5 South Pacific

5.1 Background

The Pacific islands region extends from Palau in the western Pacific ocean to the Pitcairn islands in the central Pacific. Tuna fisheries are extremely important in the region, and they are mainly exploited by foreign fishing vessels. The small island states in the region do not, individually, have the capacity to assess and manage the fish stocks in their EEZ's; only through regional cooperation can this be done effectively. The need for regional cooperation was recognised as long ago as 1947, when the South Pacific Commission (SPC) was established. The role of the SPC was to provide technical advice, training, assistance and dissemination of information in social, economic and cultural fields. With less than two percent of the region being land, not surprisingly fisheries and income from fisheries are one of the mainstays of local economies, and the relative importance of this sector led to the establishment in 1979 of the Forum Fisheries Agency (FFA), a regional agency concerned solely with fisheries.

The FFA is based in Honaria on the Solomon Islands. Its principal aims are: to promote conservation and optimal use of living marine resources in the region, particularly highly migratory species; to promote regional cooperation and coordination in fisheries policy; to secure maximum benefits from the region's living marine resources; and to facilitate collection, analysis and dissemination of information about the marine resources. The FFA secretariat has provided valuable technical advice to member governments negotiating access agreements to their EEZs with distant water fishing nations. It maintains close links with SPC, particularly through SPC's tuna and billfish assessment programme (Gubon, 1987).

The importance of the marine resources in this vast area of ocean, with many developing island states, large distant water fishing fishing fleets and a well-developed database, led to the South Pacific being selected as a prime case study area for the adaptive phase of the control of foreign fisheries project. This section of the report briefly introduces the region and its fisheries and then describes the results of collaboration with the FFA in attempts to apply the methodology to management of foreign fishing in the region.

5.2 The status of the South Pacific tuna fisheries

The Pacific Ocean accounts for two thirds of the worlds tuna catch. The Pacific islands region is the most important production area in the Pacific (25-35% of the worlds catch; Clark, 1986). The stocks of the main commercial species are considered to be exploited to varying degrees below their maximum sustainable yields. The industry looks, in the broadest possible terms, to have a bright future and a significant role to play, both on the global tuna market and in the local economies.

5.2.1 Species profiles

Tunas are the most important commercial marine species in the South Pacific. The migratory nature of tuna, called "fish without a country" by one 18th century traveller, makes management and conservation of the species difficult, particularly given its almost global commercial desirability. This is doubly so in a region of great oceanic complexity that is the South Pacific.

By far the most commercially important tuna species in the region are skipjack and yellowfin tuna. In the early 1980's, for example, these two species combined comprised 95% of the total surface catch, with yellowfin alone accounting for 70% (Sibert, 1987), though the relative proportions have changed since then, with bigeye tuna catches increasing as longlining increased. A small percentage of the catches is made up of albacore. Of the other tuna species, the recognised range of both southern and northern bluefin tuna marginally overlaps the region, but these species do not have a great commercial importance to the Island states.

Yellowfin tuna *- Thunnus albacares*

Yellowfin tuna are found in tropical and subtropical waters of the Indian, Pacific and Atlantic oceans. The yellowfin is a fast growing species. At around seven years of age a single yellowfin may attain a maximum fork length of 170 cm and a corresponding weight of 70kg, but such specimens are now not common.

Of the two main commercial species, the yellowfin is considered to be potentially more vulnerable. However, stock assessments conducted to date (e.g. Suzuki, Miyabe and Tsuji, 1989) have generally found no evidence that the yellowfin stock is being exploited unsustainably at present. However, neither do they yield any reliable estimate of the catch that the South West Pacific stock might sustain.

Skipjack tuna - *Katsuwonus pelamis*

Skipjack tuna is a cosmopolitan species, occurring in tropical and warm temperate seas. It is a relatively small tuna. The maximum size observed for skipjack from all oceans is about 110 cm, corresponding to a weight of about 34 kg, however fish in the range of 80 cm or less and up to 10 kg are most common. Skipjack are thought to spawn first at about 45 cm or about 1 year old. They are opportunistic feeders and mature at an earlier age and have a higher natural mortality rate than either yellowfin or bigeye tuna.

Only a small number of stock assessments have been carried out for the region, and most relate to yellowfin. The typical assessment for skipjack stocks in the region is that the maximum sustainable yield far exceeds the present catches (e.g. SPC, 1987).

Bigeye tuna - *Thunnus obesus*

Bigeye tuna have a worldwide distribution throughout tropical and subtropical waters down to a depth of 250 m. Bigeye are large tuna, although they do not reach the sizes of bluefin. Like other similar sized tunas they feed on a variety of fish, cephalopods and crustaceans, depending on availability. On average, bigeye grow to a maximum fork length approaching 285 cm, and weigh 450 kg. However, individuals of that size are quite uncommon. Individuals that reach 175 cm and about 115 kg are believed to be at least 8 years old. The recent average size of a bigeye taken by U.S fishermen is approximately 44 kg, corresponding to a fork length of about 125 cm and an age of four years. Bigeye are thought to mature after 4-5 years. Spawning of this species is known to occur throughout the year in the tropical band from 15^{o}N to 15^{o}S.

Albacore - *Thunnus alalunga*

Albacore is a widely distributed species found in the temperate, subtropical and tropical waters of all oceans. Albacore do not generally grow as big as yellowfin or bigeye tuna of a similar age. They are thought to grow on average to a maximum fork length of 125cm, and a weight of approximately 40 kg. They reach maturity at about five years of age. Larger albacore are known to be found in deep, cooler water, whilst smaller specimens prefer shallow warmer waters.

Within the area of the FFA lies both one of a few known albacore spawning areas There is a surface fishery for this species in the area.

5.2.2 Gears, effort and licensing in the region

Doulman (1987) reports that eleven of twenty two FFA states have locally-based tuna fleets. Additionally Japan, Korea, the United States, Taiwan and other nations operate substantial fleets in the area. The major forms of fishing methods deployed in the pursuit of these tuna stocks are purse seines, long lines, and pole and line.

Artisanal Fisheries

Artisanal fishermen exploit the marine resources on a subsistence basis. The island communities are, to varying degrees, dependent on subsistence fishing for staple foodstuffs. Topological and geomorphological characteristics determine to what extent this is so, but it is true to some extent for all of the region. Very little information is known about this side of the South Pacific fisheries, particularly regarding catches. This causes problems in stock evaluation and determining quota arrangements.

Distant Water Fishing Fleets

Distant water fishing fleets operate in the area, meeting demand for both canned tuna products, usually based on smaller or less valuable species obtained via purse seining, and for the sashimi market, usually based on larger yellowfin or bigeye caught by the longline method.

Longlines

The main longline fleets operating in the South Pacific are from Taiwan, Korea and Japan. For years, licensing agreements with the Japanese have been generating fees at a level of 4% of the overall reported catch value. Improvements to the understanding of the market, prices, relative values within markets and other features have enabled improving estimations of catch value. Improvements to compliance with catch reporting requirements have also enabled higher average catch amounts to enter into the licensing equation. In recent times, the Japanese have agreed to increase the percentage return, effectively the only negotiable parameter under the current ubiquitous licence fee formula, from 4% to 5%, thus substantially increasing the overall access fee returns.

Purse Seines

Purse seining is the most capital intensive, technologically sophisticated and efficient way of catching tuna. It is particularly directed at skipjack and juvenile yellowfin. The purse seine technique was developed in the United States and has expanded in this region as both the US fleet moved into the area and as other distant water fishing nations, particularly Japan, adopted the technology.

The 1986 US Multilateral Treaty greatly increased access income from the US purse seine fleets to an estimated 10% of gross landed value. Such was the success of that new arrangement that it caused countries to reassess their position and to push for further increases from other distant water fishing nations. Papua New Guinea argued for equivalence in Japanese fleet agreements, but this was heavily resisted by the Japanese, and the Papua New Guinea zone was eventually closed to Japanese vessels in 1987.

A major change to the distribution of the Japanese purse seine fleet has taken place in recent years with the limited fleet of 32 medium sized single seiners now being able (by Japanese regulations) to fish also in the waters of Kiribati and the Marshall Islands. The previous limit to waters of the Federated States of Micronesia (FSM) and the high seas had been retained at the insistence of other lobbies within the Japanese tuna industry (principally the pole and line and longline fleet). It has yet to be determined whether this major distributional change has adversely affected the income of FSM to the advantage of Kiribati and Marshall Islands. Other changes to the Japanese fleets may well also be in the pipeline. It has been suggested that the pole and line fleets (now less than 90 vessels from several hundred in the early 1980's) have stabilised and may well be able to offer increased licence fees as they return to profitability through exclusive production of B1 grade skipjack. Longline fleets may also undertake restructuring and perhaps focus on narrower ranges (fewer zones) in order to minimise both steaming and access fee costs - a focusing of their attention on particular areas. The changes to proportion of trip time spent in Kiribati compared to other zones has changed over the years perhaps reinforcing that argument.

Pole and Lines

Pole and line fishing in the region is reported to have declined in tandem with the expansion of purse seine vessels. The predominant two types of gear reflect the stronger commercial orientation in the fishery. There are also concerns about possible negative interactions between gears. The average size of purse seine fish is 5 kg, but the average size of longline caught fish is 25 kg. It follows that the purse seiners are exploiting size groups of fish that have not yet recruited to the longline fishery. As purse seine effort increases, it is likely that recruitment to the longline fishery will decrease, and therefore so will their catches. An analysis carried out by MRAG (1991) concluded that there was evidence that this had actually been occurring. As the value of purse seine caught fish is considerably less that that of longline caught fish, continuation of such a trend will lead to increasingly sub-optimal exploitation of the stocks.

5.2.3 Catches by fishing method, country and species in 1992

The large number of Pacific island states and of countries in which fishing vessels operating in the region are registered makes management and assessment of the fisheries exceptionally complex. A reader unfamiliar with the region may get a better idea of the extent of this complexity by inspecting the following two tables, which summarise catch data for 1992.

Catch by species, by fishing method, by flag state of fishing vessel in 1992

Flag State	Longline			Purse Seine		Pole and Line	
	AB	BE	YF	SJ	YF	SJ	YF
Australia	154	15	726	6637	633	800	1
China	-	1226	1124	-	-	-	-
Fiji	243	187	202	-	-	3705	395
French Polynesia	174	51	137	-	-	593	133
FSM	-	41	78	11657	3675	-	-
Japan	3813	30308	18354	125492	46930	43436	1661
Kiribati	-	-	-	-	-	248	303
Korea	187	17399	11910	115290	66982	-	-
Marshall Islands	-	5	38	-	-	-	-
New Caledonia	520	110	230	-	-	-	-
New Zealand	706	-	-	6720	-	-	-
Philippines	-	-	-	22199	11141	-	-
Palau	-	-	-	-	-	61	14
Russia	-	-	-	1689	437	-	-
Solomon Islands	-	-	-	5993	5093	18266	1246
Tonga	199	5	19	-	-	-	-
Tuvalu	-	-	-	-	-	6	2
Taiwan	28745	5132	4636	169400	50600	-	-
USA	-	72	79	157707	45339	-	-

Species codes: AB = albacore, BE = bigeye, YF = yellowfin, SJ = skipjack

Source: SPC Tuna Fishery Yearbook 1992.

Total catch for all species (metric tonnes), by fishing method, by EEZ in which catch was taken in 1992

EEZ	Longline	Purse Seine	Pole and Line
Australia	365	-	-
Cook Islands	-	-	-
Fiji	420	-	-
FSM	4486	40620	1781
Kiribati	3145	80036	3242
Marshall Islands	807	3909	195
Nauru	5	13203	-
Niue	-	-	-
New Zealand	-	-	-
Papua New Guinea	38	24782	-
Palau	36	2461	-
Solomon Islands	22	3125	1121
Tonga	71	-	-
Tuvalu	-	5265	-
Vanuatu	10	-	-
Western Samoa	-	-	-
International waters	862	20230	285
Other non-FFA	37	19284	13
Total	10304	212918	6637

Source: FFA Report 1993/94, based on log book returns held by FFA

In 1992, for the principal species taken by longliners were bigeye and yellowfin tuna, while skipjack dominated catches by purse seiners and pole and line fishing. By far the greatest catches were taken by purse seiners. Japan, Korea and Taiwan were the principal flag states for longliners, and these were joined by USA for purse seiners. Japan and the Solomon Islands take most of the pole and line catch.

The overall dominance of purse seine caught fish is confirmed by the second table, which now splits the total catch by the zone in which it was taken. FSM and Kiribati were the source of the largest catches, while Papua New Guinea and Nauru also had substantial purse seine catches in the zones in 1992. Note that a number of other FFA member states had either tiny or zero recorded catches taken in their zones.

5.2.4 Surveillance and Enforcement

There are several problems unique amongst the case studies to this area. Not the least of these is the size of the various member countries both in terms of land mass and of enforcement and surveillance capabilities in relation to the large area covered by the EEZ's. The point of negotiating licensing agreements with distant water fishing fleets is somewhat undermined if those same fleets can flout any territorial restrictions with impunity due to an inadequate surveillance capacity.

The huge areas of ocean that need to be patrolled and the limited means of the Pacific island states have led to a policy of targetted, rather than random surveillance. Analysis of fleet distributions has been used in the past to anticipate fleet movements during the year to provide some means to assess when and where to target surveillance activities. Unfortunately, these analyses have rarely been as successful as had been hoped. In most surveillance flights that have resulted in encounters with fishing vessels, there has either been prior information on the location of potential individual infractions or they have been discovered largely by chance.

A vessel monitoring system is being implemented, which will provide an improved key to surveillance targeting. This assumes that target vessels will be peripheral to the distribution of the main fleet or in some other area altogether. However in a number of circumstances, the distribution of vessels appears to be almost random and therefore an area where illegal fishing might be expected is not so readily deduced. To complement the vessel monitoring system, a surveillance model which develops a 'fleet trajectory' from time series data has been proposed. The projected 'trajectory' and the information gathered from the vessel monitoring system could result in more effective targeting of surveillance.

A key additional advantage of targeted surveillance is that it increases the chance that illegally fishing vessels will be aware of the surveillance activities. This in turn is then likely to increase the fishermen's perceived risk of being detected when fishing illegally, and thus the deterrence effect. The more successful the targetting, the greater will be the increase in deterrence that can be achieved with relatively modest expenditures on surveillance.

A further scheme has been introduced to deter illegal fishing. The FFA have developed a Regional Register of Foreign Fishing Vessels, as a means of controlling foreign fishing in the region. Vessels must have a good standing on the register in order to be granted a licence by any FFA member state. In addition to this, more formal ties with Australia and New Zealand have led to those countries airforces undertaking regular surveillance flights.

5.2.5 Illegal Fishing

It is suspected that the Taiwanese fleet have under-reported catches in the past, and MRAG (1991) also found that at least some Japanese vessels appear to have under-reported their catch. Misreporting is an important issue since it is likely to reduce the cost to vessels where the information they report might be used to control fishing or set fees. Where licence fees are paid on an average catch calculated from past data, under-reporting of catch will be encouraged. Under-reporting can pertain to effort, catch, and catch value. The greatest distortions to analysis will be introduced by under-reporting of catch alone.

Several more serious incidents have occurred with the US fleet. Doulman (1987) reported that between 1982 and 1986, four US tuna boats had been seized in the South Pacific: the *Danica* in Papau New Guinea (1982), the *Jeannette Diana* in the Solomon Islands (1984), and the *Ocean Pearl* and the *Priscilla M* in the Federated States of Micronesia (1985 and 1986 respectively). Many other vessels have been strongly suspected of flouting fisheries laws on a regular basis.

In the most celebrated case, the *Jeannette Diana*, an American registered purse seiner, was seized in June 1984 for illegal fishing in Solomon Islands waters. In addition to a fine of $50,400 being imposed upon the captain and owner of this vessel, the vessel, its catch, fishing gear and helicopter were forfeited to the Solomon Islands and put up for sale. As a retaliatory measure, the United States banned all imports of fish from the Solomon Islands and agreed to recompense the captain and the owners of the vessel. US vessels were promptly banned from fishing in Solomon Islands waters and the USSR was invited to begin negotiations for fishing rights. Seven months later the *Jeannette Diana* was sold back to her owners for SI$ 770,000 and the embargo was lifted.

The *Jeannette Diana* case was the most acrimonious of the four disputes. The *Danica* was, after a brief period, released to her owners for US$ 270,000 and an agreement was entered into to pay fees for the right to fish. The *Ocean Pearl* was pursued diplomatically with the threat of a regional blacklisting after threatening a boarding party. This action eventually led to a US$ 500,000 fine being levied on the owners. The *Priscilla M* was seized in port after a crew member requiring medical attention was taken to shore providing an opportunity to inspect the logbook. Eventually an out of court settlement was reached, the owners paying US$ 400,000 plus US$ 58,000 for a licence fee.

Arguably it was this series of successful arrests for illegal fishing that led to the revised licensing agreement entered into by the US fleet with the island states.

5.3 Collaborative research with the Forum Fisheries Agency

The management game developed at the conclusion of the original Control of Foreign Fisheries research project was amended so that it incorporated approximate information on the nature and extent of the South Pacific tuna fishery operating in a single EEZ. Mr J. Anderson of MRAG then visited the Forum Fisheries Agency in Honiara, Solomon Islands, in November 1993. The aim of the visit was to demonstrate the theoretical background to the project and the management game to senior professionals within the Forum Fisheries Agency and to establish collaboratively its potential usefulness and what further work would be required to adapt the game better to the particular circumstances of the South Pacific.

It was also recognised that much more detailed and current information on the tuna fisheries in the South Pacific would be needed in order to estimate reliably the various parameters of the management game. Prior to the visit, the following types of information were identified:

(a) Vessel characteristics:

FFA manages a Regional Register of fishing vessels operating in the South Pacific region. This contains, *inter alia*, the nationality of each vessel, its GRT and other vessel and gear characteristics. There is no need to be able to identify each vessel individually, so it maybe possible to gain access to summary data and avoid confidentiality problems.

Information on vessel values is also required, but this is not held on the Regional Register. Accurate values may be difficult to obtain because of the changing nature of the fishery. However, approximate values should be available for second hand vessels, and these would probably be the closest to the current market values. New prices should be readily available.

(b) Fishery information:

The principal information required consists of total catch (mt) by species and effort (days) by nationality/geartype/appropriate GRT class by geographical area. It is vital that catch rates inside and outside the different EEZs can be estimated from these data.

The corresponding prices obtained by species and gear/vessel type will be also needed in order to obtain an overall value for catches by each gear type. In principle, these are available in INFOFISH, but it would be better to get the FFA prices if available, since these are likely to reflect South Pacific prices.

(c) Surveillance and Enforcement Costs:

These are likely to be the most problematic of all the data requirements. They also cause the greatest difficulty in terms of confidentiality. It was known prior to the visit that FFA were undertaking a series of reviews of the surveillance and enforcement capabilities of each member. If this review has progressed sufficiently, liaison with the FFA Surveillance Officer, Colin Brown, may allow appropriate information to be provided.

5.3.1 Review of the management game

A seminar was conducted for a large group of the senior staff of FFA, followed by further, more informal discussions. The seminar concentrated on the simple set of decision rules and associated parameters described in the first section of MRAG (1993), on which the management game is currently formulated. The management game was set up on two computers and following the introductory description of the work, a "hands-on" session was held. Participants in the seminar were taken through the game and the predicted responses of various fleet categories to different parameter values were explored. Following the formal presentation, the opinions of the participants were sought on the viability of collecting data for the three primary aspects of the management game (surveillance operations, licensing and fine revenue). In addition, a number of the specific parameters (risk of capture *q*, the proportional parameters, *a* and *b*, and the *honesty coefficient*) were also discussed in more detail. Subsequently, further discussions were held with Gerry Geen, FFA's senior economist.

Is the game conceptually useful

FFA staff commented that attempting to develop an analytical approach to management of DWFN access to Western Pacific EEZs was a bold venture to undertake. As to whether the package could actually be of immediate practical use to FFA in terms of treaty negotiations, advice to governments, etc., it was generally felt that considerable further development was needed. The problem of quantifying surveillance costs and more importantly the returns (in terms of fines and reduction of illegal fishing) was generally agreed to be the major stumbling block.

It was also felt by FFA staff that attempting to predict the behaviour of fishermen within a framework of costs, risks and benefits was inherently difficult. The behavioural variability of vessel captains and the fact that much of the final decision making - for example covering access agreements - resulted from political bargaining, makes such an approach open to error.

It was agreed, however, that using data available at FFA it would be worthwhile to try and develop a better understanding of parameter relationships and perhaps to build in some of the realities of the region's tuna fishery (such as cooperative surveillance operations). If this were successful, the package might well prove to be of practical use in the region, at least in helping national managers develop a clearer understanding of the interaction of the primary parameters, surveillance, marginal revenue, licence fees and fine revenue.

Quantification of surveillance costs

A critical aspect of the management game was felt to be the assumption that surveillance costs can be reliably quantified. In the western Pacific region this is thought not to be the case.

The aerial surveillance programme is undertaken on behalf of the Forum nations as a whole, with each member nation allocated a certain number of surveillance hours per year. Currently the majority of these costs are borne by development funds and thus are not subject to the "free market" force of cost effectiveness. Although many regional nations do undertake surface surveillance, they are usually under the auspices of the Australian Navy (with the exception of Vanuatu. These operations tend to have a strong military training aspect to them.

Gerry Geen commented that the Australian Bureau of Agriculture and Resource Economics (ABARE) has also attempted to quantify surveillance costs for Australian fisheries. The problem they encountered was that they could not separate the multitude of reasons for undertaking surveillance operations, which obviously had national security, as well as fisheries considerations.

It is of course possible to quantify the flying costs of the RAAF and NZAF flights, but according to FFA surveillance officer, Colin Brown, the two air forces would carry out these operations anyway. He commented further that it would be possible, however, to quantify the marginal value of an extra one hour's flying time in terms of arrests, but said that despite the 1000 flying hours that the RAAF and NZAF operate on behalf of the Forum nations there has been a very low rate of capture and there were no arrests at all until 1991.

Some work on the subject of quantifying surveillance costs was due to begin (with German development funds) in Papua New Guinea in January 1994. It is obvious that as development funds from traditional donor nations dwindle, the necessity for understanding the cost-effectiveness of surveillance operations takes on a new significance.

FFA nations had recently met in Niue to establish rules for cooperation in surveillance operations and this should increase the efficiency of individual nations' surveillance operations. At the same time, however, it will cloud any relationship between surveillance costs and rates of capture by individual nations. Furthermore, the Japanese (and perhaps the Taiwanese) are apparently due to deploy their own fishery patrol vessels in the Western Pacific which will, of course, affect the efficiency of surveillance operations by a coastal state.

The probability of detection

In order to quantify the probability of capturing a vessel, *q*, one needs to relate surveillance expenditure *S* to the number of arrested vessels as a proportion of expected number of vessels fishing illegally inside the zone. There were two problems with this approach as far as data requirements are concerned.

Within the current management game, the probability of detection is related to surveillance expenditure via a theoretical search model. This obviously relies on a number of untested assumptions, and participants first discussed the possibility of using data on actual detections to quantify this relationship. It was noted that the number of data points available on which to develop this relationship is very small, perhaps 10. Secondly, as a greater understanding of the regional fishery has evolved, so the effectiveness of surveillance operations would have increased. If this is the case, one needs to be sure that one can standardise the surveillance effort on which the relationship is based.

It would, perhaps, be possible to increase the number of data points by including all contacts between surveillance and fishing vessels (whether licensed or not) and by so doing identify a deterrence effect.

A clear distinction can be drawn between the risk of detection as it is seen by the fishermen, which is the parameter he will use to guide his decisions on whether to fish illegally or not, and the actual probability of detection corresponding to the surveillance operations undertaken. What data a fisherman uses to assess his own probability of capture is, of course, difficult to quantify and how directly related a vessels perception of risk of capture (*q*) is to the state's expectation of capturing illegal fishing vessels is not clear. Much will depend on his own attitude to risk, reports from other vessels of surveillance operations, economic realities (affecting his own attitude to risk) etc. If the vessel has fished legally in the past, its expectation of capture (if it were to subsequently fish illegally) would be increased if it had numerous contacts with surveillance operations while legally in the zone. In this case there may be a strong correlation between the state's expected probability of capturing and a vessel's expectation of capture. On the other hand, vessels which have not fished inside a particular zone before may have a reduced expectation of capture.

The issue is further complicated by the possibility of illegal fleets having vessels that act as early warning of surveillance operations, whether they are licensed or not. A more realistic understanding of the behaviour of vessel masters cannot be gained from looking at catch statistics. It can only be obtained through a direct interaction with the captains themselves. Perhaps an interesting line of study would be to question vessel masters operating under one of the many bilateral and multilateral agreements in the region. Examples of these include bilateral agreements with the Japanese Government, with the Australian Government, the US Multilateral Treaty with the Forum nations, and the recent agreement signed between the Federated States of Micronesia and Taiwan. There would be presumably less incentive to fish illegally amongst these fleets, and it may help in the definition of the honesty coefficient. Questionnaires could be developed on the basis of contingency theory.

Marginal Revenue and Licence Fees

The management model aims to use a proportion of marginal revenue to constrain licence fees and fine levels (*a MR* and *b MR* respectively). This was felt to be a sound approach and one which the Forum economists have adopted during recent access negotiations.

Access fees for the Japanese fleet wishing to fish in the Australian EEZ have been calculated using both gross and marginal returns since 1990 (e.g. Geen, 1990; ABARE, 1991). In the work of the Australian Bureau of Agricultural and Resource Economics (ABARE), the value of access is determined by the relative performance of the Australian fishing zone compared on a monthly basis with the (next best) area in the Western Pacific region. A net benefit to the Japanese fleet was therefore found when the Australian zone produced a higher return on effort than any other zone in the region. In the case of 1990 data, positive returns from the Australian zone were only recorded for March, April and December. The costs of access for the Japanese fleet were therefore calculated on the basis of the value of fishing inside the zone during these three months only.

The use of marginal returns is beginning to gain acceptance with FFA and was used in advice to the Government of Kiribati during the negotiations with the Japanese longline and pole and line fleet. The methodology and approach is described in working paper 5, presented at the Twelfth Annual Meeting of Parties to the Nauru Agreement held in Palau in May 1993.

If marginal revenue is to be used as a bench mark then it is obviously critical to obtain accurate data covering catches made in international waters. Again, here the Japanese (and American) fleets are the primary sources of accurate data. For the remaining principal distant water fishing nations, Taiwan and Korea, the situation is not straightforward because of the paucity of data. Even for the Japanese fleet, data collection is not assured. The 1990 report from ABARE had to make various assumptions about the variable costs of fishing in different areas and more importantly that there was unrestricted access (and no decline in CPUE) to other fishing zones if access to Australian water was restricted. In any event the cooperation of SPC and the individual fleets is a necessity for this aspect of the project's development.

Fine levels

The management game currently calculates fine levels as a proportion of the value of a vessel plus the value of the catch itself. The current problem in this area is that although there may be defined regulations when charging vessels that have fished illegally, there is a great deal of horse trading behind the scenes which can greatly affect the actual level of fines. This makes it difficult to realistically assess expected fine revenues when optimising revenue from licensed and unlicensed vessels (problems of quantifying probability of capture notwithstanding). If management is to be based on such a model there will obviously have to be recognition of the negotiation factor. Such a parameter may prove impractical to quantify and therefore the optimal solution the model arrives at may not be realistic in its anticipated fine revenue.

Licence Fees

As is the case in the current version of the management game, access fee negotiations in the region have been based on obtaining a proportion of the total value of the catch taken inside the EEZs of Forum member nations. This was done because this method has been used almost universally in actual licensing. Internally within the management game, the licence fees were actually calculated as a proportion of marginal revenue and then converted to proportions of EEZ catch value. There is now however, a trend to use marginal values rather than gross values of access, which in the case of Australia led to a doubling of access fees with the Japanese fleet. The current policy of the FFA aims to obtain 4% of the EEZ catch value but much depends on which fleet one is dealing with. The access agreements negotiated with the Japanese fleet, for example, sets the access fee at approximately 5% of the gross value. For the Taiwanese fleet it was set at 6% but it is suspected that the Taiwanese fleet under-report catches and therefore the actual fee is probably around 3% of gross revenue.

The US multilateral treaty with Forum nations exemplifies another aspect of this complex situation, namely the importance of direct government subsidies. If one were to look at the actual charge per vessel, the fee would be equivalent to 13.5% of the total vessel income. However, through the application of subsidies the cost to the vessel is approximately 2.5% (US$50,000) of total vessel income (for 1993). The US Government pays some US $10 - 25 million as subsidy to maintain the activities of the purse-seine fleet in the region (FFA News Digest No. 4/93). The Japanese fleet also operates with the benefit of government subsidies which come in a variety of forms including access fee packages and through the provision of fisheries development aid to Pacific nations. The latter is obviously an indirect subsidy but one which would clearly benefit the Japanese fleet during access negotiations. This figure is estimated at US $1 billion per year (FFA News Digest No. 4/93).

Clearly the amount a vessel is prepared to pay in access fees can still be related to the expected revenues from fishing inside an EEZ, but the majority of the nations negotiate on behalf of fleets to set access fees, often on a multilateral basis and with high subsidy levels to cushion the costs to the actual vessel operators. The behaviour of a fleet in response to changes in access fees, as described in the management game, is unlikely therefore to be so straightforward.

The Control of Foreign Fisheries model would seem to imply a theoretically unlimited range within which the cost of a licence can be set. This ignores the economic and political realities of the Pacific region. The access agreement between Japan and Papua New Guinea, for example, was cancelled in 1987 following an attempt by Papua New Guinea to increase the cost of access from 4% to 10%. The access to Papua New Guinea was obviously not of critical importance to overall profitability of the fleet. Furthermore, other Forum nations were happy to offer access at the agreed rate of 4%. The Japanese can therefore play one country off against another until a unified negotiating front (which was an important aim of setting up FFA) is presented to distant water fishing nations.

Economic performance data for Japanese fishing vessels indicates that their ability to pay higher fees varies between vessel category. Longliners of 10-50 GRT operated at around 8% profitability, but the longlines of 50-100 GRT appear to be operating at a profit level of only 3-5% and would thus not be able to afford an increase in access fees. For the 100-200 GRT class, the vessels appear to be operating at a loss before any fees are paid. However the data on which these figures are based (Japanese Ministry of Agriculture, Fisheries and Forestry, 1992) needs to be treated with caution because of the tendency to under-report earnings and inflate costs to reduce the taxation burden. The fact that the Japanese were willing to pay 8% of value of the catch taken in Australian waters would seem to indicate that such data is unlikely to represent a true picture of the economics of fishing in the Pacific.

The honesty coefficient

How to actually quantify this parameter was discussed and it was generally agreed that it is a difficult area of study. As a first step one could, of course, simply relate it to the number of vessels apprehended from each nation but this is only a rough guideline. Exactly why one nation's fleet should be more honest than another nation's depends on the wish to create political goodwill, but this relies on significant control on the fishing fleet being exercised by a government. The Japanese fleet is generally perceived to have a higher honesty coefficient than, for example, the Taiwanese fleet, and that this results from stronger control over the fishing fleet rather than inherent dishonesty by the Taiwanese. As described earlier, it appears that the Japanese (and perhaps the Taiwanese) are going to deploy their own fishery patrol vessels in the Pacific to further the control over their fleets. This should affect the behaviour of fleets in respect of the amount of illegal fishing they undertake, and therefore change the honesty coefficients of these nations. The use of indirect subsidy to a fleet would also be an obvious tool to maintain compliance, and if more fleet access agreements are developed, then so the control should increase and level of illegal fishing decline.

Summary

The management game attempted to bring the primary aspects of Control of Foreign Fisheries under a single umbrella, whereby a nation can optimise the levels of surveillance, licence fees and fine revenue. While the modelling aspects of the work are clearly based on sound theory, one problem was that these separate aspects do not readily function as an integrated whole. The realities of the situation in the Pacific region would seem to mitigate against development of such a generic approach for the following reasons.

(a) Surveillance costs are not easy to quantify. The majority of costs are borne by development funds and are thus operating outside the requirement of cost effectiveness.

(b) Quantifying the probability of detection q is difficult because the number of data points on which to define the efficiency of the operation is small (perhaps 10). Standardisation of historical surveillance effort may also present difficulties.

(c) The behaviour of fishing vessels is likely to be highly variable depending on marginal (and seasonal) catch rates, access fees, alternative fishing grounds, the level of subsidy, etc.

(d) Licence fees are constrained within a very tight range because of:

- (i) The Nauru Agreement
- (ii) The ability (or willingness) of distant water fishing nations to pay
- (iii) The unilateral negotiation stance of Forum nations and the availability of alternative fishing areas
- (iv) The negotiating strength of distant water fishing nations

(e) Fine revenue will not be as significant as predicted in the model because of the horse-trading that follows apprehension of vessels fishing illegally and, perhaps more significantly, the political power of distant water fishing nations (as was seen, for example, in the *Jeannette Diana* affair).

5.3.2 Potential MRAG/FFA Collaboration

Following the discussions held during the trip FFA Deputy Director Andrew Wright formally invited collaboration between FFA and MRAG. He suggested that a member of MRAG staff might spend some time (perhaps 6 months) working at FFA in Honiara to collate the variety of data with particular reference to the surveillance problem and the perceptions of risk held by fishermen. He noted, however, that the diversity of factors that may impinge on the behaviour of a fleet and the revenue a state could expect to generate under different enforcement and licensing scenarios implied that meaningful results at the end of the day are by no means guaranteed.

Following further work, the then MRAG project leader, Mr David Evans, visited FFA again in February 1994. While there, he developed proposals for future collaborative research between FFA and MRAG to implement the proposals for development of the control of foreign fisheries model.

A paper detailing these proposals is attached as Appendix 1. The following set of joint studies was recommended:

(i) Infractions

Completion of listing of the infractions database by the Legal Division at FFA.

(ii) Risk perceptions study

Reliable estimation of the 'honesty coefficient' and of fishermen's perceptions of risk clearly will be very difficult. Two approaches are envisaged. The first involves analysis of proxy estimates. These can include statistics on the extent of compliance with reporting requirements on a fleet or individual vessel basis, ratios of reported catches to fleet capacity, etc.

The second approach involves direct assessment of perceived risk through the conduct of a survey of the attitudes of fishing masters in the fleets of the region. Initially, it was anticipated that MRAG would commission the design of a survey by an expert, together with the necessary background documentation. This would then be submitted to FFA for comment and input and then submitted to the US fleet through the annual consultations in March, or at another appropriate time. Following analysis, an assessment would be made about whether to extend the survey to other fleets in the fishery.

(iii) Adaptation of the management game model

Following the concerns raised by and the inputs received from FFA, adapt the model to take into account the specific needs for the region and improved parameter estimations. Specific suggestions included the following.

- Incorporate a facility to undertake sensitivity analysis for key parameters.
- Allow introduction of different surveillance scenarios.
- Allow for a more realistic depiction of each fishing fleet, incorporating various distributions of fishing power and catch rates.
- Allow introduction of conservation constraints on catch or effort,
- Different licensing circumstances may require a range of 'honesty coefficients' to be included within the model.
- Enhance the ability of the existing game to address the probability of capture from both the management and fishermen's perspectives.
- Incorporate an extension to allow modelling of management in multiple fishing zones.

(iv) Simulation study

Existing analyses suggest that there could be substantial added benefits from further regional cooperation within the South Pacific. While countries may remain satisfied at present with the rate of return, particularly since the rate changed from 4% to 5% of catch value, there are good reasons to undertake analyses of future benefits under alternative management scenarios. The two principal management mechanisms that could be applied are zone closure and the limitation of effort. Both have clear potential benefits, but they also pose problems to governments in that they have the potential to curtail gross income.

A simulation study to assess the effects of zone closure and limited effort is proposed as a way to test the claim that improved economic benefits can be obtained in the future from a multilateral agreement. Initially, this would use available statistics and public domain information on the pre-1980s Japanese distribution data.

(v) Economics of fisheries compliance control study

A concept paper for a study of the economics of fisheries compliance control was prepared as part of the proposals for future work. This described a stand-alone and major research project with the objective of developing a methodology for continuing assessment of fisheries surveillance and management economics, including operational aspects. It was recognised that a full project proposal would have to be developed from the concept paper, taking into account the specific needs of the South Pacific region, for subsequent submission to appropriate funding agencies.

5.4 Conclusion

Discussions and collaboration with the staff at the Forum Fisheries Agency have proved very successful. Of particular value was the considerable experience that several of the senior staff there have had with the types of analysis required for setting optimal levels of licence fees. As a result of these discussions, a comprehensive programme of work needed to be undertaken to apply the methodology successfully to management of the tuna fisheries in the South Pacific has been identified and specified.

The work essentially falls under two headings: adaptation of the existing model and computer software, and estimation of parameter values. The computer software developed in the original research project was intended purely as a tool to illustrate concepts to unfamiliar users, rather than as a means by which to make robust estimates of optimal licence fees, fines and surveillance strategies. Subsequent analyses in the other case studies undertaken by MRAG have used a computer program written in Turbo Pascal which avoids many of the shortcomings of the earlier spreadsheet-based software. Suggestions for improvement of the model as it applies to a single zone have been incorporated in this program, though no attempt has been made as yet to develop this as a software package for independent use.

One aspect of further development of the model has not been attempted. That involves adapting the model to cope with simultaneous management of foreign fishing in different fishing zones. Conceptually, this is not an especially difficult problem. Each state would still wish to optimise its net revenues from foreign fishing, but its range of actions would be constrained by the requirements of regional cooperation. The fishermen now have a much wider range of choices in terms of whether to fish legally or illegally in all, some or none of the various EEZs. However, the programming complexity, and even more so the data requirements, are very substantial. In view of the other data aspects outlined below, amending the model to handle multiple zones has been deferred.

With regard to parameter estimation, the principal difficulty seen is in reliably quantifying probabilities of detection of illegal fishing as a result of surveillance activities, and particularly in describing the behaviour of fishermen in response to their perceived risk of detection. In early discussions, it was suggested that the fact that much of the surveillance costs are met by development funds may invalidate the assumptions of the model. This is not actually the case; it is simple to include a given level of surveillance activity that is essentially free and then investigate the extent (if any) that it might be worthwhile for the coastal state to spend additional funds of its own to augment this surveillance. Nevertheless, it remains true that reliable estimation of the actual probability of detection for a given level of surveillance is not easy and there are few data available to estimate that probability directly from actual instances of detection.

Even fewer data exist in the South Pacific to investigate the fishermen's behaviour in response to perceived risk. The proposals for future work include both an indirect and direct approach to such an investigation. The indirect approach involves analysis of data held by FFA on what may be taken as proxies for responses to perceived risk. The direct approach involves designing and carrying out surveys of attitudes of fishermen, initially with the US fleet. Both approaches, however, do require substantial additional work.

The results of the consultations with FFA have gone a long way towards satisfying the aims of the adaptive research project in terms of application to management of foreign tuna fishing in the South Pacific. The further work needed to ensure practical application of the methodology developed has been clearly identified. However, it is clear that the scope of this work is well beyond the staff and funding available to MRAG under the present project, and significant funds would also have to be found to cover work to be carried out by FFA staff. A draft joint research project proposal between MRAG and FFA to accomplish this work has been developed, but as it will require additional external funding, further action has been deferred until the end of the current project. For the current adaptive project, those recommendations of direct relevance to single zone fishery management have been taken up in analyses conducted in the other case studies.

6 Namibia

6.1 Background

Namibia has a coastline along the south eastern Atlantic ocean of about 1350 km. It has one of the richest fishing grounds in the world because of the oceanography of the waters that lie off its coast. Namibia's EEZ waters lie within the Benguela current system, which flows north from the Southern Ocean carrying cold water. This creates an upwelling of nutrient-laden waters which support a high productivity of phytoplankton and zooplankton, species at the bottom of the oceanic food chain. These in turn support a large biomass of small shoaling pelagic fishes, which in turn support larger predators. The principal commercial species are hake and Cape horse mackerel.

The rich fisheries off the western African coast have for many years been subjected to heavy fishing pressure. Until it was disbanded, management of the fisheries from 1970 was the responsibility of the International Commission for South East Atlantic Fisheries (ICSEAF). In turn, ICSEAF countries were responsible for most of the fishing off Namibia. While heavily exploited during that period, at least ICSEAF was able to exert some hold on excess fishing pressure. However, in the period between the disbanding of ICSEAF and the declaration of the Namibian EEZ came a classic example of the tragedy of the commons, described in Fishing News International as "the last great coastal fishing free for all" (April 1994). Reportedly in excess of 200 large trawlers, all from distant water fishing nations, devastated offshore stocks, with inshore fisheries also being badly depleted.

Since the declaration of the Namibian EEZ, administration of fishing activities in the zone has been carried out by the Namibian Ministry of Fisheries and Marine Resources (MFMR). All vessels fishing inside the Namibian EEZ require a Government licence and they must submit full vessel characteristics as part of the licence application process. TACs are set annually for all of the main species except anchovy, and these are published in the Government Gazette. Access to the fishery is granted to individual companies by means of a 'Right of Exploitation', which generally lasts for one, five, or ten years. All companies holding a current right of exploitation are then able to apply for quotas on an annual basis. Quotas are allocated according to both historical participation and the policy of affirmative action.

6.2 The Status of the Namibian Fisheries

Namibia's commercial fish stocks are among the four largest in the world and the fisheries sector is recognised as one of three key areas of the Namibian economy in the future, the other two being agriculture and mining.

Distant water fishing nations that have traditionally fished in this area include Spain, the USSR, Portugal and South Korea. Distant water fishing nations have historically concentrated effort on mid- and bottom-water trawls for horse mackerel and hake. What local fleet existed targeted either inshore pelagic fish species such as pilchard and anchovies, or rock lobster.

Strategic government policy developed by the Namibian government aims to develop and improve the capacity of the domestic fishing fleet and industry. The industry (catch, processing and marketing) is made up almost entirely of private ventures and the government has stated that this will continue as a long term policy.

Since gaining independence in 1990 and declaring a 200 mile EEZ, Namibia has made significant moves in taking control of their fisheries by effectively prohibiting the activities of foreign fleets except under strict exploitation rights and licensing conditions, including a requirement to land fish in Namibian ports. A surveillance and inspection scheme is in place, and there is a policy of affirmative action, which is now providing 'newcomers' with quotas in order to force the pace of restructuring and limit foreign involvement in 'local' companies.

Government revenue from the fishery is generated via licence fees, quota levies and research levies. The licence fee is minimal and intended only to cover administrative costs. The main sources of income are the two types of levies. Quota levies are payable per tonne of quota allocated, with different rates set per species. Quota levies are payable in quarterly instalments, irrespective of how much fish is actually landed. Research levies, on the other hand, are raised per tonne of fish actually landed. Each fishing company sends in a monthly payment to the Ministry.

Comprehensive catch data is available, as all landings of fish are documented by the Ministry Inspectorate and are processed centrally for the calculation of research levies. All vessel captains are required to fill in a daily log of fishing activities which are then submitted on landing.

It is intended that these regulations will allow a domestic Namibian fishing fleet to develop over time, eventually gaining the capacity to fully exploit the Namibian marine resources.

The offshore fishery

There are two main species present in the Namibian offshore fishery, hake and Cape horse mackerel. These species are both caught primarily by trawling. The fact that the fisheries for each species yields a substantial by-catch of the other species considerably complicates monitoring, quota setting and conservation.

<u>Hake</u>

Hake are primarily taken in demersal trawls, generally during daylight hours but sometimes also at night. Hake are also taken in a directed longline fishery, and they are a common, but often unreported, by-catch of midwater trawls. This poses problems for conservation and stock assessment as midwater trawls are the favoured fishing method in the horse mackerel fishery, which is the other main offshore commercial species in Namibian waters.

Hake are potentially the most valuable of Namibian stocks, but they must be managed cautiously since the species suffered very heavily from over-exploitation by distant water fishing nations prior to the declaration of the EEZ. Conservative catch limits are currently being set with a view to rebuilding the stocks to former levels. The estimated maximum sustainable yield is between 300 and 400 thousand tons.

Hakes belong to the genus Merluccius, meaning sea pike. Related to cod, they are white-fleshed and an increasingly popular substitute for declining cod stocks. The hake fishery lies of the Namibian coast in the Benguela system between the latitudes of 15 and 30 degrees south. There are three species of hake which inhabit this region: Angolan hake (*Merluccius polli Cadena*t), shallow water hake (*Merluccius capensis Castelnau*) and deep-water hake (*Merluccius paradoxus Franca*).

M. capensis and *M. paradoxus* are the most common species caught off Namibia. *M. capensis* dominates the Namibian Shelf and is found at depths between 100 and 400 metres. *M. paradoxus* is usually taken between 300 and 500 m, but can be found at depths of up to 1000 m. The species are not separately identified in catch registers.

The mean age of the population declined in the 1970's and remained low thereafter. This can be attributed to a high degree of fishing pressure.

Both surplus production models and virtual population analyses have been used to assess hake stocks. Results of these assessments up to 1990 have tended to vary somewhat, depending on the methodology used and which relative abundance data were included. However they generally indicated that the stocks had declined under fishing pressure to historically low levels in the late 1970s, with only a modest increase since then. Most point to a need to reduce catches to allow stock recovery. Alheit (1995) cites reports from fishing fleets that catches had risen sharply at the beginning of the 1990s, which he acknowledges as difficult to explain in light of the previous assessments.

The most recent reports from Fishing News International (April 1995) are that last year's poor catches have been weathered by the fleet and they are now getting catches of up to 45 tons live weight per day. Better unit prices in the hake markets have also increased export revenues from this species. The domestic fleet of demersal trawlers fishing for hake continues to expand, with several new trawlers due to be deployed later this year, and it has roughly trebled in size since 1993 to 66 vessels, while the distant water hake fleet have halved in size over the same period to 14 vessels.

Cape Horse Mackerel - *Trachurus trachurus capensis*

The largest of the two Cape horse mackerel fisheries off south west Africa is found off Namibia. The directed fishery consists of two components, a purse seine fishery targeting juvenile fish and a midwater trawl fishery that harvests more mature fish (Punt, 1991). There are, however, substantial bycatches of horse mackerel in the demersal fishery directed at hake. The total impact of Cape horse mackerel fisheries (using 70 mm mesh nets) on hake has been estimated at around 20% of the total stocks (Lleonart, 1981).

Midwater horse mackerel are still almost entirely harvested by large trawlers from Eastern Europe. Most of these vessels are chartered under the Namsov Russian-Namibian joint venture, which produces frozen horse mackerel. The local capacity for processing horse mackerel is expected to increase in the short to medium term. One might therefore expect to see a decreasing foreign presence in this fishery as the local industry continues to expand.

The biology of this species is poorly understood, one of the few studies being that of Sedletskaya (1989). A stock assessment using an age-structured production model estimated the MSY to be in the vicinity of 85,000 t.

The inshore fishery

Typically the fleets pursuing the inshore species are based in south west Africa, rather than from all over the world as is the case with the offshore fleets. However, this has by no means insulated the inshore stocks from over-exploitation. There is generally a greater separation of species ranges in inshore waters, so that bycatches do not present a significant management problem, except in the case of the sardine/anchovy fishery.

Pilchard/sardine - *Sardinops ocellatus*

This is a coastal pelagic species of fish, growing to an average of approximately 25 cm, which forms large migratory schools. Pilchard are distributed from Angola in the northwest, round the Cape to Natal in the east. Within this region, the 'northern' stock rarely moves south of the Orange River, so the stocks are essentially separated. Pilchard are an important commercial species in the region, with Namibia sharing just under half of the total harvest.

The pilchard stocks have shown large variations in abundance. In the mid 1960's, the total stock biomass was estimated at over 10 million tonnes, but by 1970 this had dropped to 1 million tonnes and since in the late 1970's and the early to mid 1980's, it is estimated to be roughly between one tenth and one fifth of that size. Since then, there appears to have been something of a recovery, with research surveys suggesting stock sizes in 1990 to be in the range 450,000 - 750,000 t. Recovery was though to have continued during the early 1990s, although this has been slowed by the incidental catch of juvenile pilchards in the local anchovy fishery.

Unfortunately, most recent reports suggest a massive decline of 80% since 1992 to under 200,000 tonnes. This has been compounded by a northward movement by the entire stock into Angolan waters. A very small TAC (of 35,000 tonnes) has been set for 1995 and Fishing News International (April, 1995) reports that only one of three Walvis Bay canneries will operate this year, cutting seasonal factory employment by 2000.

Southern African Anchovy - *Engraulis capensis*

This fish is pelagic in shallow inshore waters, but is also found down to about 200m, forming large schools. It feeds chiefly on calanoid copepods when juvenile, gradually switching to phytoplankton when it reaches 5cm in length. Spawning is from early spring to late summer, from October to April in southern African waters, with a peak in November/December in the south, but in February off Namibia. Namibian and South African stocks are well separated by the Luderitz/Orange River cold upwelling belt. This species was hardly exploited in Southern African waters until 1965 when the use of small mesh purse seines was allowed. Since then, in some years anchovy have contributed to over half the total pelagic catch, but with considerable fluctuations, including a tendency for increased catches as the sardine fishery declined. Catches increase from April and reach a peak in May. Anchovy schools are sometimes so dense that up to 100 tonnes can be caught in a single set. The anchovy stock is exploited almost entirely by coastal South African fleets.

Southern African anchovy catches declined from 500,000 tonnes in 1980 to 300,000 tonnes in 1986. Then, in 1987, the sudden favourable conditions brought about exceptionally high egg and larval survival, allowing over 1.3 million tonnes to be caught (600,000 tonnes in South Africa), which was double the usual catch. At this point, environmental conditions for the anchovy apparently turned very unfavourable and catches fell to 300,000 tonnes in 1989 and only 150,000 tonnes in 1990.

The widely fluctuating historic stock levels shown by both pilchard and anchovy stocks are typical of these species, and they may not all be entirely due to fishing pressure. It is a well-known feature of sardine (pilchard) stocks worldwide that when they co-occur with anchovy stocks, fluctuations in sardine abundance occur in close association with the rise and fall of the anchovy stocks. This is thought to be a natural phenomenon, but is probably exacerbated by fishing pressure. Unlike the Pacific species, where this process is linked to the El Nino cycle, the exact dynamics behind South East Atlantic fluctuations are not fully understood.

Lobster

The lobster fishery has been in place since the 1920's and throughout this time there has been a fairly steady decrease in catches. Rates of growth and production of west coast rock lobster indicate that the stock is under very heavy fishing pressure. A "one-time socio-economic" concession temporarily reducing the minimum allowable size of lobster was introduced with decreasing total allowable catches. The experience of recent years, where catch rates have been very low, has suggested that TAC's are unattainable. Because it is a slow growing, long lived species, stock recovery programmes are likely to both be difficult and slow. It has been estimated that it will take seven to ten years before any dividends from such a programme will be observed.

Recent catches, quotas and licences issued

Catches and quotas for the main commercial fish species in Namibian waters are shown in the table below. Also shown are the numbers of licences issued in 1995.

Namibian Catches, Quotas and Licences Issued, 1992-1994/95.

Species	Catches (000 tons)			Quotas (000 tons)		Licences Issued
	1992	1993	1994	1994	1995	1995
Hake	98	108	109	150	150	35
Horse Mackerel	426	475	361	410	400	24
Pilchard	81	115	116	125	35	
Other small pelagics	116	74	33	90	50	28
Tuna	2.2	3.5	3.4	-	-	-

Source: Fishing News International, April 1995.

6.3 Surveillance and Enforcement

With a coastline of about 1350 km, the Namibian EEZ covers nearly 500,000 km^2. The area of most interest to distant water fishing nations, and therefore to Namibian surveillance authorities, lies within the 1000 metre contour, which is approximately midway between the Namibian coast and the outer reaches of their EEZ. This effectively halves the area to be patrolled.

In 1990, the MFMR surveillance and enforcement staff included the crews of three control vessels and four research vessels, plus inspectors for sea, land and airborne control. At that time it was also planned to purchase new surveillance planes, to replace the irregular flights made by chartered planes. What was particularly felt to hamper the surveillance efforts was the lack of a communications system to connect the fisheries control centre with the planes and patrol vessels.

In 1991 airborne patrols were undertaken by two planes. They undertook a total of 720 flying hours during the year, each patrol lasting some 6 hours with time on surveillance approximately 5½ hours. Seaborne patrols were undertaken by three vessels; one fisheries enforcement boat and two armed patrol boats. Surveillance and enforcement would be aided by development of regional agreements with neighbours to the North and South, as many of the commercial species migrate along the south western coast of Africa. A further problem in seaborne surveillance is the long coastline, which has only two ports from which patrol vessels can operate. Large distances have to be covered by each patrol boat and the reaction time to reports of vessels in certain areas will be very long.

Programmes are also in place to facilitate the monitoring of all landings and on board inspectors. The domestic courts deal severely with those caught not complying. The effectiveness of these programmes has led the MFMR to believe that it has virtually eliminated illegal fishing by unlicensed foreign vessels and generally secured effective compliance with quota limits and conservation practices by licensed vessels.

6.4 Illegal Fishing

The fish species most likely to attract illegal fishermen is hake. Other fish species of major commercial potential are either too close to the shore, yield too low a catch rate, or are quite simply not of a high enough value to be worth risking arrest. Hake, however, are offshore species of considerable value, with a high catch rate and the temptation, in the absence of adequate surveillance, is likely to be high. Of the other species, only rock lobster are also likely targets of illegal fishing.

Illegal fishing is believed to be perpetrated by fishermen from neighbouring countries or by fleets from distant water fishing nations which have historically fished in the area. Illegal fishermen from Angola in the north and South Africa in the south are believed to cross into the Namibian EEZ either at night or whilst cloaked in sea fog (a common occurrence in the region).

Fleets from distant water fishing nations, which until 1990 had unrestricted access to what are now Namibian waters have also, in some cases, been slow or reluctant to adjust to the new set of circumstances. In 1990, five Spanish bottom trawlers were apprehended with R10 million worth of hake on board, after all diplomatic efforts to stop illegal fishing had failed. At least twenty other vessels of similar origin are believed to have been fishing illegally in Namibian waters. The surveillance operations have met with considerable success since independence, confiscating ten Spanish vessels that were fishing illegally during this time. The penalty for unlicensed fishing is confiscation of both the vessel and catch.

6.5 Application of Control of Foreign Fisheries methodology

At the start of this research project, Namibia seemed an ideal choice for a case study for several reasons:

- Its waters are known to contain high value fisheries that historically have been fished by many foreign fishing vessels.
- Extensive historic data for the fisheries had been collected and published by ICSEAF. Since declaration of independence, the management of the EEZ by Namibian authorities has been well-organised and highly-centralised, so that recent data required for the adaptive research will be available directly from the Ministry of Fisheries and Marine Resources.
- The Namibian Government has taken steps to introduce significant surveillance enforcement capabilities, including the purchase of a helicopter, three patrol boats and a number of aircraft.
- The structured nature of revenue generation from research and quota levies allows an interesting and relatively simple way of modelling this aspect of the adaptive research.

As it transpired, since attaining independence fishery development in Namibia has been even more rapid than had been expected. Following an initial field visit by David Evans and Simon Holden of MRAG in early 1993, it has become clear that the primary aim of fishery development in Namibia has been to maximise the country-based fishery activities, and minimise strictly foreign-based fishing. In terms of the involvement of foreign fishing vessels, highest priority has been given to the setting up of joint ventures and establishment of major shore-based processing of the catch.

While the management of what is becoming essentially a domestic fishery does have elements in common with management of foreign fishing (in particular the need for surveillance and monitoring of a very lucrative fishery), the differences in emphasis are such that the methodology developed in the original project would not be applicable without very substantial modification. These changes, allied to the resignation from MRAG during 1994 of the project director to take up an ODA funded position in Namibia, led to a decision to defer further work on this case study area.

7 British Virgin Islands

7.1 Background

The British Virgin Islands Exclusive fishing Zone (EFZ) is approximately 73,800 km^2, extending almost due north into the Central Atlantic, sharing common boundaries with the US Virgin Islands, Puerto Rico and Anguilla. The waters around the British Virgin Islands lie across seasonal migration routes of a number of large pelagic species, such as swordfish, albacore and other tunas.

As with many other countries in the Caribbean, the 200 mile zone has an awkward shape and it is not really feasible to licence commercial operations on a unilateral basis. The close proximity of the many island nation states in the caribbean leaves each with a relatively small, narrow EFZ and the need for strong regional cooperation is evident. Regional management of commercial fishing is undertaken through the Organisation of Eastern Caribbean States (OECS), of which the British Virgin Islands is an associate member (as it is of CARICOM, the Caribbean community). A set of harmonised terms and conditions of access by foreign fishing vessels to the EFZs of member states have been adopted by OECS. However, since their adoption, it appears that relatively few foreign fishing vessels have taken up the opportunity to fish in OECS waters under these terms and conditions, probably because the OECS licence fees are very much higher than those that existed previously.

The Conservation and Fisheries Office of the British Virgin Islands Ministry of Natural Resources and Labour is responsible for licensing all fishing vessels, both commercial and sport fishing vessels. Registers of licensed vessels are maintained by the department, although for the sports fishing vessels the characteristics of these vessels are not detailed, nor are the catch data recorded.

The nearest neighbour to the British Virgin Islands is the much more heavily developed US Virgin Islands and their EFZs have a common boundary. Both commercial and sports fishing vessels based in the US Virgin Islands fish in the British Virgin Islands EFZ. For sports fishing, access to the British Virgin Islands zone requires purchase of a sports fishing licence. For commercial fishing, a Reciprocal Fisheries Agreement between the US (on behalf of the US Virgin Islands) and the UK (on behalf of the British Virgin Islands) was signed in 1979. Under this agreement, commercial fishing vessels from the two island states were allowed to continue to fish in each other's zones, provided the existing patterns and existing levels of fishing were maintained. A subsequent minute clarified the meaning of existing patterns and levels, confining it to deep line fishing and to trap and line fishing.

By any reading, this agreement gives far more favourable treatment to US Virgin Islands vessels than British Virgin Islands vessels, because of the past imbalance in levels of fishing activities between the two. It is to be hoped that the wide acceptance that payment of fees is an integral part of current licensing practice will reduce the precedent set by this agreement in any renegotiations that may occur in the future.

7.2 The Status of the British Virgin Islands Fisheries

At present, there is an effective moratorium on the licensing of foreign longline fishing vessels to take large pelagic fish within the British Virgin Islands EFZ. Sports fishing on the same stocks mainly occurs from vessels registered in the US Virgin Islands. There are also some domestic small-scale longliners operating from Anegada. A review by MRAG (1993) concluded that it should be possible to develop policies that would allow the development of a British Virgin Islands-based sports fishery, an enhanced domestic commercial fishery, and a foreign longline fishery within the British Virgin Islands zone, each of which could make an important contribution to the British Virgin Islands economy.

For sports fishing, MRAG (1993) recommended that consideration be given to encouraging investment in British Virgin Islands-based sports fishing operations, and that the existing policy with regard to the licensing of foreign sport fishing vessels, especially the low level of fees charged, could be revised with benefit. Sport fishing was believed to provide the best potential application of the Control of Foreign Fisheries methodology for the British Virgin Islands.

MRAG (1993) also concluded that revised sets of conditions and access fees could be developed for foreign fishing to allow the Government to issue appropriate numbers of licences under terms that would both benefit the country and limit interaction with domestic fishermen. It was unlikely, however, that much revenue could be raised from such licensing, and it appears that the current British Virgin Islands policy of not issuing any licences will continue.

Sport Fishing

Sport fishing has the potential to raise much more revenue than it currently does for the British Virgin Islands. Although there is little sports and game fishing based in the British Virgin Islands itself, apparently over 80% of the fish taken by sports fishermen from the neighbouring US Virgin Islands are taken in British Virgin Islands waters.

Offshore sport fishing involves trolling for game fish from small sport fishing boats or other recreational craft. By far the preferred target species is blue marlin, but other species taken include mackerels, barracuda, wahoo and bonitos. The majority of licensed sport fishing vessels in British Virgin Islands waters fish between May and August/September each year, primarily in pursuit of blue marlin. The continental shelf shared by the British Virgin Islands, the US Virgin Islands and Puerto Rico is the most popular fishing ground. The British Virgin Islands has territorial control over 948 square nautical miles of this shelf. The best blue marlin fishing grounds are found in the northern part of the shelf, in an area known as "The Saddle".

The British Virgin Islands Conservation and Fisheries Department has indicated that some 82% of all sports fishing operating out of the US Virgin Islands has been conducted in the waters of British Virgin Islands under licensing arrangements. Indeed, the waters of `the Virgin Islands' are proclaimed in tourist brochures for St Croix, St Thomas and St John as among the richest in the world for game fish. Such claims may be correct, but the benefit of that availability, including virtually all the income from sport fishing tourism, would appear largely to accrue offshore in the U.S. Virgin Islands. A further problem is that although a number of world record trophy catches have been taken in British Virgin Islands waters, these catches are accredited to the US Virgin Islands, from where the majority of vessels operate. Licence fees paid by US Virgin Islands sport fishing vessels are a very small $200 per annum.

It is clear that the current $200 licence fee paid by foreign-based sport fishing vessels for access to the stocks of British Virgin Islands waters is absurdly low. If it could be increased, then sport fishing tourism could realise its potential to become a major contributor to the British Virgin Islands foreign exchange earnings. The revenue generated from such fishing, together with associated multiplier effects, is likely to far exceed any earnings that might be made by licensing foreign commercial vessels. A further advantage of sport fishing is that only a small proportion of the available stocks is taken, particularly where a policy of releasing small fish is adopted.

An indication of the numbers of sport fishing vessels involved in the Virgin Islands fisheries is given by the table below.

Sports Fishing Vessels Based In British Virgin Islands and US Virgin Islands, 1987-92

Year	Number of sport fishing vessels		
	British Virgin Islands	US Virgin Islands	Total
1987	9	15	24
1988	8	75	83
1989	16	102	128
1990	26	70	96
1991	15	69	84
1992	21	50	71

Source: L. Blok, *pers comm*

Blue marlin -- *Makaira nigricans*

Blue marlin is a epipelagic, oceanic billfish. It is the most tropical of all the Atlantic billfish, and is slightly more abundant in the western than in the eastern Atlantic. Studies suggest the existence of possibly one or two Atlantic stocks. Two main seasonal concentrations appear to occur in the Atlantic, from January to April in the southwestern Atlantic and from June to October in the northwest Atlantic. Transatlantic movements have been documented from the western to the eastern Atlantic, along with seasonal migrations which correspond to the cooling of temperate waters in the winter. Blue marlin are most abundant in the Caribbean from April to December.

Blue marlin are one of the fastest growing of all teleosts, particularly during the first year of life, when maximum growth can be as high as 16 mm per day. Blue marlin are long lived, reportedly attaining ages of at least 25 - 30 years. They can reach a length of over 4.5 m and a weight of over 600 kg. In the north Atlantic, blue marlin spawn in the Caribbean Sea during the summer but often have a small peak of spawning in the autumn.

White marlin -- *Tetrapturus albidus*

White marlin are a pelagic, oceanic species, with a distribution ranging across the Atlantic Ocean from 35^{o}S to 45^{o}N including the Gulf of Mexico and the Caribbean. Tagging studies show a large scale migration from the coast of South America up to Canada. Migration routes are unknown, but they possibly pass through the EFZ's of the UK Dependent Territories as the fish move northward to feeding grounds in the Gulf of Mexico and the US east coast.. White marlin are present in most areas of the eastern Caribbean during the period October to June, but there are few reports of catches from the Lesser Antilles. Catches are seasonal for different regions of the Caribbean. The fisheries in the northern Gulf of Mexico and western Caribbean (including Cayman Islands) peak in September and October, while in the Virgin Islands and the Lesser Antilles the peak occurs during the period February to March.

In general, white marlin are found in waters greater than 100m deep with surface temperatures over 22^{o}c. In contrast to blue marlin, white marlin reach higher latitudes in the warm summer months and tend to congregate in areas accessible to shore-based fisheries in much greater numbers. Spawning for the white marlin in the western North Atlantic is believed to occur throughout the Caribbean, in the Gulf of Mexico, and in the straits of Florida during April and May.

Atlantic Bonito -- *Sarda sarda*

The Atlantic bonito is to be found on both sides of the Atlantic Ocean. It is an epipelagic, surface-schooling fish occurring over the continental shelf. In the western Atlantic, the Atlantic bonito commonly reaches 50 cm (fork length) and about 2 kg in weight. Distribution in the Caribbean is unclear: there are reports of *S. sarda* in the Caribbean from Cuba, the Leeward and Windward Islands and the US Virgin Islands. There is little information on the stock structure or migrations of the Atlantic bonito, but the seasonal sport fishery off Florida suggests that some seasonal migration may be occurring.

Wahoo -- *Acanthocybium solandri*

Wahoo is an elongate fusiform oceanic species, often solitary or forming small loose aggregations rather than well defined schools. It is distributed throughout the tropical and subtropical waters of the Atlantic, Pacific and Indian oceans. The size of wahoo ranges between 100 and 170 cm (fork length), the size increasing as one moves further away from the equator. Wahoo is common in the Caribbean and surrounding areas. There is most probably only one single stock for the whole region.

Commercial Fisheries

As there seems little potential for licensing of foreign commercial fishing vessels in British Virgin Islands waters in the near future, only a brief resume of the previous commercial fishery and species will be given.

Swordfish -- *Xiphias gladius*

In the wider Caribbean area, commercial longline fisheries for swordfish are operated mainly by vessels from the U.S and Venezuela. In British Virgin Islands waters, US longline vessels have been licensed to take swordfish. Demand for swordfish is high, particularly from hotels and restaurants. Presently demand exceeds the supply caught by British Virgin Islands nationals, resulting in imports totalling US $640,000 per annum. Catches of swordfish in British Virgin Islands waters by US longline vessels between 1984-90 averaged 90 tonnes (equivalent to US$800,000 per year at 1991 prices), with minimal fluctuations in catch rates during the seven year period. The returns to the British Virgin Islands through licence fees represented approximately 4-5% of the landed value.

Swordfish are the most widely distributed billfish and occur in all tropical, subtropical and temperate seas. They appear to have the widest water temperature tolerance among the billfish, since they are found in waters with surface temperatures ranging from about 5-27^{o}C. ICCAT recognises several possible stock hypotheses for Atlantic swordfish, including a discrete stock in the North Atlantic. The preferred habitat of the swordfish is believed to be near the edge of continental shelves in waters from 100 - 3,000 m deep, near oceanic frontal zones, or near sea mounts and mid-ocean islands. Swordfish grow rapidly and may live 25 or more years. At age five females can reach up to 220 cm (approx 110 kg), males being slightly smaller.

A number of assessments of swordfish stocks have been carried out by ICCAT. Since 1989, increasing concern has been expressed about their status, and allowable catches have been reduced with a view to promoting stock recovery.

Yellowfin tuna - *Thunnus albacares*

Yellowfin tuna are found worldwide in tropical waters. In the Atlantic, the greatest oceanic concentrations of yellowfin are found between the equator and ± 15^{o} latitudes. For assessment purposes, ICCAT considers Atlantic yellowfin tuna to be composed of two stocks, one in the eastern Atlantic and one in the western Atlantic, with some mixing between them. In the spring and summer, the western Atlantic concentrations of yellowfin move towards the Central Atlantic and the Cape Hatteras and Caribbean regions. Substantial concentrations can be found in the Gulf of Mexico during this period.

The yellowfin is a fast growing species. At around seven years of age a single yellowfin may attain a maximum fork length of 170 cm and a corresponding weight of 70kg, but such specimens are not common. The average size in the Gulf of Mexico longline fishery is about 140 cm, corresponding to a weight of about 50 kg and an age of 3-4 years. The average age of sexual maturity is about 3 years, when the fish weigh about 25 kg. In the western Atlantic, spawning takes place mainly during the months of April through June. The Caribbean Sea and the lesser Antilles unquestionably constitutes an active spawning area for the western Atlantic stock. Spawning also occurs in the Gulf of Mexico.

Skipjack tuna - *Katsuwonus pelamis*

Skipjack tuna is a cosmopolitan species, occurring in tropical and warm temperate seas. It is a relatively small tuna. There is no evidence that the western Atlantic skipjack tuna stock undertakes migrations, although seasonality in the Japanese longline fleet (1956-68) catches suggests that skipjack are most abundant in the Caribbean during January to March, when they are distributed along the Lesser Antilles from Puerto Rico down to Trinidad. There they are found in fast moving schools along the edges of reefs. From April-May onwards, they start moving in towards the coasts and are found around the coral reefs and shallows. At this time of the year they are found together with shoals of blackfin tuna. They may come very close to the coast in summer. Skipjack are less abundant at the beginning of autumn, when they move from the coastal zone to the continental shelf.

The maximum size observed for skipjack from all oceans is about 110 cm, corresponding to a weight of about 34 kg, however fish in the range of 80 cm or less and up to 10 kg are most common. Skipjack are thought to spawn first at about 45 cm or about 1 year old. They are opportunistic feeders and mature at an earlier age and have a higher natural mortality rate than either yellowfin or bigeye tuna.

ICCAT recognises that several possible stocks could exist, including a western Atlantic stock. The commonest commercial fishing methods for skipjack in the Caribbean are purse-seining, pole and line and trolling. Most skipjack are taken as a by-catch by purse seiners, and pole and line boats from Cuba and Venezuela. Skipjack is important to certain fishing states in the eastern Caribbean, Dominica and St. Lucia between them take about 90 mt per year, and Barbados about 80 mt. Most islands currently record skipjack together with other species such as blackfin tuna and Atlantic bonito in their fishing records.

Albacore - *Thunnus alalunga*

Albacore are cosmopolitan in tropical and temperate waters of all oceans, and they range from 40^{o}S to 50^{o}N, but are not found at the surface between 10^{o}N and 10^{o}S. Larger albacore are known to be found in deeper cooler waters, smaller specimens are caught in shallow warmer waters. Two stocks of albacore are known to occur in the Atlantic, most probably divided along 5^{o}N, with little or no exchange occurring between the two stocks. There is some disagreement about which stock the Caribbean catch comes from, though it is most likely to be from the northern stock. There are no specific abundance or catch data for albacore in the Caribbean, although the Japanese longline fishery off the Leeward Islands (1956-68) found most albacore present in the Caribbean during the period April to June. In the Caribbean region albacore catches are restricted to an area to the north near Bermuda, where they are targeted by Taiwanese vessels. Very few albacore are caught in the Lesser Antilles; occasionally a few are caught by the artisanal fisheries.

7.3 Surveillance and Enforcement

All surveillance and enforcement activities in the British Virgin Islands are undertaken by the Police. In 1989, a fast Halmatic patrol boat was supplied by the British Government, and in 1992, a Piper Navajo aircraft was also purchased for British Virgin Islands by the UK. Recurrent costs for operation of both the patrol boat and the aircraft are met by the Government of British Virgin Islands, but there is some assistance with funding from the OECS Fisheries Unit for a limited number of dedicated fisheries surveillance patrols each year.

The primary task of these platforms is smuggling interdiction (particularly drugs and illegal immigrants) and customs duties. Although there is close liaison with the fisheries department for dedicated patrols, fisheries enforcement is very much a lower priority than the above tasks, for obvious reasons. A list of all licensed vessels (mainly sport fishing boats) is provided to the patrol craft for every trip by the Fisheries

Department. However, specific fisheries-related training for the crews of the patrol boat and aircraft has not been undertaken. The crewing arrangements for the patrol boat provide for shift changes during 16-hour cruises for 3 days per week and single crew for 8-hour cruises 4 days a week, thus allowing a significant deterrent for illegal activities.

Senior police officials hold the view that the enhanced surveillance capability of the police provided by the patrol boat and the aircraft have caused a significant reduction in drug trafficking. It is possible that this enhanced capability will also have discouraged illegal fishing. Recent data on the distributions of longline sets by US fishing boats indicate that indeed fishing effort since 1990 has been concentrated further off-shore.

7.4 Illegal Fishing

The extent of illegal fishing is not known. As foreign sport fishing vessels may fish legally inside the British Virgin Islands EFZ by purchasing a $200 licence, it seems unlikely that there would be much incentive to fish illegally. This, of course, would change if the licence fee were increased substantially. It is in fact illegal for sport fishing craft to fish within 3 miles of the British Virgin Islands coastline without completing customs and immigration formalities. Violations of laws of this type are not the concern of the current project.

Equally little is known about illegal commercial fishing in British Virgin Islands waters. There is a lot of sea traffic in the region and it is quite likely that vessels may fish as they make passage through the EFZ waters, but no commercial vessels have been detected illegally fishing.

7.5 Application of Control of Foreign Fisheries methodology

Field visits to the British Virgin Islands under a previous ODA-funded project had identified two possible applications of the control of foreign fisheries methodology. The first, and most obvious, was an application to sports fishing in the British Virgin Islands EFZ. As indicated earlier, a large fleet of sport fishing vessels based in the nearby US Virgin Islands regularly fishes in British Virgin Islands waters, but it is currently subject to only a very nominal licence fee. The potential exists for the British Virgin Islands to substantially increase the revenue accruing to it from this fishing.

The second possible application was to the licensing of foreign longline fishing vessels. The British Virgin Islands had previously issued small numbers of licences to foreign fishermen in the 1980s, but dissatisfaction with the benefits that licensing had generated led to an 1990 order from the Ministry to stop such licensing. Since then, there has been an effective moratorium on large-scale commercial longline fishing.

Since the start of the adaptive phase of the current project, a number of attempts have been made to set up a working arrangement with the British Virgin Islands to undertake the studies necessary. Unfortunately, this did not prove possible, and in March 1994 it was decided reluctantly to abandon any further attempts to pursue this potential case study.

8 British Indian Ocean Territory

8.1 Background

The British Indian Ocean Territory (BIOT) encompasses the Chagos Archipelago, centred at 6 degrees south, 72 degrees east on the southern-most part of the Chagos-Laccadive Ridge. The archipelago consists of five atolls and a number of submerged banks, the largest of which is the Great Chagos Bank and all of which are actively growing reefs.

The climate is affected by the prevailing winds: from December to March, the wettest months, moderate winds are experienced from the north-west, while from June to September strong south-east trade winds blow. The transitional periods of April-May and October-November are periods of light variable winds and frequent calms. The area is subject to the South Equatorial current, which flows westward during both of the major wind seasons. It is thought that this water movement, in conjunction with the bank topography, supports some upwelling of nutrient rich water. The limited flats of the BIOT reefs, when considered in relation to their remote oceanic location and lack of obvious bottom sources of primary productivity, imply that the oceans must contribute significantly to the productivity of the reef fish (MRAG, 1994).

The islands of Nelsons, Peros Bahnos, Salomon and Diego Garcia were originally inhabited and were minor producers of salt fish, mainly from the demersal fishery, although some handlining for shark and predatory teleost fish also occurred. In the early 1970's the atolls were evacuated, with the exception of Diego Garcia which is now a US naval facility. These unpopulated islands and reefs are largely undisturbed, and up to the time they left, the local people had a minimal impact on the marine resources (Frazier, 1977).

8.2 The Status of the British Indian Ocean Territory Fisheries

There are two distinct fisheries in BIOT waters, an inshore fishery concentrating on reef fish, and an offshore fishery concentrating on several tuna species, principally skipjack and yellowfin, which spend part of their annual migratory cycle in and around BIOT waters.

The Inshore Fishery

Inshore licences to fish in BIOT waters have been taken up by Mauritanian vessels. Companies from the Seychelles and South Africa have also shown interest in the past.

Mothership-catcher boat (dory) fishing operations employ handlines to exploit demersal stocks of snappers, groupers and emperors, occasionally using trolling methods to catch pelagic species when moving between demersal fishing sites. Refrigerated mother-ships with blast freezer and frozen storage facilities deploy up to 20 dories, each crewed by three fishermen employing baited hooks and handlines. The fishery traditionally operates during the period May - September. Fishing is generally conducted in shallow water (less than 50 m deep) on the submerged banks or reefs surrounding the atolls of the Archipelago. Demersal species of the families Lutjanidae, Lethrinidae and Serranidae are targeted. Fishing within the lagoons of the Archipeligo is prohibited, but this is believed to have occurred in the past.

Present catches are well below the estimated sustainable yield and continued fishing at present levels of effort is not considered to pose a threat to the resource. Indeed, it is likely that overall effort could safely be increased, although continued catch monitoring and assessment of the fishery are necessary to reduce the possibility of local depletion, for instance, on say a smaller bank, such as Blenheim reef.

Although any stock depletions appear to be localised and harvests currently run below the estimated maximum sustainable yields, periodic local depletions indicate the significant fishing power exerted in a short space of time by this type of operation. It should be remembered that fish are being extracted from a highly delicate, immensely significant, marine ecosystem. Large slow growing top predators are the target of the reef fishery, and their removal will have as yet undetermined consequences for the fish community structure and bio-diversity of the reef and lagoon habitats. These target species are outlined briefly below.

Lutjanidae - Snappers and Jobfish

These are perch-like fish with a moderately elongated and fairly compressed body. There are many species in the Western Indian Ocean and they are very important to the region, both in terms of their function in the ecosystem and as a highly valued commercial species. All snappers are predators, usually active at night, and feed mainly on crustaceans and fish. Certain species act as a control on the numbers of prey species (e.g. parrot fish), which if allowed to increase in number, can damage coral.

The most common lutjanid species in BIOT waters are:

> *Pristipomoides filamentosus* (Bluespotted jobfish), an elongate, robust snapper. It is found in water between 80 and 360 metres deep over rocky bottoms along the edge of the continental shelf and around isolated oceanic islands and banks.
>
> *Lutjanus bohar* (Two spot red snapper), a heavy bodied snapper with a slightly convex head profile. It is usually found and caught in shallow coral reef areas down to depths of 70 metres. It feeds on crustaceans and fish, but large specimens feed almost exclusively on fish. It occupies an ecological niche as a higher predator within the reef environment.
>
> *Lutjanus gibbus* (Humpbacked red snapper), a small deep bodied snapper. This species inhabits shallow waters in rocky and coral reef areas to depths of 60 metres.

Serranidae - Groupers, Seabass, Coral Trout

Once again there are many species from this family found in the western Indian Ocean. Most species inhabit coral and rocky reefs. All are predators on fish and invertebrates, sometimes including lobsters and crabs. They are important species in a variety of fisheries including subsistence, sport and commercial fisheries.

Main species fished in BIOT waters include:

> *Epinephelus morrhua* (Comet grouper), an apparently rare fish found at depths of 120 to 370 metres.
>
> *Plectropomus leopardus* (Bluedotted coral trout), one of many species of coral trout in the region, found between 10 and 30 metres depth in coral reefs.
>
> *Variola louti* (Moontail seabass), a widespread species, common in coral reefs. It is found in a depth of water between 5 and 100 metres. Sale of this species has been banned in Mauritius, where it has been reported to have caused ciguatera poisoning.

Lethrindae - Emperors

This family consists of medium to large perch-like fish inhabiting tropical and subtropical areas of the Indo-Pacific. The favoured habitat is coral reefs and rocky areas, but they can also be found in coastal waters on soft substrates. This family is characterised by stout crushing jaws which help it to fulfil its predatory role in the marine environment. They usually form small schools and swim close to the bottom.

The main species is *Lethrinus variegatus* (Variegated emperor), which inhabits coral reefs up to depths of 160m and feeds on crustaceans, molluscs, echinoderms and fish.

A recent report (MRAG, 1994) concluded that there is a need for a thorough investigation of reef fish communities and the sustainability of fishing at Diego Garcia, with a view to providing better management advice to ensure the conservation of the biodiversity of the reef community. Growth of licensed commercial fishing, particularly at Salomon, shows that a proper baseline survey of fishing and reef fish communities on the outer islands of BIOT is highly desirable. The resources are of immense scientific value and potentially of medical value. In the long term, the resource could also be of value for eco-tourism. To achieve the BIOT objectives whilst deriving the benefits of controlled exploitation, the resource needs to be sustainably managed on the basis of well-researched information.

The Offshore Fishery

There are two main fishing seasons in the BIOT FMCZ: the period between July to September is dominated by Taiwanese longline vessels targeting large, deep-swimming tunas. Between November and February the Taiwanese fleet is joined by the European purse-seine fleet (Spain and France) which targets surface swimming tunas.

Purse Seines

Purse seiners search for fish on the surface during daylight. The vessels generally have a number of RADAR units including both X-ray and S-ray RADAR, the higher frequency S-ray is the primary fish detection tool. Fishing masters search for flocks of seabirds feeding on baitfish. Baitfish are generally accompanied by tuna swimming beneath them. The different patterns of movement displayed by flocks of birds can indicate what sort of tuna may be present. At close range (<1 km) a side scan sonar is used to estimate the size of the tuna school itself. Searching takes place at 12 - 14 knots. Several targets may be investigated before the net is shot.

On shooting, a powerful auxiliary vessel is deployed from the stern of the purser and steams around to form a circle of net around the school. It is suspended at the surface from buoys and weighted at the bottom by the purse rings and the heavy wire passing through them, known as the footrope. Powerful winches aboard the purser are then used to winch in the footrope which has the effect of closing the purse and trapping the tuna inside a large torus-shaped bag. The net itself is then gradually hauled aboard by a power block and immediately flaked onto the stern, ready for the next shoot. Once most of the net has been hauled the bag of fish is concentrated alongside the purser, and brailing commences. Brailing involves using a 'scoop-net' with a capacity of about 5 mt to transfer the fish from the net onto the vessel. A typical shoot will last ten to fifteen minutes. Hauling takes a minimum of 1.5 hours, possibly longer, depending on the quantity of fish caught. Typically purse-seine vessels cannot fish in wind and sea state greater than force 5 to 6.

Logbook returns show average catches by purse seine vessels of eight tons of skipjack and 36 tons of yellowfin up to the end of the 1993/94 season. There are two main targets of purse seine fishing: free-schoolingfish or fish asociated with logs or other floating objects. The former is the most common in BIOT waters. Fishing on logs is conducted by a few Mauritian registered purse seiners. Logs are identified, radio tagged and nets are shot around them every morning. This reduces search time and therefore costs. Artificial logs and other flotsam are sometimes used.

Longlines

A longline, as its name implies, consists of a main line, up to 100 km long with a large number of baited hooks attached by branch lines (snoods). Longline vessels target large tunas, which may exceed 90 kg in weight, as well as billfish such as marlin and swordfish. The main-line (with snoods) is shot from the stern of the vessel and forms a series of arcs suspended, every kilometre or so, from surface buoys. The lines are generally shot perpendicular to the current at vessel speeds of 10 to 12 knots. The shooting process takes about five hours. Shooting normally takes place between dawn and midday. Hauling generally commences immediately on completion of the shoot. A variety of buoys, light-buoys and larger floats are attached at regular intervals, in addition to which a number of radio transponder beacons are attached (typically five or six per set). The radio transponders transmit unique callsigns. They are located by the vessel using HF radio direction-finding equipment. Despite the large number of buoys deployed by longliners they are not considered to represent a significant danger to navigation; the buoys themselves are relatively small and the lines are typically tens of metres below the surface.

Species profiles

Skipjack tuna - *Katsuwonus pelamis*

Skipjack tuna is a cosmopolitan species, occurring in all tropical and warm temperate seas. It is a relatively small tuna. The maximum size observed for skipjack from all oceans is about 110 cm, corresponding to a weight of about 34 kg, however fish in the range of 80 cm or less and up to 10 kg are most common. Skipjack are thought to spawn first at about 45 cm or about 1 year old. They are opportunistic feeders and mature at an earlier age and have a higher natural mortality rate than either yellowfin or bigeye tuna.

A curious feature of skipjack tuna is their attraction to floating logs and flotsam. In order to enhance catches fishermen sometimes mark logs with radio beacons and return to them on a regular basis. Why tuna congregate round flotsam is not fully understood. Purse seine fishing fleets have come to depend more and more on log-associated schools. Since these schools consist principally of skipjack (70%), records show an increasingly high skipjack catch.

Current indications suggest that the skipjack stock in the Indian Ocean seems to be in a good condition. No limitations are currently placed on effort directed at this species. Skipjack tuna's resilience stems from its ability to spawn at small sizes, extended spawning area, rapid turnover and large population.

Skipjack are usually used by the canning industry, as they do not command as high a price as larger species.

Yellowfin tuna - *Thunnus albacares*

Yellowfin tuna are found in tropical and subtropical waters of the Indian, Pacific and Atlantic oceans. The yellowfin is a fast growing species. At around seven years of age a yellowfin may attain a maximum fork length of 170 cm and a corresponding weight of 70kg, but such specimens are not common. Of the two main commercial species taken by purse seine, the yellowfin is considered potentially to be more vulnerable. However, there is not considered to be excess pressure being placed on yellowfin populations by the purse seine or longline fisheries in the western Indian ocean.

Purse seine vessels harvest younger schooling yellowfin, which often congregate with skipjack schools. Purse seining provides fish largely for the canned market and the quality of fish is considered inferior to quality from longline vessels. This is partly because of the size of fish (smaller) and partly because of the damage caused to flesh during harvest. Mature yellowfin tuna are targeted by longline vessels and usually enter the more valuable fresh and frozen fish markets. These fish are individual swimmers, and are located in deeper waters than the schooling juveniles.

Bigeye tuna - *Thunnus obesus*

Bigeye tuna have a worldwide distribution throughout tropical and subtropical waters down to a depth of 250 m. Bigeye feed on a variety of fish, cephalopods and crustaceans, depending on availability. They grow to a maximum fork length approaching 285 cm, and weigh up to 450 kg. However, individuals of that size are now quite uncommon. Fish of 175 cm and about 115 kg are believed to be at least 8 years old. They are thought to mature after 4-5 years. Spawning is known to occur throughout the year in the tropical band from 15°N to 15°S.

Hsu (1993) estimated the maximum sustainable yield for bigeye tuna in the Indian Ocean to be 37,850 t, which, if accurate, suggests that the Indian Ocean bigeye stock is at, or close to, an optimal level of exploitation. There are, however, some questions over unrecorded longline catches. If these are substantial, then current harvests may be in excess of the maximum sustainable yield.

Catch History inside BIOT FCMZ

Longliners			
Year [1]	Number of Licensed Vessels	Total Vessel Months Licensed	Total Catch (metric tonnes)
91 [2]	8	14	[3]
92	10	14	[3]
93	24	32	332.565
94	37	50	147.927 [4]
Purse Seiners			
Year [1]	Number of Licensed Vessels	Total Vessel Months Licensed	Total Catch (metric tonnes)
91 [2]	3	12	932
92	3	36	451
93	44	106.5	31719
94	44	164	794 [4]

Notes :

[1]Fishing year runs from 1st April through to 31st March of the following year e.g. 92 runs from 01/04/92 to 31/03/93.

[2]Fishing year 1991 runs from the declaration of the zone in October 1991 through to 31st March 1992.

[3]No logbook or radio reports were submitted by the longline fleet for 91 or 92.

[4]Logbook returns for 94 are incomplete. Preliminary estimates based upon radio reports only show catch levels of 759 MT for the longline fleet and 2041 MT for the purse seine fleet.

This table shows that there has been substantial variability in annual catches, even when the changes in numbers of licensed vessels are taken into account. This is probably due to annual differences in the migration patterns of the tuna; in some years they occur in high concentrations inside the BIOT FCMZ, while in other years only a few fish are found in those waters.

8.3 Licensing

In 1991 the Commissioner for the British Indian Ocean Territory (BIOT) declared a 200 nm Fisheries Conservation and Management Zone around BIOT. As the above table indicates, in the first two years of operation of the FCMZ, only a modest number of longliners sought licences and not all of these exercised the right to fish in the FCMZ. Most longliners fished for just one month. Even fewer purse seiners were licensed and fished, though they remained within the FCMZ for a longer time. In 1993/94, however, the numbers of licences issued both to longliners and purse seiners increased dramatically, and these numbers were maintained into 1994/95.

When the FCMZ was first declared , a fixed licence fee per month was charged for longliners, while purse seiners paid a fee that varied with the size of the vessel (measured in GRT). These fees were fixed until the end of the 1993/94 season, when different formulas were used. Licence fees charged are shown in the following table.

Gear type	Fee (£ per calendar month)	Period
Longline	2700	1/10/91 to end of 1993/94 season
	3,684 if GRT < 400 4.17 GRT + 2,016 if 400 ≤ GRT≤ 600 4,500 if GRT > 600	1993/94 season to date
Purse seine	5.23 GRT + 5,500	1/10/91 to end of 1993/94 season
	11,990 if GRT < 300 7.4 GRT + 9,770 if 300 ≤ GRT < 2,058 25,000 if GRT > 2,058	1994/95 season to date

8.4 Surveillance and Enforcement

Shipborne surveillance has been carried out in the BIOT FCMZ since its declaration. Between November 1994 and February 1995, this was supplemented by a chartered fishery patrol vessel (FPV).

As noted above, very few vessels had been licensed to fish within the FCMZ during the first two years of its operation. However, there were two incidents during 1993 in which foreign fishing vessels were found operating illegally. One of these vessels, a Japanese longliner, incurred a near record penalty fine, including confiscation of the catch (see below). The effect of this incident was startling. Immediately after the apprehension and fine of the longliner, 44 purse seiners and 32 longline vessels applied for and were granted licences. This apparent change in the perceived risk associated with illegal fishing on the part of the fishermen plays a key part in the analyses described below.

The unlicensed Japanese longliner was detained on suspicion of illegal fishing within the FCMZ in November 1993. In the event the vessel owners pleaded guilty to the offence 'Not having their lines stowed in a manner to indicate they were not fishing'. The size of the penalty was significantly increased by confiscation of the catch on board and the fishing gear, which were valued in excess of £1 million.

The provision in the BIOT Fisheries (Conservation and Management) Ordinance which allows for prosecution of unlicensed vessels for having unstowed fishing gear (i.e. fishing gear which is not stowed in such a manner that it is not readily available for use for fishing) is particularly important for the surveillance and control of longline vessels. It is difficult to catch longliners in the act of fishing and collect sufficient evidence to prosecute for illegal fishing. These vessels can fish in virtually all weathers and it is relatively easy for them to cut and abandon a deployed fishing line at the approach of an FPV and attempt to evade capture. However, it may take longer for them to stow all fishing gear on board in the manner prescribed for vessels on innocent passage through the FCMZ. Providing a Fisheries Protection Officer can board the vessel and collect the necessary evidence it may then be possible to bring a prosecution under the heading of 'unstowed fishing gear'.

Purse seiners, however, are more vulnerable to detection with fishing gear deployed in the water. It takes several hours to set and retrieve the net, which itself is so valuable that abandoning it is not an option. Therefore if the FPV can detect and approach an unlicensed vessel during this vulnerable period it should be relatively easy to collect evidence of illegal fishing.

The fines specified in the BIOT Fisheries (Conservation and Management) Ordinance 1991 are as follows:

Offence	Penalty
Fishing without a licence	£300,000 fine
Failure to comply with the terms and conditions of licensing	£100,000 fine
Carrying on board fish not taken under the authority of and in accordance with a fishing licence	£200,000 fine
Failure to provide or provision of false information required for the application of a fishing licence	£15,000 fine
Failure to notify a Fisheries Protection Officer of fish on board prior to entering and/or leaving the Fishing Waters	£50,000 fine
Unstowed fishing gear	£100,000 fine
Transhipment without a licence	£50,000 fine
Failure to comply with the terms and conditions of a transhipment licence	£20,000 fine
Failure to provide information required for the application of a transhipment licence	£15,000 fine
Provision of false information for the application of a transhipment licence	£20,000 fine
Obstruction of a Fisheries Protection Officer when acting in the exercise of his powers under the Ordinance	£100,000 fine
Other offences for which no penalty is specified	£100,000 fine
Any offence	Forfeiture of fishing gear, instruments or appliances used in the committing of an offence, and any fish on board a fishing boat.
Any offence	Forfeiture of licence and fees paid for that licence. Barring from holding a licence for a period of 3 years
Minor offences admitted by the offender	Administrative penalty: monetary fine not exceeding one third of the maximum fine applicable.
Failure to pay a fine [for a period of 30 days after the date of the order of the court]	Detention of fishing boat [forfeiture of fishing boat]

8.5 Illegal Fishing

Illegal fishing in the inshore fishery is thought to have occurred within lagoons, but no arrests have been made.

There is believed to have been a substantial amount of illegal fishing in the offshore fishery in the first few years after declaration of the FCMZ, both by longliners and purse seiners, but this was not detected during surveillance operations. However, in 1993 two foreign fishing vessels, the Japanese longline vessel described above and a Taiwanese vessel were pursued, detained and fined for illegal activities in the BIOT FCMZ.

8.6 Application of Control of Foreign Fisheries methodology

Although not initially selected, the foreign fishery around BIOT presents a very instructive case study for the adaptive phase of this research. This is particularly so because the fisheries management regime for BIOT has been operating during the term of this adaptive project, and its design was based heavily on the results of the previous Control of Foreign Fisheries research project. Thus in a sense a study of the current success of the BIOT regime is one of the actual application of the methodology, rather than just its potential application.

For the BIOT zone, very little was known about the fish resources within the FCMZ or the extent of fishing activities by the various foreign fleets prior to setting up the management regime. There was previously no restriction on foreign fishing activities, and no reporting requirements. Thus BIOT represents an ideal case study of the setting up of a management regime in the presence of great uncertainty, both on the part of the managers and of the fishermen. The few years of operation of the regime have certainly seen major changes, as has been indicated earlier.

The most notable event that has occurred was the sudden increase in applications for licences following the very large fine levied on the Japanese longliner. It seems reasonable to put this down to a major shift in the perception of risk associated with illegal fishing on the part of the foreign fishermen. Probably, in the first few years the foreign fishermen, who had previously been free to fish in the area without fee, felt that the risk of being detected fishing illegally was negligible, and thus it was not worth paying for a licence. The imposition of the fine would have greatly changed that view, and it also turned out that the season following their application for licences *en masse* actually was a very good one in terms of catches and catch rates in the BIOT FCMZ. That happy coincidence might be expected to have reinforced the changed views on the relative values of fishing with or without a licence. The most recent year, however, has seen rather poor catches and catch rates inside the zone, arguably insufficient to justify the cost of the licence fee.

The analysis described below is aimed particularly at investigating the potential effects of different perceptions of risk and of highly variable marginal revenues from fishing within the zone. The effectiveness of the additional surveillance activities will also be examined.

As indicated earlier, two types of fishing methods are used in the BIOT FCMZ. Of these, longlining activities have tended to be concentrated in fairly restricted areas within the FCMZ, where catch rates are highest. This represents an ideal situation for targeted surveillance: only a part of the zone has to be patrolled. In contrast, areas fished by the European purse seine fleet tend to have been much more widely dispersed over the northern half of the zone, with no consistent areas of concentration. Surveillance for illegal fishing activities by purse seiners must therefore be conducted over a much wider area. We therefore have concentrated our analysis only on the purse seine fleet.

As a final caveat, it should be noted that throughout this analysis, only rounded numbers have been used. It part this is an acknowledgement of the degree of uncertainty in the numbers, but also some issues of confidentiality arise. For similar obvious reasons, less detail is given in the description of the analysis of surveillance than has been used in that analysis.

8.6.1 Estimates of purse seine fishery parameters

The following parameters have been estimated for the 1993/94 season from analyses of log book returns and information supplied by licensed purse seine vessels.

Fishing method:	Purse seine
Number of vessels:	40
Value of average hold contents	£250,000
Average catch value inside FCMZ during licensing period	£750,000
Average catch value outside FCMZ during licensing period	£450,000

These parameters immediately suggest that during 1993/94, there was a very substantial advantage to be gained from fishing within the BIOT FCMZ. The catch available from the BIOT FCMZ was on average worth $300,000 more than it would have been if fishing had only taken place outside the FCMZ. It is, however, most unlikely that this will always be the case. A thorough analysis of the comparative advantage requires catch rate data for simultaneous fishing activities both inside and outside the zone. This was not available prior to the 1993/94 season, because so few licences had been issued. More anecdotal evidence, however, indicates that the 1993/94 season was probably exceptional in terms of the comparative advantage of fishing in the FCMZ. Certainly, the 1994/95 season does not seem to have been anything like as successful.

There are two immediate implications. The first is that analyses based on the parameters above may in some sense represent a best case in terms of the attractiveness of licences and this needs to be borne in mind when interpreting the results. The second is that from the fishermen's point of view, the potential value of a licence is rather uncertain. On the one hand, it is clear that it is definitely worthwhile purchasing a licence in good years, and paying a relatively substantial fee, but in other years, when there are few concentrations of fish in the FCMZ, the expenditure of funds for a licence may be wasted.

8.6.2 Uncertainty and perceptions of risk

Prior to the declaration of the BIOT FCMZ, the decision by fishermen on whether to fish in what would become BIOT waters would have been a purely operational one, based on where the concentrations of tuna in the area were known or likely to be. It is highly likely that immediately after the declaration of the FCMZ, the fishermen saw little reason to depart from this policy in such a remote region.

As outlined in section 2 of this report, decisions such as these on the part of the fishermen will be based on a comparison of the expected benefit from purchasing a licence, which is just the expected catch less the licence fee, with the expected loss, which is either the value of the catch foregone by not fishing in the FCMZ, or the expected fine if fishing illegally within the FCMZ.

Different levels of uncertainty are associated with these various expectations. There is no uncertainty about the licence fee: it is a fixed and known cost. Furthermore, it is not directly related to catches taken within the FCMZ, rather it is based on the size of the vessel. Uncertainty is present in whether or not in the coming season it will be worthwhile to fish in the FCMZ. At the time that vessels are invited to apply for licences, it is unlikely that fishermen will have any real idea whether this is a year when concentrations will be inside the FCMZ. Fishermen will, however, be able from past experience of their fishing within the area to estimate the average historical advantage of being able to fish within the FCMZ. Note that, while the fishermen are likely to have access to this information, at the start at least this information will not be available to the fishery managers.

There is a second level of uncertainty, however, in which the lack of information lies with the fishermen, and not the managers. This is uncertainty about the real probability of detection, and to a lesser extent about the fines that might actually be levied. The product of these, of course, is the expected fine. If we assume that fishermen continued to follow their presumed historical operating patterns after the declaration of the FCMZ, it would follow that if the season was one in which most tuna were outside the FCMZ, they would only spend sufficient time in the FCMZ to prove that, after which they would fish legally outside the FCMZ. In this case, it seems reasonable that they might consider the likelihood of detection to be vanishingly small. Probably, only if the FCMZ season is a "good" one are they likely to fish inside the

FCMZ long enough for them to consider initially that they had any real chance of being detected. What evidence there is does not suggest that the 1991/92 and 1992/93 seasons were as good as the 1993/94 season.

These considerations suggest that it should perhaps not have been unexpected that few vessels took up licences in the first two seasons, with fishermen taking the view that the probability of detection was very low, and possibly also that any fine actually imposed would probably not be very high, despite the published fine levels.

To put this into perspective, on the declaration of the FCMZ the licence fee for a 2000 GRT purse seiner fishing for two months was roughly £32000. If they thought, mistakenly, that the maximum fine they would be likely to face was (say) £320,000, then the probability of detection would have to have been as high as 0.1 before, on expectations alone, it might be better to buy a licence. As they were probably risk prone in the early days of the FCMZ, the likely decision is even clearer. The decision becomes much less clear, however, if the maximum fine is considered to be of the order of £1,000,000. Note that the £32000 licence fee amounts to roughly 4% of the value of the catch taken inside the zone in that season.

The fining of the Japanese longliner, with a fine of over £1 million, would clearly have dramatically altered the perceptions of risk for the purse seiners, especially given the very high cost of their fishing gear, which would be forfeited as part of the overall penalties. Now, with certain knowledge of very high fines and an observation that illegal fishing can indeed be detected, it is not at all surprising that the risk may no longer be considered worthwhile. The positive reinforcement provided by the good 1993/94 FCMZ season no doubt also helped make the decision seem sensible.

8.6.3 Modelling the probability of detection

The basic model describing the probability of detection as a function of the level of surveillance activities is described in section 3.2. The actual probability of detection of a single vessel on a single day is closely related to the proportion that is effectively searched each day of the area within the FCMZ in which the vessel is likely to be fishing. The probability of detection in a season then depends on the number of days in the season the vessel spends fishing in the FCMZ and the number and length of surveillance trips. A key assumption is that the daily positions of fishing vessels is random.

Based on information supplied about the cruise tracks taken, the average speed and the detection width of the vessel, the proportion searched of the area in which purse seiners might be found was calculated and the corresponding detection probability for a four day cruise was estimated, taking into account that vessels typically spend approximately one month out of the two-month season fishing in the zone.

It is argued in section 8.4 that purse seiners are particularly vulnerable to arrest for illegal fishing when their fishing gear is deployed in the water, as it is too valuable to abandon. At other times, it may well be possible for them to either avoid the patrolling vessel or at worst face a much lower fine. To take account of this, the base probability of detection on a cruise was multiplied by a further factor representing the average proportion of time the gear would have been deployed during 1993/94 to derive the final probability of detection and arrest for an offence for which a large fine is payable.

In 1994/95, surveillance and observation activities were carried out from a chartered vessel in the BIOT FCMZ. This cruise lasted 60 days. It has been assumed in the calculations that the cost of surveillance was £5000 per day. Based on its planned cruising speed and effective detection width, this vessel was capable of searching some 17% of the normal purse seine fishing area within the FCMZ each day. If it searched for all 60 days, then the probability that an illegally fishing vessel would be detected at least once is essentially 1. If the cruise length is reduced to 30 days (close to the minimum viable) and account is taken of down time and other observer duties, that would leave around 20 days of effective time searching. Using this figure, and accounting for vessels being in the FCMZ only half the time and for the probability that a purse seiner has deployed its gear at the time of detection, the resulting probability of detection and arrest at least once, and the expected number of detections and arrests during a season, were estimated.

8.6.4 Optimal licensing policy

The BIOT scenario, with just (effectively) one fleet, represents a particularly simple application of the Control of Foreign Fisheries methodology.

Using the data for the 1993/94 fishing season, the average net benefit per vessel for fishing within the FCMZ was £300,000. In principle, the fishermen should have been prepared to pay up to this amount for a licence fee in 1993/94, provided this amount still is less than the expected fine. If we take the value of the purse seine fishing gear that would be forfeited on successful prosecution to be £1,000,000, then the maximum fine under the legislation for fishing without a licence would be £1.3 million plus the value of the catch, totalling £1.55 million. The expected fine resulting from normal surveillance and one 30 day chartered surveillance cruise exceeded the maximum possible licence fee, and greatly exceeded the maximum £50,000 payable for a two-month licence under the newly-raised fee schedule. For 1993/94 at least, higher licence fees would have been justifiable.

In practice, however, the 1993/94 season was probably much better than usual. The preliminary catch data for the 1994/95 season indicates that only just over 2000 t were taken by 44 licensed purse seiners. For a full two-month season, that equates to only around 50 t per vessel, so that the maximum licence fee in 1994/95 was roughly equivalent to the gross value of the catch. It remains to be seen what reaction the fishermen will have to this poor year following a good year. Without better historical information on past catch rates inside and outside the FCMZ, it is impossible to calculate better estimates of the optimal licence fee. What remains clear, however, is that it is essential that the perceived risk of detection when fishing illegally remains sufficiently high that fishing without a licence is not a viable option.

On the above calculations, the expected fine with a 30-day surveillance cruise and with normal surveillance is more than ten times the maximum licence fee, which should be more than sufficient for deterrence. Its cost is also relatively modest, representing around £3750 per licensed purse seiner; i.e. 7.5% of the licence fee. This modest proportion, however, relies on there being some 40 licensed vessels. Should this number drop substantially, then so will the per-vessel cost of the surveillance.

There being no apparent conservation problem for the tuna in the BIOT region, the presumed goal of the BIOT administration is to have as many vessels as possible take up BIOT fishing licences. To achieve that goal, it is necessary to set licence fees at a level such that fishermen will be prepared to buy them in both good and bad years, and to carry out surveillance at such a level that fishermen are deterred from the alternative of fishing without a licence. On the calculations performed, to be quite sure of deterrence it would appear that both normal and chartered surveillance are necessary.

9 South Georgia

9.1 Background

South Georgia, a Dependent Territory of the United Kingdom, lies approximately 800 nautical miles south-east of the Falkland Islands at 53 56'S, 34 45' W, in FAO Statistical Subarea 48.3. It represents the most important fishing region in the Atlantic Sector of the Southern Ocean. Approximately 80% of all catches in FAO Area 48 have been taken around South Georgia in Subarea 48.3. Reported catches from around the South Sandwich Islands in Subarea 48.4 have been negligible.

The Government of South Georgia and the South Sandwich Islands (SGSSI) has implemented a Fisheries Conservation and Management Regime around SGSSI following the declaration by the Commissioner of SGSSI of a Maritime Zone on May 7th, 1993. Legislation establishing the regime was enacted in July 1993. Since 2nd August 1993, all vessels wishing to fish within the 200 mile Maritime Zone must be licensed.

Management of the fisheries around South Georgia is conducted under the procedures and regulations laid down by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). CCAMLR, a component of the Antarctic Treaty system, oversees the management and conservation of living resources within the Southern Ocean. Vessels wishing to fish in the SGSSI Maritime zone must obey CCAMLR regulations and also seek licences from the South Georgia Government. Licence fees to fish within the SGSSI Maritime Zone reflect the costs of monitoring, surveillance, administration and analysis of data from the fishery.

Most South Georgia fisheries for finfish are heavily constrained by the need to conserve the fish stocks in the region. Consequently the issue of licenses is very heavily restricted. There are however a large number of fishing vessels with a desire to exploit the marine resources there. This bottleneck creates a strong incentive to fish illegally.

9.2 The Status of the South Georgia Fisheries

Earlier in this century, fishing in this region was entirely shore based, carried out by sealers, then later, further offshore by whalers. Early attempts to establish a shore based fishing industry failed and to date none has been established. In 1962, the first offshore fishing trials took place and large scale harvesting began around South Georgia in 1969/70. Distant water fishing fleets, initially from the former Soviet Union, GDR, Bulgaria, Poland and Japan, and later from Chile and Korea, have been the major operators in the region. Very heavy fishing pressure in the early 1970's resulted in the complete collapse of some stocks. The catch history since 1970 is shown in Figure 9.1.

Figure 9.1 Catches by species group in Subarea 48.3 since 1970

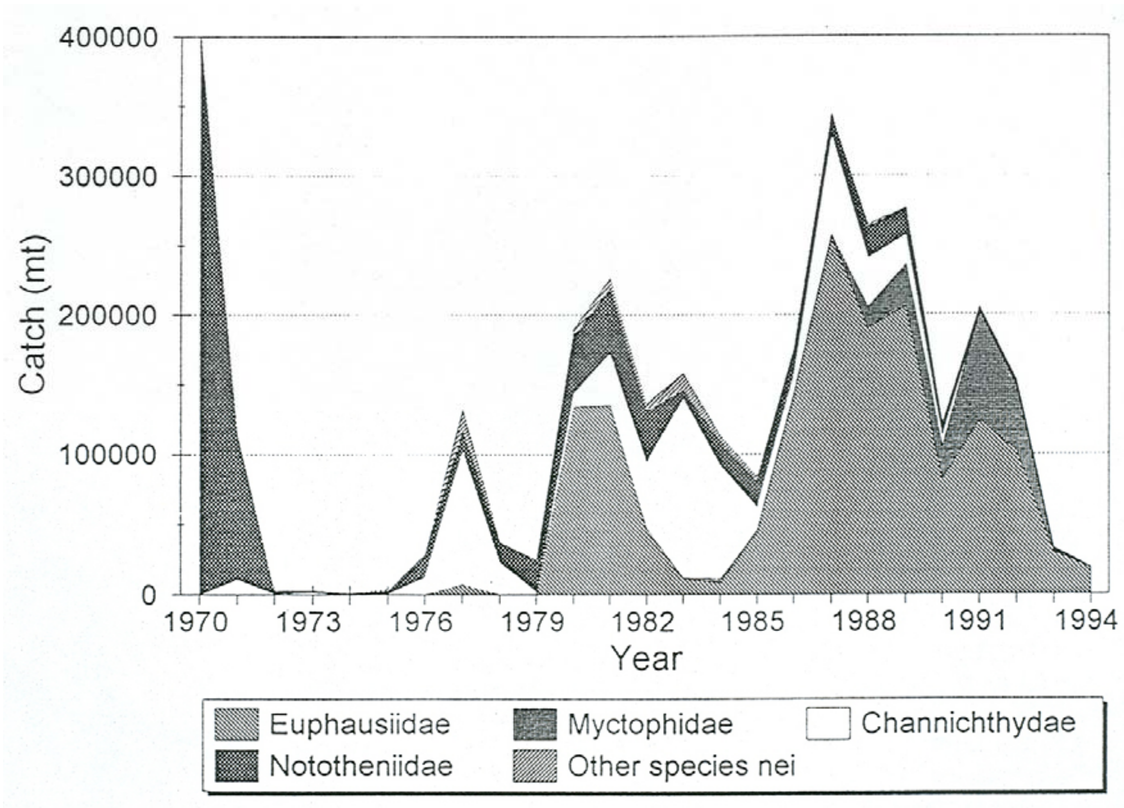

Figure 9.1 indicates that the fisheries around South Georgia have gone through a number of phases. Huge catches of Nototheniidae (almost all *N. rossii*) in 1970 were followed by the very sudden collapse of that fishery, and since then Nototheniidae have not made a substantial contribution to the catches. In the late 1970s, catches were dominated by Channicthydae, but then the krill fishery commenced in 1980, and with the exception of the years 1982-85, the bulk of the catches since 1980 have been krill. A new fishery for myctophids started in the late 1980s, but catches have recently fallen to zero with the departure of the fishing fleet of the forrmer Soviet Union. Catches of the larger finfish have declined dramatically since the late 1980s. Further details of fisheries for individual species is given below.

A number of conservation measures have been introduced by CCAMLR for different krill and fish stocks around South Georgia and the South Sandwich Islands. The following is a summary of the substance of Conservation Measures introduced by CCAMLR relating to Subarea 48.3 (South Georgia) up to the end of the Commission meeting in November 1994.

- 1984: Commercial fishing was prohibited within 12 miles of South Georgia (Conservation Measure 1/III, CCAMLR 1984). Mesh size regulations introduced with minimum mesh sizes set at 120mm for *N. rossii* and *D. eleginoides*, and 80mm for *G. gibberifrons*, *Lepidonotothen squamifrons* and *C. gunnari* to apply from 1/9/85 (Conservation measure 2/III, CCAMLR 1984).

- 1985: Ban on all directed fishing for *N. rossii* (Conservation measure 3/IV, CCAMLR 1985).

- 1986: Agreement to the principle of setting catch limits to regulate fishing around South Georgia (Conservation measure 7/V, CCAMLR 1986).

- 1987: TAC for *C. gunnari* in the 1987/88 season set at 35,000 tonnes for FAO Subarea 48.3 (Conservation measure 8/VI, CCAMLR 1987)). Establishment of a 10-day catch reporting system to allow predictive setting of a date for closure of the fishery in conjunction with the TAC (Conservation measure 9/VI, CCAMLR 1987). Prohibition of directed fishing for *C. gunnari* and associated by-catch species in Subarea 48.3 between 1/4/88 and 1/10/88 (Conservation measure 10/VI, CCAMLR 1987).

- 1988: Prohibition of directed fishing for *C. gunnari* and associated by-catch species in Subarea 48.3 between 4/11/88 and 20/11/89 (Conservation measure 10/VI, CCAMLR 1988a). This followed a total reported catch of 21,600 tonnes since the opening of the fishery on 1/10/88 (see above), which was in excess of the TAC for the season recommended by SC-CCAMLR (approximately 10,000 tonnes - CCAMLR 1988b)

- 1989: TAC for *C. gunnari* in the 1989/90 season set at 8,000 tonnes for Subarea 48.3; prohibition of the use of bottom trawls for targeting *C. gunnari* (Conservation measure 13/VIII, CCAMLR 1989)). Prohibition of directed fishing for *C. gunnari* and associated by-catch species in Subarea 48.3 between 20/11/89 and 15/1/90 and between 1/4/90 and 4/11/90 (Conservation measure 15/VIII, CCAMLR 1989). Establishment of a 5-day catch reporting system to allow predictive setting of a date for closure of the fishery in conjunction with the TAC (Conservation measure 17/VIII, CCAMLR 1989).

- 1990: Mesh size regulation for *C. gunnari* amended - minimum mesh size set at 90mm, to apply from 1/11/91 (Conservation measure 19/IX, CCAMLR 1990a). TAC for *C. gunnari* in the 1990/91 season set at 26,000 tonnes for FAO Subarea 48.3; in addition, the by-catch of *G. gibberifrons* not to exceed 500 tonnes and *L. squamifrons*, *Ch. aceratus* and *Ps. georgianus* not to exceed 300 tonnes each; ban on bottom trawling to continue (Conservation measure 20/IX, CCAMLR 1990a)). Prohibition of directed fishing for *C. gunnari* in Subarea 48.3 between 1/4/91 and 4/11/91 (Conservation Measure 21/IX, CCAMLR 1990a). Prohibition of directed fishing for *Patagonotothen brevicauda guntheri* in Subarea 48.3 for the 1990/91 season (Conservation Measure 23/IX, CCAMLR 1990). Continuation of the 5-day catch reporting system (Conservation measure 25/IX, CCAMLR 1990a). TAC for *Dissostichus eleginoides* in the 1990/91 season set at 2,500 tonnes for FAO Subarea 48.3 (Conservation measure 24/IX, CCAMLR 1990). Catch and effort data reporting system introduced (Conservation measure 25/IX, CCAMLR 1990). Effort and biological data reporting system for *D. eleginoides* introduced (Conservation measure 26/IX, CCAMLR 1990)

■ 1991: Measures to minimise the incidental mortality of seabirds during longlining operations introduced (Conservation measure 29/X, CCAMLR 1991). Banning of the use of net monitor cables from the 1994/95 season (Conservation measure 30/X, CCAMLR 1991). Precautionary catch limits on *Euphausia superba* introduced (Conservation measure 32/X, CCAMLR 1991). Closure of the fishery for *C. gunnari* for the 1991/92 season, defined as the period from 2/11/91 to the end of the Commission meeting in 1992 (Conservation measure 33/X, CCAMLR 1991a). Prohibition of a directed fishery for *G. gibberifrons*, *Ch. aceratus*, *Ps. georgianus*, *L. squamifrons* and *P. guntheri* for the 1991/92 season, defined as above (Conservation measure 34/X, CCAMLR 1991a). TAC for *Dissostichus eleginoides* in the 1991/92 season set at 3,500 tonnes for FAO Subarea 48.3 (Conservation measure 35/X, CCAMLR 1991). TAC for *Electrona carlsbergi* in the 1991/92 season set at 245,000 tonnes for FAO Subarea 48.3 (Conservation measure 38/X, CCAMLR 1991).

■ 1992: Allocation of precautionary catch limits for *E. superba* to subareas of Area 48 (Conservation measure 46/XI, CCAMLR 1992). Prohibition of the directed fishery for *G. gibberifrons*, *Ch. aceratus*, *Ps. georgianus*, *L. squamifrons* and *P. guntheri* in Subarea 48.3 for the 1992/93 and 1993/94 seasons (Conservation measure 48/XI, CCAMLR 1992). TAC for *C. gunnari* in the 1992/93 season set at 9,200 tonnes for FAO Subarea 48.3; ban on bottom trawling to continue. Prohibition of directed fishing for *C. gunnari* in Subarea 48.3 between 1/4/93 and the end of the Commission meeting in 1993 (Conservation Measure 49/XI, CCAMLR 1992a). 5-day catch reporting system applies for *C. gunnari* (Conservation measure 51/XI, CCAMLR 1992a). Monthly effort and biological data reporting system for trawl fisheries applies for *C. gunnari* (Conservation measure 52/XI, CCAMLR 1992a). The by-catch in Subarea 48.3 of *G. gibberifrons* not to exceed 1,470 tonnes, *Ch. aceratus* not to exceed 2,200 tonnes, and *L. squamifrons*, *N. rossii* and *Ps. georgianus* not to exceed 300 tonnes each (Conservation Measure 50/XI, CCAMLR 1992a). TAC for *Electrona carlsbergi* in the 1992/93 season set at 245,000 tonnes for FAO Subarea 48.3 (Conservation measure 53/XI, CCAMLR 1992). TAC for *Dissostichus eleginoides* in the 1992/93 season set at 3,350 tonnes for FAO Subarea 48.3 (Conservation measure 55/XI, CCAMLR 1992).

■ 1993: Revised measures to minimise the incidental mortality of seabirds during longlining operations introduced (Conservation measure 29/XII, CCAMLR 1993). Reduction in the use of packaging bands (Conservation measure 63/XII, CCAMLR 1993). TAC for *C. gunnari* in the 1993/94 season set at 9,200 tonnes for FAO Subarea 48.3; ban on bottom trawling to continue. Prohibition of directed fishing for *C. gunnari* in Subarea 48.3 until 1/1/94 and between 1/4/94 and the end of the Commission meeting in 1994 (Conservation Measure 66/XII, CCAMLR 1993). Precautionary TAC for *Electrona carlsbergi* in the 1993/94 season set at 200,000 tonnes for FAO Subarea 48.3 (Conservation measure 67/XII, CCAMLR 1993). The by-catch in Subarea 48.3 of *G. gibberifrons* not to exceed 1,470 tonnes, *Ch. aceratus* not to exceed 2,200 tonnes, and *L. squamifrons*, *N. rossii* and *Ps. georgianus* not to exceed 300 tonnes each (Conservation Measure 68/XII, CCAMLR 1993). TAC for *Dissostichus eleginoides* in the 1993/94 season set at 1,300 tonnes for FAO Subarea 48.3; season split into 5 equal time periods with no more than one vessel fishing at any one time; each vessel to carry a scientific observer; fishing plan for scientific purposes specified (Conservation measure 69/XII, CCAMLR 1993). TAC for *Paralomis spinossissima* in the 1993/94 season set at 1,600 tonnes for FAO Subarea 48.3 (Conservation measure 74/XII, CCAMLR 1993). Experimental harvest regime specified for *Paralomis spinossissima* for the 1993/94 to 1995/96 seasons in FAO Subarea 48.3 (Conservation measure 75/XII, CCAMLR 1993).

■ 1994: Revised measures to minimise the incidental mortality of seabirds during longlining operations introduced (Conservation measure 29/XIII, CCAMLR 1994). Prohibition of the directed fishery for *G. gibberifrons*, *Ch. aceratus*, *Ps. georgianus*, *L. squamifrons* and *P. guntheri* in Subarea 48.3 for the 1994/95 and 1995/96 seasons (Conservation measure 76/XIII, CCAMLR 1994). TAC for *Paralomis spinossissima* in the 1994/95 season set at 1,600 tonnes for FAO Subarea 48.3 (Conservation measure 79/XIII, CCAMLR 1994). TAC for *Dissostichus eleginoides* in the 1994/95 season set at 2,800 tonnes for FAO Subarea 48.3; each vessel to carry a scientific observer (Conservation measure 80/XIII, CCAMLR 1994). Precautionary TAC for *Electrona carlsbergi* in the 1994/95 season set at 200,000 tonnes for FAO Subarea 48.3 (Conservation measure 84/XIII, CCAMLR 1994). The by-catch in Subarea 48.3 of *G. gibberifrons* not to exceed 1,470 tonnes, *Ch. aceratus* not to exceed 2,200 tonnes, and *L. squamifrons*, *N. rossii* and *Ps. georgianus* not to exceed 300 tonnes each (Conservation Measure 85/XIII, CCAMLR 1994).

Prohibition of a directed fishery for *C. gunnari* in Subarea 48.3 for the 1994/95 season (Conservation Measure 86/XIII, CCAMLR 1994).

Finfish Fishery

Commercial exploitation of finfish began around South Georgia in 1970. Historically, the most important fishing nations have been the former USSR and Poland.

Nine species of finfish comprise the majority of commercially harvested finfish from Subarea 48.3; five have been target species, the other four by-catch species. Presently, only *Dissostichus eleginoides*, *Champsocephalus gunnari*, and *Electrona carlsbergi* are target species, all other species being either protected or regarded as a by-catch. Table 1 summarises the key information for the target and by-catch species caught within subarea 48.3.

Table 1 Key statistics for commercially harvested finfish in Subarea 48.3

Species	Code	Common Name	Catch Type	TL max (cm)	Depth (m)	Gear	Marketing	Peak Catch(t)	Mean Annual Catch 1970-1992
Notothenia rossii	NOR	Marbled Rockcod	Target (Protected)	90	0-500	Bottom trawl	Frozen, often caught for roe	399704	24395.3
Lepidonotothen squamifrons	NOS	Grey Rockcod	Bycatch	55	10-570	Bottom trawl	Frozen, fishmeal	2937	395.2
Patagonotothen guntheri	NOT	Patagonian Rockcod	Target (Protected)	23	140-320	Semi-pelagic trawl	Fishmeal	36758	7366.8
Electrona carlsbergi	ELC	Lanternfish	Target	10	50-1500	pelagic	fishmeal/oil	78488	8689.3
Champsocephalus gunnari,	ANI	Mackerel Icefish	Target	64	100-700	Semi-pelagic trawl	Frozen whole or fillets	128194	25215.5
Dissostichus eleginoides.	TOP	Patagonian Toothfish	Target	215	70-1500	Longline	Frozen fish, fishmeal	8311	1123.4
Gobionothen gibberifrons	NOG	Humped Rockcod	Bycatch	55	5-750	Bottom trawl	Frozen fish	11758	2493.8
Psuedochaenichthys georgianus,	SGI	S. Georgia Icefish	Bycatch	60	0-500	Bottom Trawl	Frozen whole or fillet	13015	942.5
Chaenocephalus aceratus	SSI	Blackfin Icefish	Bycatch	75	5-770	Bottom Trawl	Frozen whole or fillet	2066	357.4

TL = Total Length

Toothfish - *Dissostichus eleginoides.*

Catches of toothfish are on record from the late 1970's, but the species was possibly harvested by the Soviet Union a decade earlier. These catches were quite small, however. In 1985/86, Soviet vessels conducted an experimental longline fishery for the Patagonian toothfish and following that catches increased sharply. In 1986/87, the catch was 1199 t and in 1989/90 it rose to 8311 t. Since then, a deep water longline fishery targeting toothfish has developed rapidly in the area around South Georgia and on a bank to the west of Shag Rocks.

The toothfish is a large predatory fish, long-lived and slow growing, which grows to over 2 metres in length, and has been caught down to depths of more than 2500 metres. It has a high market value. Because the fishery around South Georgia is a new fishery for a species whose life history characteristics suggest it may be particularly vulnerable to exploitation, TACs set by CCAMLR have been rather cautious and substantial additional restrictions have been placed on the activities of vessels. At present, each fishing vessel must have a CCAMLR observer on board at all tims when fishing. A Conservation Measure regulating the deployment and recovery of longlines has also been agreed by CCAMLR in an attempt to reduce the incidental mortality of seabirds, particularly albatrosses, in this fishery. TACs for toothfish set by CCAMLR are given in the following table.

TAC's for toothfish in Subarea 48.3

Split year	TAC (tonnes)	Conservation Measure
1990/91	2500	Conservation measure 24/IX
1991/92	3500	Conservation measure 35/X
1992/93	3350	Conservation measure 55/XI
1993/94	1300	Conservation measure 69/XII
1994/95	2800	Conservation measure 80/XIII

The species is also exploited in Chile, Argentina and the Kerguelen Islands. Recently a toothfish fishery has developed within the Falklands Outer Conservation Zone (FOCZ). Whether these fisheries take toothfish from the same or different stocks as those taken around South Georgia is unknown.

Icefish - *Channichthyidae* and Rockcod - *Notothenidae*

The *Notothenia rossii* fishery collapsed in 1971/72, following landings in excess of 500,000 tonnes in the preceding two years. A CCAMLR Conservation Measure aimed at protecting this species has been in force since 1985. This prohibits directed fishing on *N. rossii* and aims to keep the bycatch as low as possible.

During the mid-1970's effort was redirected towards the icefish *C. gunnari*, which became the most important finfish resource on the South Georgia shelf. The catches of this species peaked in 1983 at 128,000 tonnes. However, catches of *C. gunnari* declined in the late 1980s and CCAMLR closed the fishery for the 1991/92 season. A TAC of 9,200 tonnes was set for the following two seasons, but directed fishing for this species has been banned since 1991/92 The use of bottom trawls to take *C. gunnari* has also been banned since 1989.

Lanternfish - *Myctophidae*

The lantern fish, *E. carlsbergi*, dominated total finfish catch in Subarea 48.3 between 1989 and 1992. This species was taken by trawlers operating pelagic gear of the same type as used for krill harvesting. This relatively recent fishery appears to have been undertaken by krill trawlers shifting their attention towards myctophids towards the end of the southern winter. Most of the catch was taken in the vicinity of the Antarctic Convergence, to the north west of Shag Rocks. A precautionary TAC of 245,00 tonnes, was set by CCAMLR in 1992, however there has been no reported commercial catch since that year.

Krill - *Euphausia superba*

Krill are small, shrimp-like crustacea, of which the most widely exploited species is *Euphausia superba*. Krill occur within a wide circumpolar belt between the Antarctic continent and the polar front, although the highest concentrations are found in the Bransfield Strait, Scotia Sea, and near South Georgia. Exploratory fishing for krill by the USSR began in 1961/62. The total catch from the Southern Ocean by countries including the former Soviet Union, Japan, Poland, Chile, Korea and Taiwan, has been approximately 500,000 tonnes annually since 1979/80.

Krill are caught mainly by stern trawlers using large mid-water pelagic trawls. Daily catches per vessel can reach 150 tonnes. Rapid autolysis (self dissolution of tissues) of the tail flesh demands prompt processing within 1-3 hours of catching. Krill is processed into a variety of products including frozen tails, paste and sticks for human consumption, and is also utilized as feed meal for animals, or bait for sports fishermen. The processing of krill is an expensive operation because of the need for the removal of the high fluoride levels present in the exoskeleton.

Total krill biomass has been estimated at between 125 and 750 million tonnes. The current estimate of krill biomass in the South Georgia region is 1.5 million tonnes, based on data from a near synoptic survey conducted in 1980/81 (FIBEX). The present total allowable catch for krill set by CCAMLR for the whole of Area 48 is 1.5 million tonnes. If the total catch of *E. superba* in Subareas 48.1, 48.2 and 48.3 in any fishing season exceeds 620,000 tonnes then precautionary catch limits to be agreed by CCAMLR will be applied.

Crab - *Paralomis*

Two species of crab of the genus *Paralomis* (Lithodid 'King' or 'Stone' crabs) are found around South Georgia: *Paralomis spinosissima* and *P. formosa*. These species share similar geographic distributions from the Scotia Sea north to the Atlantic continental shelf waters of South America. The former is found in depths of 100 to 800m, and the latter down to 1600m.

An exploratory voyage targeting these species was undertaken by a US vessel between July and November 1992. The total catch was approximately 300 tonnes, with an average catch of approximately 7kg per pot .

A CCAMLR Conservation Measure has been in force since 1992/93 limiting fishing effort to one vessel per CCAMLR member. A TAC of 1600 tonnes applies to Subarea 48.3. No fishing for crabs under this Conservation Measure has yet taken place. Fishing gear is limited to crab pots; use of all other methods of catching crab (e.g. bottom trawls) is prohibited. Minimum landing sizes (carapace width) for *P. spinosissima* and *P. formosa* are currently 102mm and 90mm respectively. Only male crabs can be taken.

9.3 Licensing within the SGSSI Maritime Zone

As a first step to obtaining a fishing licence for the SGSSI zone, the owner or charterer must complete a Fishing Vessel Registration Application Form in respect of the vessel concerned. The purpose of this exercise is to provide advance notice to the Director of Fisheries of the precise nature, characteristics and attributes of a fishing vessel. No fee is charged for this. A fishing licence application can then follow, for which a payment is required.

Four licences were granted in 1994 for the toothfish fishery. There were a substantially greater number of applicants. A condition of the toothfish licence in that year was that only one vessel is permitted to fish in the zone at a time. Furthermore each vessel was required to have a CCAMLR observer on board. This was because of the conservation concerns arising from stock assessments carried out by CCAMLR. The toothfish fishery is currently the mainstay of finfish fishing in the region.

9.4 Surveillance and enforcement

Management of the fisheries around South Georgia is conducted under the procedures and regulations laid down by CCAMLR. Annual quotas are set by CCAMLR and catches taken against these quotas are reported to CCAMLR under an agreed reporting scheme. Regular within-season reporting of catches allows the CCAMLR secretariat to give fishing nations good notice of the likely closing date of the season, which occurs as soon as the full quota has been taken.

CCAMLR has no platform or budget for conducting surveillance activities. Over recent years, however, a system of observation and inspection has been developed. Under this system, member nations nominate their own observers and inspectors, and make arrangements to transport them to this particularly remote area of the world. Very few inspections have been carried out to date and those that have been have led to concerns that conservation measures are not being adhered to.

In 1990, the South Georgia Government set up a regime to monitor transhipment activity at South Georgia. A marine officer stationed at South Georgia records all relevant information from these transhippments which, if within 12 miles of the South Georgia coast, had to be conducted in Cumberland East Bay. This was assisted by informal observations from the bi-weekly Royal Airforce supply plane. After the declaration of the Maritime Zone by the Government of SGSSI in 1993, all transhipments within 200 miles had to be conducted within Cumberland East Bay. In addition, all fishing activity within the Zone had to be licensed.

The new fisheries management regime included provision for surveillance by a Fisheries Patrol Vessel (FPV). The Government of SGSSI does not have a patrol vessel of its own, however there is a well established fisheries management regime within the Falkland Islands Outer Conservation Zone which has at least one, and from time to time two, ocean-going FPV's at its disposal. Sub-charter arrangements have been made with the Falklands regime for the provision of an FPV vessel for short surveillance voyages to South Georgia.

The main threat of illegal fishing was considered to come from the longline fishery for toothfish. The TAC's set by CCAMLR over recent years have been low due to considerable uncertainty in the status of the stock(s) being exploited by this new fishery. This severely limited the number of licences which could be issued by the Governmnet of SGSSI and a large number of applications therefore had to be turned down. The opportunities for unlicensed vessels to fish elsewhere were limited and the incentive to poach was high.

Two surveillance voyages were made in January and February 1994. During these trips three longline vessels were inspected, two of which were subsequently prosecuted and fined for illegal activities inside the Zone. Since then there have been a number of other trips and one further prosecution of a longliner has resulted.

9.5 Illegal fishing

As mentioned above, the main threat of illegal fishing was considered to come from the longline fishery. Other fisheries for finfish, including the rockcod and icefish, have not generated much commercial interest in recent years. The rockcod fishery has been closed by CCAMLR since 1985 and potential catch rates indicated by bottom trawl surveys are still very low. The status of the icefish fishery is extremely uncertain at present. Recent trawl surveys have indicated that the stock biomass fluctuates considerably even in the absence of commercial fishing, possibly in response to food availability (krill) and predation pressure (fur seals). Catches in the past were mainly taken by the former Soviet Union. Since the collapse of the eastern bloc distant water fishing capability no new commercial interest has been generated.

The threat of illegal fishing from the krill fishery is considered to be minimal. There is no immediate conservation threat from the krill fishery, at least as far as the krill themselves are concerned, and therefore no effective limit on the number of licences. The cost of a krill licence is low, reflecting the relatively low value of the product, and in fact the degree of commercial interest has fallen considerably since the break up of the Soviet Union. The incentive to poach in this fishery is therefore low.

Two vessels were caught fishing illegally for toothfish in early 1994, the *Antonio Lorenzo*, a Chilean longliner, and the *Mirgorod*, a vessel from the Russian Federation converted for the purpose of longlining. The *Antonio Lorenzo* was not actually fishing at the time of inspection but the presence of baited hooks and a general state of readiness of fishing gear indicated an imminent intention to do so. Fresh toothfish remains were found in the factory area of the ship and there were various indications that recent movements and activities of the vessel had been fabricated. This vessel was fined £50, 000 plus costs of approximately £23,000.

The *Mirgorod* was licensed to fish for toothfish but was found fishing inside the Zone prior to the start of the licence period. She had illegally harvested 20.7 tonnes of toothfish in about one week's fishing. Her captain pleaded guilty to fishing without a licence and the vessel owners were fined a total of £84,000.

A third vessel, the *Ihn Sung 66*, was inspected in the Maritime Zone in December 1994. Although she was not fishing at the time of the inspection, her Captain later pleaded guilty to illegal fishing after one of her longlines was found deployed in the vicinity. The owners were fined £90,000.

Other unlicensed fishing vessels have been found in the Maritime Zone from time to time, but no additional prosecutions have resulted. Given the geographical location of South Georgia, however, the frequently quoted excuse, that vessels are on 'innocent passage' through the Zone, is difficult to accept.

9.6 Application of Control of Foreign Fisheries methodology

For the fisheries around South Georgia, those that have produced the largest catches in recent years, i.e. krill and myctophids, there seems little likelihood that any illegal fishing will take place in the near future. For both of these fisheries, catches remain well below the precautionary TACs set by CCAMLR, and licences are available at modest cost to all who wish them. Directed fishing on a number of the finfish species around South Georgia is banned, and the proximity of the fishing grounds to South Georgia suggests that again there is little likelihood of illegal fishing. However, the toothfish fishery is highly lucrative, and there is a high demand for a small number of available licences.

The special feature of the toothfish fishery that makes it ideal as a case study for the Control of Foreign Fisheries project is that as well as being highly lucrative, it is subject to a major conservation constraint, both on catches and on the number of vessels allowed to fish. This feature makes it unique amongst the other case study areas. In all other cases, any foreign fishing vessel that applied for a licence was granted one, provided it was prepared to pay the licence fee. Foreign fishermen would therefore fish illegally only if they considered the cost of a licence fee exceeded the expected penalties they would incur for fishing without a licence. For the South Georgia toothfish fishery, however, only very few licences can be granted (e.g. 4 in 1993/94). Many more vessels applied for licences, and for the unsuccessful applicants the only way they can fish in the preferred areas is to fish illegally. This places a much greater premium on surveillance and enforcement than in the other cases.

The fact that three vessels have already been successfully prosecuted for illegal activities demonstrates firstly to the fishery managers that there is some illegal fishing, and secondly to the fishermen that there is some risk of detection that can lead to a fine. That said, however, the level of fine imposed is rather low in comparison with the likely value of catches taken within the Zone. When that is matched with what is clearly a relatively low risk of detection and subsequent prosecution, it seems likely that the expected fine for fishing illegally may not provide a great disincentive. The analysis described below is aimed at determining the extent to which that is true, and what different levels of surveillance activity and/or fines may be necessary to provide a better deterrent.

9.6.1 Estimates of longline fishery parameters

The following parameters have been estimated from analyses of data obtained from CCAMLR and submitted to the Government of SGSSI by licensed toothfish longline fishermen.

Fishing method:	Longline
Number of vessels fishing before restrictions on licences :	15
Number of licensed vessels in 1994/95 :	4
Value of average hold contents	£600,000
Average catch value inside zone during licensing period	£900,000
Average catch value outside zone during licensing period	£600,000

These parameters emphasise the attractiveness of fishing within the SGSSI Maritime zone. The catch available from the zone was on average worth £300,000 more than it would have been if fishing had only taken place outside the zone. This advantage should be an incentive to the licensed vessels to pay a reasonably substantial sum as a licence fee. More importantly, however, it acts as a very strong incentive for illegal fishing for those vessels unable to obtain a licence.

9.6.2 Modelling the probability of detection

The basic model describing the probability of detection as a function of the level of surveillance activities is described in section 3.2. The actual probability of detection of a single vessel on a single day is closely related to the proportion that is effectively searched each day of the area within the Maritime zone in which the vessel is likely to be fishing. The probability of detection in a season then depends on the number of days in the season the vessel spends fishing in the Zone and the number and length of surveillance trips. A key assumption is that the daily positions of fishing vessels is random.

Unlike the purse seine fishery around BIOT, the principal toothfish fishing areas occupy only a small part of the Maritime Zone. The highest catch rates are made when fishing along the 1000 m depth contour.

Furthermore, as the depth contours are very close in that region, the distance from the 1000 m depth contour within which one would expect to find longliners is quite small. For effective surveillance activities, it suffices to steam along the 1000 m depth contour with the knowledge that a high proportion of vessels fishing for toothfish should be detected by the radar. The length of the 1000 m contour fished for toothfish has been estimated at approximately 1000 nm.

Surveillance activities are presently carried out by a vessel based in Port Stanley on the Falkland Islands. A typical surveillance cruise takes some 7 days, of which approximately three days are spent within the toothfish grounds. For the purposes of these calculations, it has been assumed that he cost of the surveillance cruise is around £5000 per day and thus £35,000 per cruise. The present strategy is to undertake a surveillance cruise when information has been received that illegal fishing is taking place. For the analysis here, we shall assume no specific targeting.

Based on the average speed and the detection width of the vessel, it was estimated that most, but not all of the 1000 m contour is searched in three days. When account is taken of the estimated proportion of time spent fishing each month, this allows the calculation of a detection probability for each three-day cruise.

9.6.3 Optimal surveillance policy

Unlike the other case studies, in which the objective was to determine a joint licensing and surveillance policy that maximized net income to the coastal state, the key problem in the SGSSI toothfish fishery is to devise a surveillance policy that deters illegal fishing and thereby ensure conservation of the stock. The small number of licences available to be issued is controlled by TAC set by CCAMLR. This requires a somewhat different type of analysis to the other case studies.

The ideal surveillance policy would be one in which the extent of surveillance and the resulting expected fine are sufficiently high that unlicensed fishermen are completely deterred from fishing illegally. Following the principles outlined in section 2 of this report, this will occur if the expected fine for illegal fishing exceeds the expected benefit from illegal fishing. Using the parameters in section 9.6.1, that implies that the expected fine should exceed £300,000. In principle, this can be achieved by a suitable combination of high fines on conviction for illegal fishing activities and a sufficiently high detection probability. The difficulty is that this must be achieved at no net cost to the Government of SGSSI. In fact, for the ideal policy it has to be achieved at a cost not exceeding the net licence revenue (after other research and management costs have been subtracted). Potential fine income should not be counted, since under the ideal policy there will be no unlicensed fishing and thus no vessels to arrest or fines to be levied.

In the most recent season, licences were issued to four vessels on the basis of sealed bids, so the actual licence fees are not available. For the analysis here, we will assume that the licence fee paid was £10,000 per vessel month, a modest increase on licence fees for earlier seasons. It is immediately apparent that this assumed licence fee is much less than the estimated value to the fishermen of fishing within the Maritime Zone. Arguably, the fishermen could afford to pay considerably more for a licence. However, partly militating against this is the fact that the licensed vessels face additional expenses in meeting the cost of having a CCAMLR observer on board, and other CCAMLR Conservation Measures constraining the fishing practices used by licensed vessels may also be viewed by these vessels as an additional cost. These additional costs do not affect the licence revenue received by the Government of SGSSI, which for a two-month season will amount to £80,000.

Ignoring other costs, the licence revenue is sufficient to fund just two surveillance cruises. Using the parameters estimated in section 9.6.2, this implies that the expected fine faced by a vessel fishing illegally is of the order of three quarters of the likely fine faced on conviction. Based on past experience (see section 9.5), under current policy this seems unlikely to exceed £100,000 even when conviction for fishing without a licence is secured. Thus the expected fine faced by the fishermen is much less than the estimated value of fishing within the Zone, and thus it will not act as a sufficient deterrent to illegal fishing.

The number of licences has been fixed at 4. If no increase can be achieved in the licence fees per vessel from our assumed value, then the licence income is also fixed, and thus so is the maximum number of surveillance cruises that can be undertaken. It follows that the only way in which a greater level of deterrence can be achieved is by increasing the level of fines paid on conviction. To ensure deterrence from illegal fishing, the expected fine must exceed £300,000. This requires that the actual fine for illegal fishing at this level of surveillance should be at least £400,000.

It was suggested earlier that the licence fees are considerably less than the estimated value of fishing within the Zone. If these could be increased, then more surveillance could be undertaken, increasing the probability of detection and thereby reducing the amount by which fines would need to be increased. For example, if the licence fee for a two-month season were increased to £50,000, then the larger licence income would be sufficient to fund up to 5 surveillance cruises. If five cruises were undertaken (covering a substantial proportion of the season), this would increase the probability of a vessel being detected at least once nearly to 1, and the fine needed just to balance the estimated value of fishing within the zone to less than £200,000.

In both cases, the fines required just to balance the estimated value of fishing exceed the fines that have actually been levied on fishermen convicted of illegal fishing. In practice, given the risk proneness of typical fishermen, to provide an effective deterrent it would be necessary for the expected fine to exceed by some good margin the value of fishing within the Zone. This can only be achieved if the levels of fines are increased substantially.

The above analysis has been aimed at modelling and affecting the decisions made by an individual fisherman contemplating illegal fishing. At least in the short term, while illegal fishing activities continue, from the point of view of the Government of SGSSI surveillance cruises are likely also to raise revenue from fines paid by arrested and convicted fishermen. These, of course, can partly or fully defray the costs of the surveillance cruise. On any one cruise, the estimated probability of detecting a single illegal fishing vessel is sufficiently high for the expected fine based even on a £100,000 maximum fine to exceed the cost of a cruise. Balancing this, however, is the not insignificant probability that the vessel will not be detected, and therefore no fine revenue collected.

If more than one vessel fishes illegally, then the corresponding probability of failing to detect any unlicensed fishermen decreases quite quickly. It seems likely, therefore, that in the short term some more surveillance cruises than can be fully funded by licence revenue could reasonably safely be undertaken. The safety factor could be increased if intelligence had been received immediately prior to the cruise that illegal fishing was taking place. It must be realised, however, that the more the surveillance is successful, the smaller should be the number of vessels fishing illegally and thus the less certain it will be that fines will result from individual cruises.

In the BIOT case study, specific account was taken of the fact that only for a proportion of the time was it likely for a surveillance vessel to gather evidence of illegal fishing activities that would warrant payment of the maximum fine. Successful convictions for illegal fishing have been achieved at South Georgia, so clearly it is possible to gather suitable evidence. However, it is by no means certain that every detection of an unlicensed vessel will result in suitable evidence of illegal fishing. Given the past successful prosecutions, it is probable that unlicensed fishermen will be somewhat more wary of potential patrol vessels, so the above analysis might exaggerate the real probability of detection and conviction. Clearly the detailed tactics of surveillance after initial detection of a vessel will be very important to the resulting chance of conviction. That topic, however, is beyond the scope of this project.

10 Conclusions of Adaptive Research

The scenario envisaged in the Control of Foreign Fisheries research project was of a developing coastal state whose 200 mile EEZ contains a stock or stocks of fish that foreign fishing fleets wish to exploit. The coastal state wishes to manage the fishery through the licensing the foreign fleets in such a way that the net revenue accruing to it is maximized.

In the Control of Foreign Fisheries research project, a theoretical framework was set up in which the decisions of the fishermen on whether or not to fish in the EEZ, and whether or not to purchase licences were modelled, as were the options for the coastal state on the level of licence fees to set and the amount of surveillance that should be undertaken to deter unlicensed fishing. Using this framework, optimal policies for the coastal state were determined and a number of general principles were derived. The objective of the current adaptive project was to investigate the extent that the methodology and results obtained can be used in practice by developing countries. This was to be achieved through detailed analysis of a number of case studies.

Potential case studies selected at the start of the project were the tuna fisheries in Seychelles waters, the tuna fisheries in the South Pacific, the hake fisheries off Namibia and the sports fishery in British Virgin Islands waters. Subsequently, two more case studies with special features were added: the tuna fishery in the recently declared Fishery Conservation Management Zone around the British Indian Ocean Territory (BIOT), and the toothfish fishery in the Maritime Zone around South Georgia and the South Sandwich Islands (SGSSI).

As detailed in the preceding sections, the research methodology was successfully applied in three of these case studies (Seychelles, BIOT and SGSSI), and practical advice on current policies on licensing, surveillance and penalties was developed. For the South Pacific, the complexity of the fisheries and of the management issues in the area implied that substantial additional research was necessary in order to estimate parameters necessary to apply the methodology. A research plan to accomplish this was developed collaboratively with staff of the Forum Fisheries Agency, but there was insufficient funding available to carry this out as part of the current project. The other two potential case studies, in Namibia and the British Virgin Islands, were not carried through to completion. This is because the Namibian Government has pursued a policy of maximizing local fishery development and minimizing foreign fishing, thus making it not a suitable case study, while in the case of the British Virgin Islands it was not possible to make suitable arrangements.

The principal conclusion from these case studies is that it is indeed possible to apply the methodology and results developed in the Control of Foreign Fisheries research project to develop practical advice on management of foreign fishing. In order to apply the methodology, it is necessary first to undertake two types of analyses. In the first of these, catch and effort data pertaining to fishing both inside and outside the coastal state's EEZ must be analysed in order to determine the estimated benefits to foreign fishermen of fishing within the EEZ. In the second, estimates need to be made of the probabilities of detection and successful arrest of unlicensed fishing vessels arising from different levels of surveillance activities.

For both types of analysis, it is necessary to tailor the analysis to match the particular fisheries and surveillance characteristics of the region or country. For the BIOT and SGSSI case studies, this was relatively simple because only a single fishery, fishing fleet and state was involved. For the Seychelles, the situation was rather more complicated, with a number of fleets taking different species at different times of the year, and thus the analyses and interpretation of the catch and effort data were rather more complex. For the South Pacific, the situation was so complex, with multiple fisheries, fleets and states, that it was only possible within the time and funds available to detail the research and analyses that needed to be done before applying the methodology. The South Pacific is clearly a special case, but it remains true that the data analyses necessary to apply the methodology can be quite time consuming and complex.

Several points arose from the case studies that are of particular interest and they warrant highlighting. The first of these is that each of the case studies emphasised the importance of imposing large fines for illegal fishing activities. This was also a primary conclusion of the original Control of Foreign Fisheries research project. In each case study, the funds available to the coastal state to pay for surveillance activities were very limited. If there is a significant benefit associated with fishing inside the EEZ, then it is reasonable for the coastal state to want to set quite high licence fees. This is only possible, however, provided the expected fine faced by the fishermen for unlicensed fishing considerably exceeds the licence fee. If the amount of surveillance that can be afforded is limited, this can only be ensured by imposing very high fines, as is the case with the BIOT regime.

The importance of affordable surveillance is very clear in the SGSSI case study, where deterrence of illegal fishing is the primary management issue. Again, the key to achieving this is large fines. An interesting additional point that arose in that case study was that, in the long term at least, revenue that potentially accrues from penalising illegal fishing should not be treated as a positive benefit. At least in principle, it may appear that more revenue might possibly be made from fines for illegal fishing than from licence revenue. However, the basis for allowing only a small number of licences for that fishery was that to allow more may endanger the long term conservation of the stock. It follows therefore that the management aim should be to strongly deter any unlicensed fishing. Only if this is successful (thus generating no revenue from penalties) will there be a sustainable fishery in the future from which revenue from any source can be generated.

The BIOT case study particularly emphasised the vital difference between the perceived and actual risks of detection when fishing illegally. For the first three seasons after the Zone was declared, exactly the same levels of surveillance activities were maintained. For the first two of these seasons, there were few licence applications from foreign fishing vessels. However, following the near record fine imposed on one vessel for illegal fishing activities, there was a sudden rush on the part of the foreign fleets to obtain licences. Clearly this arose because their perceived risk of being detected and fined had risen to a sufficient level that the expected fine now exceeded the cost of obtaining a licence, though the actual risk had not changed at all.

While this single arrest had a major effect on fishermen in BIOT waters, it is important that any heightened perception of risk is maintained. For this to occur, it is necessary that fishermen remain aware of continuing surveillance activities. In BIOT, this is being achieved by the cruises being undertaken by an additional fisheries patrol vessel. In other cases, a degree of targeting (and thus an increased chance of detection) can be incorporated into surveillance missions by making use of reports from other sources that illegal fishing activities are occurring.

In the earlier Control of Foreign Fisheries research project, it was found that licence fees should be calculated as a proportion of the marginal benefit arising from fishing inside the EEZ, rather than as a proportion of the catch taken within the zone. This is because the value to the fisherman of obtaining a licence arises from the difference between the catches that can be taken inside and those taken outside, rather than just the amount of catch taken in the zone. A feature of several of the case studies, particularly in the Seychelles and BIOT, was that when these benefits were estimated from the available data, there was strong inter-annual variability in the estimated benefits. In calculating appropriate levels of licence fees, average estimated benefits were used in the main, but this still meant that in some years the cost of a licence might considerably exceed the actual benefit gained. Should this occur several years in a row, foreign fishermen may become increasingly reluctant to continue to seek licences. A case therefore can be made that licence fees perhaps should include some element that takes account of the effort expended in the zone.

11 References and Acknowledgements

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