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MANAGEMENT OPTIONS FOR THE DEEPWATER BOTTOMFISH FISHERY IN THE KINGDOM OF TONGA

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1.0 EXECUTIVE SUMMARY

This is a report on the Management options for the deepwater bottomfish fishery in the Kingdom of Tonga. The report describes the fishery, presents possible strategies for fishery development and management, and outlines specific management measures. At the request of the Tongan Fisheries Department this report does not recommend particular management plans. Rather a range of options to develop and manage the fishery are presented and evaluated.

Deepwater snappers, emperors, and groupers have been caught commercially using lines and baited hooks in depths of about 200m in the Kingdom of Tonga since 1980. Research suggests that the resource is fragile, involving slow-growing species with long life spans and limited habitats. At present, the level of profitability of the fishery is low, and the fleet of 28ft vessels is declining.

Alternative management objectives include maximizing participation in the fishery, maximizing sustainable yield, or maximizing economic yield from the fishery. Additional objectives, such as the improvement of fish quality, fleet safety and efficiency, may be added to any of the three broad objectives.

Although maximizing participation and employment may be an appropriate goal in an artisanal fishery which provides food and employment for a local community, this is not necessarily true in a commercial fishery in which most of the catch is exported. In this case, maximizing efficiency (and thereby net profits in the form of foreign exchange to the country as a whole) may be a more appropriate objective.

Assuming that "larger" vessels are 20% more efficient than standard 28ft vessels, the numbers of vessels required to take the maximum sustainable yield (MSY) for different numbers of annual fishing trips are:

- 44 vessels (28ft) completing 30 fishing trips per year;
- 33 vessels (28ft) completing 40 fishing trips per year;
- 21 "larger" vessels completing 50 fishing trips per year.

The number of vessels required to take the maximum economic yield (MEY) from the fishery is approximately one half that required to take the maximum sustainable yield (given above).

Of the management regulations discussed, some are clearly inappropriate (e.g. legal minimum lengths), and others are impractical due to high enforcement costs (e.g. closed areas). Output controls on catches (quotas) also present difficulties in enforcement. Of all the options discussed, the licensing of vessels fishing for export species (possibly in conjunction with some vessel and gear restrictions) allows the government some control in preventing biological and economic overfishing at the lowest level of enforcement difficulty and cost.

2.0 INTRODUCTION

The fishery for deepwater snappers, groupers, and emperors in Tonga began in 1980, and later a comprehensive data-collection program was started in 1986. The fishery was initially developed with the aim of relieving fishing pressure on the inshore reefs and to increase the supply of fish to the domestic market. In more recent years, the development of export markets for the more valuable species has changed the nature of the fishery. The commercial fishery is now Tonga's largest and the catch is exported to Hawaii, Japan, and New Zealand. More bottomfish reach the Hawaiian market from Tonga than from most other South Pacific island nations, including Fiji.

Considering the new status of the deepwater bottomfish fishery, it is appropriate to revise the original objectives and management plan. The overall objectives of fisheries development in the Kingdom of Tonga, as stated in the 5-year (1990-1995) Fisheries Development Plan, are to:

> "Create an environment conducive to the development of private sector involvement in fisheries; encourage commercial production of quality fish and marine products for both domestic consumption and exportation; encourage alternative fishing habits to prevent overexploitation of traditional fishing grounds; encourage technology transfers to increase the productivity and profitability of fishing activities; encourage the development of market outlets, both locally and overseas, for fish and other marine products; improve the existing marketing systems; improve fish handling techniques and encourage fish processing under quality control measures; develop aquaculture; develop the Fisheries Department's scientific and technical services to support the development of the sector."

To conform with guidelines for the preparation of fishery management plans contained in the Tongan Fisheries Act 1989 (Part II), this report on the management of the deepwater bottom fishery is organized under the following topics:

- a description of the current status of the fishery, including levels of exploitation, and trends in development of the fishing fleet;
- a presentation of possible objectives for the development and management of the fishery;
- an outline and evaluation of the development and management measures which may be applied to the fishery in order to achieve the objectives.

The authors of this report were asked specifically by the Tongan Fisheries Department not to recommend particular options, therefore objectives and management measures are presented in the form of options and evaluations for discussion. The selection of the management objectives and appropriate regulations is a Tongan Government policy decision.

3.0 CURRENT STATUS OF THE BOTTOMFISH FISHERY

3.1 Fishing areas

Deepwater snappers, groupers, and emperors are caught on both shallow water coastal shelves and banks, and offshore seamounts (Figure 1). However, most of the fish species targeted for export are found on the offshore seamounts, at depths exceeding 200m. Most of the catch from the shallower banks comprise species suitable only for the domestic market. These can be regarded as two separate fisheries, although there is a certain degree of overlap. Using the length of the 200m isobath as an index of fishable habitat, Langi and Langi (1988) estimated the length of this isobath as 294 nautical miles for all seamounts and 930 nautical miles for all fishable habitats, including the different seamounts and islands of the Tongan archipelago.

Another separation occurs between the fishery centered around the main island Tongatapu (mainly the seamounts south of Tongatapu) and those of the outer islands (mainly Vava'u and Ha'apai). Tongatapu is the center of the export fishery, since the main fish buyers operate from there and Fua'amotu airport has direct air services to Honolulu and Auckland. Difficulties of transport from the outer islands to the main center and lower prices paid for export species because of transport costs, are among the contributing factors to the lower catches of the outer islands, whose fishers tend to target species for the domestic market. Table 1 shows a general lower catch rate in Vava'u than in Tongatapu, although these results must be viewed with caution as only a small number of vessels were sampled in Vava'u over the period.

Table 1: Annual average catch rate (number of fish per trip) in Vava'u and Nuku'alofa, 1987-1991 (data from Fisheries Department, Tonga).

SPECIES	1987	1988	1989	1990	1991
VAVA'U					
Pristipomoides filamentosus	3	40	19	16	20
Etelis coruscans	14	18	23	33	54
All bottomfish species	55	168	119	92	97
TONGATAPU					
Pristipomoides filamentosus	34	32	42	19	19
Etelis coruscans	24	34	44	83	69
All bottomfish species	132	184	195	182	134

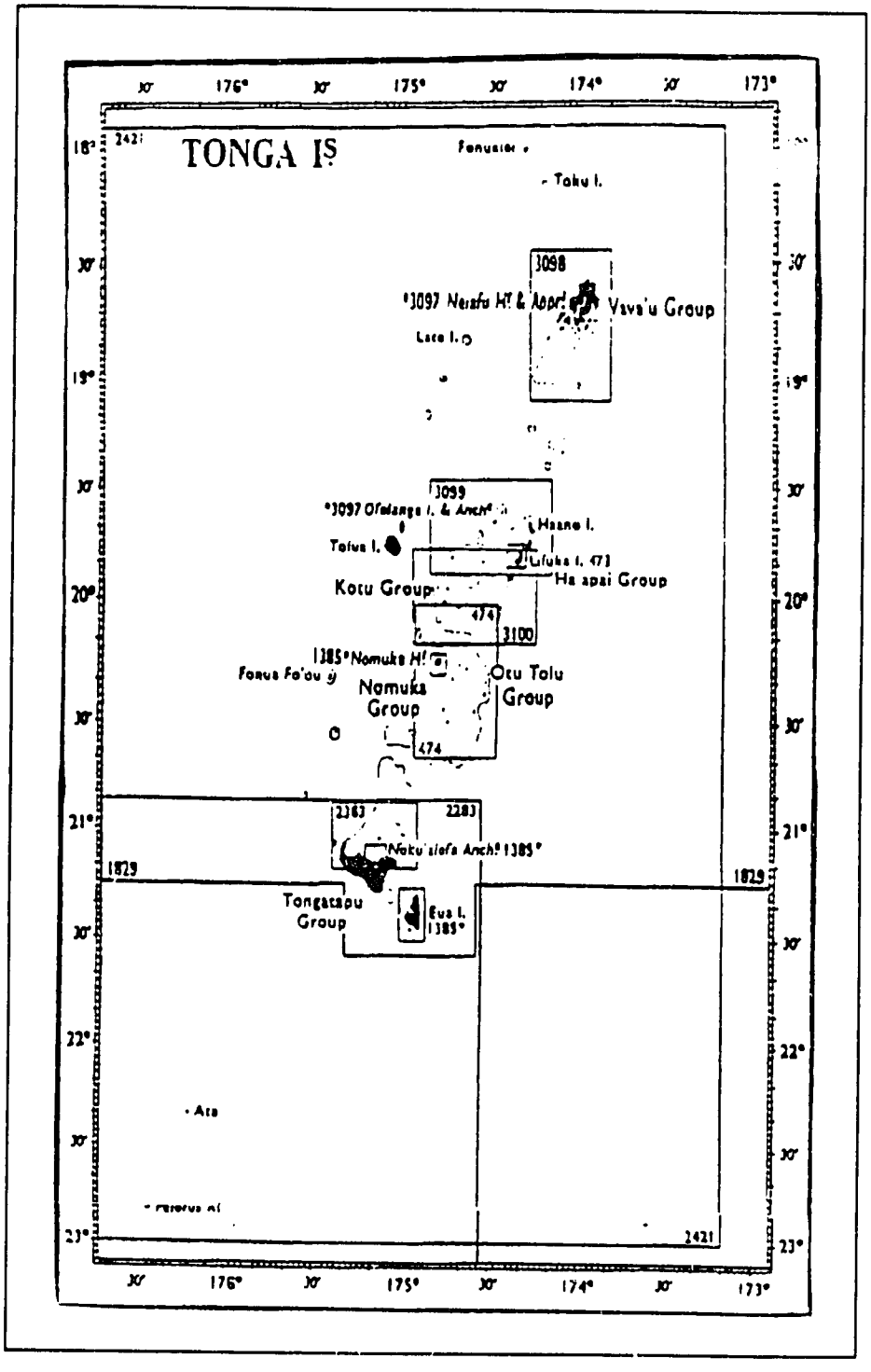

Figure 1: Fishing grounds for deepwater snappers in Tonga.

3.2 The Fleet

The FAO/UNCDF boat-building scheme aimed to provide a fleet of 40 vessels designed for bottomfishing, with the intention of relieving fishing pressure from inshore reefs. The earlier vessels built were 20 feet in length, equipped with two Samoan handreels, and fished the banks close to the main islands. Later, 28ft vessels, equipped with four handreels, were built. These ranged further offshore. Forty fishing vessels were completed by 1988 and, with a number of privately-built vessels, the total fleet size was 44 vessels. By this time, the export market for the more valuable species was well established and vessels often traveled far beyond their intended range. Some vessels traveled distances of 200 nautical miles offshore to seamounts south of Ata in search of the high-priced fish. Fishing depths commonly reached 400m, and sometimes 600m.

Safety on board the vessels has been a low priority. Vessels carried radios with only a 25km range, and often neglected to carry the sails designed to be used for backup propulsion. Lack of attention to safety and the low maintenance of engines and gear, led to vessels becoming unseaworthy. According to Fisheries Department records, six boats were lost at sea, one was destroyed by fire and six were repossessed. By late 1992, the fleet was estimated to have declined to 19 boats. In Vava'u, many of the remaining vessels are reluctant to venture far offshore because of the likelihood of breakdown (mainly engine failure).

In Tongatapu (at the beginning of 1994), there were five 28ft vessels currently fishing for export fish, together with four 32-42ft vessels, two of which were equipped with electric reels. Further introduction of larger vessels is planned.

The Vava'u fleet consists of six 28ft, one 20ft and one 40ft vessels, which mainly fish for bottomfish and sell to the Friendly Islands Marketing Cooperative (FIMCO). The price paid for the fish is lower than in Nuku'alofa, due to generally poorer quality and costs of transport to Nuku'alofa. There is thus less motive to fish intensively, so many of the vessels fish only part-time. Another important function of the Vava'u vessels is to transport passengers and produce from the smaller islands of the Vava'u group to the main center, Neiafu. For three months during 1992 all vessels abandoned the fishery in order to harvest beche de mer, due to the rapid development of a market for beche de mer, with prices of T$ 12.00 per kilo, dried. This beche de mer fishery came to an abrupt end when a minimum size regulation was imposed by the Fisheries Department. Most of the Vava'u vessels are in a poor state of maintenance and generally unseaworthy.

The Ha'apai fleet consists of three Nomuka boats, two of which fish as part of the Nuku'alofa fleet, and one which mainly collects fish from Ha'apai fishers and transports it to Nuku'alofa. Another 32ft vessel from Tungua is presently tied up at the wharf in Nuku'alofa. The other 28ft vessel is from Fonoi. No data have been collected from Ha'apai, as there is no central landing site. The fishery may be considered more as a supplier of fish for local rather than overseas markets.

At the beginning of 1994 it was estimated that only 20 vessels were actively engaged in the bottomfish fishery.

3.3 Fish exporters

Alatini Fisheries Co. Ltd owns one 28ft and one 38ft vessel and manages 6 similar boats which sell their fish to the company. The company plans to purchase another larger vessel in the near future. Fish are exported to Hawaii, Japan and New Zealand. The by-catch of mixed fish (30% of total catch) is sold on the local market. In mid-1993 the six fishing vessels managed by Alatini Fisheries were taken over by FIMCO.

Maritime Products Tonga Ltd (TOMAP) has been operating as a fish exporting company since 1985. The company has recently purchased two larger vessels which use electric reels in addition to its 35ft vessel, and its 28ft vessel. A new 35ft vessel, built locally, is planned to join the company. Hawaii and Japan are the current markets targeted.

FIMCO is primarily an exporter of agricultural produce and handicrafts, but also exports smaller volumes of bottomfish to Hawaii (previously through Alatini Fisheries). By mid-1993, FIMCO began paying higher prices to fishers and exporting directly to the Hawaiian market. The six vessels previously managed by Alatini Fisheries now sell to FIMCO.

Eniasi Fatongia began operations in 1989 and by 1992 was exporting about 200-300 kg per week, mostly from Vava'u. This operation ceased business in mid-1993.

The Government of Tonga's Fisheries Department also exported bottomfish caught by its vessels to the Hawaiian market until mid-1993.

Although the exact figure is not known, the total volume of bottomfish exported overseas is estimated to be around 150 tons per year.

3.4 Fish quality and markets

There have been several reviews concerning the quality of bottomfish exported from Tonga to overseas markets (Elsy, 1984; Crossland, 1985; Roberts, 1991; Bartram, 1993). All of these recommended that a system of quality control be initiated in order to achieve the highest possible returns on the overseas markets. These reviews also discussed major problems to be overcome, including the following:

- poor handling of the fish at sea;
- lack of adequate ice carried on board vessels;
- poorly designed ice boxes;
- frequent breakdown of onshore ice-making machinery.

There is a need for improvement in quality, particularly with respect to fish landed in the outer islands where transport to Nuku'alofa has to be arranged. A shipment of poor-quality fish not only fetches a very low price, thereby representing a waste of a valuable resource but, more importantly, gives Tongan seafood exports a bad reputation in the overseas markets. A recent shipment of poor-quality fish exported to Hawaii fetched only 50-60 cents per pound as compared to US$ 3.85, the average price obtained by the more reliable exporters. No system of quality control exists except that imposed by the local fish buyers.

At present, the best price paid to fishers is T$ 4.50 for high-value export species, T$ 3.50 for the same species under 2 kg, and T$ 3.00 for locally sold mixed species.

Currently there is no value-added processing, such as fish smoking, drying and filleting on export fish, although fish fillets are produced for the local market. Roberts (1991) recommended that value-added processing be investigated.

3.5 Level of exploitation

Available data are consistent with a resource which is fragile and easily susceptible to overfishing. The species are slow-growing and long-lived; initial catches of large-sized, older fish are replaced by those of younger, smaller fish. Many seamounts are very small and they support limited populations which are easily depleted.

The total annual catch of all bottomfish throughout the Kingdom of Tonga is estimated to have reached a maximum of 514 tons in 1987, and it subsequently declined to less than 200 tons in 1992 (Table 2).

The most recent analysis of the data (King, 1992; Latu and Tulua, 1992) using surplus yield models (Appendix A) suggests that the maximum sustainable yield for the five main export species *(Etelis coruscans, Etelis carbunculus, Pristipomoides filamentosus, Epinephelus morrhua* and *Epinephelus septemfasciatus)* is approximately 350 tons per year, and the MSY for the two major export species *(Etelis coruscans* and *Pristipomoides filamentosus)* is estimated at 210 tons per year. Both MSYs were exceeded in 1987. With the subsequent decline in effort due to fleet attrition, catches have been below the MSY since that year. The number of vessels in the fleet had declined to 19 by the end of 1992, however, the recent addition of larger vessels with greater fishing power could result in increased catches of the most valuable species during 1994.

The difference in efficiency or fishing power (if any) between the standard 28ft vessel and the newly introduced larger vessels is not known (see Section 7.0 on Monitoring the Fishery). To a large extent, any difference in efficiency will depend on the gear restrictions applied (e.g. on the number and type of reels). A faster steaming time to the fishing grounds is likely to mean that more trips may be completed in a year. If it is assumed that "larger" vessels are 20% more efficient than standard 28ft vessels, the numbers of vessels required to take MSY, for different numbers of annual fishing trips are:

- 44 vessels (28ft) completing 30 fishing trips per year;
- 33 vessels (28ft) completing 40 fishing trips per year;
- 21 "larger" vessels completing 50 fishing trips per year.

The number of vessels required to take the maximum economic yield from the fishery is approximately one half of the vessel numbers given above (see 3.6 - Fishery Economics).

Table 2: Annual catch (tons) of component species and fishing effort in the Tongan deep-slope fishery between 1986 and 1992.

SPECIES	1986*	1987	1988	1989	1990	1991	1992*
Pristipomoides filamentosus	0.09	137.34	91.95	85.24	20.29	36.48	41.50
Prisitpomoides flavipinnis	21.38	24.00	22.53	15.44	3.33	5.33	------
Etelis coruscans	18.08	82.13	71.17	110.75	115.81	104.35	17.89
Etelis carbunculus	6.68	44.92	16.05	11.29	10.04	15.80	15.43
Epinephelus morrhua	21.71	17.04	10.47	8.76	1.98	3.25	6.54
Epinephelus septemfasciatus	57.62	110.09	26.72	37.51	31.22	45.65	1.73
Lethrinus chrysostomus	0.04	32.88	65.01	34.49	9.58	16.30	-------
Other species	24.96	65.63	147.64	99.78	21.91	29.43	32.25
Total landings	210.57	514.04	451.55	403.26	214.16	256.58	115.34
Effort (trips)	214	1409	1091	885	491	608	569
Effort (reel hours)	15764	103562	80189	65048	36089	44688	41821
CPUE (kg/trip)	983	365	414	457	436	422	202
CPUE (KG/reel hour)	13.30	4.96	5.63	6.20	5.93	5.74	2.76
% of catch sampled	55	24	55	41	45	40	88
Fleet size	32(?)	37	44	36	30	27	19

*data for years 1986 and 1992 are based on short sampling periods.

3.6 Fishery economics

Financial analyses (King, 1992; in press; Latu and Tulua, 1992; Fakalolo, 1992) suggest that profit levels in the fishery have been low and that a typical 28ft vessel operates either very close to, or below, the break-even point to where income from fish sales balances costs (Appendix B). Fishing vessels complete an average of 30 trips of approximately five days duration per year, and an average of 3.5 reels is used for three days fishing in each five-day trip.

If an improvement in efficiency reduces fishing costs, and an increase in fish quality increases revenue, the point of MEY will be displaced towards the MSY. In these cases, a larger number of vessels would be required to obtain the MEY.

3.7 Summary of main points

- The MSY is estimated to be approximately 350 tons per year for the five export species (210 tons per year for the two main species).

- Although MSY was exceeded at the peak of the fishery, current catches are below this level which is mainly due to loss of vessels from the fishery. This situation is likely to change with the addition of newer and larger vessels to the fleet.

- The original fleet of 28ft vessels is becoming obsolete, but larger vessels are entering the fishery.

- Levels of fishing effort required to take the maximum sustainable yield (MSY) and the maximum economic yield (MEY) are:

LEVELS OF EFFORT	28 ft vessels (30 trips)	28 ft vessels (40 trips)	"larger" vessels (50 trips)
MSY	44	33	21*
MEY	22	n/a	n/a

*assuming that "larger" vessels are 20% more efficient than the standard 28ft vessel

- The fishery overall is unprofitable, although profits are still achieved by the most successful vessels in Nuku'alofa. The efficiency and profitability of the newer larger vessels entering the fishery are unknown.

4.0 MANAGEMENT OBJECTIVES

The original objective of developing the deepwater bottomfish fishery in Tonga was to divert fishing pressure from the inshore reefs. This has been achieved to the extent that an alternative fishery has been developed, although fishing pressure on inshore areas remains excessive. The deepwater bottomfish fishery has become Tonga's largest commercial fishery. Therefore, considering the new status of this fishery, it is appropriate to review and revise the original objectives and management plans.

Historically, the main objective of fisheries management has been the conservation of fish stocks. In modern fisheries management this limited aim is extended to address additional economic, social and environmental objectives such as fishers' welfare, economic efficiency, the allocation of resources, and environmental protection. The broad objectives of fisheries management may, therefore, include the conservation of fisheries resources and their environment, the maximization of economic returns from the fishery, and payment of fees to the community from profits made by the exploitation of a public resource. Underlining all these objectives is the need to ensure that fisheries are exploited in an ecologically sustainable manner.

Three possible broad and alternative objectives are those of maximizing either participation, sustainable yield, or economic yield from the fishery. These are presented briefly below. Additional objectives, which may be added to any of the three broad objectives, are also discussed.

4.1 Maximizing participation

Management controls are either not imposed at all, or minimum controls are designed and imposed to restrict gear (e.g. minimum boat sizes, and basic hand-operated reels). New vessels are free to enter the fishery. With these minimal restrictions, the fleet would be large but relatively inefficient.

Advantages:

- Management and enforcement costs are either zero or low.
- Participation and employment in the fishery (at least in the short term) will be maximized.

Disadvantages:

- Profitability will remain low or negative and the fishery may have to be subsidized (e.g by providing subsidized fuel, or subsidized boat replacements).
- If fish prices and profitability do improve, new entrants to the fishery will cause overexploitation of the resource and falling catch rates.

4.2 Maximizing sustainable yield

Maximize the total catch weight from the fishery by allowing increases in the number and size and efficiency of vessels.

Advantages:

- Financial returns (gross profits) to the country from export sales will be maximized.

Disadvantages:

- Management and enforcement costs will be incurred.
- At the point of maximum sustainable yield, financial returns (net profits) from the fishery will be low or negative.

4.3 Maximizing economic yield

Maximize the net profit to the country from the fishery. Encourage a fleet of small, but highly-efficient, vessels.

Advantages:

- Financial returns (net profits) from the fishery will be maximized.
- At the point of maximum economic yield, the fishery will not be biologically overexploited.

Disadvantages:

- Management and enforcement costs will be incurred.
- Participation in the fishery will be relatively low.

4.4 Conservation of the resource

Emphasize measures to ensure conservation of the resources to prevent both biological and economical overfishing.

Advantages:

- Allow the fishery to be monitored and management guidelines set according to the research results.
- Enable the fishery authority to monitor the fishery and put in measures that would prevent over-utilization of the resource.
- Institute training program for local fishery scientist.

Disadvantages:

- The cost of research and monitoring incurred, which would likely be beyond the financial capabilities of Government.

4.5 Additional objectives

4.5.1 Local control of the fishery

A local fishing vessel refers to any vessel owned by a Tongan subject or permanent resident, or owned by a company in which at least 51% of the voting shares are owned by Tongan subjects as defined by the Fisheries Act, 1989. Under this Act, the Government also has the right to enter into fisheries access agreements with foreign nationals.

An alternative to total local control of the fishery is to allow foreign fishing vessels to take fish up to an estimated maximum sustainable yield from offshore fishing areas (distant seamounts) which are inaccessible to the Tongan fleet. Based on vessel type, or class, or landings, license fees accrue to the government and people of Tonga.

The disadvantages of this approach are many. They include the loss of employment opportunities for local fishers, as well as the burden of placing observers on board the foreign vessels to ensure that the total allowable catch is not exceeded. Foreign vessels landing catches in Tonga would also compete with local fishers for limited air cargo space.

4.5.2 Quality control

The improvement of post-harvest catch handling and quality control to maximize the value of the catch may form part of the overall objectives. Whichever alternative is chosen, it is in the interests of the fish exporters to maintain high standards of quality. Exports from well-established fish exporting companies are likely to be of high quality; however, some controls and guidelines are necessary, especially for new exporters entering the industry.

A full quality-control system would involve the government inspection of all fish intended for export. Approval to export would be given only for fish reaching a defined minimum standard of quality. The requirement for inspection before exportation may place a largely unnecessary burden on fish exporters, and may delay the air shipment of a highly perishable product.

An alternative to inspection of all exports would be the random inspection of fish being landed and processed for export. This would allow the close monitoring of new entrants to the fish-exporting sector.

An important consideration in the quality control program will be to meet, for fish exported to the United States, HACCP guidelines. HACCP (Hazard Analysis Critical Control Point) represents a major shift in the way seafood is inspected. It will apply to any processor that exports fisheries products to the United States. HACCP will probably be implemented by early 1996.

4.5.3 Increase fleet efficiency

The increasing use of larger vessels with more modern fishing gear, combined with the attrition of the original fleet, is a new development in the bottomfish fishery and is likely to contribute to increased efficiency. Increasing fleet efficiency is particularly relevant if the main objective is to maximize economic returns from the fishery. The use of larger vessels is desirable on safety grounds considering the great distances to offshore fishing areas. On the other hand, limiting the size and power of fishing vessels potentially allows a finite resource to be shared by a greater number of fishers (see Section 5.0 - Option F).

The change in fleet structure also has important social implications. The original fleet of 28ft vessels is now aging and, due to the general low profitability of the fishery, very few fishers will be in a position to replace their boats. Those that remain in the fishery will face increasing maintenance costs and increasing competition from the newer larger vessels entering the fishery. The 28ft vessels are likely to compete poorly with the larger vessels because of their limited ice-carrying capacity and shorter ranges. Larger vessels are more able to carry the quantities of ice required to produce higher quality fish.

Current boat owners may eventually either drop out of the fishery, become crew members on larger vessels, or enter into partnerships with other fishers to purchase a larger vessel. The first of these alternatives will cause the loss of accumulated experience gained in the fishery. Mechanisms to allow present fishers to remain in the fishery could be investigated. This could take the form of financial management advice and, for those who demonstrate the required management skills, access to Development Bank loans.

5.0 REGULATORY OPTIONS

Three of the above alternative objectives (4.2, 4.3 and 4.4) require the imposition of controls or regulations on the fishery in order to achieve the respective objective.

5.1 Enforcement of regulations

Fisheries management strategies usually require one or more regulations which, to be effective, must be enforced. The first and most important aspect of enforcement is education, whereas prosecution should be regarded as a measure of last resort. Users of a resource should be made familiar with any regulations and the reason for their imposition. Public meetings, leaflets, press articles, and poster displays may be used to publicize regulations, and to provide fishers with an appreciation of the need for regulations. If the majority of users support the aims of the regulations, peer pressure becomes a strong deterrent to those disregarding the law.

Although prosecution should be regarded as a measure of last resort, necessary regulations must be rigorously enforced. Regulations which are imposed but unenforced, either due to insufficient enforcement staff or to overly complex and impractical rules, will fall into disrepute. If regulations are unenforced, benefits will accrue to those who ignore the regulations at the expense of those who fish according to the rules. Penalties applied should be significant to the offender and relevant to the offense.

The freedom to catch fish without control is now, more than ever, likely to be at the expense of someone else's freedom to do the same thing. Therefore, some of these freedoms must be sacrificed to allow the continuing use of the resource by present and future generations. The renewability of fisheries resources depends on accepting controls which not only protect fish stocks, but ensure that the environment in which they live does not deteriorate.

Implementing fisheries regulations will lead to costs involved in enforcement and surveillance. In Tonga these costs may be large due to the great distances involved. In the worst case, the cost of policing a regulation could be greater than the benefits gained. The lack of a strong infrastructure and budget to enforce fisheries regulations in Tonga suggests that any controls placed on the fishery should be direct and relatively easy to enforce.

5.2 Fisheries regulations

Fisheries regulations are imposed on a fishery to support a strategy designed to achieve predefined objectives. Regulations are used either to reduce or contain effective fishing effort *(input controls)*, or to restrict the total catch *(output controls)* to predefined limits. Some regulations are designed to protect particular parts of the stock. Juvenile or undersized fish can be protected by regulations such as minimum mesh sizes, legal minimum lengths and closures. The breeding stock can be protected by closed seasons.

A range of regulatory options is presented and evaluated below. The authors of this report have been asked specifically not to recommend particular options, because the selection of both a management objective and appropriate regulations is a Government policy decision. The options discussed below are not mutually exclusive and allow that a combination of regulatory measures may be applied to the fishery.

Option A: Legal minimum lengths

Making it illegal to retain fish smaller than a prescribed minimum size may have application in certain fisheries where the catch is not harmed by the fishing method. Fish that are too small are returned to the sea. In Tongan waters, minimum length regulations are currently applied, or recommended, for several different marine species, including lobsters and beche de mer. This type of regulation is not suitable for deepwater species, as the survival of fish returned to the sea after being hauled to the surface from deep water is likely to be low.

Option B: Closed seasons

Fishing can be banned during particular seasons (temporal closures). If the period of recruitment (the addition of young fish) is short and well-defined, a closed season at the time of recruitment can allow juvenile fish to grow to a more marketable size and, depending on natural mortality rates, the total catch may be increased. Closed seasons during the spawning period can allow adults to breed without interference. Seasonal closures are applied presently to mullet in Tonga.

There is no evidence that seasonal closures would be of any benefit to the bottom fishery, as the recruitment periods and spawning seasons of the species are extended and ill-defined. In addition, juvenile fish may be recruited to seamounts from other distant areas. Economically, the problems with seasonal closures are that fishing (and particularly fish marketing) is interrupted and boats sit idle in the absence of any alternative fishing activity.

Option C: Closed areas

Fishing can be banned in particular areas (spatial closures) to protect spawning stocks. The deepwater species involved appear to spawn on all seamounts; therefore, it is not known whether any particular area is more important than others in providing larvae and new recruits to the fishery as a whole. Additionally, closed areas are particularly expensive to enforce, and require the use of large patrol vessels.

Option D: Rotational closures (periodic harvesting or pulse fishing)

Different fishing grounds (seamounts) may be periodically closed and opened to fishing on a rotational basis. Potentially this allows fishing areas time to recover from intense fishing and may result in an increased reproductive output. Unlike total seasonal closures, rotational closures allow a continuous supply of product to processors. Rotational closures are, however, likely to complicate and therefore increase the costs of policing the regulation.

The efficacy of this measure, which has been recommended for the bottom fishery by Latu and Tulua (1991) depends on the time required for local seamount stocks to recover from heavy fishing. Because of the slow growth rates of the species, the recovery time is likely to be long and individual areas would have to be closed for many years to be of benefit. Seamounts close to Tongatapu, which have not been fished for five years because they were thought to have been depleted, are currently producing high catch rates (W. Holden, pers. comm.). If this observation is a true reflection of recovery time, then a rotation scheme allowing each seamount a five-year rest period may be required.

Rotational closures are expensive to police and require the use of a sea-going patrol vessel. Alternatively, if all fishers recognize the value of the measure, voluntary agreements to avoid closed areas may be attempted.

Option E: Limiting the efficiency and types of fishing gear

In many fisheries regulations include restrictions on size of nets and the number of hooks used. At present in Tonga restrictions are applied or recommended for gillnets, seine nets, cast nets, and fish fences (permanent maze traps). In the case of the deepwater bottomfish fishery, regulations could ban the use of more than four reels, and also ban the use of electric reels.

From an economic point of view, gear regulations lead to economic inefficiency since they raise the cost of catching fish. These regulations may be appropriate in the case of artisanal inshore Pacific fisheries where the resource provides employment or food for a large number of fishers. In this context, employment and food gathering may be chosen in favor of efficiency. The deepwater bottomfish fishery, however, is strictly a commercial export operation and there is a good economic case for allowing fishers to become as efficient as possible, in order to compete with the marketing of similar species from other Pacific countries.

Option F: Limiting the length and engine power of vessels

Limiting the size and power of fishing vessels potentially allows a finite resource to be shared by a greater number of fishers.

Alternatively, efficiency would be increased by allowing larger vessels with newer technology to replace the 28ft vessels as they leave the fishery. Also, the use of larger vessels may be justified on the grounds of safety at sea and the large distances to many fishing grounds. However, as larger vessels have the potential to carry more than the usual four fishing reels, and to work more days at sea (in rougher weather), effective fishing effort may increase to the extent that the resource becomes over-exploited. This could be counteracted by imposing gear restrictions (see Option E).

The addition of larger, more efficient vessels into the fleet may accelerate the rate of loss of 28ft vessels, especially those competing on the same fishing grounds. A possible measure to reduce this effect would be to restrict the larger vessels to fishing in areas which are remote and difficult for smaller vessels to reach; this measure is

presently being contemplated in Western Samoa, but would be difficult to enforce in Tonga.

Option G: Limiting vessel numbers

License limitation, as opposed to an open access system, has been introduced in fisheries in many parts of the world. A limited number of vessels, or vessel owners, are given licenses to fish. The number of licenses issued is set at a level at which it is believed capable of regulating the fishing effort required to take some predetermined total allowable catch (TAC).

A catch quota system could be applied only to the valuable export species *(Etelis coruscans, Etelis carbunculus, Pristipomoides filamentosus, Epinephelus morrhua* and *Epinephelus septemfasciatus)* and would not exclude artisanal fishers from catching these species for their own consumption, or from catching and selling a wide range of related, shallower-water species.

In most restricted-access fisheries, licenses may be transferred from one fisher to another, and the value of a license will reflect its future earning ability. If fishers retain all, or a high proportion, of the economic rent from a fishery, licenses can acquire a very high value. In terms of loan repayments, this places a high cost burden on new entrants, and makes it difficult for younger fishers entering the fishery.

Although license values may be determined by the government, it is difficult to ensure that license transfers between individuals do not involve some additional ("black-market") payment. An alternative is to make licenses non-transferable, in which case the license reverts to the government in the event that a license-holder either leaves the fishery or ceases to fish. The government can then re-issue the license by various means such as by lottery or auction.

Limiting entry alone may not be sufficient to contain fishing effort, as experience has shown that fishermen try to maximize their effort by getting more equipment, and bigger boats and engines. This may be allowed for by either:

- placing restrictions on gear and vessel size (see Options E and F). or,
- reducing the fleet size as overall efficiency increases; this would be difficult unless vessels (licenses) leaving the fishery were not replaced.

Enforcement would involve periodic checks to ensure that vessels landing catches held valid licenses. Enforcement would be simplified, and made more workable, if it were made illegal for fish exporters to buy from unlicensed fishers. However, unlicensed fishers may attempt to circumvent the regulations by selling their catch to exporters through licensed fishers. A suitable deterrent would be that license holders engaging in this activity risked the possibility of losing their licenses. Another problem may be that unlicensed fishers may sell their catches to non-export buyers. Due to the high value of the species caught, the scope for local sales in Tonga is limited, but may include a small number of tourist restaurants and hotels.

G1: Limiting vessel numbers to maximize profits

The best available estimate (Latu and Tulua, 1992) is that 16 vessels should be licensed to sell export fish in order to produce the maximum economic yield from the fishery. Because of the increase in fish prices paid to fishers since this report, the appropriate number of vessels is 22. This number is based on the fishing power of a standard 28ft vessel.

At this level of effort, large excess profits can be made by license holders. The view may be held that the community, which has had to forgo its right to fish in favor of the license holders, is entitled to share in these profits. In such cases, excess profits from the exploitation of a public resource may be collected in the form of fishing license fees. This ensures that excess profits from the exploitation of a nationally-owned resource are shared by the country as a whole, rather than remaining with a selected few individuals.

Decisions on which vessels currently in the fleet would get licenses would be difficult. The issuing of licenses could be based on a points system, with points awarded for number of years in the fishery and previous catch rates. It is important that the licenses be issued only to those fishermen dedicated to full-time bottomfishing, considering that a fisher may apply for a license without any real intention to fish full-time, but in the hope that the license may gain some future sale value. To avoid this, licenses held should be reviewed periodically and a license holder may be asked to provide evidence of his catch sales during the year.

G2: Limiting vessel numbers to maximize catch

The best available estimate (Latu and Tulua, 1992) is that 16 to 19 vessels should be licensed to sell export fish in order to produce the maximum sustainable yield from the fishery. This number is based on the fishing power of a standard 28ft vessel, and may have to be decreased if larger vessels (with greater fishing power) are given licenses.

At this level of effort catch rates, and therefore profits, made by license holders would be lower than that under option G1. As this number of vessels is similar to the number of vessels believed to be in the fleet currently, problems of selecting license-holders would be minimal.

Option H: Global catch quotas

Global catch quotas are used to restrict the catch from a resource to a predetermined TAC. A catch quota system could be applied only to the valuable export species *(Etelis coruscans, Etelis carbunculus, Pristipomoides filamentosus, Epinephelus morrhua* and *Epinephelus septemfasciatus)* and would not exclude artisanal fishers from catching these species for their own consumption, or from catching and selling a wide range of related, shallower-water species.

Once a TAC is set for the above species, fishers compete to secure a large personal catch before the overall catch quota is reached and the fishery is closed. The

consequences of this are that fishing seasons become shorter, and costs increase as fishers overcapitalize to gain a competitive edge. In addition, safety is compromised as fishers feel compelled to go to sea irrespective of the weather. Also, due to this competitiveness, boat maintenance during the fishing season is minimal, further compromising safety. Related disadvantages are similar to those for seasonal closures in which fishing is discontinuous, and, after the season, boats and factories sit idle. An alternative to global catch quotas is to apply catch quotas to individuals, or to individual fishing units (see Option J).

Option I: Individual catch quotas

Individual Transferable Quotas (ITQs) are allocated to individual fishers, who then have a guaranteed share of the total allowable catch of particular resource species. These species would include the valuable export species *(Etelis coruscans, Etelis carbunculus, Pristipomoides filamentosus, Epinephelus morrhua* and *Epinephelus septemfasciatus)* and would not exclude artisanal fishers from catching these species for their own consumption, or from catching and selling a wide range of related, shallower-water species.

A total allowable catch is estimated for the above species and this is divided into individual quotas. The proportion of the TAC allocated to a fisher may be decided on the basis of either equal allocations to all fishers, the past history in the fishery, vessel size, or according to a point score system based on a combination of these. It is also possible to offer ITQ units by auction or tender. An ITQ allocation can be either harvested or traded by the fisher. A guaranteed share of the resource allows a fisher to go fishing when market demand is high, and to spend non-fishing time on boat and gear maintenance. A result of this is that catches are often harvested over a longer period. The capacity to trade an ITQ means that less efficient fishers can sell all or part of their quota to more efficient operators for the market price of the quota.

Catch quotas have been recommended for deepwater bottomfish fisheries in other Pacific Islands regions, including the deepwater snapper fishery in Fiji. The main problem with using ITQs is the difficulty in ensuring that quotas are not exceeded. If quotas are based on catches recorded in logbooks, there is a strong motivation for fishers to under-report catches and, if quotas are based on the catch sold to registered processors, there is a temptation to sell to "black-market" buyers and restaurants.

6.0 CONSULTATION WITH USER GROUPS

Many fishers and fish exporters have been consulted during the preparation of this report and, at present, two public meetings have been held with members of these user groups - one in Vava'u and one in Tongatapu. Minutes of these meetings are held in Ministry of Fisheries files.

The fishers' main concerns included the need to upgrade their vessels and equipment, particularly with the installation of Global Positioning System (GPS) and radio equipment. There was also general agreement on the need to improve the quality of fish intended for export. Some fishers proposed that the Ministry of Fisheries should act as the sole fish quality assessment and marketing body for Tonga.

Although the need to monitor and assess deepwater fish stocks was supported, some fishers had reservations regarding management regulations. Some felt that regulations were not needed and feared that these, if imposed, would limit their access to fishing grounds.

7.0 MONITORING THE FISHERY

Whichever options and management measures are selected, a permanent, even if low level, system of data collection should be established to monitor the "health" of the fishery and to determine the effectiveness (or otherwise) of management strategies. Catch per Unit of Effort (CPUE) is one of the most important condition indicators for a fishery. Catch and fishing effort information are the basic data requirements and these may be supplemented by the regular collection of length-frequency data. In many licensed fisheries, the completion and submission of fishing logs, with catch and fishing effort by area, is a legal requirement of participation in the fishery. A trend of falling catch rates may indicate that a fishery is being exploited above the sustainable rate and a decrease in the mean length of fish in the catch (estimated from length frequency data) may indicate the same thing.

From a financial viewpoint, fishing costs and catch values should also be monitored. The early detection of trends, such as increasing fishing costs or decreasing market values of the catch, for example, may suggest that a change in fisheries management strategies is required in order to maintain profitability.

The basic assumption of using CPUE data to monitor and judge the health of a fishery is that changes in CPUE accurately reflect changes in the abundance of fish in the stock. However, there are many circumstances in which measures of CPUE are poor indices of abundance. Most of the problems in using CPUE data relate to the differences between the way fishing effort is measured (recorded or *apparent* effort), and the way in which effort may be actually changing in efficiency (actual or *effective* effort). If fishing becomes more efficient, catches will be greater for a given amount of apparent effort. In this case, recorded catch rates will show an increase even though the abundance of fish in the stock may be decreasing.

Effort may be measured with varying degrees of refinement. In a drop-line fishery where fishing vessels use a varying number of vertical lines with baited hooks, annual effort may be measured a number of ways. For example, the number of fishing vessels, the number of fishing trips per year, the number of hours fished, the number of hours each line is used, or the number of hours each hook is used. The corresponding units of CPUE would be catch per trip, catch per hour, catch per line-hour, and the catch per hook-hour.

In general it is better to use finer units (catch per hook-hour) than coarser units (catch per trip), although practical difficulties (such as the fishers not having watches) will affect the decision on which units to use. Coarse measures of effort may make it impossible to detect changes in effort which occur at finer levels. If fishing effort was recorded as the number of trips completed per year, for example, the measure would be unable to detect the fact that fishers may have increased the number of days worked on each trip. In this case, CPUE defined as the catch per trip would not show any decrease over time even though stock numbers may actually be falling.

Even in a developed fishery, new gear and ways of locating fish are continually being discovered. The use of GPS navigating systems and electric reels, for example,

presumably makes the fleet more efficient. In the case of improvements in efficiency, more fish will be caught for the same amount of apparent effort, and recorded CPUEs will give the misleading impression that abundance of the stock is high (or even increasing!) when in fact it is decreasing. The same effect would occur if effort was measured in terms of the number of vessels, and less efficient vessels were gradually replaced by more efficient ones.

It will be important to estimate the difference in *fishing power* (if any) between the standard 28ft vessel and the new larger vessels. If catch rates are recorded for individual vessels, effort can be standardized to allow for the fishing powers of different vessels. This can be most simply done when any of the larger vessels are operating on the same fishing grounds at the same time as the standard 28ft vessels. If the mean catch of the larger vessel is 20% higher than the smaller vessel, for example, then each hour that the smaller vessel works would have to be multiplied by 1.2 to get the standardized fishing effort. In cases where the different fishing power of fishing units are not taken into account, quite misleading information may be obtained.

8.0 DISCUSSION

A range of options to develop and manage the deepwater bottomfish fishery have been presented and evaluated. Although the authors of this report have been asked specifically not to recommend particular options, the following discussion is presented in the interests of aiding the Government of Tonga in its selection of appropriate management objectives and regulations.

At the FAO World Fisheries Conference in Rome (1984), it was recognized that open access to unmanaged fisheries had resulted in competition for limited resources, overcapitalization, and the depletion of stocks. To prevent such consequences, one of the recommendations of the conference was that governments should seek to ensure that fishers have clearly-defined fishing rights and that the allowable catches do not exceed the productivity of the resources. Methods of addressing the rights of fishers include either allocating rights to the capacity to fish (through input controls such as license allocation), or allocating rights to a specified share of the resource (output controls in the form of catch quotas).

Although maximizing participation and employment may be an appropriate goal in an artisanal fishery which provides food and employment for a local community, this is not necessarily true in a commercial fishery in which most of the catch is exported. In this case, maximizing efficiency (and thereby net profits in the form of foreign exchange to the country as a whole) may be a more appropriate objective.

Of the management options discussed, some are clearly inappropriate (e.g. legal minimum lengths), and others are impractical due to high enforcement costs (e.g. closed areas). Output controls on catches (quotas) also present difficulties in enforcement. The licensing of vessels fishing for export species (possibly in conjunction with some vessel and gear restrictions) allows the government some control in prevented biological and economic overfishing at the lowest level of enforcement difficulty and cost. Whichever option is chosen, improvement of post-harvest catch handling and quality control to maximize the value of the catch is desirable, but this should not hinder the marketing efforts of fish exporters.

All suggested management objectives depend upon the skills of experienced fishers and exporters for the continuation and development of the fishery. None of the alternative objectives should involve a radical restructuring of the fishery, in which case these accumulated skills could become lost.

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10.0 APPENDICES

APPENDIX A. Yield estimates

Production models were based on fishing effort expended in deep water (on the sea-mounts) and presumably targeted the five export species. Dynamic production analyses appeared to produce no meaningful results. Both the Fox and Schaefer equilibrium production models were based on a reasonable linear fit of the catch-per-effort data and result in estimates of sustainable yields of about 350 tons for all deepwater species and 210 tons for the two most common species (Figure A1).

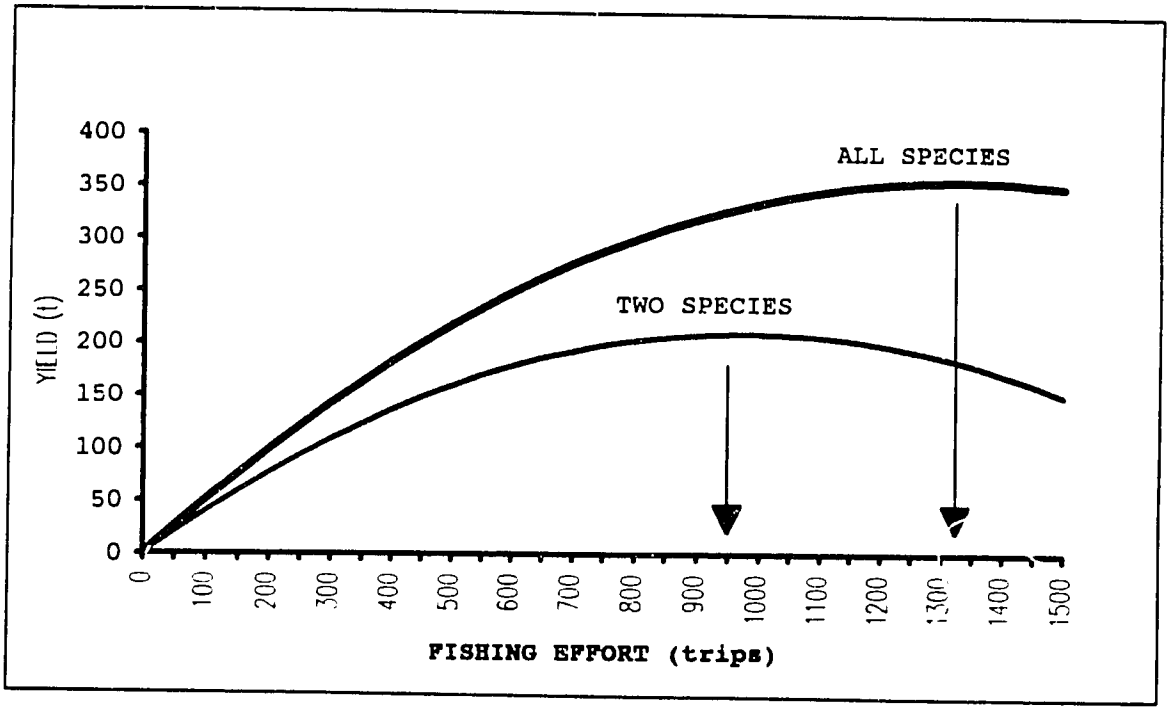

Figure A1: The relationship of yield (annual catch in tons) of all five deepwater species (top curve), and of the two main export species *Etelis coruscans* and *Pristipomoides filamentosus* (bottom curve) to fishing effort (number of trips) in the deepwater snapper fishery in Tonga.

APPENDIX B. Financial analyses

Financial data shown in Table 1 are based on what is believed to be a typical deepwater snapper fishing operation in 1992/1993.

TABLE 1: Estimated fishing costs of a deepwater snapper fishing vessel operation in Tonga (1992/1993).

INITIAL INVESTMENT:	COST (T$)
fully equipped vessel*	26,000
FIXED COSTS (per year):	
vessel loan repayments (11%)**	2,860
vessel amortisation over 10 yrs	2,600
repairs & maintenance	2,000
insurance (non-comprehensive 4.5%)	1,170
Total fixed costs (per year)	8,630
RUNNING COSTS (per trip):	
crew payments	450
fishing gear replacement	32
fuel	105
food, etc.	29
bait (@ T$ 4.65/kg)	52
ice (@ T$ 0.15/kg)	62
repairs per trip	17
miscellaneous	29
Total running costs (per trip)	776
Total running costs (per year***)	23,280
TOTAL ANNUAL COSTS (T$)	31,910

* vessel price subsidized by Tongan government
** all but 4 vessels believed to be currently repaying loans
*** based on 30 trips of 5 days duration (3 fishing days) per year

A break-even curve (where returns to fishermen balance the total cost of fishing) was produced (Figure B1) from the data in Table 1. This suggests that, at a price to fishermen of T$ 4.00 per kg, long-term mean catch rates from a commercial vessel would have to be greater than 3.8 kg per line hour to be profitable.

The cost data from Table 1 and price per kg of T$ 4.00 were used to superimpose a fishing cost line on a surplus yield curve in terms of revenue (Figure B2). Profits from deeper-water species were maximized at a lower fishing effort of approximately 670 trips, or 22 typical (28ft) fishing vessels completing 30 trips per year.

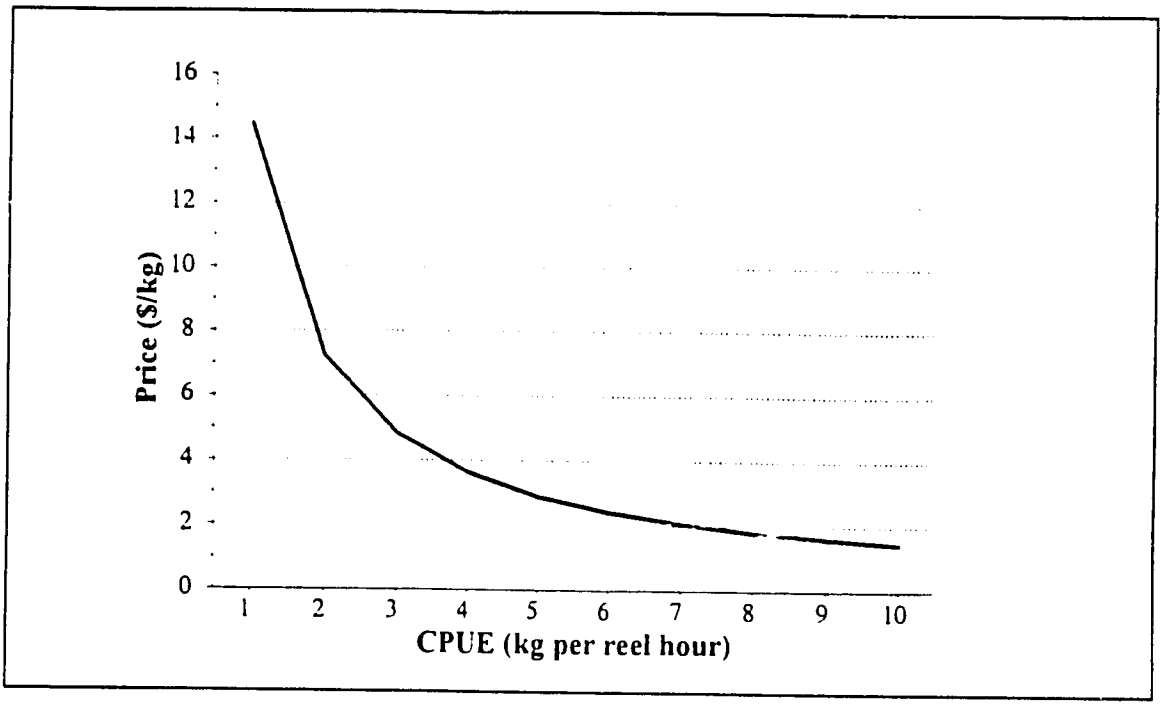

Figure B1: Breakeven curve for a typical snapper fishing vessel in Tonga. The curve shows the relationship between catch rate (kg per reel hour) and fish price ($ per kg) required to balance the cost of fishing.

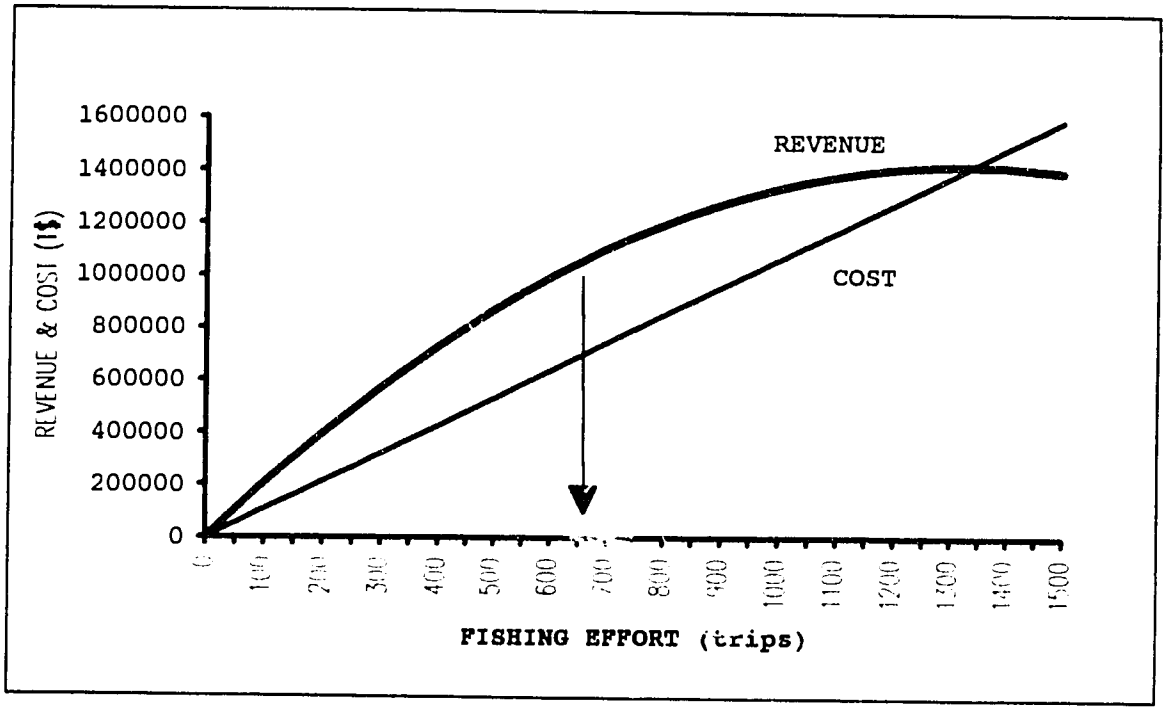

Figure B2: The relationship of revenue (curve) and fishing costs (straight line) in T$ millions to fishing effort (number of trips) in the deepwater snapper fishery in Tonga.