch and the number of boats in operation within each boat-gear category.

In Chapter 7, the model was used to predict the success of a series of alternative management options in achieving the aim of reducing the high level of exploitation within the inshore region. Success was evaluated using a series of biological, economic and socio-economic performance measures, and assessed against a number of management criteria. Management options were ranked on their ability to match a given set of management criteria using simulated output from each performance measure. For example, a policy that led to the recovery of the inshore demersal stock biomass would be ranked higher than an alternative policy that showed little or no sign of recovery. The total ranked score for each management policy was aggregated over all performance measures.

After the most successful management options were identified, a number of alternative 'what-if' scenarios were investigated to determine whether the same set of options remained the most successful.

8.2.1 Performance of alternative management options

A number of different management options were tested in Chapter 7. This section summarises the success of each method in achieving the aims of management in Seychelles.

Loan system

Manipulation of the loan system failed to improve the status of the inshore reef and demersal stocks. More importantly, the strategies performed worse than leaving the fishery at status quo. There are several reasons which can help explain this outcome.

Without any form of regulation, financial incentives used to purchase a large boat do not exclude such fishers from then entering the inshore region. Outputs from the model clearly showed a resulting increase in the number of large inshore boats. Such an unregulated increase in the number of these boats exacerbated the decline in the inshore demersal stock.

Within the artisanal fishery, large boats undertaking single day trips within the inshore region are more likely to supply the domestic market rather than sell their catch directly to a fish centre. This generates a comparatively high level of net income. The resulting profit was far in excess of that generated by similar groups of fishers in small boats. Such a difference in net income between small and large boat-gear categories had been recorded as part of a costs and earnings survey of Seychellois fishers conducted in 1998 by Mees *et al.* (1998). Therefore, if additional financial incentives such as loans are made available, a group of sufficiently experienced small boat fishers will attempt to purchase a large boat and continue fishing in the same region.

Loan policies were ranked poorly as a result of their failure to halt further declines in inshore reef and demersal stock biomass. In turn, such policies also incur additional costs to government as a result of the additional level of borrowing. This further reduced the appeal of these policies.

It should be noted that the success of loan policies depended on the current resource status. Sensitivity analyses showed that if reef and total demersal stock biomass were to immediately decrease by 25% in the first year of management, loan strategies became a viable policy. Decreasing inshore stocks by 25% reduced the level of total catch. This reduced all net income levels to their minimum acceptable level or below. As a result fishers in small boats within the inshore region attempted to switch boat-gear categories or leave the fisheries sector. In addition, new fishers entering the fisheries sector looked for employment within the more profitable offshore region.

Boat owner-operators of large inshore boats must also decide whether to sell up or temporarily transfer to the offshore region, where a greater abundance of fish is available.

Gear restrictions

The number of traps used per fisher has important consequences to the profitability of the fishing unit. For example, simulating a 25% reduction in the number of traps reduced catch levels to such an extent that the reef stock showed signs of making a brief recovery. This increase in biomass, however, led to a cyclical pattern of boat investment, over-exploitation of the resource and finally a decrease in net profits. As a result, the management option had little or no influence on the recovery of the inshore demersal stock.

A much higher restriction on the number of traps prevented any chance of generating a profit. This enabled the reef stock biomass to make an almost complete recovery to unexploited levels. However, many fishers were forced to switch boat-gear categories or leave the fisheries sector. Those who remained were transferred to other inshore boat-gear categories, rather than offshore. This had an a severe impact on the status of inshore demersal resources, leading to further resource depletion.

The reduction in exploitation of reef biomass allowed the recovery of this resource. The high abundance of reef fish were then sufficient to allow remaining trap fishers to generate a small profit. As a few additional trap-fishers entered the fishery, a new equilibrium point was established, where the reef stock was allowed to remain lightly exploited. Without access restriction, additional fishing effort reduced the reef biomass such that the levels of reef catches were no longer profitable. After a small group of fishers had left the fishery, the biomass was able to recover, leading to higher catches which generated higher profits an so on.

Following the 25% reduction in reef and total demersal stock biomass, restrictions placed on the number of traps used has little effect on the overall ranking.

Boat restrictions

On average, boat restrictions are by far the most successful management options described for the recovery of the inshore stock biomass. Two approaches to restrict the number of boats operating within the inshore region were simulated: licence fees

and limited entry (non-licence).

The introduction of licence fees and/or limited entry schemes is complex. Difficult issues concerning the equitable distribution of harvesting rights must be addressed. The success of boat restrictions will be somewhat determined by the level of monitoring and enforcement by the management institution. These additional costs have not been included in the overall assessment of costs to the government.

Licence fees

Fixed annual licence fees do not physically restrict the number of boats operating within the inshore region. However, they can be used to control the level of fishing effort, by excluding fishers who are unable to afford the annual licence fee.

A management policy that introduces an annual licence fee for small boats equivalent to their government fuel subsidy does far better than leaving the fishery at status quo. First, this is because the government is able to reduce many of the costs of subsidies to the fisheries sector, and secondly the increased licence fee will prevent many fishers to afford to enter the fishery. As the stock biomass begins to make a recovery, without access restrictions, greater levels of net income may be such to attract effort back into the fishery.

Introducing a compulsory annual licence fee for small boats had the immediate effect of reducing the level of net income for all fishers in small boat-gear categories. In the model, the level of profit decreased to their minimum acceptable level or below. Many fishers were then forced to switch to an alternative more profitable boat-gear category, or leave the fisheries sector. Without a similar licence fee for large boats, many fishers were able to switch from small boats to large inshore boats. As a direct result, the inshore demersal stock showed no sign of recovery. In contrast, however, fishing pressure was removed from the inshore reef stock, which then began to show signs of a recovery. As the level of stock biomass increased, however, the levels of catches for the remaining trap-fishers also increased. When the total net income generated from the increased catches exceeded the minimum acceptable level of income, the absence of access restrictions allowed additional trap-fishers to enter.

This resulted in the stock returning to an over-exploited state, and the financial benefits were dispersed. Without control over the number of boats operating within the fishery, this cyclic pattern of boat investment continued throughout the management period.

The introduction of a fixed annual licence fee for small boats performed better than any of the loan strategies. It enabled the reef stock to make a brief recovery and reduced the total cost of government subsidies. The policy, however, may be considered inequitable for several reasons :

Selecting fishers only from small boats targeted a vulnerable socio-economic group, which already have a low level of net income in comparison to the majority of boat owner-operators of large boats. Only the richest of these fishers will be able to purchase an annual licence fee. A proportion of the remaining fishers will therefore have to leave the fisheries sector to find alternative employment.

When the stock biomass was reduced by 25% it had little effect on the combined rank scores. Although this policy appears to have performed better than either loan or gear restrictions, it favours rich fishers who are able to purchase the cost of a licence fee.

Limited access

By far the most effective means of improving the status of inshore fish stocks was to physically limit the number of boats within the inshore region. In total, five management options were selected to simulate different levels of access restriction within the inshore region.

On average, the higher the level of access restriction to the inshore zone, the better the management option performed. A number of similarities were observed in the output of the results.

Restricting further access to the inshore region by either large or small boats did not enable the recovery of either the reef and inshore demersal stocks. However, this action did help prevent further deterioration of the resource base, and helped to

stabilise income levels for each boat-gear category. More importantly, a small increase in the number of fishers operating offshore was observed. The management policy was therefore partly successful at relocating fishing effort that would otherwise have entered the inshore fisheries.

Increasing the level of limited access within the inshore region led to a number of interesting conclusions. With no opportunity for additional fishing effort within the inshore region, additional fishing effort had been successfully diverted away from the inshore region to exploit resources further offshore.

A reduction in the number of small and large boats helped to increase the status of inshore stocks. This recovery led to an increase in the levels of catches for remaining inshore boats. In turn, higher catches increased the level of net income for fishers in small boats.

Surprisingly, however, the biomass of inshore stocks continued to show small fluctuations, even with a constant number of inshore boats. Although the number of boats remained constant, the number of crew per boat had fluctuated. As profit levels increased for inshore fishing boats, additional fishers became crew members, instead of purchasing a boat (small or large). As a result, a higher level of boat restriction increased the number of crew per boat.

Due to the profit share system, the number of crew per boat was sensitive to the level of net income. Too many crew would decrease the level of biomass such that catches would fall, and total income levels drop. Some fishers would then leave the inshore region, allowing the biomass to recover, and so on.

Limiting the number of inshore boats showed that boat owner-operators are both capable and willing to become skippers or crew members to continue fishing within the inshore region. A similar observation was found when the Seychelles Fishing Authority tried to introduce a limited boat licence for the lobster fishery. Although the number of boats were restricted, the number of crew members per boat substantially increased, making the proposed management of the fishery nonsensical (Mees pers. comm., 1999). If however, the number of crew members were also

restricted, the status of the inshore stocks show a greater improvement in the rate of recovery.

Summary of management policy performance

In summary, further manipulation of the current soft loan scheme was shown to have little effect on allowing the status of the inshore stocks to recover, which was also at a greater cost to government.

Although severe trap restrictions were shown to allow the reef fishery to make a recovery, this led to the under-utilisation of the resource. A reduction in the number of traps also encouraged trap-fishers to switch to alternative inshore fisheries. This had the effect of further reducing the status of the stocks in the inshore region.

By far the most successful management options were to restrict access to the inshore region. The introduction of a licence fee without access restrictions initially reduced the level of fishing effort on the inshore fish stocks until sufficient profits were generated to encourage new levels of fishing effort to enter. Any benefits to be gained from the management policy are therefore dissipated between the additional number of fishers.

The physical restriction of boats within the inshore region enables the stocks to make a good recovery to sustainable levels. This policy, however, may lead to the inequitable distribution of income for those fishers who have been selected to remain in the fishery.

The aim of this study was not to determine how the management options can be implemented, rather to determine which, if any, are suitable for further investigation. Upon the identification of a suitable candidate, additional research is required to determine how the management option can be implemented.

8.3 Contribution to tropical fisheries management

This research has provided a number of contributions to tropical fisheries management

A bio-socio-economic model was developed by Yew (1993) to examine the outcome of a number of access restrictions and licence agreements for the small pelagic fishery in northwest peninsular, Malaysia. Similar to the current study, the simulation model utilised surplus production models to describe the population dynamics of several fish stocks. The socio-economic sub-module, however, was simplistic and only described the benefits and costs of fishing operations which target different species. Both economic and social benefits were calculated in terms of the resource rent and the producer surplus. The model did not, however, attempt to simulate the decision-making processes of fishers within different socio-economic groups in response to a number of alternative future scenarios. Furthermore, no information was available to test the model or replicate historical trends within data sets.

Lleonart *et al.*(1996) extended a bio-economic model to incorporate fishers' behaviour in order to evaluate a number of management strategies. These strategies, however, aimed to maximise fishing mortality within a set legal limit of effort by investing in new technology in order to increase their catchability. Unlike the current study, the model did not attempt to acquire empirical data to parameterise the model, but rather assumed that fishers decision-making behaviour will always attempt increase their catchability to the extent possible given their financial capacity.

Fishers' decision-making processes were empirically studied by Opaluch & Bockstael (1984). Within this study it was shown that fishers responded to economic incentives of expected returns from the fishery, but only after these incentives surpass a substantial threshold. Similar observations were also reported in the present study, where considerable financial incentives (50%+ increase in annual net income) were required before fishers were willing to consider switching to an alternative boat-gear category. No attempt was made during Opaluch & Bockstael's study, however, to monitor the consequence of their decisions on the status of a resource, or to predict the outcome of future management scenarios.

Several authors have used a multi-objective optimization framework within which to study the bio-socio-economic effects of several conflicting management criteria (e.g. Charles, 1989; Sylvia and Enriguez, 1994; Sylvia and Cai, 1995). Although these studies have attempted to simulate the fishery labour dynamics, they have made several important assumptions. These include that fishers prefer (i) as much opportunity to fish as possible and (ii) higher rather than lower income levels. These models do not, however, attempt to simulate the decision-making processes of different socio-economic groups operating within the fishery system. Furthermore, they do not attempt to study the interaction between a number of alternative fisheries. Similar to previous studies (e.g. Yew, 1993) the models do not use empirical data to fit the model or replicate historical patterns.

with particular reference to Seychelles.

- This study has generated the first bio-socio-economic model for tropical artisanal fisheries;

Although an increasing volume of theoretical bio-socio-economic fishery models are appearing in the literature the author is not aware of a similar applied model which has been developed for a specific fishery that has also been used to evaluate a range of alternative management policies. *

- This study has provided a novel approach to fisheries management;

It has identified a powerful and novel approach to assessing the success of potential fisheries management options. The bio-socio-economic model allows the identification of factors which are likely to affect the success of such management options, and track the suitability with respect to the aims of biological sustainability and social equity. It takes into account not only fish biology, but also human behaviour.

- The data have been used to identify a number of socio-economic groups within the Seychelles artisanal fishery.

These groups can be used as a point of reference in future data collection. Fisheries socio-economic survey data have not previously been used in the Seychelles to identify specific groups which have been used to identify their decision-making processes.

- A number of 'key' socio-economic variables have been identified which will facilitate more routine socio-economic data collection in Seychelles. In turn more frequent socio-economic assessments can be made enabling a greater understanding of the Seychelles fishing community for management.

- For the first time, a direct comparison has been made between the previous 1989 socio-economic survey and the 1997 survey to identify trends within the artisanal fishery.

* Having identified a range of management scenarios that enable the status of the inshore stocks to recover to long-term sustainable levels, further consideration should be given to other non-institutional approaches such as co-management. Having analysed these additional options, a strategy to implement the most successful management policy should be adopted within the Seychelles artisanal fishery.

8.4 FURTHER RESEARCH

This section will also attempt to answer some of the potential criticisms of the work performed.

In an overview of the artisanal fishery it was found that insufficient data was available to model the seasonal and/or spatial details of the fishery. The absence of this data prevented the model from being used to simulate closed areas and/or seasons.

This study has not attempted to describe how these alternative management options can be implemented within the Seychelles. It is acknowledged that the severe reduction in the level of fishing effort may be both politically unpopular and difficult to implement. With these points in mind, other forms of management such as co-management should also be considered.

At present, there is only poorly resolved spatial information available on the location of all artisanal fishing activities. It has therefore been assumed in the model that all inshore fishers exploit a finite region defined within a 10 nmile boundary of the main granitic islands of Mahé, Praslin and La Digue (fishing sector 1). It is possible, however, that fishing effort has increased within the inshore region, as more powerful and efficient fishing boats have become available to exploit new fishing grounds further from areas of settlement. An increase in fishing effort which encompasses a greater area could not be detected from present fisheries statistics which may conceal a local decline in the abundance of the inshore resources closer to areas of settlement. Greater spatial resolution of catch information may enable more accurate assessments of the status of the inshore stocks and their resilience to over-exploitation.*

8.5 CONCLUDING STATEMENT

The inshore fish stocks of the Seychelles artisanal fishery are currently over-exploited. Attempts to alleviate this problem have been unsuccessful. This study has developed a unique bio-socio-economic model of the Seychelles artisanal fishery. This model has been used to evaluate the performance of a number of alternative management policies. These policies aimed at alleviating the high level of fishing pressure on the status of the inshore fish stocks.

The current loan system was found to be unsuccessful in reducing fishing pressure within the inshore region. Continuation of the current management policy will lead to a further decline in the status of the inshore fish stocks. This study showed that of the policies examined, boat restrictions within the inshore region were the most effective. However, the socio-economic component of the model showed that these policies would lead to an inequitable distribution of income. Further investigation is required to identify a management policy which is both effective and equitable.

Appendix A.1 Assessment of inshore trap fishery within fisheries Sector 1 using CEDA analysis.

A1.1 Introduction

The Seychelles trap fishery is conducted within the inshore region, known as Sector 1. Fishers may use a variety of trap types depending on whether they operate directly from the shore, or from small boats.

The exploited fishing areas around the three main islands of Mahe, Praslin and La Digue in water depths ranging from 0-35 m was estimated at 557 km^2, however the total potential area of reef potentially suitable for trap fishing is nearly 2,000 km^2 (FAO/IOP,1979).

An analysis of the catch and effort data will provide the necessary input parameters (r and K) for the production model within the bioloigcal sub-model of the bio-socio-economic model (see Section 4.3, Chapter 4).

A1.2 Methods

A time series of catch and effort data for the trap fishery were available from secondary sources of data and the catch assessment survey (Lablache et al.,1988; Art_fish database.). Catch data comprised total demersal catch obtained during fishing. Effort data was based on the number of traps employed by each fisher in each year. These data covered the period 1979-1997 (Table A1.1).

Table A1.1 Catch and effort data available for the inshore reef fishery.

Year	Catch (tonnes)	Effort (traps/year)
*1979	557.0	-
1980	580.0	105,000
1981	500.0	78,000
1982	440.0	65,000
1983	630.0	121,000
* 1984	480.0	-
1985	540.0	135,000
1986	610.0	209,552
* 1987	286.7	137,121
1988	464.1	132,990
1989	463.4	97,152
1990	264.9	73,418
1991	506.5	118,987
1992	645.6	160,923
1993	543.4	134,449
1994	404.5	85,4563
1995	416.0	92,143
1996	438.6	106,669
1997	306.0	89,855

The catch and effort data were analysed using the computer package CEDA (MRAG Ltd, 1992). This package is able to apply a range of depletion models to CPUE data in order to estimate the required parameters for the current study; r (the intrinsic rate of growth) and K (carrying capacity). The reader is referred to the software manual for more information on the potential methods which can be employed using CEDA. Using CEDA, the Schaefer model was fitted to the data.

A previous assessment of the fishery was conducted by Lablache *et al.*, (1988) using the Fox production model. They provided a preliminary estimate of $\hat{K}$ from the trap fishery as 600 mt over an estimated area of 557 km^2. The assessment did not, however, provide details of the intrinsic rate of population increase (r) and the carrying capacity (k).

The results of this study are now presented in Section A1.3.

* These values were not used in the analysis either due to missing data or uncertainties in the quality of the information.

* The actual parameter values used to produce the results described in this thesis (K = 1,780; r = 1.05; MSY = 468), correspond to an earlier fitting of the Schaefer production model using CEDA. Use of these revised estimates would lead to very small differences in the individual simulated trajectories, but no difference at all in the ranking of alternative management options.

A1.3 Results

Prior to 1979, only traditional wooden pirogue vessels were known to exert fishing effort upon the inshore reef resources. At the beginning of the 1980s, however, skiffs with powerful outboard motors became more popular and vastly increased the level of fishing effort exerted within the inshore region. For stock assessment purposes, CEDA enables the user to specify the initial proportion of population size before the start of the dataset. Due to the low level of exploitation prior to 1979, it was considered appropriate to set the initial proportion of population size to 1.0 (max).

A Schaefer production model was fitted to the catch and effort data using least squares. Due to a lack of contrast in the data, a relatively poor fit was obtained ($r^2 = 0.48$). To estimate the 90% confidence limits, a process of bootstrapping was employed within CEDA. This showed parameter estimates for K had a slightly skewed distribution.

Using the Schaefer production model, the maximum sustainable yield can be calculated from (rK)/4. The MSY for the reef fishery is therefore equivalent to 474 tonnes per year. Using the bootstrap technique, the 90% confidence interval for this parameter was also estimated. The results for r, K and MSY parameters are shown in the table below.

Parameter	Value *	90% Confidence Interval
K	1,826	1,219 - 3,239
r	1.04	0.60 - 1.65
MSY	474 tonnes	463 - 512 tonnes

A1.4 Discussion

The estimate of *r* may appear relatively high in comparison to other estimates of *r* used in the model (see Chapter 4). However, the majority of the species retained in the reef fishery consist of fast growing Siganids (see Ntiba and Jaccarini, 1990) in contrast to the slow growing emperors, groupers and snappers found in the demersal fishery.

The range of MSY values suggests that the potential yield for the reef fishery lies below the previous estimate of 600 t (Lablache *et al.*, 1988). The relatively poor fit of the model ($r^2 = 0.48$), would indicate that these results must be viewed with caution. It should be noted, however, that the mean annual catch for the period 1979 to 1997 (478 t), was also consistent with this new estimate.

Appendix 2.1

Table A2.1 Estimated number of sampling units within each category of the population (proportion of total in brackets)

Geographic Area	Boat-type						
	On Foot	Pirogue	Outboard	Inboard	Schooner	S.I.	Total
NW Mahe	0.636	0.212	10.6	7.42	0	0	**19.08**
	(0.003)	(0.001)	(0.050)	(0.035)			**(0.090)**
NE Mahe	0	1.06	12.51	39.0	19.72	7.21	**80.56**
		(0.005)	(0.059)	(0.184)	(0.093)	(0.034)	**(0.380)**
E Mahe	0.848	2.54	14.42	13.57	0	0	**31.38**
	(0.004)	(0.012)	(0.068)	(0.064)			**(0.148)**
W Mahe	2.12	1.06	8.48	10.18	11.66	0	**23.11**
	(0.010)	(0.005)	(0.040)	(0.048)	(0.055)		**(0.109)**
NE Praslin	1.70	4.45	15.05	6.15	3.39	0	**30.74**
	(0.008)	(0.021)	(0.071)	(0.029)	(0.016)		**(0.145)**
NW Praslin	0.636	4.88	9.54	1.70	0	0	**16.96**
	(0.003)	(0.023)	(0.045)	(0.008)			**(0.080)**
La Digue	1.91	0.424	5.72	2.12	0	0	**10.6**
	(0.009)	(0.002)	(0.027)	(0.010)			**(0.050)**
Totals	**7.84**	**14.84**	**76.53**	**80.13**	**25.44**	**7.21**	**212.0**
	(0.037)	**(0.070)**	**(0.361)**	**(0.378)**	**(0.120)**	**(0.034)**	**(1.000)**

Sampling units greater than 0.5 were rounded up to the nearest integer.

Appendix 2.2

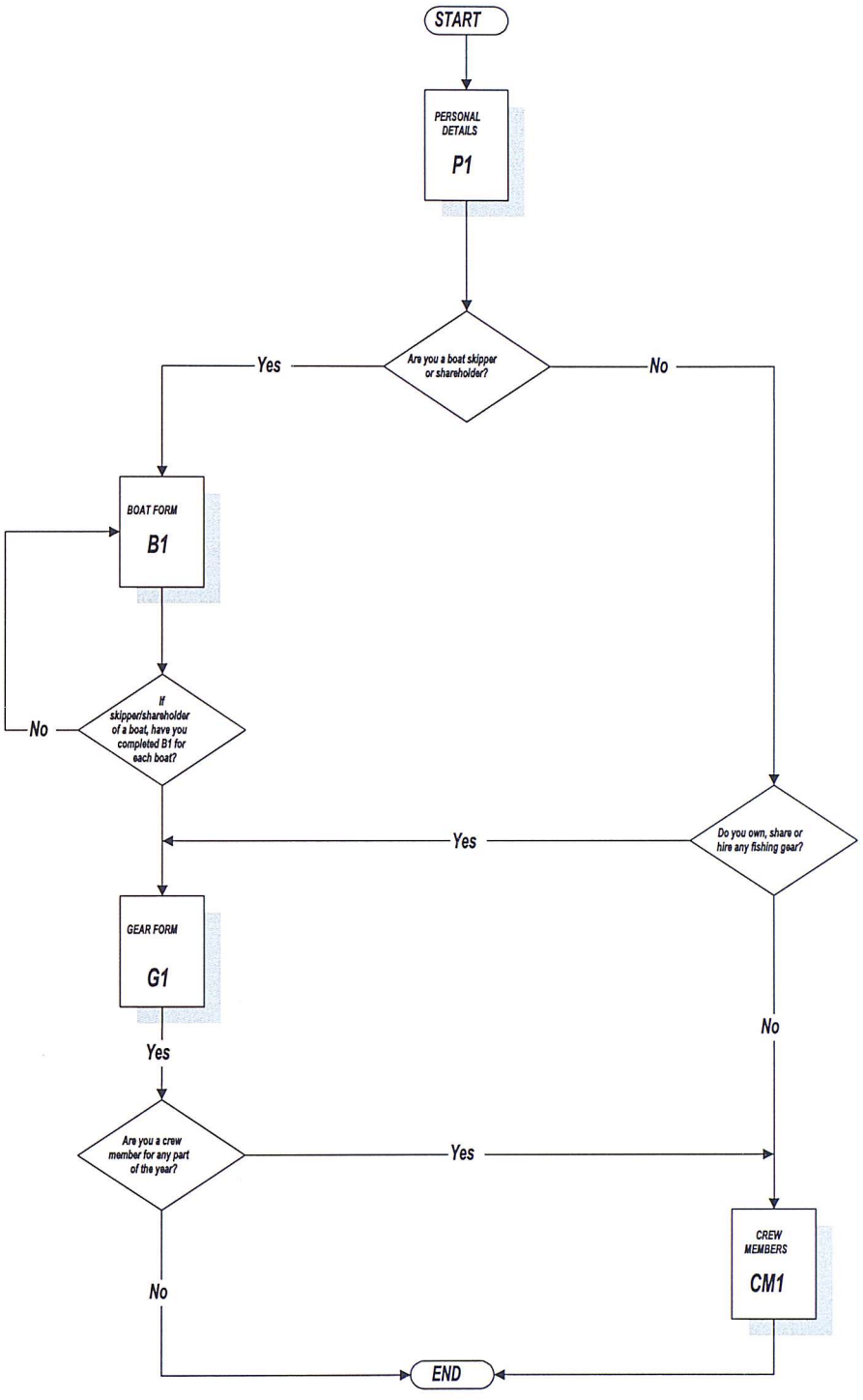


Figure A2.1 Schematic training diagram to indicate order of sub-form completion.

Appendix 2.3 A copy of the formal questionnaire used during the 1997 socio-economic survey.

Field Worker: _____	Date: __/__/97
Landing Site: _____	Serial Number: ☐☐☐

SOCIO ECONOMIC SURVEY OF FISHERMEN SEYCHELLES 1997

PERSONAL DETAILS

1 **How old are you:** ☐☐

2 **Marital status:**

Married	1. ☐
Concubine	2. ☐
Single	3. ☐
Divorced	4. ☐
Widowed	5. ☐

3 **What was your father's occupation:**

Fishermen	1. ☐
Boat builder	2. ☐
Fish trader	3. ☐
Farmer	4. ☐
Government employee	5. ☐
Other: Specify _____	6. ☐

4 **Are you:** ☐ Full-time ☐ Part-time

5 **How many years have you worked as a fisherman:** ☐☐ Full-time ☐☐ Part-time

6 **Where did you learn your fishing skills:**

Father	1. ☐
Other fishermen	2. ☐
Foreign fishing vessel	3. ☐
Maritime school	4. ☐
Other	5. ☐ Specify _____

7 **Describe your education:**

None	1. ☐
Primary	2. ☐
Secondary	3. ☐
National Youth Service	4. ☐
Seychelles polytechnic	5. ☐
Other	6. ☐ Specify _____

8 **How many children do you have:** ☐☐ (If none, go to 11)

9 **How many children *less than* 6 years:** ☐

10 **Give the number of children *over* 6 years who:** **Total** ☐

a) Never been to school		☐
b) Still at school	- *Primary*	☐
	- *Secondary*	☐
	- *National Youth Service*	☐
	- *Seychelles polytechnic*	☐
	- *Other*	☐
c) Finished: highest level	- *Primary*	☐
	- *Secondary*	☐
	- *National Youth Service*	☐
	- *Seychelles polytechnic*	☐
	- *Other*	☐

11 **How many dependants do you have:** Children under 18 years of age: ☐
Adults more than 18 years of age: ☐

12 **How many people normally live in your household:** ☐☐

13 **Are you the major income earner for the household:** ☐ Yes ☐ No

14 **Do any of your *family* work in:**

		What Relation
Canning factory	1. ☐	_____
Fish processing (SMB)	2. ☐	_____
Fish centre/trader	3. ☐	_____
SFA	4. ☐	_____
Fish Marketing	5. ☐	_____
Stevedores	6. ☐	_____
Bait collection	7. ☐	_____
Other: Specify _____	8. ☐	_____

15 **Describe your activities during the past 12 months:**

	NW Monsoon	Inter-Monsoon	SE Monsoon	Inter-Monsoon
Fishing	☐	☐	☐	☐
Fish trader	☐	☐	☐	☐
Boat builder	☐	☐	☐	☐
Farmer	☐	☐	☐	☐
Government employee	☐	☐	☐	☐
Other: Specify _____	☐	☐	☐	☐

16 **Where do you live (village name, island):**

Village: _____ District: _____ Island: _____

17 **Who is the owner of the house you live in:**

Yourself	1. ☐
Another family member	2. ☐
Private landlord	3. ☐
Government	4. ☐
Other	5. ☐

Specify _____

18 **Do you pay rent (if applicable):** No ☐
Yes ☐ How much per month (Sr) _____

19 **Give details of the construction of your house (tick one box only within each category)?**

Walls	Corrugated iron sheets/asbestos	1. ☐	
	Wood/stone/mud	2. ☐	
	Bricks/stone/cement	3. ☐	
	Other	4. ☐	Specify _____
Floor	Earth	1. ☐	
	Stone/cement	2. ☐	
	Wood	3. ☐	
	Tiles	4. ☐	
	Other	5. ☐	Specify _____
Roof	Tin sheets	1. ☐	
	Corrugated iron sheets	2. ☐	
	Asbestos tiles	3. ☐	
	Roofing tiles	4. ☐	
	Other	5. ☐	Specify _____

20 **Which of the following do you have/own:**

Running water	- stream	☐
	- untreated	☐
	- treated	☐
TV		☐
Video		☐
Bicycle		☐
Motorbike		☐
Car/Pick-up		☐
Truck		☐
Telephone :	- direct	☐
	- mobile	☐
	- both	☐
Cooker :	- gas	☐
	- electricity	☐
Stove	- kerosene	☐
	- wood	☐

21 **Are you:**

A Skipper or boat shareholder ☐ (go to 26)

OR

B Crew member ☐ (go to 22)

22 **Did you try to obtain a loan to purchase:**

	Boat	Engine	Gear	Transport
Yes	☐	☐	☐	☐
No	☐	☐	☐	☐

(If no to all, go to 25)

23 **Where did you try:**

	Boat	Engine	Gear	Transport
Family	☐	☐	☐	☐
Friends	☐	☐	☐	☐
Consortium	☐	☐	☐	☐
Bank	☐	☐	☐	☐
Development Bank	☐	☐	☐	☐
YES	☐	☐	☐	☐
Credit Union	☐	☐	☐	☐
Employer	☐	☐	☐	☐
Other: Specify _____	☐	☐	☐	☐

24 **Why were you unsuccessful:**

	Boat	Engine	Gear	Transport
No Mortgage or guarantee	☐	☐	☐	☐
Personal contribution	☐	☐	☐	☐
Don't know	☐	☐	☐	☐
Other: Specify _____	☐	☐	☐	☐

25 **Do you use any fishing gear:**

Yes ☐ complete GEAR FORM (G1) (go to 57)

No ☐ complete CREW MEMBERS (CM1) (go to 67)

26 **How many boats do you skipper or share with someone else:**

	Boat code	Number
Pirogue (<15 Hp)	P	☐
Pirogue (>15 Hp)	OB	☐
Fibre-glass (<15 Hp)	OB	☐
Fibre-glass (>15 Hp)	OB	☐
Traditional whaler	IB	☐
Lekonomie	IB	☐
Lavenir	SC	☐
Nouvo Lavenir	SC	☐
Traditional schooner	SC	☐
12 m La Digue	SC	☐
18 m La Digue	SC	☐
Cygnus	SI	☐
Other: Specify _____		☐

Now go directly to 27

[NB: Complete additional Boat Form (B2) if more than ONE boat]

BOAT FORM

Field Worker: _____ **Date (dd/mm):** _ _/_ _/97
Landing Site: _____ **Serial Number:** ☐☐☐
Boat Type: _____ **Engine size:** ____ **(Hp) Make:** _____

27 **What is:** Name of the boat _____
Licence number _____
Registration number _____

28 **Who owns:**

		Boat	Engine	Gear
Yourself	1.	☐	☐	☐
Yourself with family	2.	☐	☐	☐
Yourself with crew	3.	☐	☐	☐
Yourself & other personnel	4.	☐	☐	☐
Other: Specify _____	5.	☐	☐	☐

29 **Are you:**
Boat owner/part shareholder 1. ☐
Paid skipper (non-boat owner) 2. ☐ (If paid skipper go to 36)
Hiring the boat from someone else 3. ☐
Other: 4. ☐ Specifiy _____

30 **How many people own:**

Boat: ☐☐ Engine: ☐☐ Gear ☐☐

If more than 1, what proportion is owned by you:

Boat: ☐☐☐ Engine: ☐☐☐ Gear ☐☐☐

31 **What is this boat used for:**

Main fishing boat 1. ☐
Spare boat 2. ☐
Hired out to other fishermen 3. ☐
Owned jointly, and operated by other men 4. ☐
Other: Specify _____ 5. ☐

32 **Was it:** New ☐ Second-hand ☐

33 **How much did you pay (Sr):**

Boat _____ Engine _____ Boat & Engine _____ Gear _____

34 **Date of purchase (mm/yy):**

Boat _ _/_ _ Engine _ _/_ _ Boat & Engine _ _/_ _ Gear _ _/_ _

35 **If second-hand, how old were they when you purchased them (yrs):**

Boat ☐☐ Engine ☐☐ Boat & Engine ☐☐ Gear ☐☐

36 **Do you you have a loan:**

	Boat	Engine	Gear
Yes	☐	☐	☐
No	☐	☐	☐

If No to any, did you try for one Yes ☐
No ☐ (If Yes or No, go to 45)

37 **Did you need to provide a guarantee to obtain a loan:**

No ☐
Yes ☐ How?

Sponsored by someone	1. ☐
Sponsored by SFA	2. ☐
House/land	3. ☐
Deposit	4. ☐
Other: Specify _____	5. ☐

38 **Did you obtain:**

One loan for one item	1. ☐
One loan to cover all items	2. ☐
Separate loan for each item	3. ☐

39 **Source of loan for each item:**

	Boat	Engine	Boat & Engine	Gear
Family	☐	☐	☐	☐
Friends	☐	☐	☐	☐
Consortium	☐	☐	☐	☐
Bank	☐	☐	☐	☐
Development Bank	☐	☐	☐	☐
YES	☐	☐	☐	☐
Credit Union	☐	☐	☐	☐
Employer	☐	☐	☐	☐
Other: Specify _____	☐	☐	☐	☐

40 **Date loan received (month/year):**

Boat: __/__ Engine: __/__ Boat & Engine: __/__ Gear: __/__

41 **How many months/years for loan repayment:**

Boat: _____ Engine: _____ Boat & Engine: _____ Gear: _____

42 **Rate of interest charged (%):**

Boat: ☐☐☐ Engine: ☐☐☐ Boat & Engine: ☐☐☐ Gear: ☐☐☐

43 **Is interest per month/year:**

	Boat	Engine	Boat & Engine	Gear
Month	☐	☐	☐	☐
Year	☐	☐	☐	☐

44 **What is:**

	Boat	Engine	Boat & Engine	Gear
Amount or value of loan (Sr):				
What was your contribution:				
Amount outstanding:				

45 **Which of the following modifications or additions have been given to the boat:**

Modifcation	Date fitted to boat (mm/yy)	Total Cost (Sr)	New or Secondhand (N/S)	How old when bought (years)?	Needed a Loan? (Y/N)
1. Larger engine	/				
2. Full/partial decking	/				
3. Boat elongation	/				
4. Ice box	/				
5. Cabin	/				
6. Sail	/				
7. Safety equipment	/				
8. Echo sounder/fish finder	/				
9. Electric fishing reels	/				
10. GPS Unit	/				
11. Solar panal	/				
12. Other Specify:	/				

46 **What is the *boat* used for during the following seasons (tick all relevant boxes):**

Season	Fishing	Repairs	Fishing & Repairs	Other:	Specify
NW Monsson	☐	☐	☐	☐	
Inter-monsoon	☐	☐	☐	☐	
SE Monsoon	☐	☐	☐	☐	
Inter-monsoon	☐	☐	☐	☐	

47 **How many fishermen including yourself go on each fishing trip:** ☐☐

48 **Do you take the same crew all the time:**

Yes ☐
No ☐ Why

Alcohol 1. ☐
Not motivated 2. ☐
Too old 3. ☐
Not enough money 4. ☐
Crew rotation 5. ☐
Other 6. ☐ Specify _____

49 **Do you do a:**

Share system	1. ☐	
Fixed salary system	2. ☐	(If fixed salary system, go to 54)
Salary with profit	3. ☐	

50 **Excluding bouyon, how are the shares paid:**

Money	1. ☐
Fish	2. ☐
Both	3. ☐

51 **Is the catch shared before it is sold:** Yes ☐ No ☐

52 **Do fishermen keep their own personal catch to sell:** Yes ☐ No ☐

53 **How many shares do the following receive:**

	Ratio
Yourself (skipper)	☐
Fishermen	☐
Other crew (mechanic\cook)	☐
Boat owner (if different to skipper)	☐
Expenses: Boat	☐
Engine	☐
Gear	☐
Unknown (i.e. keep own catch - tick box)	☐
Other: Specify _____	☐

54 **Are running costs deducted before sharing the profits:** Yes ☐ No ☐

55 **Which items are deducted from the revenue (fish/money) before profits are shared, or else who pays for:**

	Cost deducted	Skipper	Skipper & Crew	Crew Only	Other Boat Owner
Fuel	☐	☐	☐	☐	☐
Ice	☐	☐	☐	☐	☐
Bait	☐	☐	☐	☐	☐
Food	☐	☐	☐	☐	☐
Transport	☐	☐	☐	☐	☐
Cost for selling fish	☐	☐	☐	☐	☐
Maintenance: Boat	☐	☐	☐	☐	☐
Engine	☐	☐	☐	☐	☐
Gear	☐	☐	☐	☐	☐
Loan repayment	☐	☐	☐	☐	☐
Insurance	☐	☐	☐	☐	☐
Other: Specify _____	☐	☐	☐	☐	☐

56 **Do you use any fishing gear:**

Yes	☐ complete GEAR FORM (G1)	(If yes, go to 57)
No	☐ complete CREW MEMBERS (CM1)	(If no, go to 67)

GEAR FORM

Field Worker: _____ **Date (dd/mm):** __/__/97
Landing Site: _____ **Serial Number:** ☐☐☐
Boat Type: _____ **Engine size:** ____ **(Hp) Make:** _____

57 **How many gear you own, share or hire:**

Gear Description	Code	Own	Share	Hire
Harpoon	HAR	☐	☐	☐
Active trap	FIXA	☐	☐	☐
Static trap	FIXS	☐	☐	☐
Dropline		☐	☐	☐
Longline		☐	☐	☐
Beach seine	BS	☐	☐	☐
Bottom-set gillnet	GNS	☐	☐	☐
Encirling gillnet	GNC	☐	☐	☐
Handline	LHP	☐	☐	☐
Kalé (Hoopnet)		☐	☐	☐
Other: Specify _____		☐	☐	☐

58 **For each gear:**

Gear	Gear Size (hook no./m of net)	Mesh Size (if relevant)	Cost to replace (yr/mth)	Comments

59 **Where do you fish during each season:** (see map with SFA fishing sectors)

Gear	NW Monsoon	Inter-monsoon	SE Monsoon	Inter-monsoon

60 **Do you always go to the *same* beach, reef or bank to fish:**

Yes ☐ Please asterisk (*) which in 59
No ☐

61 **If you catch small/undersized fish what do you do:**

	Alive	Dead	Comments
Throw them overboard (discard)	☐	☐	
Sell them	☐	☐	
Use for bait	☐	☐	
Consumption	☐	☐	
Other Specify _____	☐	☐	

62 **Where do you land your catch during each season:**

Gear Code	Landing Site Name			
	NW Monsoon	Inter-monsoon	SE Monsoon	Inter-monsoon

63 **If you receive part or all of the catch, where do you usually sell it during (tick all relevant boxes):**

	NW Monsoon	Inter-monsoon	SE Monsoon	Inter-monsoon
1. Roadside/landing site	☐	☐	☐	☐
2. District market	☐	☐	☐	☐
3. Victoria market	☐	☐	☐	☐
4. Fish traders	☐	☐	☐	☐
5. Fish centre: which _____	☐	☐	☐	☐
6. Restaurants/hotels	☐	☐	☐	☐
7. Other Specify: _____	☐	☐	☐	☐

64 **Do you have a written contract or informal agreement with:**

		Specify Who
SMB/fish centre	1. ☐	
Fish trader	2. ☐	
Restaurant	3. ☐	
Hotel	4. ☐	
Other: Specify: _____	5. ☐	

65 **For each boat-gear type, what fish do you mainly catch (e.g. job gris) during each season (max 4 fish). Where do you usually sell it? Complete one or more location indicated in 63**

Boat-gear type	NW Monsoon		Inter-monsoon		SE Monsoon		Inter-monsoon	
	Species	Selling location	Species	Selling location	Species	Selling location	Species	Selling location
	1 2 3 4		1 2 3 4		1 2 3 4		1 2 3 4	
	1 2 3 4		1 2 3 4		1 2 3 4		1 2 3 4	
	1 2 3 4		1 2 3 4		1 2 3 4		1 2 3 4	
	1 2 3 4		1 2 3 4		1 2 3 4		1 2 3 4	
	1 2 3 4		1 2 3 4		1 2 3 4		1 2 3 4	

66 **Are you also a Crew Member:**

No ☐ If no, complete GENERAL QUESTIONS GE1 form (go to 78)
Yes ☐ If yes, complete CREW MEMBERS CM1 form (go to 67)

Seychelles Fishing Authority **CM1**

CREW MEMBERS

Field Worker: _____ **Date (dd/mm):** __/__/97
Landing Site: _____ **Serial Number:** ☐☐☐
Boat Type: _____ **Engine size:** ____ **(Hp) Make:** _____

67 **Describe your activities during each season:**

Season	Fishing	Repairs	Fishing & Repairs	Other:	Specify
NW Monsoon	☐	☐	☐	☐	_____
Inter-monsoon	☐	☐	☐	☐	_____
SE Monsoon	☐	☐	☐	☐	_____
Inter-monsoon	☐	☐	☐	☐	_____

68 **Are you:**

Fishermen 1. ☐
Mechanic 2. ☐
Cook 3. ☐
Other 4. ☐ Specify: _____

69 **How many boats have you worked on in the past 12 months:** ☐☐

70 **What boats are these and when did you work on them. What was your reason (if any) for leaving:**

Boat Type	Dates (mm/yy - mm/yy)	Reason for leaving
	-	
	-	
	-	
	-	
	-	
	-	

71 **Which of the following items do you provide for each boat:**

Boat Type	Bait	Equipment	Food	Other Specify:

72 **Excluding bouyon, how do you get paid:**

Money	1.	☐
Fish	2.	☐
Both	3.	☐
Other	4.	☐ Specify: _____

73 **Is the catch shared before it is sold:** Yes ☐ No ☐

74 **Do you keep your own personal catch:** Yes ☐ No ☐

75 **If you receive part or all of the catch, where do you usually sell it (tick all relevant boxes):**

	NW Monsoon	Inter-monsoon	SE Monsoon	Inter-monsoon
1. Roadside/landing site	☐	☐	☐	☐
2. District market	☐	☐	☐	☐
3. Victoria market	☐	☐	☐	☐
4. Fish traders	☐	☐	☐	☐
5. Fish centre: which _____	☐	☐	☐	☐
6. Restaurants/hotels	☐	☐	☐	☐
7. Other Specify _____	☐	☐	☐	☐

76 **Do you have a written contract or informal agreement with:**

SMB/Fish Centre	1.	☐
Fish Trader	2.	☐
Restaurant	3.	☐
Hotel	4.	☐
Other	5.	☐ Specify: _____

(Now go to 79)

77 **For each boat-gear type, what fish do you mainly catch (e.g. job gris) during each season (max 4 fish). Where do you usually sell it? Complete one or more location indicated in 75**

Boat-gear type	NW Monsoon		Inter-monsoon		SE Monsoon		Inter-monsoon	
	Species	Selling location	Species	Selling location	Species	Selling location	Species	Selling location
	1 2 3 4		1 2 3 4		1 2 3 4		1 2 3 4	
	1 2 3 4		1 2 3 4		1 2 3 4		1 2 3 4	
	1 2 3 4		1 2 3 4		1 2 3 4		1 2 3 4	
	1 2 3 4		1 2 3 4		1 2 3 4		1 2 3 4	
	1 2 3 4		1 2 3 4		1 2 3 4		1 2 3 4	

Now go to 78

GENERAL QUESTIONS

Field Worker: _____ **Date:** __/__/97
Landing Site: _____ **Serial Number:** ☐☐☐

78 **Did you ever belong to the Fishermen's Association:**

Yes ☐
No ☐ Would you like to become a member of such an organisation? Yes ☐ No ☐

79 **Would you like to participate in any future management discussions:**

Yes ☐
No ☐

80 **How has fishing changed in your lifetime:**

_____

_____

_____

_____

_____

81 **Do you have any comments you wish to make to SFA:** Please use the space provided below

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Appendix 2.4 Kolmogorov-Smirnov two-sample test for comparing frequency distributions

The Kolmogorov-Smirnov two-sample test was used to statistically compare the form of the frequency distributions, where the age frequency distributions studied are continuous (Sokal & Rohlf, 1981).

The null hypothesis is that the two samples are distributed identically. The test is therefore sensitive to differences in location, dispersion, skewness etc. It is based on the unsigned differences between the relative cumulative frequency distributions of the two samples. Comparisons between the observed and the expected critical values results in decisions as to whether the maximum difference between the two cumulative frequency distributions is significantly different.

The Kolmogorov-Smirnov test was used to assess the difference between the age frequency distributions of fishers within the artisanal fishery during 1997 and the total working population during 1994. This is now presented as an example (Table A2.1). This example used the formation for large sample sizes (both n_1 and n_2 >40).

Table A2.2 Kolmogorov-Smirnov test to compare the age frequency distributions of fishers within the artisanal fishery during 1997 and the total working population during 1994.

Age Class (yrs)	Frequency		Cumulative Frequency (F)		$\frac{F_1}{n_1}$	$\frac{F_2}{n_2}$	$d = \left\lvert \frac{F_1}{n_1} - \frac{F_2}{n_2} \right\rvert$
	Fishery	Population	Fishery F_1	Population F_2			
<20	0	1,402	0	1,402	0.00	0.04	0.04
21-30	9	10,397	9	11,799	0.08	0.38	0.29
31-40	28	9,969	37	21,768	0.35	0.70	0.35 ← D
41-50	22	5,121	59	26,889	0.56	0.86	0.30
51-60	28	3,207	87	30,096	0.82	0.96	0.14
>60	19	1,181	106	31,277	1.00	1.00	0.00
TOTAL:	n_1=106	n_2=31,277				D:	0.35

Where D is the largest unsigned difference

An approximate two-tailed critical value for the test statistic D can be calculated as:

$$D_a = K_a \sqrt{\frac{n_1 + n_2}{n_1 n_2}}$$

where

$$K_\alpha = \sqrt{\frac{1}{2}\left[-\ln\left(\frac{\alpha}{2}\right)\right]}$$

Thus for $\alpha = 0.05$, $K_{0.05} = 1.36$, and so $D_{0.05} = 0.013$

The results indicate that D (0.35)>$D_{0.05}$(0.013). Hence the age frequency distributions are significantly different at the 5% level.

Appendix 2.5

Table A2.3 Age structure of fishers (%) within different sub-strata of the 1989 survey.

Details	Crew member (%)		Skipper (%)		Boat owner-operator (%)			
					With loan		Without loan	
	Small	Large	Small	Large	Small	Large	Small	Large
	n = 35	*n = 74*	*n = 26*	*n = 37*	*n = 19*	*n = 28*	*n = 34*	*n = 9*
< 20 yrs	3	3	4	0	0	0	0	0
21-30 years	34	16	12	5	5	18	18	22
31-40 years	23	35	35	36	26	29	29	22
41-50 years	23	24	27	27	26	25	32	34
51-60 years	11	18	19	27	42	21	18	22
> 60 years	6	4	4	5	0	7	0	0

Table A2.4 Number of years full-time work experience of fishers (%) within different sub-strata of the 1989 survey.

Details	Crew member (%)		Skipper (%)		Boat owner-operator (%)			
					With loan		Without loan	
	Small	Large	Small	Large	Small	Large	Small	Large
	n = 35	*n = 74*	*n = 26*	*n = 37*	*n = 19*	*n = 28*	*n = 34*	*n = 9*
< 1 year	0	0	0	0	0	0	0	0
1-5 years	26	15	12	0	5	4	12	0
6-10 years	20	24	23	5	21	11	24	33
11-15 years	20	18	15	19	32	29	6	11
16-20 years	11	15	8	19	5	18	6	22
> 20 yrs	23	28	42	53	37	38	53	33

Table A2.5 Education of fishers (%) within different sub-strata of the 1989 survey.

Details	Crew member (%)		Skipper (%)		Boat owner-operator (%)			
					With loan		Without loan	
	Small	Large	Small	Large	Small	Large	Small	Large
	n = 35	*n = 74*	*n = 26*	*n = 37*	*n = 19*	*n = 28*	*n = 34*	*n = 9*
None	6	15	19	11	11	7	15	22
Primary	63	62	62	76	63	61	68	56
Secondary	29	22	15	13	26	29	18	22
Advanced	3	1	4	0	0	3	0	0

Table A2.6 Father's occupation (%) within different sub-strata of the 1989 survey.

Details	Crew member (%)		Skipper (%)		Boat owner-operator (%)			
					With loan		Without loan	
	Small	Large	Small	Large	Small	Large	Small	Large
	n = 35	*n = 60*	*n = 25*	*n = 37*	*n = 19*	*n = 28*	*n = 34*	*n = 9*
Fisher	43	60	44	32	11	32	29	78
Fish Trader	0	0	0	3	0	0	0	0
Boat Builder	0	2	4	8	5	0	3	0
Farmer	0	3	12	3	5	14	9	0
Govt. employee	3	2	0	8	11	0	12	0
Other work	54	33	40	46	68	54	47	22

Table A2.7 Where fishers learnt their fishing skills (%) within different sub-strata of the 1989 survey.

Details	Crew member (%)		Skipper (%)		Boat owner-operator (%)			
					With loan		Without loan	
	Small	Large	Small	Large	Small	Large	Small	Large
	n = 35	*n = 74*	*n = 26*	*n = 37*	*n = 19*	*n = 28*	*n = 34*	*n = 9*
Father	14	26	23	19	21	21	35	44
Other fishers	77	68	77	70	74	75	65	33
Foreign vessel	0	0	0	0	0	0	0	0
Maritime study	0	0	0	3	0	4	0	0
Other	9	6	0	8	5	0	0	22

Table A2.8 Marital status of fishers (%) within different sub-strata of the 1989 survey.

Details	Crew member (%)		Skipper (%)		Boat owner-operator (%)			
					With loan		Without loan	
	Small	Large	Small	Large	Small	Large	Small	Large
	n = 35	*n = 74*	*n = 26*	*n = 37*	*n = 19*	*n = 28*	*n = 34*	*n = 9*
Married	14	24	15	35	47	39	44	56
Concubine	51	39	54	49	53	43	35	22
Single	34	35	27	14	0	14	21	11
Divorced	0	1	0	2	0	0	0	11
Widowed	0	1	4	0	0	4	0	0

Table A2.9 Average number of dependants under and over 18 years of age, household size and dependancy ratio within different sub-strata of the 1989 survey.

	Crew member		Skipper		Boat owner-operator			
					With loan		Without loan	
Details	Small	Large	Small	Large	Small	Large	Small	Large
Dependants <18	2.9	2.9	-	-	2.8	3.5	2.9	2.7
Dependants >18	2.8	2.5	-	-	2.8	2.7	2.9	2.3
Household size	4.8	5.3	-	-	5.7	6.3	6.1	6.6

Table A2.10 Average number of children and total below 6 years of age within different sub-strata of the 1989 survey.

	Crew member		Skipper		Boat owner-operator			
					With loan		Without loan	
Details	Small	Large	Small	Large	Small	Large	Small	Large
Mean	4.1	3.6	4.3	4.2	4.1	5.3	5.2	4.3
Total < 6 yrs	1.2	1.2	1.0	1.1	1.4	1.2	1.2	1.8

Table A2.11 House ownership (%) within different sub-strata of the 1989 survey.

Details	Crew member (%)		Skipper (%)		Boat owner-operator (%)			
					With loan		Without loan	
	Small	Large	Small	Large	Small	Large	Small	Large
	n = 35	*n* = 74	*n* = 7	*n* = 10	*n* = 19	*n* = 28	*n* = 34	*n* = 9
Fisher himself	40	28	-	-	42	43	56	67
Family member	46	35	-	-	37	39	21	22
Private landlord	6	18	-	-	5	14	3	11
Government	9	14	-	-	11	4	12	0
Other	0	5	-	-	5	0	9	0

Table A2.12 Quality of housing within different sub-strata of the 1989 survey.

Details		Crew member (%)		Skipper (%)		Boat owner-operator (%)			
						With loan		Without loan	
		Small	Large	Small	Large	Small	Large	Small	Large
		n = 35	*n = 74*	*n = 26*	*n = 37*	*n = 19*	*n = 28*	*n = 34*	*n = 9*
Owner	3-6	0	0	0	5	0	0	0	0
	7-9	93	100	100	90	100	92	95	100
	10-12	7	0	0	5	0	8	5	0
Non-	3-6	0	2	0	0	0	0	0	0
Owner	7-9	100	98	100	100	91	100	100	33
	10-12	0	0	0	0	9	0	0	67

Table A2.13 Consumer items purchased by different sub-strata for the 1989 survey.

Details	Crew member (%)		Skipper (%)		Boat owner-operator (%)			
					With loan		Without loan	
	Small	Large	Small	Large	Small	Large	Small	Large
	n = 35	*n = 74*	*n = 25*	*n = 37*	*n = 19*	*n = 28*	*n = 35*	*n = 9*
Car/Pick-up	0	4	0	3	5	4	3	33
Motorbike	0	0	0	0	5	4	0	0
Bicycle	11	1	4	8	5	4	15	0
TV	23	23	23	51	63	61	56	56
Video	3	3	15	14	21	36	18	22

Table A2.14 House ownership and marital status of crew members (%) for the 1997 survey.

	Married		Concubine		Single	
	Small	Large	Small	Large	Small	Large
Fisher	50	69	50	9	8	38
Parents/family	50	15	50	45	84	32
Private Landlord	0	8	0	9	8	15
Government	0	8	0	28	0	15
Other	0	0	0	9	0	0

Appendix 2.6

Table A2.15 Test Results

Box's M	275.654
F Approx.	1.951
df_1	112
df_2	4640.527
Sig.	0.000

Tests null hypothesis of equal population covariance matrices.

Appendix 2.7 The Seychelles government YES soft loan initiative.

The majority of loans disbursed by the YES initiative (85%) were given to fishers 40 years of age and under (Table 2.17). This provides strong evidence in support of the observed increase in young age classes recruiting specifically to the inshore sector.

Table A2.17 Number of loans disbursed by YES initiative between 1996 and 1998 by age class.

Details	1996	1997	1998	Total	%
< 20 yrs	6	9	2	17	10
21-30 years	22	27	12	61	35
31-40 years	18	33	17	68	40
41-50 years	4	10	5	19	11
51-60 years	0	3	4	7	4
> 60 years	0	0	0	0	0
Total	50	82	40	172	100

Data Source: (SIDEC, 1999).

Although it appears that the YES initiative has been partly successful in creating new employment opportunities within the fisheries sector, this trend cannot be confirmed with the current data available. For example, it remains unclear as to what extent the YES initiative has actually increased fishing effort within the inshore region. Many existing fishers may have used the scheme to replace or upgrade their own ageing vessels.

Uncertainties in the success of the YES initiative to increase employment and hence the number of small boats operating inshore, also creates further uncertainty over the status of the resource base in this region. The YES initiative could still be exacerbating this situation.

- Since 1996, the government YES soft loan initiative has been successful in disbursing over 145 loans to a group of young fishers, 40 years of age and under. Uncertainties remain however, over the number of new employment opportunities actually created and the likely impact this has had on the inshore resource base. The results also indicate that the level of inshore fishing effort may be partly controlled by the

availability of soft loans, whether they are used to purchase additional vessels or replace part of the existing fleet.

- Skippers (non-boat owners) are a homogenous group of relatively old and more experienced fishers. It could be argued that the YES soft loan initiative has provided financial incentives for young crew members by-pass this category to purchase their own boat with relatively little or no experience. Evidence to support this assumption is given by the presence of younger age classes within owner-operators of small boats.

Following an analysis of the results of the 1997 socio-economic survey, it has been shown that the government YES soft loan initiative has been instrumental in maintaining a high level of fishing effort within the inshore region. The government may therefore be able to reduce the level of fishing effort by restricting the number of commercial small boats purchased by the soft loan scheme.

It has been shown that the government YES soft loan initiative has been instrumental in maintaining a high level of fishing effort within the inshore region. The government may therefore be able to reduce the level of fishing effort by restricting the number of commercial small boats purchased by the soft loan scheme.

Appendix 4.1 Estimated total number of days spent fishing by small boat-gear categories between 1986-97. *(The results assume that average trip length for small boat = 1.0 day).*

	Ave. Number of Boats (b_y)†			Total Man days (L_y)†			Number of fishers per boat (ϖ_y)‡			Number of trips per year (d_y)		
Year	Trap	Handline	Both	Trap	Hand	Both	Trap	Handline	Both	Trap	Handline	Both
86	41.5	86.0	40.0	-	26,862	13,735	1.94	2.10	2.09	-	149	164
87	37.2	75.4	33.4	9,660	18,855	8,078	1.87	2.20	2.24	139	113	108
88	49.8	72.6	19.1	13,810	17,275	4,145	1.88	2.25	2.11	148	106	103
89	49.8	68.0	14.0	13,167	13,482	4,295	1.88	2.11	2.06	141	94	149
90	54.4	90.7	27.8	8,493	13,224	5,097	1.86	2.10	2.22	84	69	82
91	67.4	78.1	31.4	15,856	12,015	6,445	1.90	2.13	2.10	124	72	98
92	71.2	70.9	30.8	20,952	11,700	7,572	2.06	2.12	2.10	143	78	117
93	68.4	73.3	35.7	16,625	13,216	7,455	1.98	2.14	2.17	123	84	96
94	69.3	61.0	30.5	14,223	13,006	4,670	1.90	2.03	1.85	108	105	83
95	64.3	67.1	34.3	14,223	12,564	5,331	1.95	2.09	2.07	113	90	75
96	64.9	57.0	31.0	14,553	13,116	4,857	2.04	2.22	2.17	110	103	72
97	71.1	65.3	33.8	10,696	14,235	-	2.13	2.32	2.17	70	94	-

Source;

†*SFA Technical Reports (1987-1998).*

‡*Art_Fish database; SFA, 1998.*

Appendix 4.2 Estimated total number of fishing trips by large boats operating within both inshore and offshore fishing regions between 1986-97.

Year	Number of boats (b_y)†	Man days (L_y)†	Number of Fishers (ϖ_y)‡	Average Trip length (i_s)‡		Number of trips per year (d_y)	
				Inshore	Offshore	Inshore	Offshore
86	74	62,648	5.41	1.24	4.48	126	35
87	84	78,876	5.42	1.24	4.48	140	39
88	91	74,179	4.98	1.24	4.48	132	37
89	97	58,876	5.19	1.24	4.48	94	26
90	102	70,450	5.18	1.24	4.48	108	30
91	111	67,699	5.04	1.24	4.48	98	27
92	108	52,496	4.91	1.24	4.48	80	22
93	103	56,128	4.82	1.24	4.48	91	25
94	104	52,660	4.71	1.24	4.48	87	24
95	103	56,404	4.31	1.24	4.48	103	28
96	103	65,897	4.17	1.24	4.48	124	34
97	105	49,769	3.76	1.24	4.48	102	28

Source;

†*SFA Technical Reports (1987-1998)*

‡*Art_Fish database; SFA, 1998*

Appendix 4.3 Estimation of q-values for the small boat reef fishery

	Biomass	Catch	Boats (b_y)†		Crew Num. (ϖ_y)‡		Days fishing (d_y)		Ave. Trap p/p		Traps Set (E_{yr})			
Yr	(B_{yr})	(C_{yr})	Trap	Both	Trap	Both	Trap	Both	Trap	Both	Trap	Both	Total	Est. q
86	1,283	543	41.5	39.9	1.94	2.09	130	164	6.18	4.02	64,542	54,959	119,501	0.00000354
87	1,184	419	37.2	33.4	1.86	2.22	139	108	4.76	3.66	45,698	29,358	75,056	0.00000471
88	1,223	523	49.8	19.1	1.87	2.12	148	103	4.56	4.03	62,794	16,766	79,560	0.00000538
89	1,153	512	49.8	14	1.88	2.06	141	149	4.28	2.62	56,399	11,282	67,681	0.00000655
90	1,102	280	54.4	27.8	1.86	2.22	84	82	3.89	4.12	33,036	20,859	53,894	0.00000471
91	1,285	458	67.4	31.4	1.91	2.12	124	98	4.31	3.75	68,615	24,417	93,032	0.00000383
92	1,271	543	71.2	30.8	2.05	2.12	143	117	4.78	2.55	99,736	19,439	119,174	0.00000358
93	1,175	590	68.4	35.7	1.99	1.93	123	96	4.14	2.47	69,362	16,326	85,688	0.00000586
94	1,043	444	69.3	30.5	1.90	1.85	108	83	4.35	3.41	61,869	15,916	77,784	0.00000547
95	1,062	448	64.3	34.3	1.91	1.91	113	75	5.40	4.78	74,833	23,475	98,308	0.00000429
96	1,077	456	64.9	31	2.04	2.17	110	72	5.35	3.94	77,809	19,044	96,853	0.00000437
97	1,084	306	71.1	33.8	2.13	2.17	70	72	5.27	3.02	55,995	15,977	71,972	0.00000392
													Average:	0.00000469

Source;

†*SFA Technical Reports (1987-1998)*

‡*Art_Fish database; SFA, 1998*

Appendix 4.4 q values for inshore handline for large and small boats. Where (A) is small boat handline only, (B) is small boat trap & handline, and (C) is large boat inshore handline only.

	Biomass	Catch (C_{yr})		Boats (b_y)†			Crew Num. (ϖ_y)‡			Days fishing(d_y)			Man Days (L_{yr})				Est. q	
Yr	(B_{yrs})	Small	Large	A	B	C	A	B	C	A	B	C	A	B	Small	C	Small	Large
86	3,200	289	417	67.9	39.9	46.1	1.94	2.09	5.59	130	164	126	17,087	10,519	27,606	32,499	0.00000327	0.00000401
87	3,262	209	361	75.4	33.4	55.2	1.86	2.22	5.30	139	108	140	19,459	6,176	25,635	40,844	0.00000250	0.00000271
88	3,460	194	307	72.6	19.1	58.8	1.87	2.12	4.87	148	103	132	20,075	3,204	23,279	37,776	0.00000241	0.00000235
89	3,722	238	371	68.0	14.0	66.1	1.88	2.06	5.00	141	149	132	18,001	3,316	21,317	43,561	0.00000299	0.00000229
90	3,861	207	753	90.7	27.8	70.1	1.86	2.22	4.71	84	82	132	14,159	3,901	18,060	43,564	0.00000297	0.00000447
91	3,637	216	636	78.1	31.4	73.2	1.91	2.12	4.47	124	98	132	18,456	5,014	23,469	43,156	0.00000254	0.00000406
92	3,537	133	782	70.9	30.8	72.7	2.05	2.12	4.35	143	117	132	20,777	5,870	26,647	41,752	0.00000141	0.00000529
93	3,383	237	824	73.3	35.7	69.4	1.99	1.93	4.07	123	96	132	17,967	5,089	23,057	37,284	0.00000303	0.00000653
94	3,088	201	521	61.0	30.5	70.0	1.90	1.85	4.01	108	83	132	12,519	3,599	16,118	37,031	0.00000403	0.00000456
95	3,133	194	801	67.1	34.3	70.2	1.91	1.91	3.99	113	75	132	14,461	3,782	18,243	37,009	0.00000339	0.00000691
96	2,905	134	742	57.0	31.0	70.4	2.04	2.17	3.99	110	72	124	12,773	3,722	16,495	34,724	0.00000280	0.00000736
97	2,790	128	582	65.3	33.8	71.2	2.13	2.17	3.77	70	72	102	9,758	4,074	13,832	27,271	0.00000332	0.00000765
																Average:	0.00000289	0.00000485

Source;

†*SFA Technical Reports (1987-1998)*

‡*Art_Fish database; SFA, 1998*

Appendix 4.5 Demersal catch from inshore handlines

Where:

B_{max} = 3,810 tonnes

B_{start} = 3,810 tonnes

r = 0.48

	Biomass	Catch (tonnes) (C_{yr})		
Yr	(tonnes) (B_{yr})	Small	Large	Total
86	3,810	289	417	706
87	3,104	209	361	570
88	2,810	194	307	500
89	2,664	238	37	608
90	2,440	207	753	960
91	1,901	216	636	852
92	1,505	133	782	914
93	1,028	237	824	1061
94	328	201	521	722
95	-250	194	801	995
96	-1,373	134	742	876
97	-3,146	128	582	710

Appendix 4.6 Offshore handline

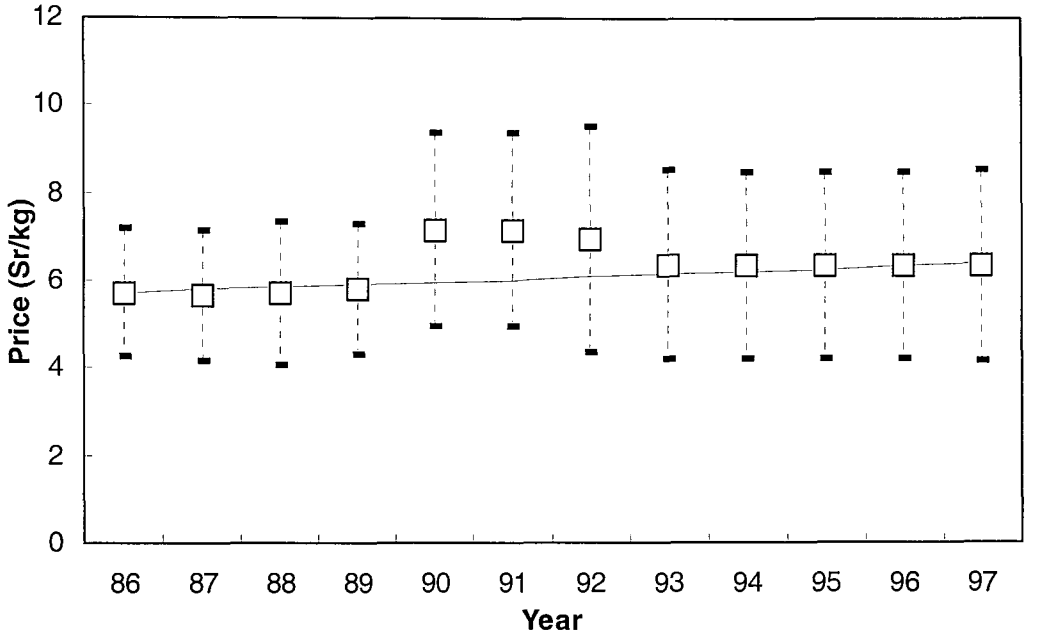
Yr	Biomass (B_{yr})	Catch (C_{yr})	Boats (b_y)†	Crew (c_y)‡	Trip (i_s)‡	Days (d_y)	Man Days (L_{yr})	Est. q
86	40,000	717.0	19.77	5.13	35	4.48	15,865	0.0000011
87	40,417	803.0	23.64	5.51	39	4.48	22,573	0.0000009
88	40,548	659.5	25.2	5.03	37	4.48	20,741	0.0000008
89	40,759	724.7	28.32	5.38	26	4.48	17,817	0.0000010
90	40,802	992.9	30.06	5.3	30	4.48	21,244	0.0000011
91	40,555	1,454	31.35	5.34	27	4.48	20,280	0.0000018
92	39,968	134.2	31.14	5.27	22	4.48	16,245	0.0000002
93	40,983	866.7	29.73	5.52	25	4.48	18,539	0.0000011
94	40,773	937.2	30	5.38	24	4.48	17,329	0.0000013
95	40,596	995.1	30.09	4.62	28	4.48	17,675	0.0000014
96	40,448	876.5	30.18	4.35	34	4.48	20,141	0.0000011
97	40,491	710.0	30.51	3.77	28	4.48	14,505	0.0000012
							Average:	0.0000011

Source; †SFA Technical Reports (1987-1998); ‡Art_Fish database; SFA, 1998

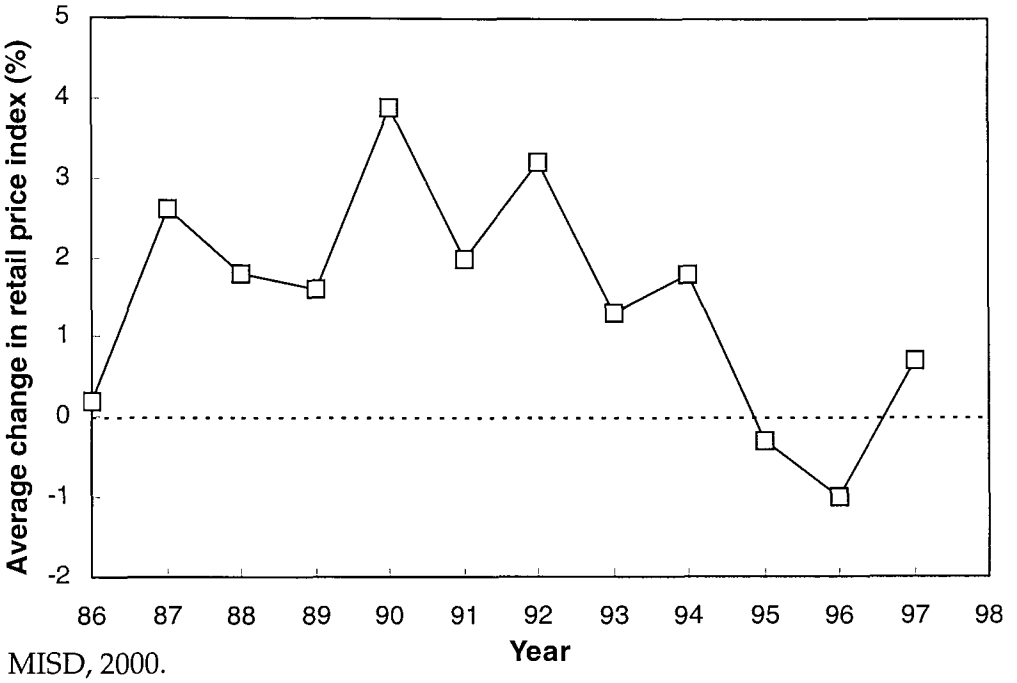
Appendix 4.7 Estimation of fuel voucher subsidy for outboard and inboard powered vessels between 1991 - 97.

	Annual fuel subsidy per vessel (Sr)	
Year	Outboard (petrol)	Inboard (diesel)
1991	1,356	2,984
1992	1,965	4,058
1993	2,827	5,518
1994	4,127	7,505
1995	6,025	10,207
1996	8,797	13,881
1997	8,797	13,881

Appendix 4.8 Total average fish price (± standard deviation) for Oceana Pty fish centre, with rate of inflation at 1% per annum (solid line).



Appendix 4.9 Average change in retail price index to estimate rate of inflation in Seychelles between 1986 and 1997.



Source: MISD, 2000.

Appendix 5.1 Proportion of decisions made by each socio-economic group within both small and large boat-gear categories.

Small Boats

Table A5.1 Socio-economic group 1.

Decision Rule	Decisions made at different financial status			Total
	Stay the same	Leave fishery	Change	
1	0.54	0.00	0.46	1.00
2	0.64	0.00	0.36	1.00
3[c]	0.00	0.20	0.80	1.00
3[d]	0.22	0.45	0.33	1.00
4	0.00	0.35	0.65	1.00

Table A5.2 Socio-economic group 2.

Decision Rule	Decisions made at different financial status			Total
	Stay the same	Leave fishery	Change	
1	0.33	0.00	0.67	1.00
2	0.33	0.00	0.37	1.00
3[a]	0.00	0.00	1.00	1.00
3[b]	0.00	0.00	1.00	1.00
4	0.00	0.00	1.00	1.00

Table A5.3 Socio-economic group 3.

Decision Rule	Decisions made at different financial status			Total
	Stay the same	Leave fishery	Change	
1	0.75	0.00	0.25	1.00
2	0.40	0.20	0.40	1.00
3[a]	0.00	0.00	1.00	1.00
3[b]	0.00	0.50	0.50	1.00
4	0.00	0.25	0.75	1.00

[c] Decision proportion of fishers who originally wanted to 'change' when reached minimum acceptable level of income.

[d] Decision proportion of fishers who originally wanted to 'stay the same' when reached minimum acceptable level of income.

Table A5.4 Socio-economic group 4.

Decision Rule	Decisions made at different financial status			Total
	Stay the same	Leave fishery	Change	
1	0.50	0.00	0.50	1.00
2	0.16	0.16	0.68	1.00
3[a]	0.50	0.50	0.00	1.00
3[b]	0.00	0.00	1.00	1.00
4	0.33	0.33	0.33	1.00

Table A5.5 Socio-economic group 5.

Decision Rule	Decisions made at different financial status			Total
	Stay the same	Leave fishery	Change	
1	1.00	0.00	0.00	1.00
2	0.00	0.00	1.00	1.00
3[a]	0.00	0.00	1.00	1.00
3[b]	0.00	0.00	0.00	0.00
4	0.00	0.00	1.00	1.00

Large Boats

Table A5.6 Socio-economic group 1.

Decision Rule	Decisions made at different financial status			Total
	Stay the same	Leave fishery	Change	
1	1.00	0.00	0.00	1.00
2	0.75	0.00	0.25	1.00
3[a]	0.00	0.20	1.00	1.00
3[b]	0.33	0.67	0.00	1.00
4	0.00	0.75	0.25	1.00

[a] Decision proportion of fishers who originally wanted to 'change' when reached minimum acceptable level of income.

[b] Decision proportion of fishers who originally wanted to 'stay the same' when reached minimum acceptable level of income.

Table A5.7 Socio-economic group 2 (no fishers present in group).

Decision Rule	Decisions made at different financial status			Total
	Stay the same	Leave fishery	Change	
1	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00
3[a]	0.00	0.00	0.00	0.00
3[b]	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00

Table A5.8 Socio-economic group 3.

Decision Rule	Decisions made at different financial status			Total
	Stay the same	Leave fishery	Change	
1	1.00	0.00	0.00	1.00
2	0.88	0.00	0.12	1.00
3[a]	0.00	0.00	1.00	1.00
3[b]	0.29	0.42	0.29	1.00
4	0.24	0.38	0.38	1.00

Table A5.9 Socio-economic group 4.

Decision Rule	Decisions made at different financial status			Total
	Stay the same	Leave fishery	Change	
1	0.50	0.00	0.50	1.00
2	1.00	0.00	0.00	1.00
3[a]	0.00	0.00	0.00	0.00
3[b]	0.00	0.00	1.00	1.00
4	0.00	0.00	1.00	1.00

[a] Decision proportion of fishers who originally wanted to 'change' when reached minimum acceptable level of income.

[b] Decision proportion of fishers who originally wanted to 'stay the same' when reached minimum acceptable level of income.

Table A5.10 Socio-economic group 5.

Decision Rule	Decisions made at different financial status			Total
	Stay the same	Leave fishery	Change	
1	0.67	0.00	0.33	1.00
2	0.50	0.50	0.00	1.00
3[a]	0.00	0.00	0.00	0.00
3[b]	0.00	0.50	0.50	1.00
4	0.00	0.50	0.50	1.00

[a] Decision proportion of fishers who originally wanted to 'change' when reached minimum acceptable level of income.

[b] Decision proportion of fishers who originally wanted to 'stay the same' when reached minimum acceptable level of income.

Appendix 5.2

$$p(x) = a\left(\left(\frac{e^{\frac{(-k-k_{ave})}{\varepsilon}} - e^{\frac{(k-k_{ave})}{\varepsilon}}}{2\left(e^{\frac{(k_{ave})}{\varepsilon}} - e^{\frac{(-k_{ave})}{\varepsilon}}\right)}\right) + 0.5\right)$$

Equation A5.1

In this equation, k_{ave} is the average net income (SR28,572) for members working outside the fisheries sector. k is the net income (SR) generated from the boat-gear category.

Appendix 6.1 Comparison of simulated model output with simulated socio-economic data.

The model was set up to simulate the number of fishers within each socio-economic group during 1986 using the proportions of fishers within each group identified within the 1997 survey. This assumes that the proportion of fishers have not changed substantially since 1986.

This section illustrates the total numbers of fishers within each socio-economic group of different boat-gear categories for the estimated historical data (Figure A6.1) and the simulated tuned (Figure A6.2) and untuned mode (Figure A6.3).

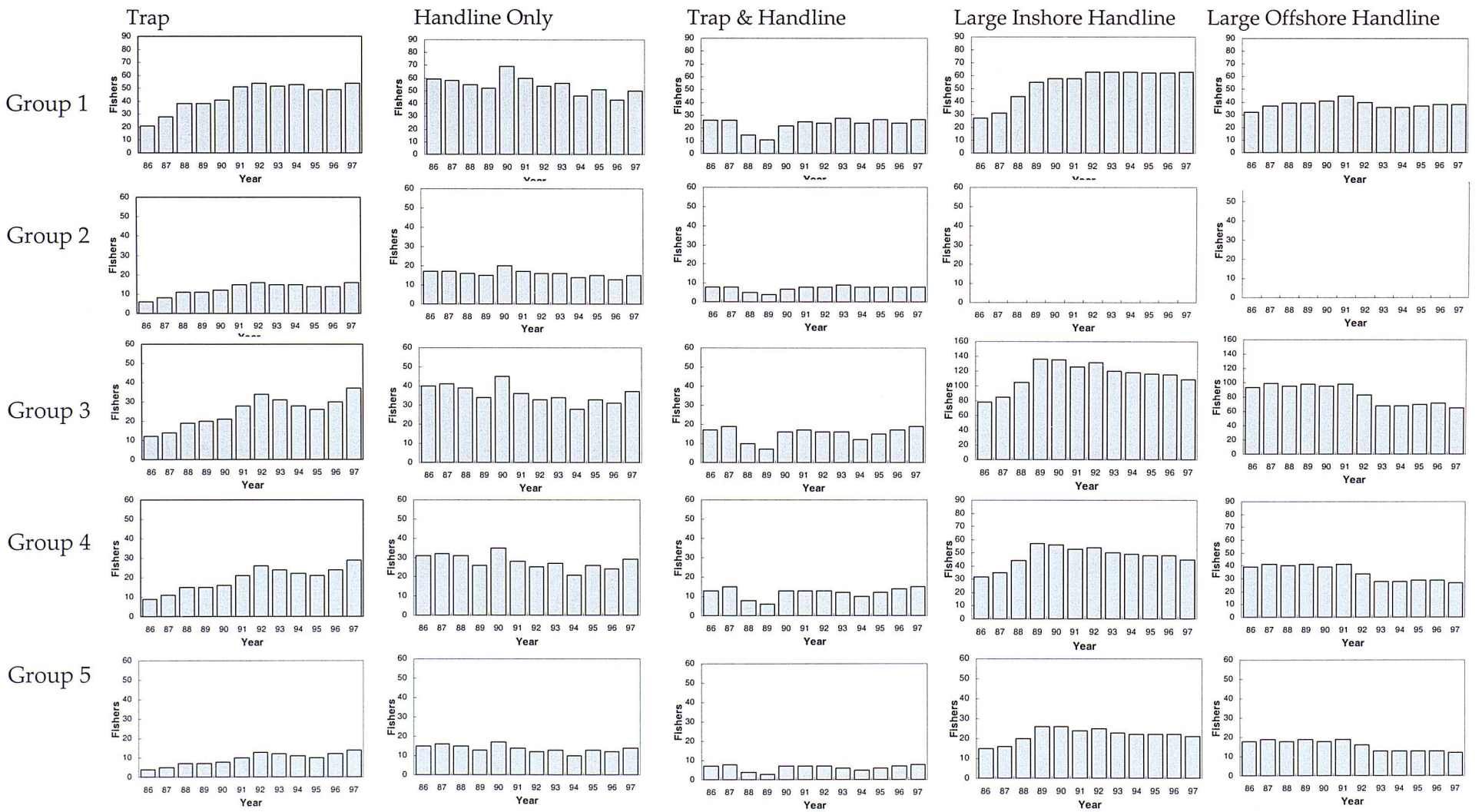


Figure A6.1 Number of fishers within each socio-economic group (1-5) for different boat-gear categories of the artisanal fishery.

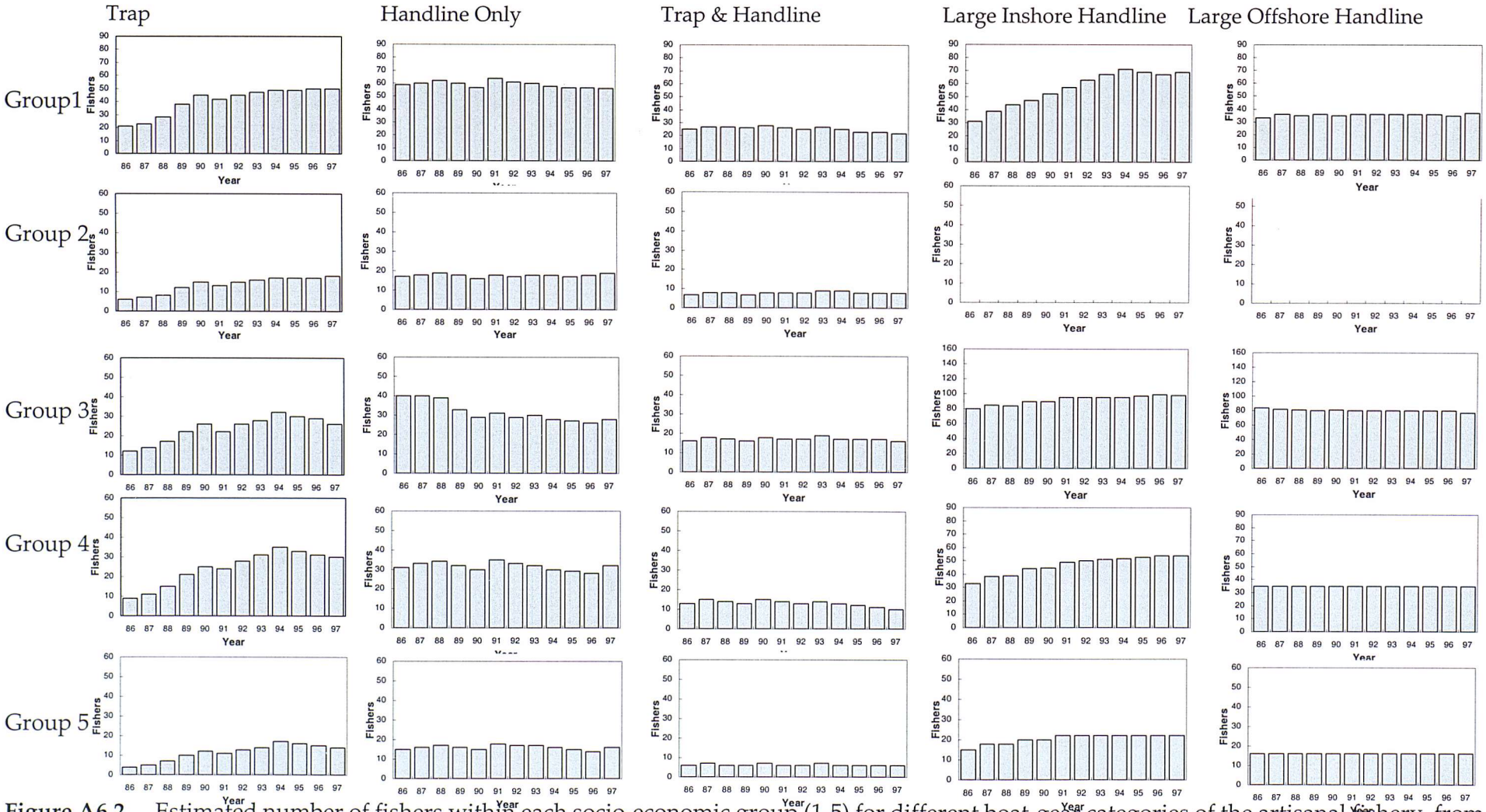


Figure A6.2 Estimated number of fishers within each socio-economic group (1-5) for different boat-gear categories of the artisanal fishery, from tuned model outputs.

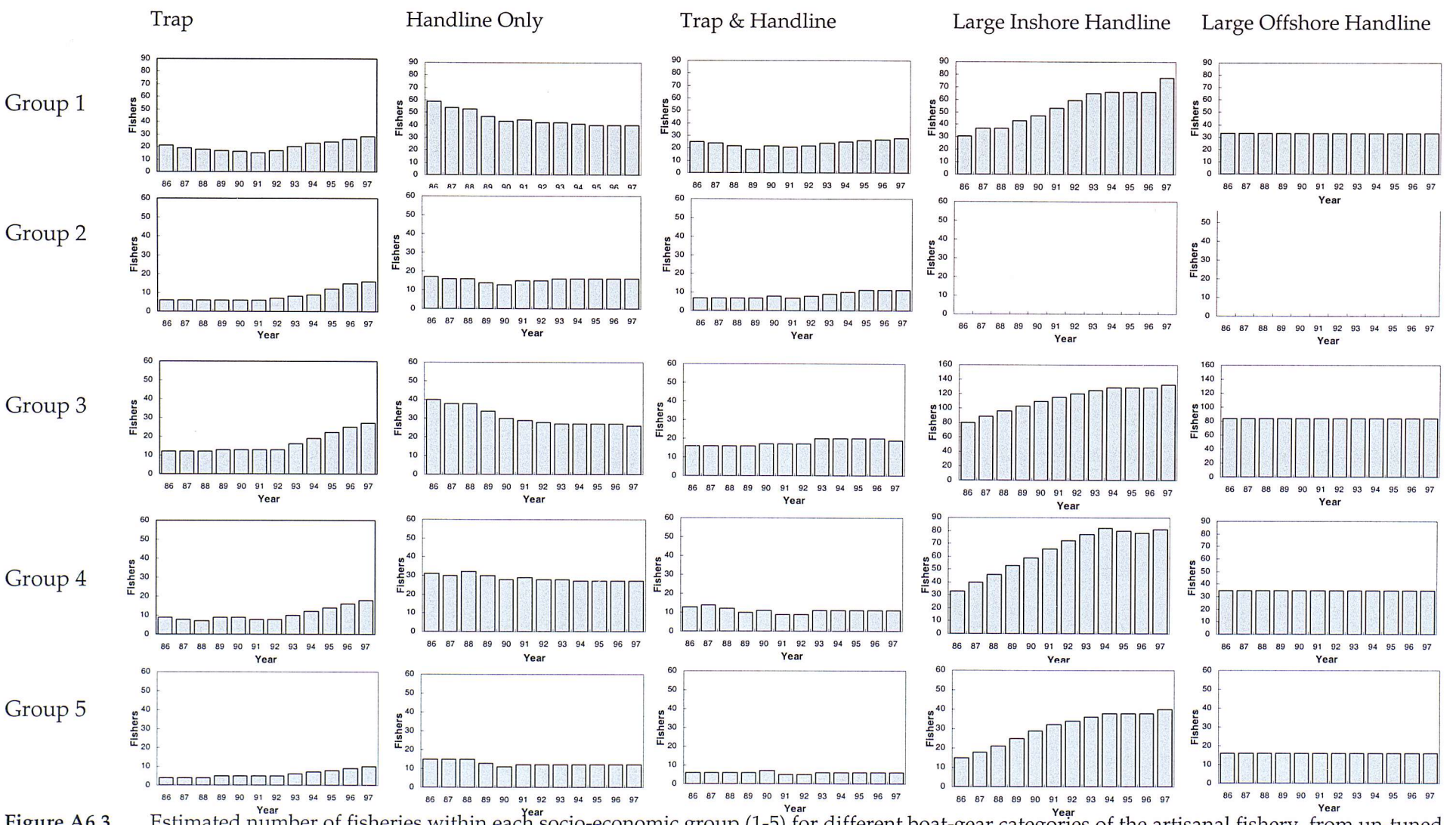


Figure A6.3 Estimated number of fisheries within each socio-economic group (1-5) for different boat-gear categories of the artisanal fishery, from un-tuned model outputs.

Appendix 6.2 Details of un-tuned technical model parameters

Table A6.1 Estimated average number of fishing trips between 1986 and 1997 by different boat-gear categories from the untuned model.

Year	Trap-only	Handline-only	Trap & handline	Large inshore	Large offshore
86	160	149	164	126	35
87	139	113	108	140	39
88	148	106	103	132	37
89	141	94	149	94	26
90	84	69	82	108	30
91	124	72	98	98	27
92	143	78	117	80	22
93	123	84	96	91	25
94	108	105	83	87	24
95	113	90	75	103	28
96	110	103	72	124	34
97	70	94	41	102	28

Appendix 7.1 Performance of 15 alternative management options determined by a series of biological, economic and socio-economic performance measures.

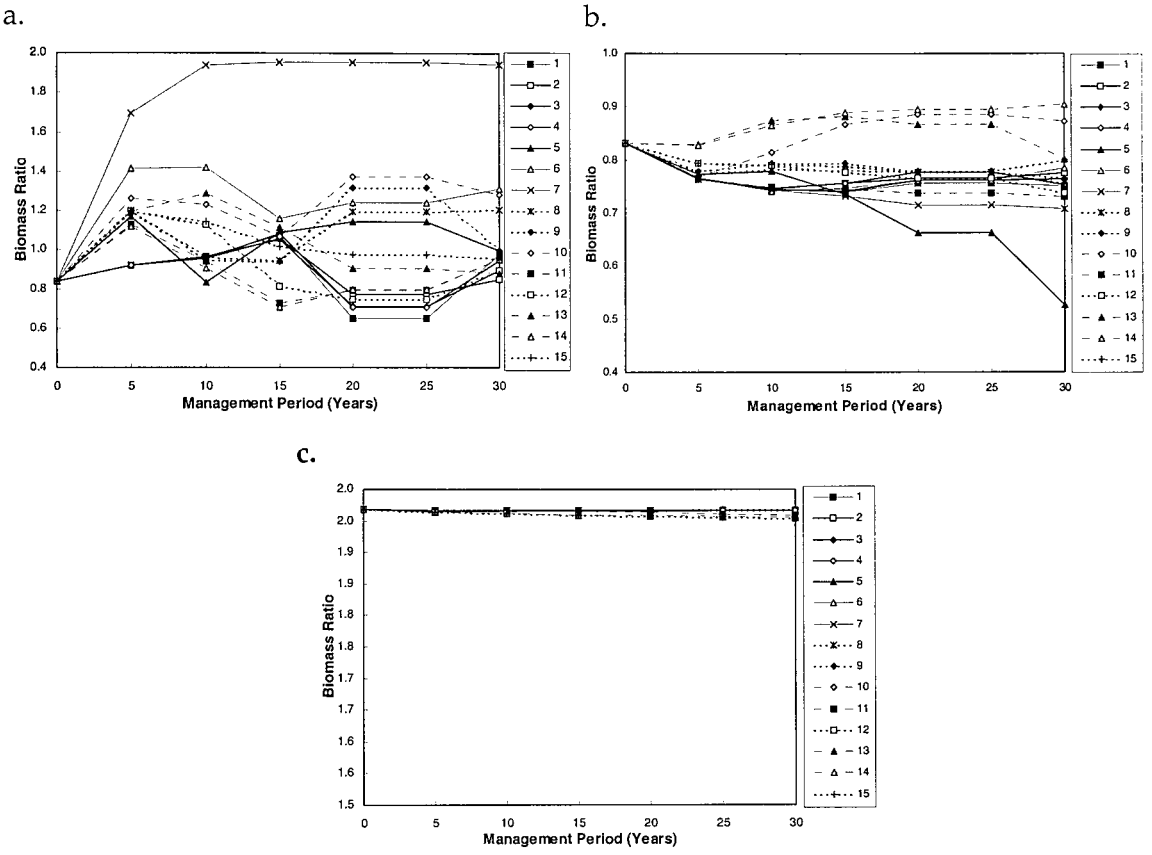


Figure A7.1 Estimated biomass ratio (B_{yr} / B_{MSY}) of 15 alternative management options over successive 5 year intervals up to 30 years: a) reef b) inshore demersal and, c) offshore demersal. The maximum sustainable yield is achieved where biomass ratio is 1.0 [Note differences in scale].

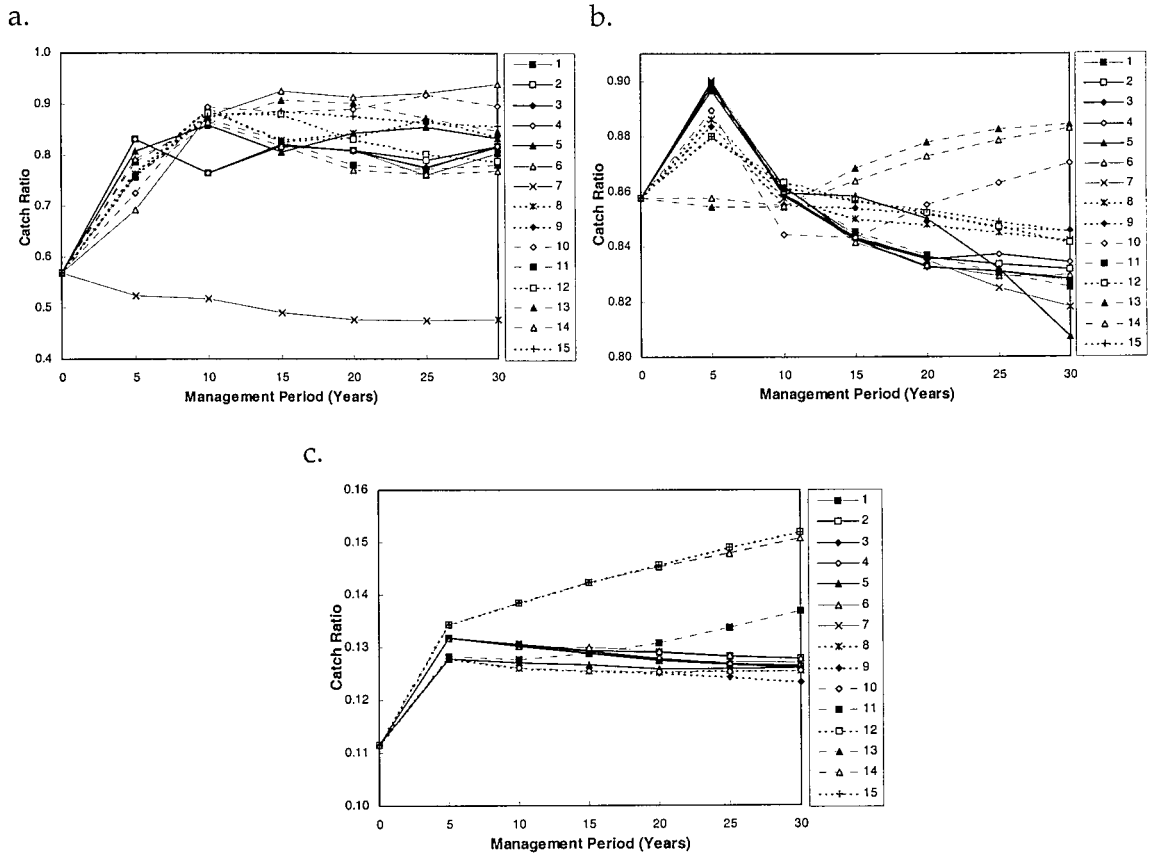


Figure A7.2 Estimated cumulative total catch ratio (C_{yr} / C_{MSY}) of 15 alternative management options over successive 5 year intervals up to 30 years: a) reef b) inshore demersal and, c) offshore demersal [Note differences in scale].

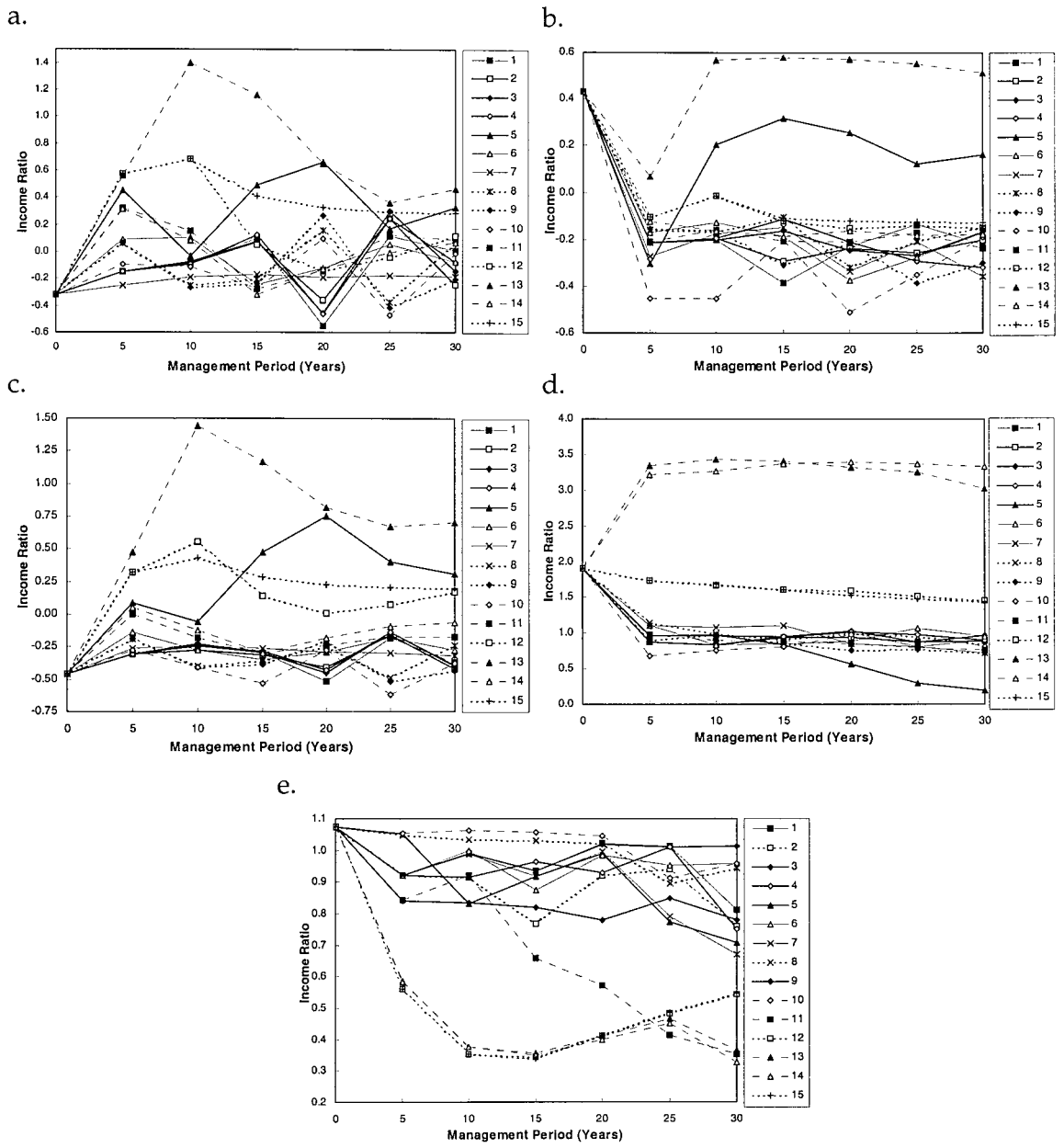


Figure A7.3 Estimated income ratio ((i_{yr} / $i_{average}$) - 1) of 15 alternative management options over successive 5 year intervals up to 30 years: a) trap-only b) handline-only c) trap & handline d) large inshore and, e) large offshore. The national average level of income is equivalent to an income ratio of 0 [Note differences in scale].

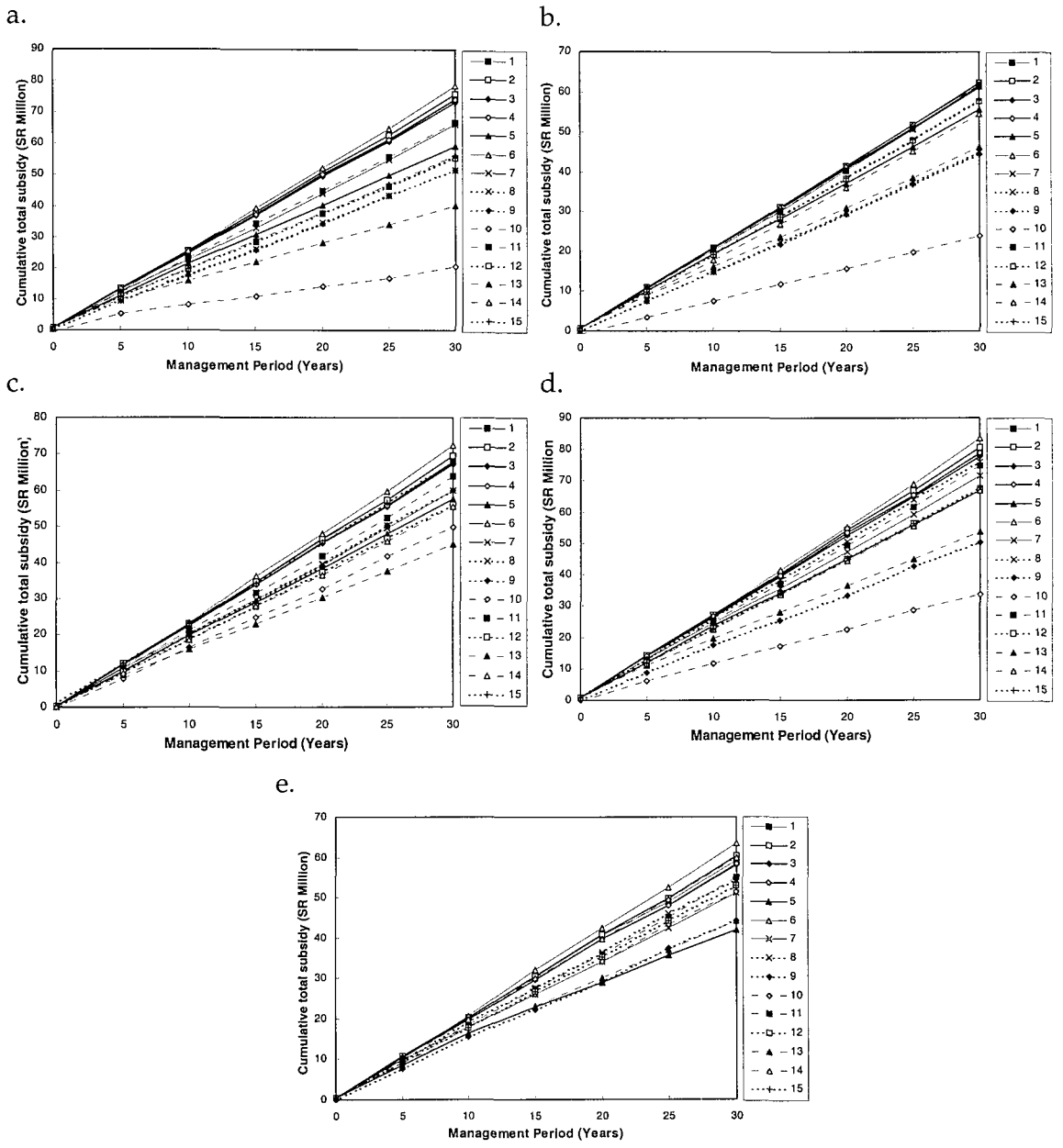


Figure A7.4 Estimated total government subsidy over a simulated period of 30 years for a range of alternative management options (1-15): a) trap-only b) handline-only c) trap & handline d) large inshore and, e) large offshore.

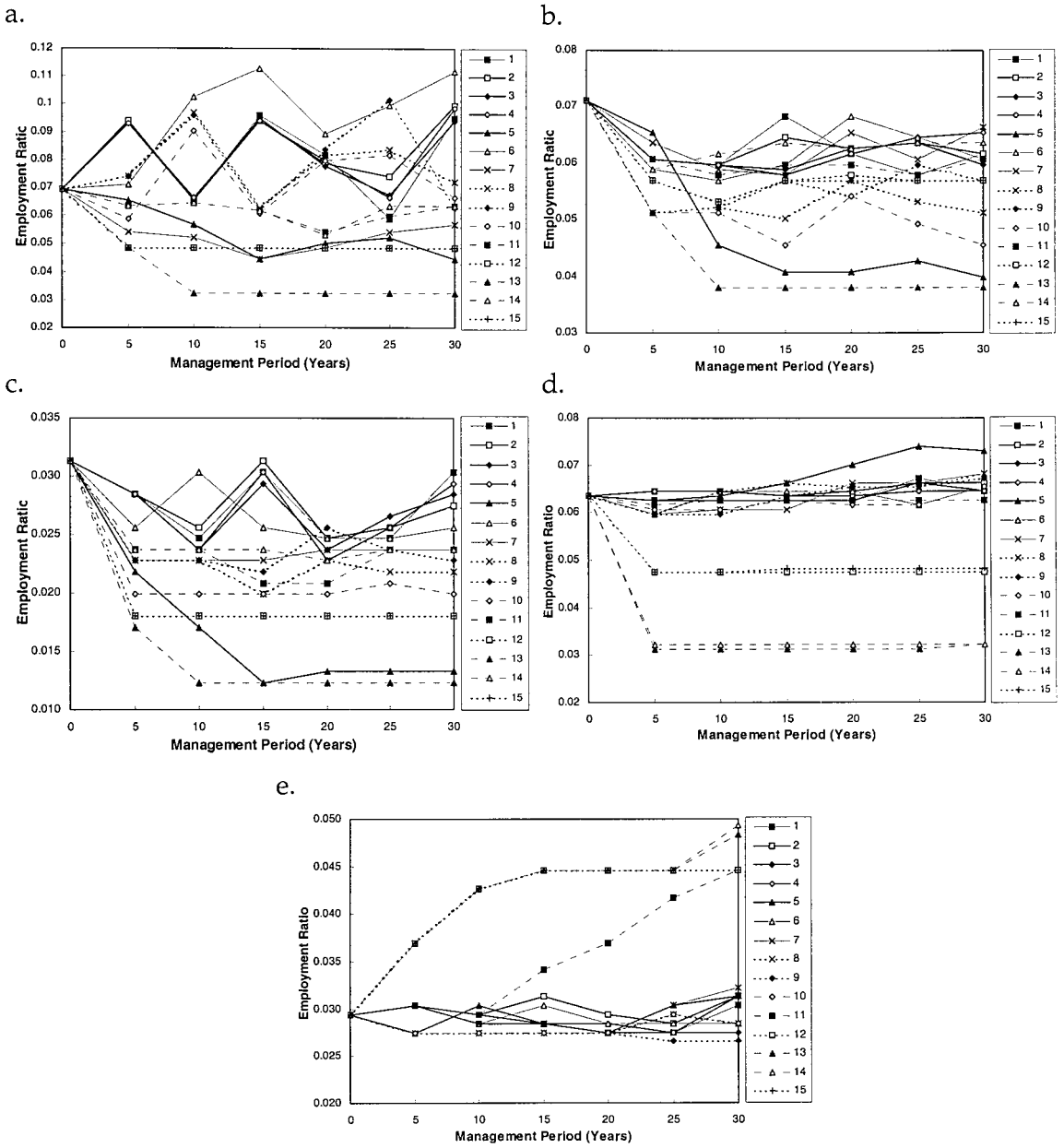


Figure A7.5 Estimated owner-operator employment ratio (L_{yr} / L^*) of 15 alternative management options over successive 5 year intervals up to 30 years: a) trap-only b) handline-only c) trap & handline d) large inshore and, e) large offshore. Where L* represents total number in available labour force (fisheries sector and pool). [Note differences in scale].

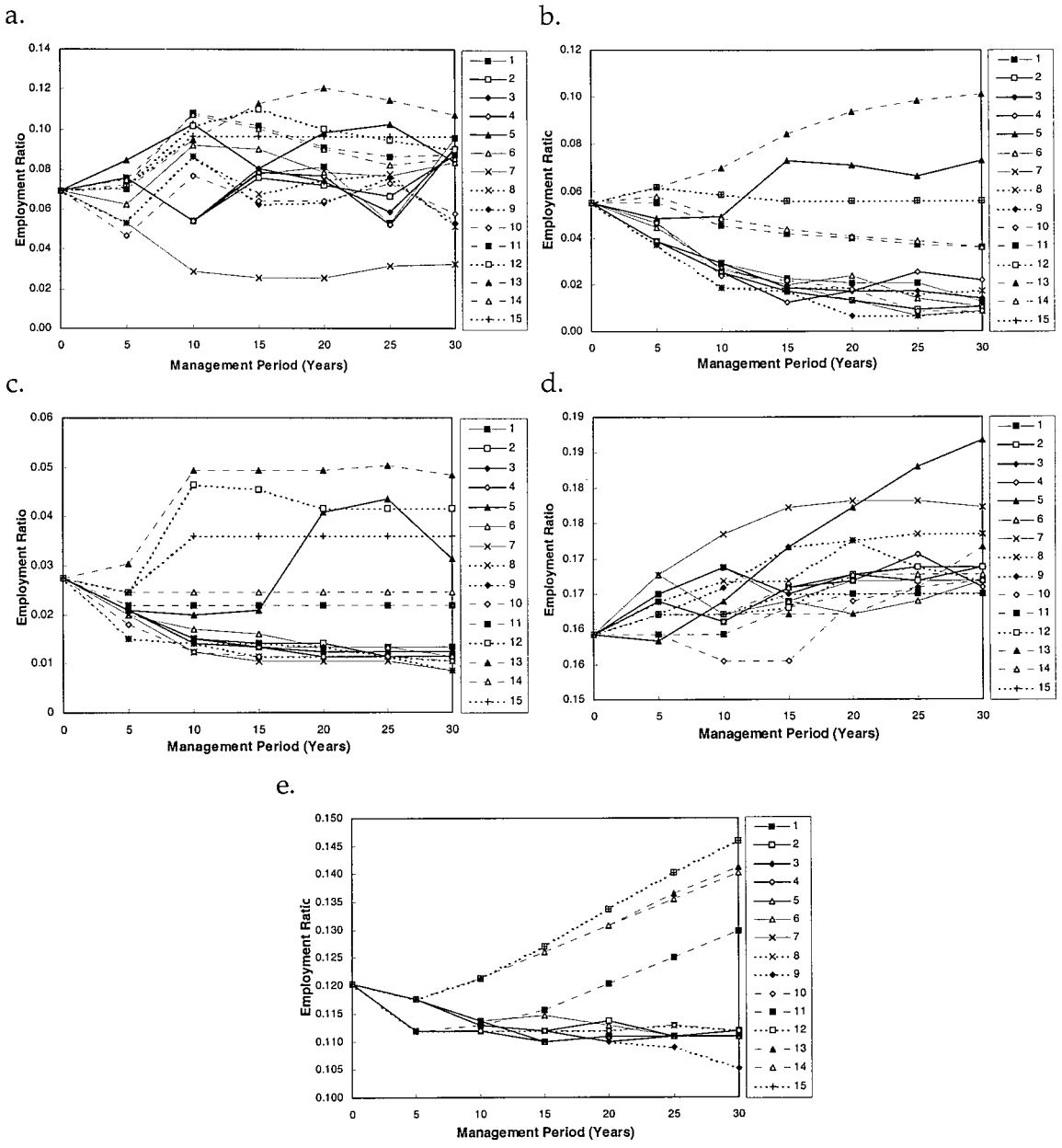


Figure A7.6 Estimated crew member employment ratio (L_{yr} / L^*) of 15 alternative management options over successive 5 year intervals up to 30 years: a) trap-only b) handline-only c) trap & handline d) large inshore and, e) large offshore. Where L* represents total number in available labour force (fisheries sector and pool). [Note differences in scale].

Appendix 7.2 Performance of 6 future scenarios for each performance measure, determined by a series of biological, economic and socio-economic performance measures. [Where 1) control 2) increase in pool numbers 3) decrease in pool numbers 4) increase in offshore fish prices 5) 25% reduction in semi-pelagic fish population and, 6) 25% reduction in reef and demersal fish populations]

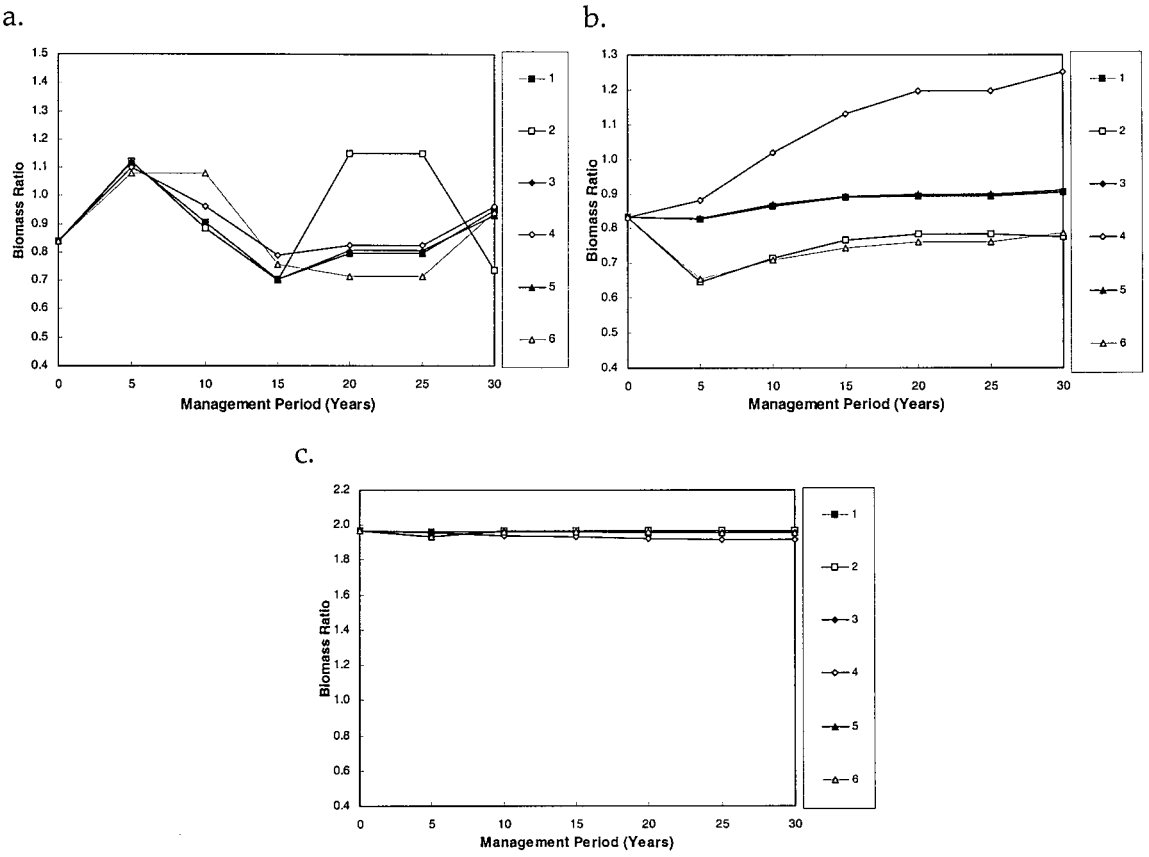


Figure A7.7 Estimated biomass ratio (B_{yr} / B_{MSY}) for 6 future scenarios over successive 5 year intervals up to 30 years: a) reef b) inshore demersal and, c) offshore demersal. The maximum sustainable yield is achieved where biomass ratio is 1.0 [Note differences in scale].

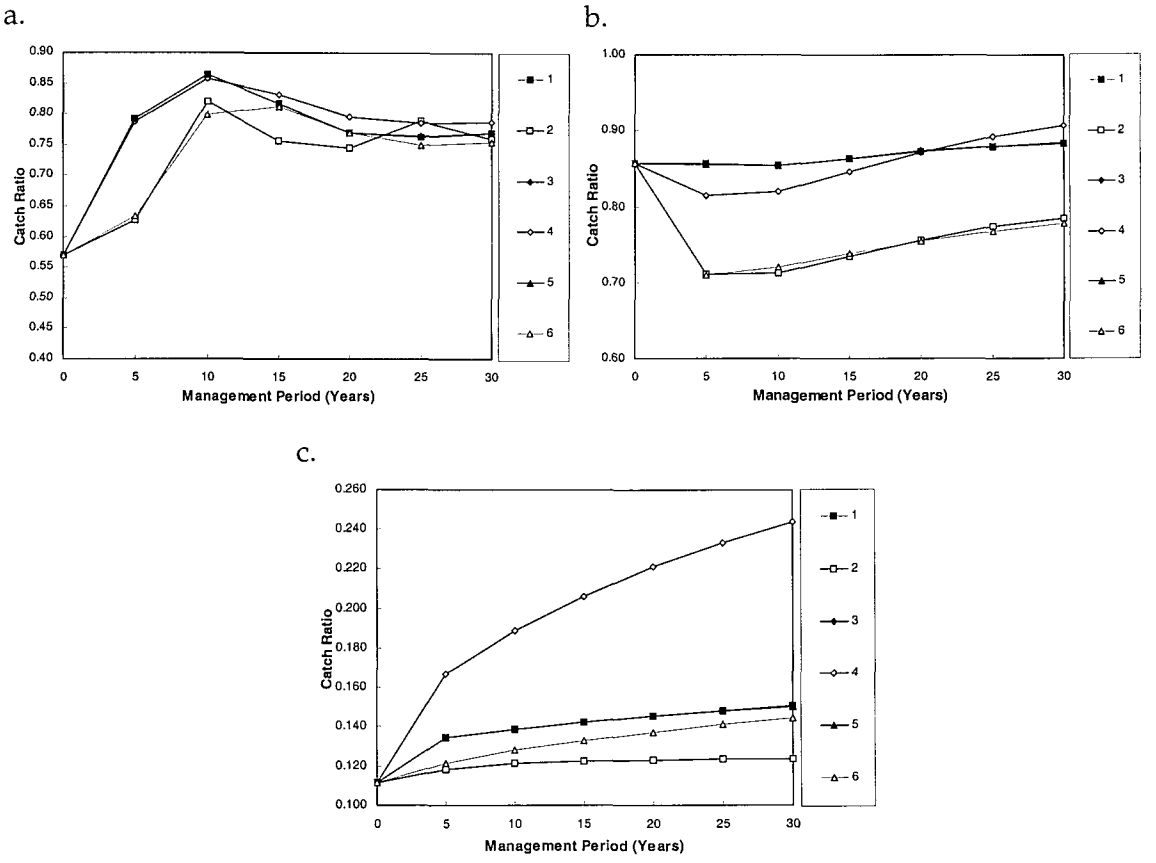


Figure A7.8 Estimated total accumulated catch ratio (C_{yr} / C_{MSY}) for 6 future scenarios over successive 5 year intervals up to 30 years: a) reef b) inshore demersal and, c) offshore demersal [Note differences in scale].

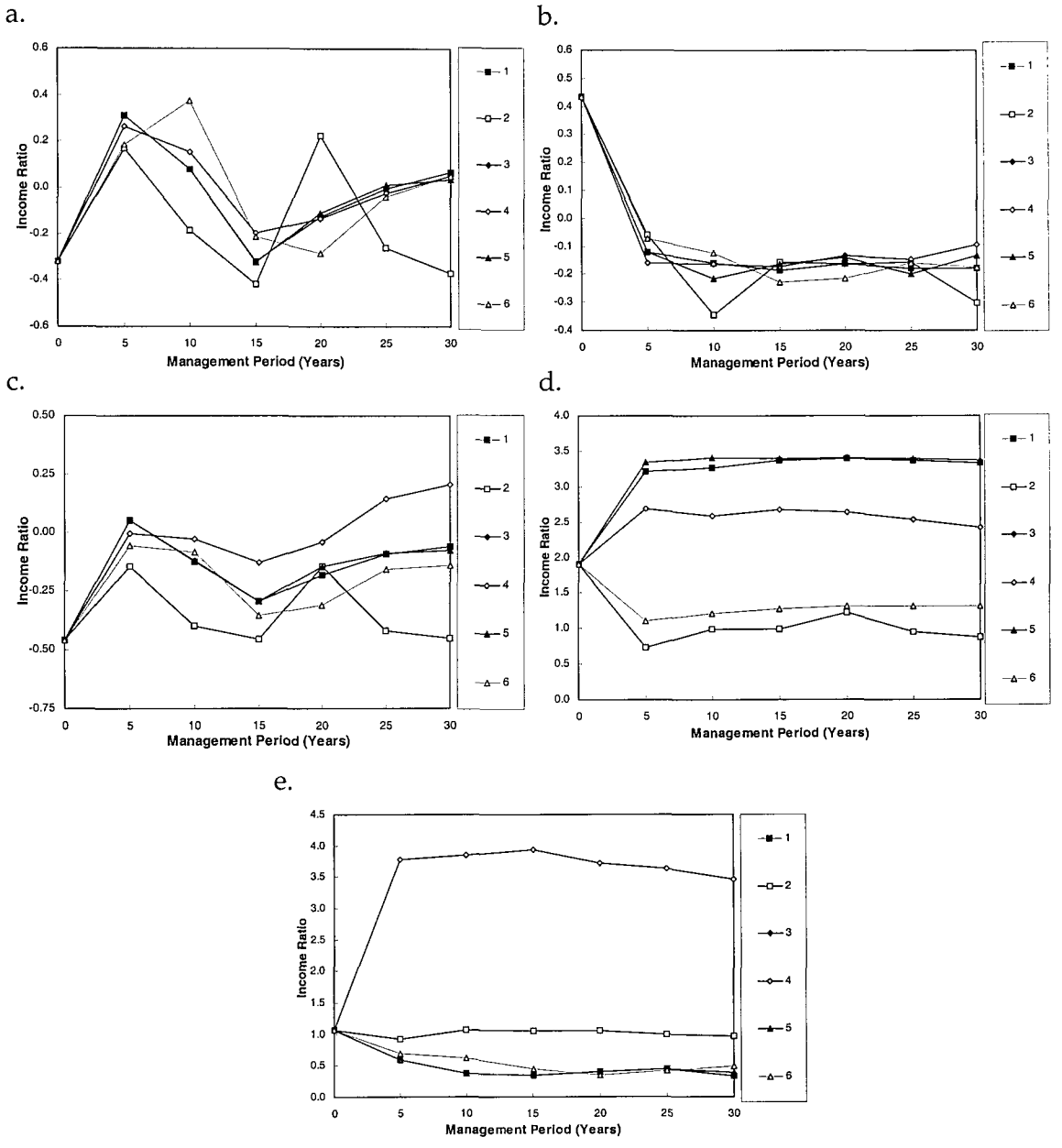


Figure A7.9 Estimated income ratio ((i_{yr} / $i_{average}$) - 1) for 6 future scenarios over successive 5 year intervals up to 30 years: a) trap-only b) handline-only c) trap & handline d) large inshore and, e) large offshore. The national average level of income is equivalent to an income ratio of 0 [Note differences in scale].

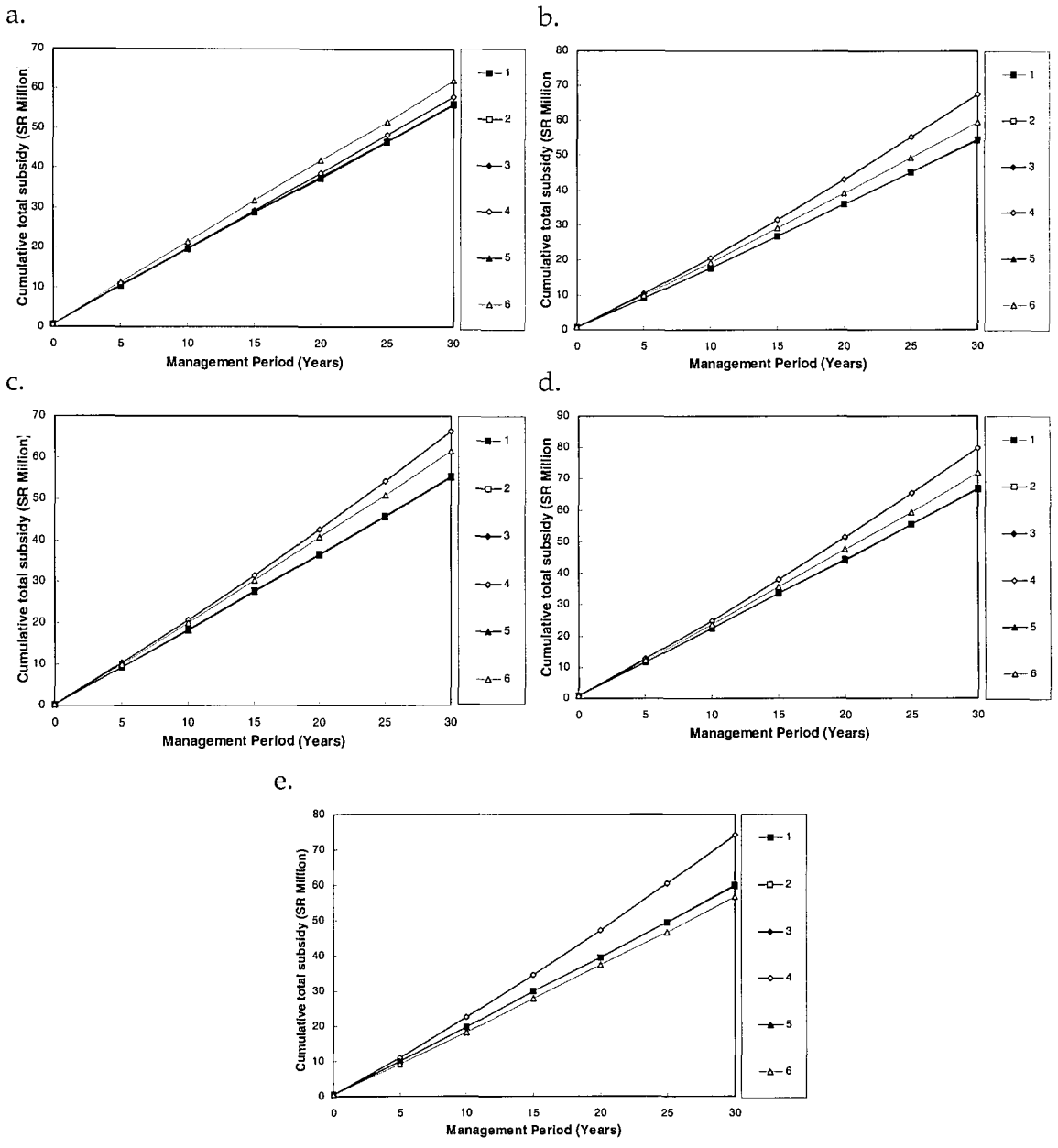


Figure A7.10 Estimated total government subsidy (SR million) for 6 future scenarios over a simulated period of 30 years: a) trap-only b) handline-only c) trap & handline d) large inshore and, e) large offshore. [Note differences in scale].

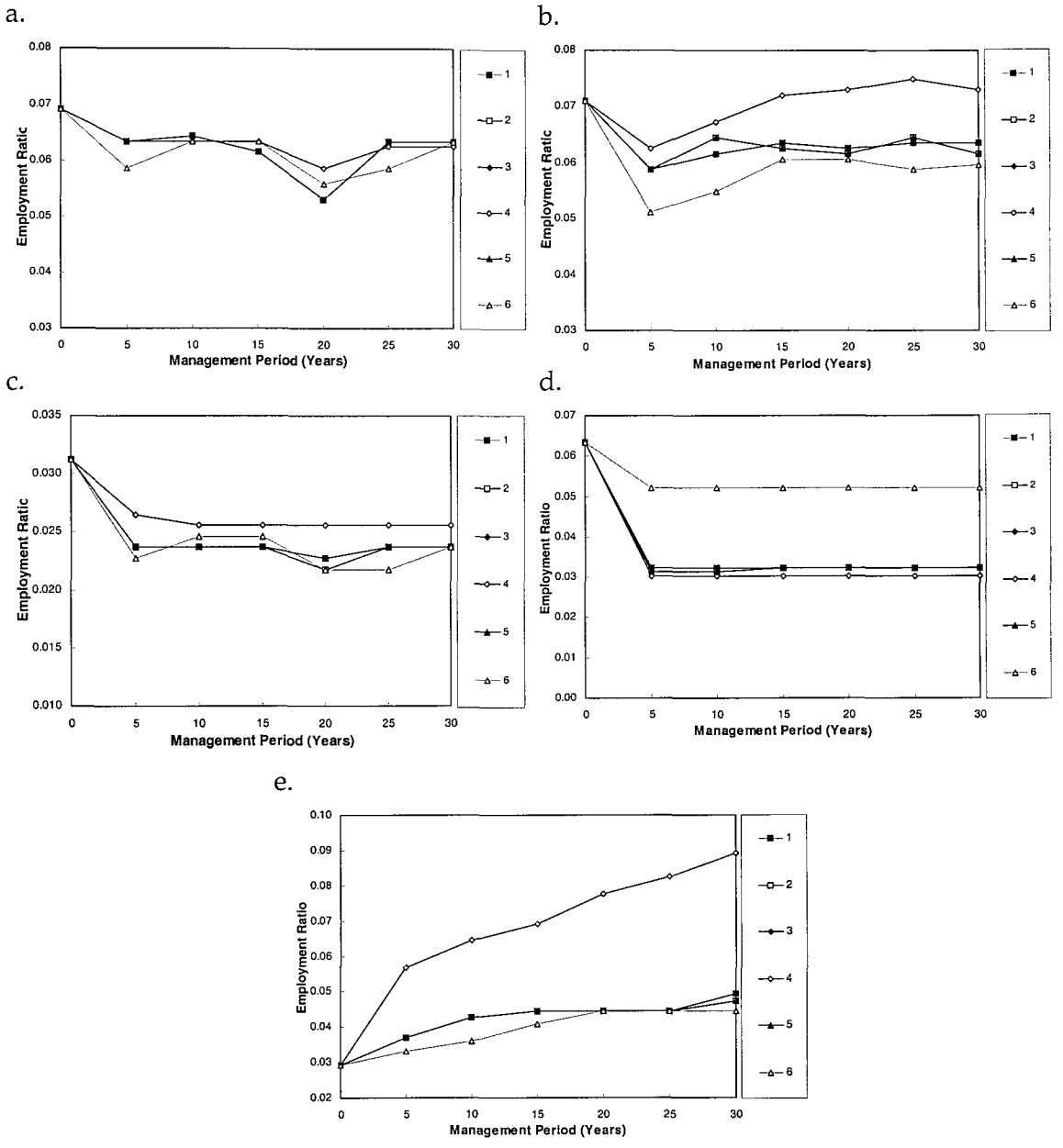


Figure A7.11 Estimated owner-operator employment ratio (L_{yr}/L^*) for 6 future scenarios over successive 5 year intervals up to 30 years: a) trap-only b) handline-only c) trap & handline d) large inshore and, e) large offshore. Where L* represents total number in available labour force (fisheries sector and pool). [Note differences in scale].

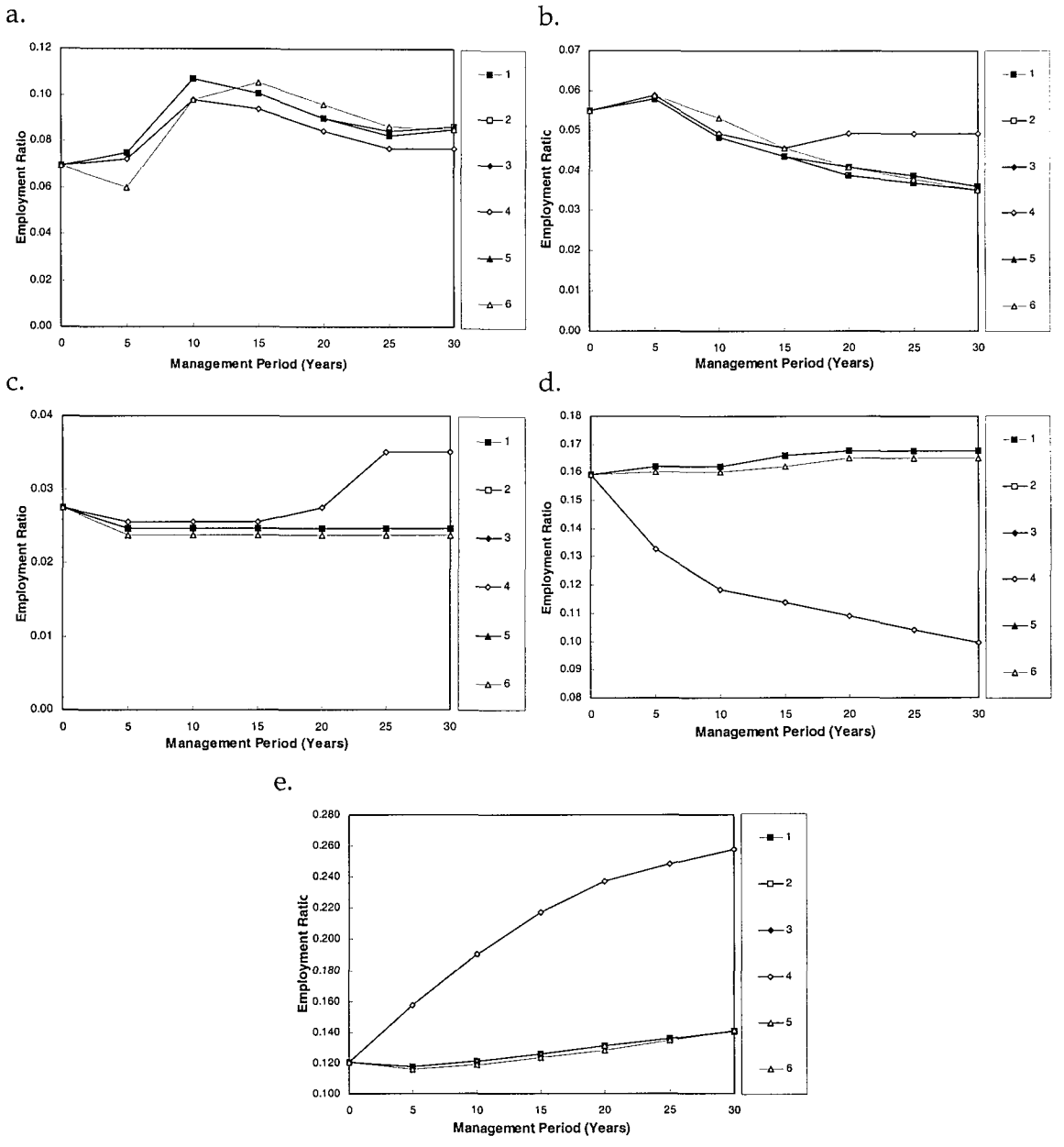


Figure A7.12 Employment of crew members for alternative scenarios: 1) control 2) increase in pool numbers 3) decrease in pool numbers 4) increase in offshore fish prices 5) 25% reduction in semi-pelagic fish population and, 6) 25% reduction in reef and demersal fish populations for each performance measure: a) trap-only b) handline-only c) trap & handline d) large inshore with handlines and, e) large offshore with handlines.

Appendix 7.3 Re-calibrated rank scores for biological, economic and socio-economic performance measures for 6 future scenarios: 1) control 2) increase in pool numbers 3) decrease in pool numbers 4) increase in offshore fish prices 5) 25% reduction in semi-pelagic fish population and, 6) 25% reduction in reef and demersal fish populations. Control is management option 14 in previous analysis.

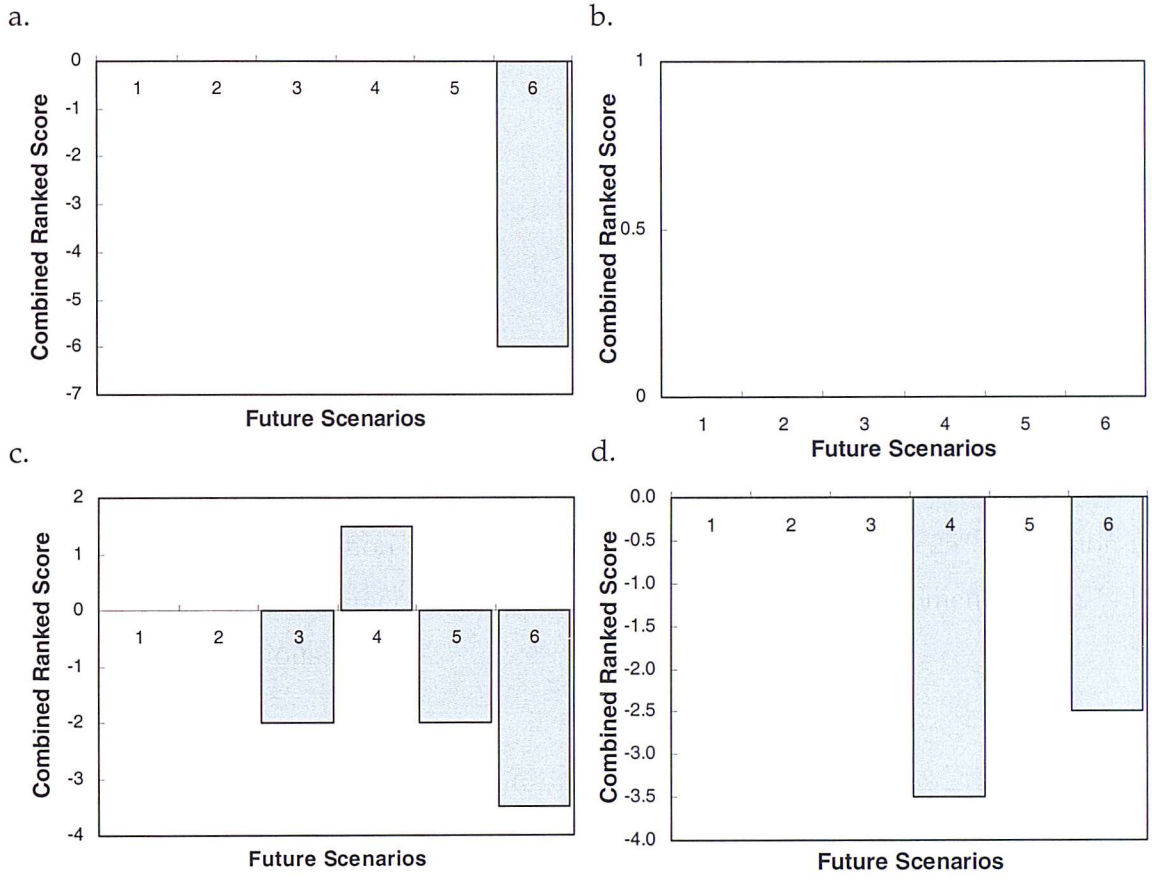


Figure A7.13 Re-calibrated ranked scores for future scenarios (1-6) for each performance measure: a) biological b) employment c) level of income and, d) total government subsidy.

Appendix 7.4 Performance of 15 alternative management options determined by a series of biological, economic and socio-economic performance measures following a 25% reduction in inshore reef and total demersal stock biomass.

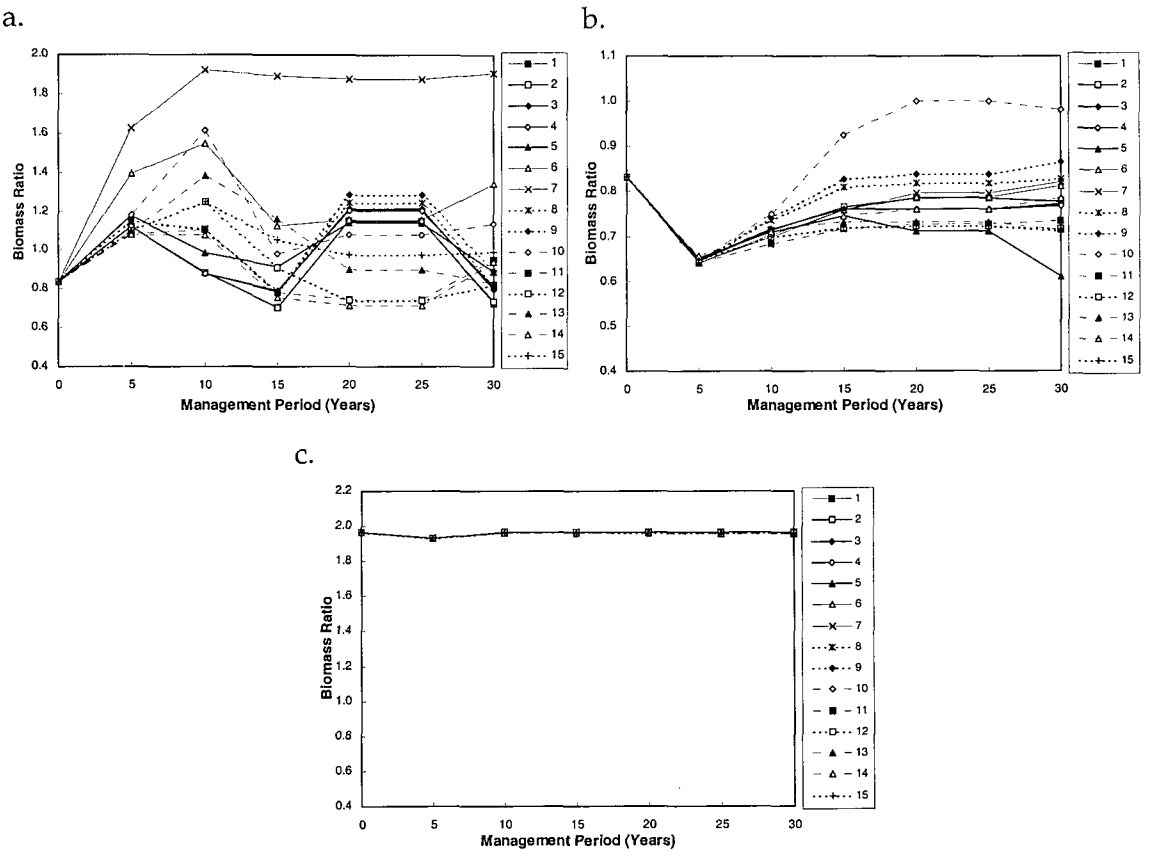


Figure A7.14 Estimated biomass ratio (B_{yr} / B_{MSY}) of 15 alternative management options following 25% reduction in reef and demersal stock biomass over successive 5 year intervals up to 30 years: a) reef b) inshore demersal and, c) offshore demersal. The maximum sustainable yield is achieved where biomass ratio is 1.0 [Note differences in scale].

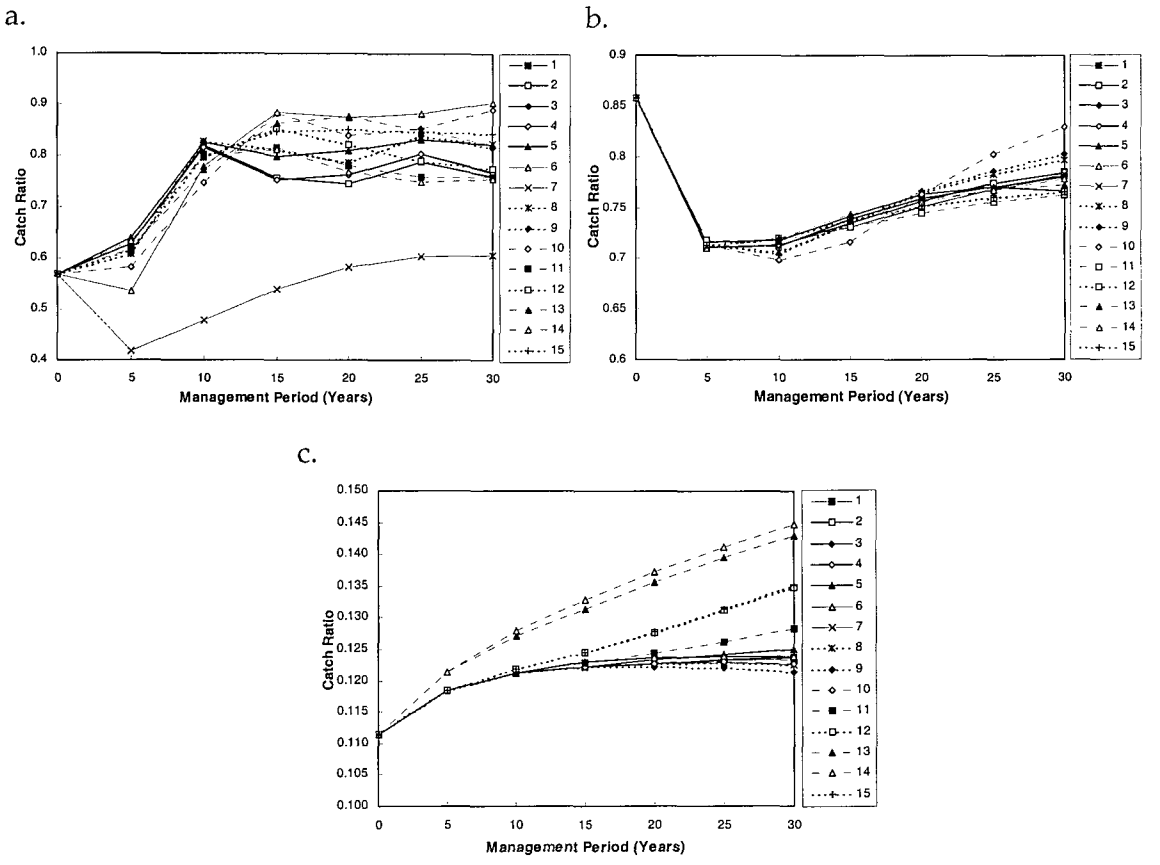


Figure A7.15 Estimated cumulative total catch ratio (C_{yr} / C_{MSY}) of 15 alternative management options following 25% reduction in reef and demersal stock biomass over successive 5 year intervals up to 30 years: a) reef b) inshore demersal and, c) offshore demersal [Note differences in scale].

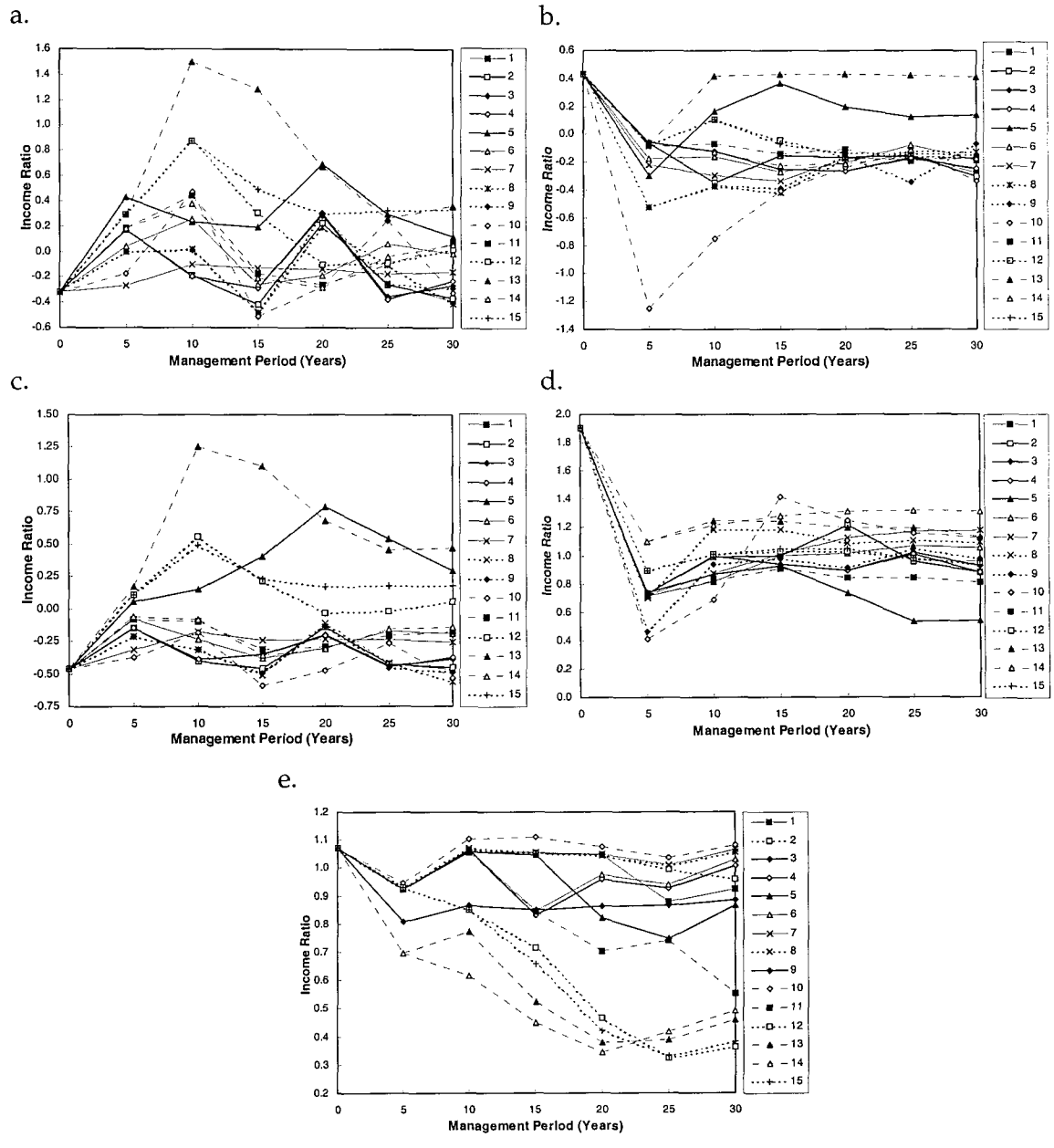


Figure A7.16 Estimated income ratio ((i_{yr} / $i_{average}$) - 1) of 15 alternative management options following 25% reduction in reef and demersal stock biomass over successive 5 year intervals up to 30 years: a) trap-only b) handline-only c) trap & handline d) large inshore and, e) large offshore. The national average level of income is equivalent to an income ratio of 0 [Note differences in scale].

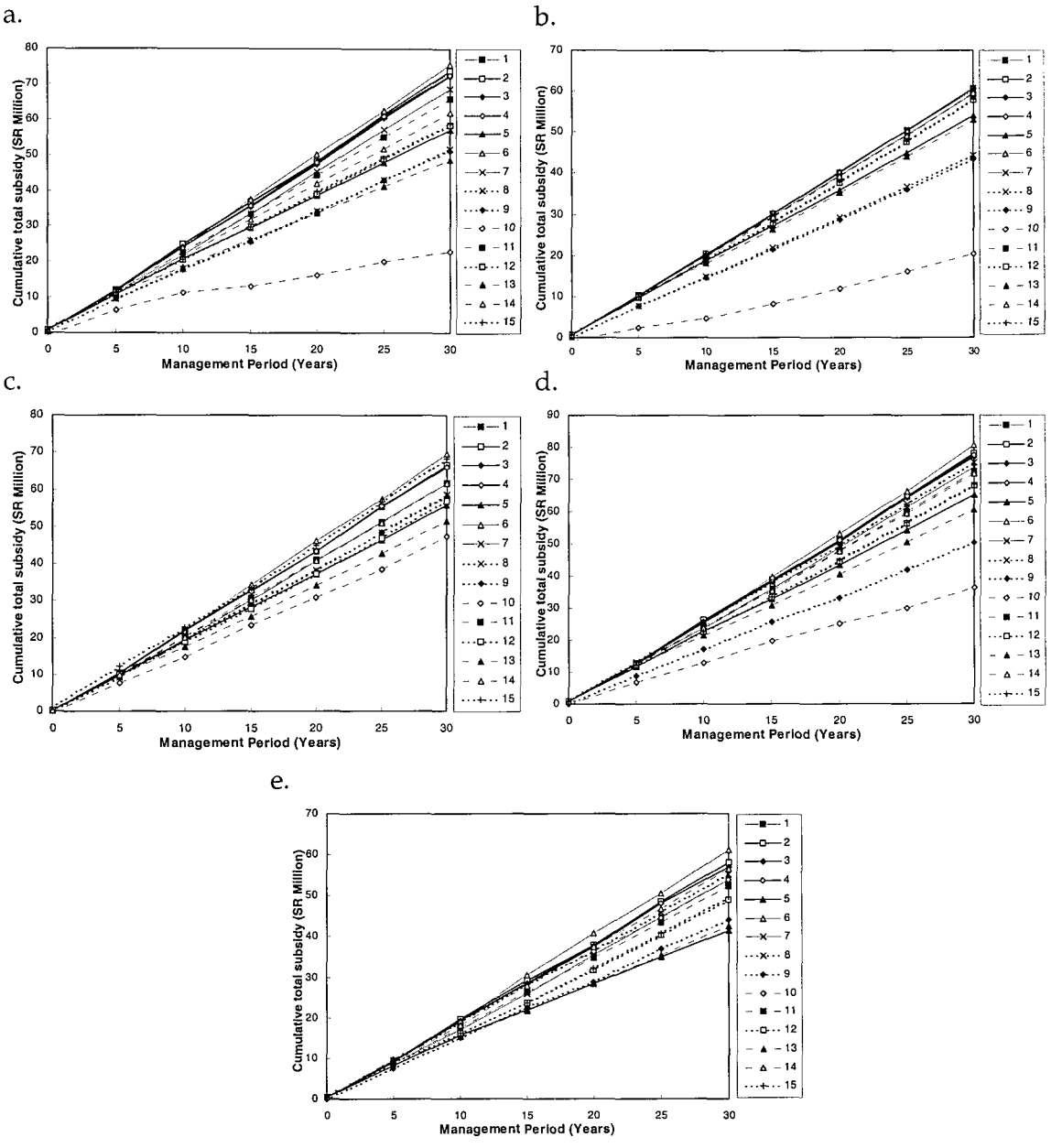


Figure A7.17 Estimated total government subsidy of 15 alternative management options following 25% reduction in reef and demersal stock biomass over successive 5 year intervals up to 30 years: a) trap-only b) handline-only c) trap & handline d) large inshore and, e) large offshore.

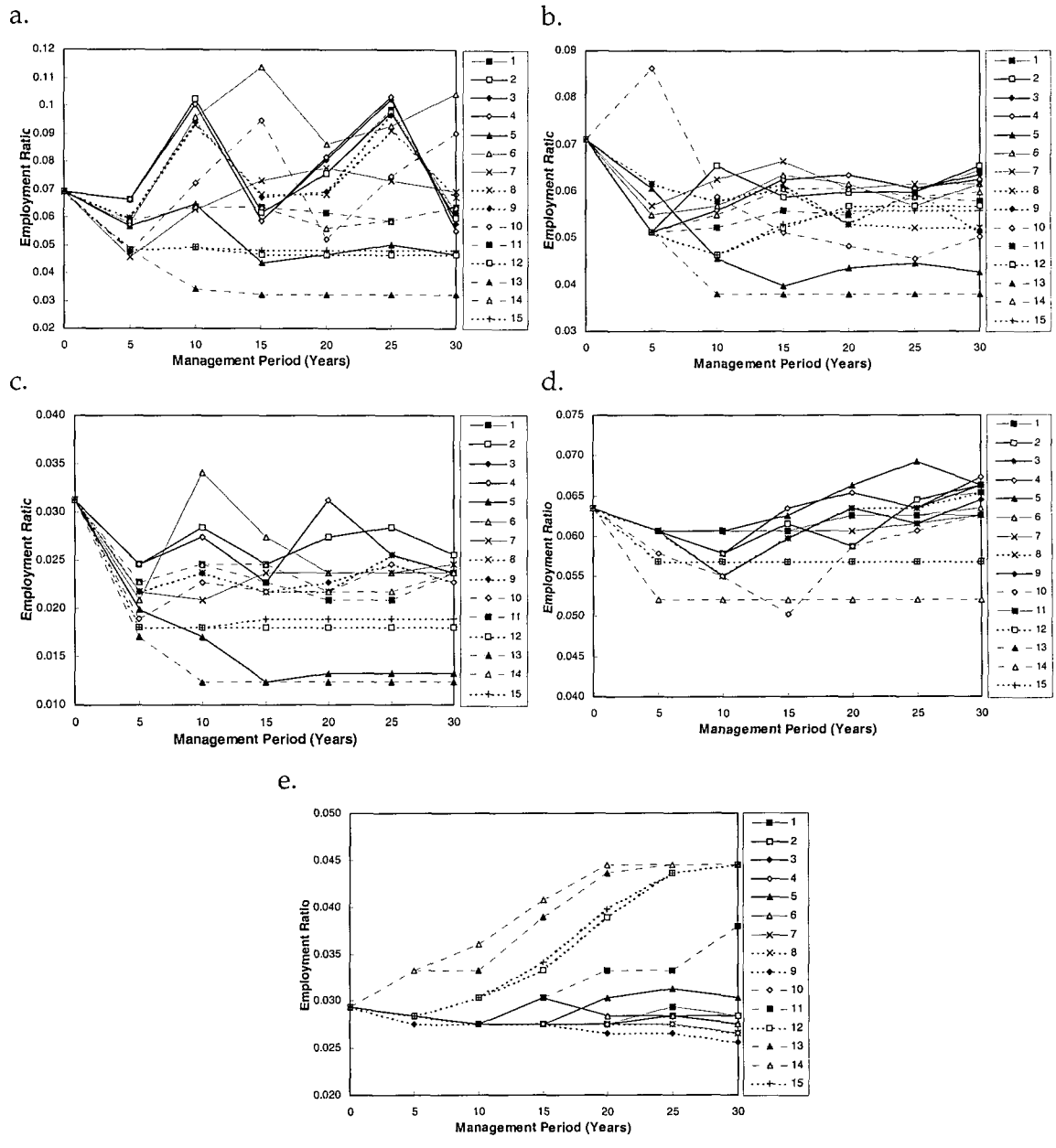


Figure A7.18 Estimated owner-operator employment ratio (L_{yr} / L^*) of 15 alternative management options following 25% reduction in reef and demersal stock biomass over successive 5 year intervals up to 30 years: a) trap-only b) handline-only c) trap & handline d) large inshore and, e) large offshore. Where L* represents total number in available labour force (fisheries sector and pool). [Note differences in scale].

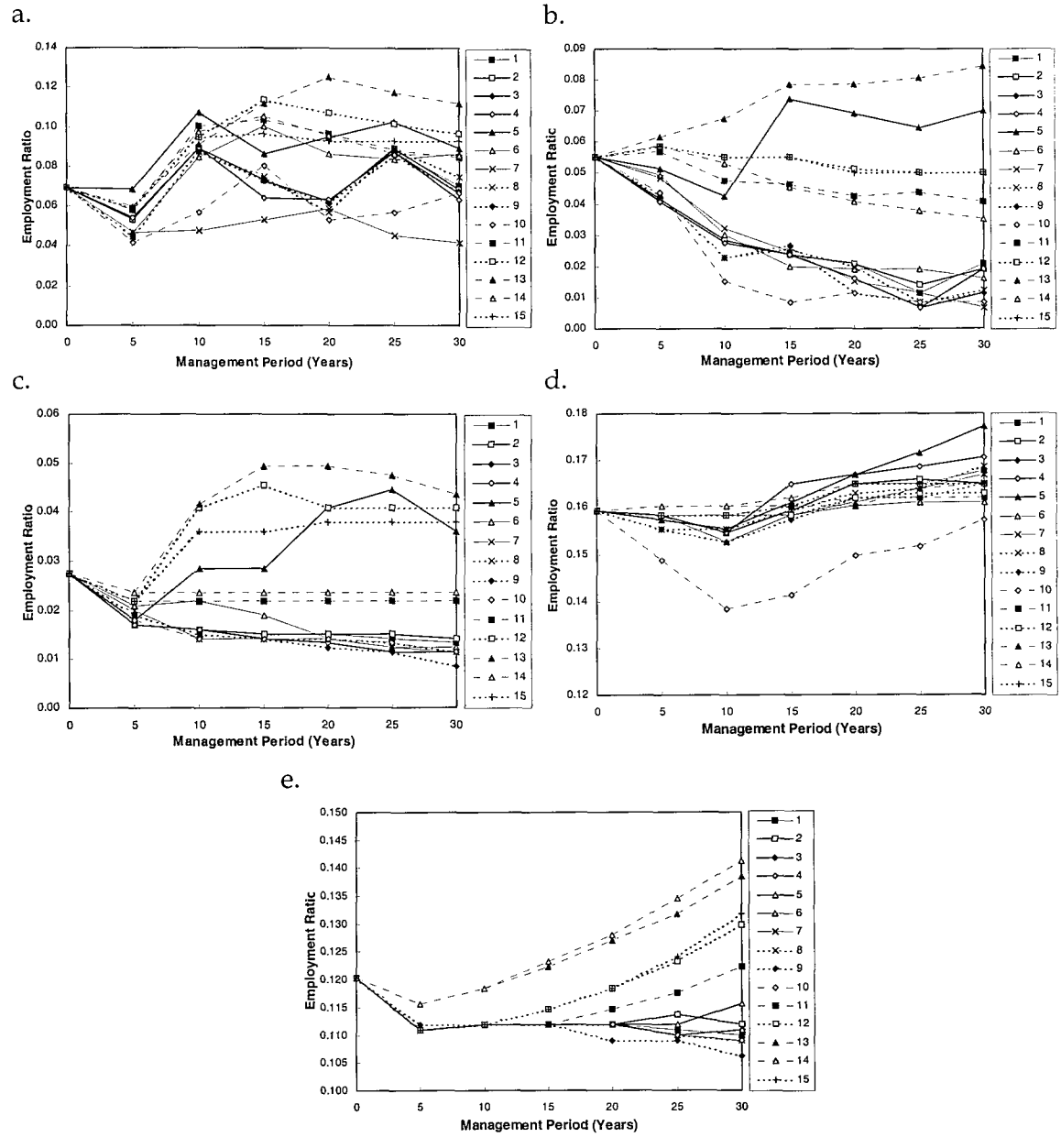


Figure A7.19 Estimated crew member employment ratio (L_{yr} / L^*) of 15 alternative management options following 25% reduction in reef and demersal stock biomass over successive 5 year intervals up to 30 years: a) trap-only b) handline-only c) trap & handline d) large inshore and, e) large offshore. Where L* represents total number in available labour force (fisheries sector and pool). [Note differences in scale].

Appendix 7.5 Re-calibrated rank scores for biological, economic and socio-economic performance measures for 15 management options (1-15) following a 25% reduction in reef and demersal stock biomass.

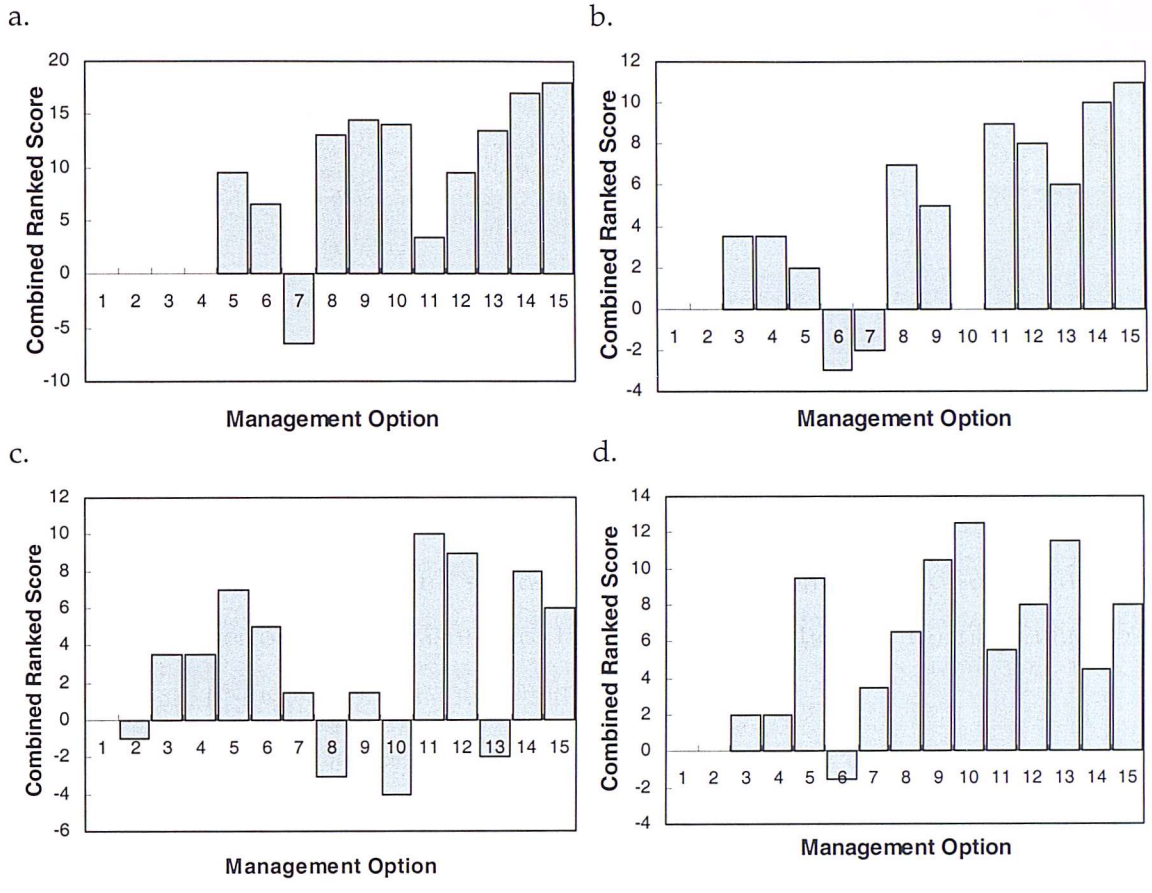


Figure A7.20 Re-calibrated ranked management options (1-15) for each performance measure following 25% reduction in reef and demersal stock biomass: a) biological b) employment c) level of income and, d) total government subsidy.

Bibliographic Comments

During the course of this work, a number of references were consulted that were of direct relevance to the research field, but for a variety of reasons it was not considered appropriate to quote them directly in the text. These are indicated by the asterisk (*) alongside each reference.

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