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ANALYSES OF THE DEEP WATER DEMERSAL FISHERY IN TONGA

Pacific Islands Marine Resource Project
Tonga Component
Project No. 879-0020

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ABBREVIATIONS

CPUE	Catch per unit effort
MSY	Maximum sustainable yield
mm	Millimeter
cm	Centimeter
m	Meter
km	Kilometer
kg	Kilogram
nm	Nautical mile
kts	Knots
l	Litre
mt	Metric ton
C	Centrigrade
rh	Reel hours

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1.0 EXECUTIVE SUMMARY AND RECOMMENDATIONS

1.1 Executive Summary

Deep-water snappers, emperors, and groupers have been caught commercially in Tonga since 1980, and data on the fishery has been collected since late 1986. Biological results available are consistent with a resource which is fragile, involving slow growing species with long life-spans and limited habitats.

The existing level of data collection, however, is inadequate for a fishery that represents one of the most valuable resources in Tonga. An expanded sampling strategy for improved coverage, both by fishing area and by depth, is needed; this will require sufficient financial support.

Analyses suggest that although overall demersal fishing effort (in depths from 40 m to 400 m) has decreased to approximately 60% of the maximum value attained in 1987, fishing effort in depths greater than 200 m on more valuable species, particularly the longtail snapper *Etelis coruscan,* has more than doubled in the same period. These deep-water species, in particular, appear to be under threat from over-exploitation.

For species in depths greater than 200 m, sustainable yields of from 200 to 300 tons may be obtained at from 40,000 to 60,000 actual reel hours (equivalent to approximately 20 to 30 full-time vessels). However, at this level of fishing effort, financial returns (i.e., returns less fishing costs) from the fishery are approaching zero. Profits from deeper-water species are maximized at a lower fishing effort of approximately 15,000 to 27,000 reel hours, or 7 to 13 fishing vessels.

Possible management measures are presented and discussed. These include the exclusion of foreign vessels, and the removal of government boat-building subsidies; the intention to build an additional 10 subsidized vessels will increase fishing effort by approximately 50%, and result in lower mean catch rates per vessel. The management measures discussed that would limit the number of vessels through a vessel registration or licensing system is likely to be the most acceptable. Policing such a measure is unlikely to be onerous due to the limited number of processors, which would be permitted to purchase deep-water snapper from licensed vessels only.

1.2 Recommendations

1.2.1 It is recommended that particular attention be directed to the fishery in depths greater than 200 m, where species of higher value appear to be under particular threat from over-exploitation.

Although overall demersal fishing effort has decreased to approximately 60% of the maximum value in 1987, fishing effort on the deeper and more valuable species (e.g., the longtail snapper) has increased over 100%.

1.2.2 It is recommended that additional support be made available for improving data collection (particularly for catch and effort data) both by fishing area and by depth.

Data collection is presently inadequate for a fishery that represents one of the most valuable in Tonga. Both catch and fishing effort should be recorded by four depth bands (i.e. <100 m, 100-150 m, 150-200 m, and >200 m), and from fishing ports other than Nuku'alofa. It is also recommended that the recording of length-frequency data be recommenced for major species.

1.2.3 It is recommended that effort be made to improve estimates of biological parameters, particularly growth and mortality.

The only suitable method for estimating growth for the species under discussion is by the analysis daily growth rings on otoliths (fish ear-bones); these analyses, however, would have to be completed at an overseas institution, and would require appropriate funding (growth analyses, however, should have a lower priority than the collection of reliable catch and effort data).

1.2.4 It is recommended that the deep-water snapper fishery be managed on the basis of maximizing profits to fishermen and the country rather than maximizing yield in catch weight.

The estimated level of deep-water (i.e., below 200 m) fishing effort to maximize profits is from 15,000 to 27,000 actual reel hours, equivalent to from 7 to 13 full-time fishing vessels. Although sustainable yields (in weight) of from 200 to 300 tons may be taken at from 40,000 to 60,000 actual reel hours (equivalent to approximately 20 to 30 full-time vessels), profits at this level of fishing effort are approaching zero. At present fishing effort in deep-water is approximately 19 fishing vessels.

1.2.5 It is recommended that data on the economic viability of fishing operations be collected on a regular (but not necessarily frequent) basis.

Economic and marketing appraisals both require price and cost information to be collected from fishermen and processors. Estimates of catch rates, fish prices and fishing costs are the basic parameters which allow a reasoned judgement on the level of exploitation at which the fishery remains profitable.

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1.2.6 It is recommended that methods of fish marketing be examined with a view to aiding exporters to maximize the market value of the catch.

Although increased participation in the fishery is unlikely to be beneficial, the value of the landed catch may be increased by addressing aspects such as the improvement of catch quality and transport facilities (between Vava'u and Nuku'alofa, for example), and by assisting exporters in promoting Tongan deep-water snapper on overseas markets.

2.0 AVAILABLE DATA

Of South Pacific countries, Tonga has had one of the longest time-series of data from deep-water snapper fisheries, and has often shown an impressive involvement with data analysis. Deep-water snappers, emperors, and groupers have been caught commercially in Tonga since 1980. The present 1991 species composition of the demersal catch is shown in Table 1.

Table 1. Composition of the catch of demersal species in the Tongan line-fishery for 1991.

SPECIES	TONGAN NAME	WT (t)	NUMBERS
Depths > 200M?			
Etelis coruscans	palu tavake	116.18	36,303
Etelis carbunculus	palu malau	17.08	4,880
Epinephalus septemfasciatus	mohuafi, tonu	76.50	2,620
Epinephalus morrhua	ngatala	3.70	1,158
TOTAL (depths > 200 m)		213.46	44,961
Depths < 200 M?			
Lethrinus chrysostomus	manga	11.23	9,363
Pristipomoides filamentosus	palu hina	40.10	12,153
Pristipomoides flavipinnis	palu sio'ata	5.93	4,238
other species		52.75	20,058
TOTAL (All Depths)		323.45	90,770

Data collection, which appears to have been previously based on a good relationship between fishermen and the fisheries authorities, has deteriorated. Coverage is restricted to the island of Tongatapu, and there is no precise estimate available of total fishing effort for the whole country.

Data collection is presently inadequate for a fishery that represents one of the most valuable resources in Tonga, and it is recommended that additional support be made available for the task. Expanded collection of catch and effort data by fisheries officers based in Vava'u and Ha'apai is needed. It is also necessary to record catch and effort by depth (see Section 2.5).

Data reporting and analyses have been satisfactory, although the most recent interim report contains inconsistencies and inaccuracies. Biological results are consistent with a resource which is fragile, involving slow growing species with long life-spans and limited habitats.

A summary of information obtained from records and analyses is provided below with comments. Although analyses were conducted on data for most major component species, interest is particularly directed to the most valuable and threatened species in depths greater than 200 m, particularly the longtail snapper, *E. coruscans*; an appendix shows typical analyses and results for this species.

2.1 Resource Area

The length of the 200 m isobath is typically used to estimate available bottomfish habitat. Based on this estimate, 930 nm of Tongan waters are bottomfish habitat (Langi & Langi), of which 294 nm are seamounts (Latu & Tulua, 1991).

2.2 Growth

Growth estimates are unavailable for Tongan species, and those from similar species in Hawaii and the Marianas have been assumed. The major deep-water species, *Etelis coruscans*, is slow growing ($K=0.17$) and reaches an asymptotic length ($L\infty$) of 97 cm. Using these estimates, the largest individuals found in Tonga are approximately 20 years old.

As length-frequency data from slow-growing long-lived fish are unsuitable for estimating growth rates, the only suitable method for estimating growth is by the analysis of daily growth rings on otoliths (fish ear-bones). It is recommended that funds be sought to have otoliths collected from Tongan species and analyzed at a suitable overseas institution. These analyses, however, have a lower-priority than the collection of reliable catch and effort data.

2.3 Natural Mortality

The estimation of natural mortality rates is difficult without accurate growth information. For *Etelis coruscans*, instantaneous rates of approximately 0.3 year $^{-1}$ (about 26% per year) appear reasonable.

2.4 Length-Frequency Data

At present fish are not being measured, and the collection of length-frequency data ceased in 1991. The justification for this is that such data are unsuitable for estimating growth rates. Although this is true, length-frequency data are useful in determining mean sizes and fishing-induced changes in stock composition; the data may also be used to estimate mortality-growth ratios (Z/K) (see Appendix). It is recommended that the measuring of major species be recommenced.

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2.5 Fishing Effort and Catch

"Reel hours" referred to in this report are as recorded by the Department of Fisheries. Fishermen appear to have reported all daylight hours spent on the fishing grounds (approximately 13 hours per day) as fishing time. In reality, only the early and late part of each day appears to be fished, with some vessels using only one of the four reels at times between to check catch rates. The actual fishing time is believed to be approximately 7 hours per day.

There is a great variation in the number of trips a vessel completes in one year (from 2 to 48 trips). However, an average operation for one vessel consists of 28 trips of approximately 5 days duration per year; an average of 3.5 reels is used for 3 days fishing in each 5-day trip. Recording fishing times as 13 hours per day instead of the actual 7 hours, causes a discrepancy between "recorded reel-hours" and "actual reel hours" as shown in the following table.

Table 2. The annual fishing effort (Actual reel-hours, and Recorded reel-hours) imposed by an average fishing vessel operation.

TRIPS PER YEAR	28
LENGTH OF TRIP	5 days (2 days steaming plus 3 days fishing)
NUMBER OF REELS	3.5 (average number of reels used)
FISHING TIME PER DAY	7 hours (but 13 recorded)
ACTUAL FISHING EFFORT	2,720 reel hours per vessel per year
RECORDED FISHING EFFORT	3,822 reel hours per vessel per year

NOTE: That unless otherwise referred to in this report, fishing effort should be taken to mean "Recorded Fishing Effort"; this may be converted to "Actual Fishing Effort" by multiplying by 7/13, or 0.56. Conversions are provided in the following Table 3.

Table 3. Recorded vs actual fishing effort conversions.

Number of Vessels	Recorded Reel Hours	Actual Reel Hours
10	38,220	20,580
12	45,864	24,696
14	53,508	28,812
16	61,152	32,982
18	68,796	37,044
20	76,440	41,160
22	84,084	45,276

At present in Tonga, up to 19 vessels are involved in catching demersal fish beyond the reefs. Only some of these vessels, perhaps up to 11, actively and consistently fish for deep-water snappers. There is great variation in the number of trips a vessel completes in one year (from 2 to 48 trips). Based on recorded and anecdotal information, an average operation for a vessel consists of 28 trips per year each approximately 5 days in duration. An average of 3.5 reels is used for 3 days fishing in each 5-day trip. Recording fishing time as 13 hours per day instead of the actual 7 hours, causes a discrepancy between "recorded reel-hours" and "actual reel hours" as shown in Table 3.

Available statistics (Table 4) show that overall demersal fishing effort has steadily decreased to approximately 60% of the maximum value reached in 1987. However, these data represent overall demersal effort, and mask the increasing trend of fishermen to fish in deeper water for more valuable species, particularly *Etelis coruscans*. It is suggested (Section 4) that there has been an increase in effort in deep-water (>200 m) in spite of a decline in overall demersal fishing effort.

Table 4. Estimated fishing effort (recorded reel hours) and catch (in tons) of all demersal species in Tonga (corrected data for 1986-1990 from Latu & Tulua, 1991). Data for 1986 recorded for November and December only, and multiplied by six.

	1986	1987	1988	1989	1990	1991
EFFORT (rh)	15,786.0	122,775.0	91,020.0	86,202.0	59,340.0	75,713.0
CATCH (t)	210.6	633.0	484.7	450.1	281.6	323.5
CPUE (kg/rh)	13.3	13.4	12.0	11.9	7.5	8.1

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The fact that effort is recorded as overall fishing effort (depths from 40 m to 400 m) rather than by depth-zone is a serious flaw in the present monitoring system (see Section 3). This makes assessing changes in catch rates (CPUE) of component species difficult, and means that there is no reliable information of the depth distribution of major species.

Fishermen fish in depths which will yield target species that are in highest demand, e.g., *Etelis* spp. in deep water or *Pristipomoides* spp. in shallow water. However, as only overall (all depths) effort is recorded, changes in catch rates of a particular species are likely to reflect changes in target location by fishermen rather than changes in fish abundance.

It is recommended that fishing effort be recorded by four depth bands (i.e., <100 m, 100-150 m, 150-200 m, and >200 m). For previously collected data, a not entirely satisfactory method of partitioning effort is suggested in Section 3.

At present, data collection is restricted to vessels operating out of the island of Tongatapu, with infrequent visits to other islands. It is recommended that fisheries officers based in Vava'u and Ha'apai be trained and involved in the collection of catch and effort data for forwarding to the Head Fisheries Office.

2.6 Yield

The lack of partitioning of fishing effort by depth (Section 3.0), and the lack of growth estimates makes estimating sustainable yield (even more than usually) hazardous. A summary of estimated sustainable annual yields is presented in Table 5.

Table 5 suggests that yields of approximately 200 to 300 tons may be taken from the deep-water fishery (below 200 m). The analyses also suggest that, excluding economic considerations, this yield could be taken by an actual fishing effort of from 40,000 to 60,000 actual reel hours per year (equivalent to 20 to 30 vessels completing 28 trips per year).

However, economic yield (returns minus fishing costs) from the deep-water fishery are maximized at approximately 15,000 to 27,000 actual reel hours, equivalent to from 7 to 13 full-time fishing vessels. At the present level of fishing effort (approximately 19 fishing vessels) financial returns from the fishery are less than 30% of this maximum (see Section 5.0.)

Estimates of total yield from the demersal fishery as a whole (all depths from 40 to 400 m) are less reliable, but 400 to 770 tons may be regarded as a preliminary rough estimate.

Table 5. Summary of estimated sustainable annual yields for the Tongan deep-water snapper fishery below 200 m.

Yield (T)	Source	Comments
170 to 770	Latu & Tulua (1991)	For all seamount species; Using Allen's model; depends on input value for natural mortality.
400 to 560	Present review (Section 5)	For all seamount species;based on Schaefer and Fox models applied to unadjusted catch and effort - model has poor fit
30 to 300	Present review (Section 5)	For deep-water species only; based on Schaefer and Fox models applied to partitioned catch and effort
230 to 250	Present review (Section 7)	For deep-water species only; based on simulation model
225 maximum	Present review (Section 5)	For *E. coruscans* only; based on length-based Thompson & Bell analysis

2.7 General Comments

Research work has been restricted to addressing biological aspects of the fishery. However, it is also important to collect data on marketing and economic viability. Economic and marketing appraisals both require price and cost information from fishermen and processors. Estimates of the expected catch rates, the level of exploitation at which catches are sustainable, and price and cost information are the basic parameters which allow a reasoned judgement on whether or not a fishery will continue to be biologically and economically viable. An analysis of the economic viability of fishing operations is included in Section 5.

Increasing participation in the Tongan fishery is unlikely to be beneficial. The value of the landed catch, however, has potential to increase by addressing aspects such as the improvement of catch quality and transport facilities (between Vava'u and Nuku'alofa, for example), and by assisting exporters in promoting Tongan deep-water snapper on overseas markets.

3.0 PARTITIONING FISHING EFFORT BY DEPTH

For previously collected data, an approximate method of partitioning effort between depths is suggested below. During each fishing operation, a vessel's depth of fishing will be reflected in the proportion of species with different depth distributions in the vessel's total catch. The proportion of the total fishing effort spent by each vessel in depths optimal for deep-water snapper (>200 m), may be estimated by multiplying the total fishing effort E(total) by the ratio of the catch numbers of the four deep-water species, C(deep), relative to the total catch numbers of all seven demersal species, C(total):

$$E(deep) = E(total) \times C(deep)/C(total)$$

For 1991 data (see Table 1):

$$E(deep) = 75713 \times 44961/70712 = 48141 \text{ reel hours}$$
or 63.6% of the total demersal effort

For the purpose of this calculation, all *Etelis* and *Epinephelus* species were assumed to be from deep-water (>200 m), and other species were from shallow-water (Table 1). This assumes that species from all depths have similar collective biomasses and catchability. A more serious problem with the method is the inherent circularity of using catch to partition effort into shallow-water and deep-water components, and then using the partitioned effort to estimate catch-rates). The results of this analysis are shown in Table 6.

Table 6. Estimated fishing effort (reel hours) and catch (tons) in deep-water (>200 m).

	1986	1987	1988	1989	1990	1991
EFFORT (rh)	4,761.0	40,999.0	17,112.0	29,050.0	38,868.0	48,141.0
CATCH (t)	104.1	351.6	159.6	220.6	223.3	213.5
CPUE (kg/rh)	21.9	8.6	9.3	7.6	5.8	4.4

Two noteworthy trends emerge from an examination of the adjusted data presented in Table 6. First, there appears to have been a steady increase in effort in deep-water (to 58% of the total demersal fishing effort of 75,713 recorded reel hours in 1991) in spite of a decline in overall demersal fishing effort. This appears to be the result of fishermen targeting the more valuable species (particularly *Etelis coruscans*) in deep water. Second, the results show a steady decline in catch per reel hour and result in quite a different yield analysis to one using unadjusted data (i.e., the analysis in Latu & Tulua, 1991). A surplus yield analysis is presented in Section 4.

4.0 YIELD ANALYSES

The advantage of surplus yield models is that they are based on records of catch and effort only, and are independent of estimates of biological parameters such as growth and mortality. The decrease in catch-per-reel-hour (Table 6) was used to produce the surplus yield curves shown in Figure 1.

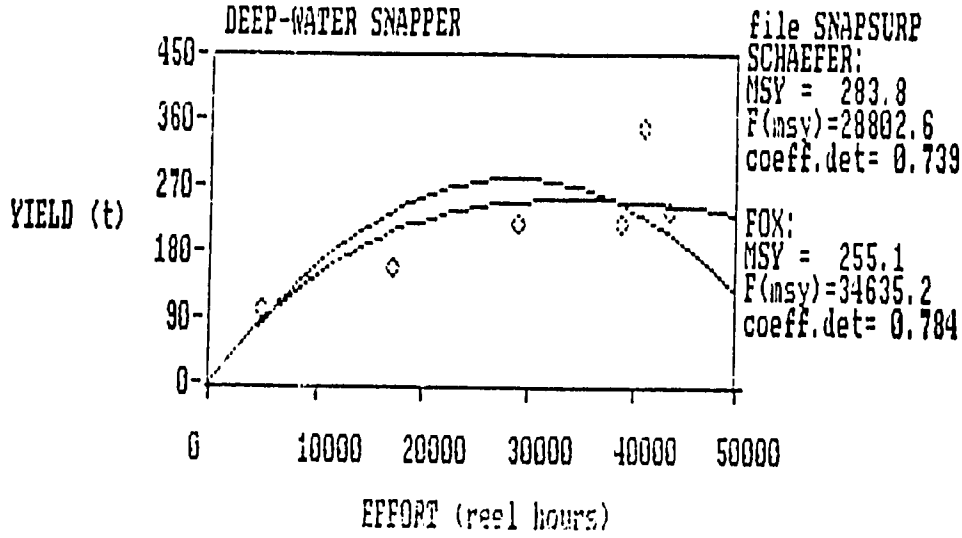

Figure 1. The relationship of yield (annual catch in tons) to fishing effort (reel-hours) in the deep-water snapper fishery in Tonga (species below 200m).

Both the Fox and Schaefer models are based on a reasonable linear fit of the data, and result in estimates of sustainable yields of 255 tons and 284 tons, respectively. A similar analysis for all demersal species has a poor fit, but produces estimates of sustainable yield for all species of 400 and 560 tons, respectively.

A prediction of catches by length-class for various levels of exploitation (using a length-based Thompson & Bell analysis) is shown in Figure 2. These analyses are dependent on input values for the number of fish in initial size-classes and the natural mortality rate.

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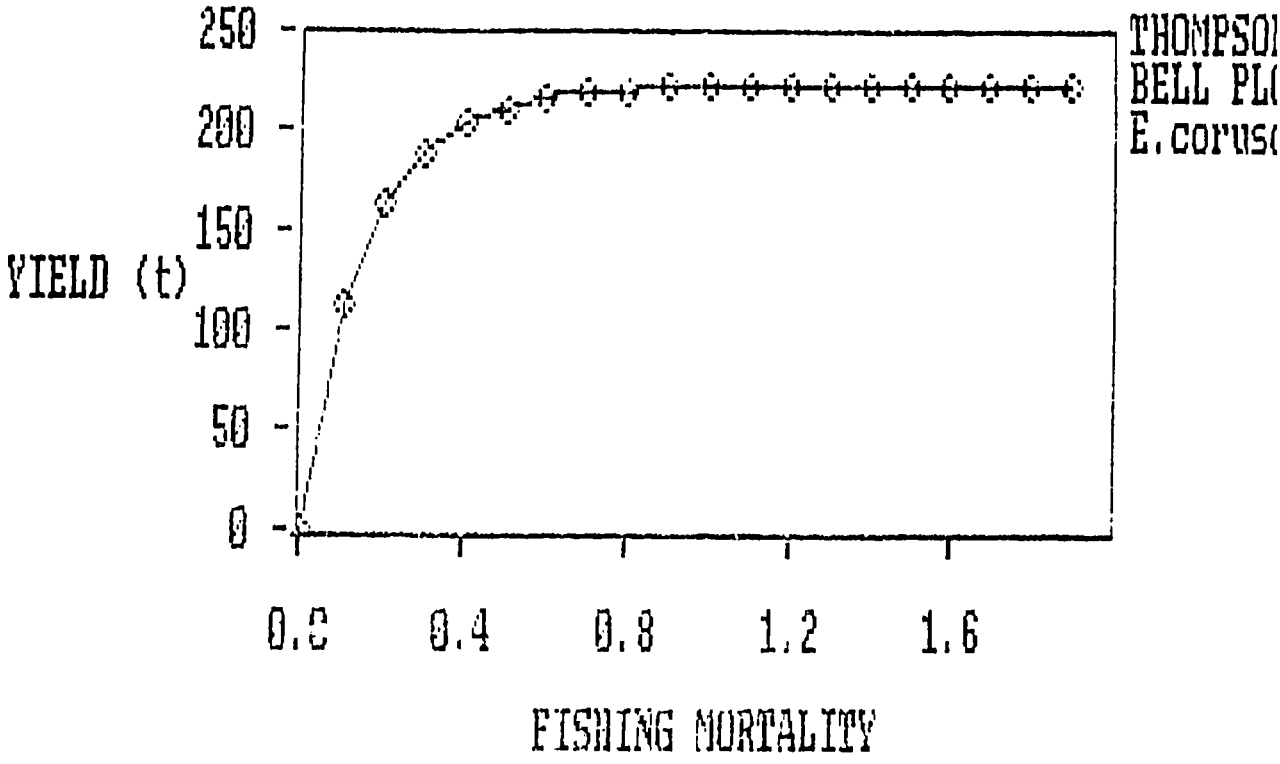

Figure 2. Predictive length-based analysis of yield for the longtail snapper, *Stelis coruscans*, at various levels of fishing mortality (F).

The Thompson & Bell analysis (Figure 2) an asymtotic maximum yield of 255 tons is reached at F>0.8.

5.0 FINANCIAL ANALYSIS OF A TYPICAL FISHING OPERATION

Preliminary financial data, based on a typical deep-water snapper fishing operation in early 1992, are given in Table 7.

The economic aspects of a commercial operation may be examined as the effects of catch rates, fishing effort, and product price on a vessel's net return. Break-even curves (where returns to fishermen just balance the total cost of fishing) are instructive in assessing the economic viability of a commercial operation.

Preliminary break-even curves (using the computer program BRAKEVEN) are shown in Figure 3. These suggest that, at a price to fishermen of T$3.5 per kg, long-term mean catch rates from a commercial vessel would have to be greater than 4 kg per line hour to be profitable.

Table 7. Preliminary estimated fishing costs for a deep-water snapper fishing vessel in Tonga. NOTE: Based on preliminary data collected in January-February, 92.

	COSTS (T$)
INITIAL INVESTMENT	
Fully equipped vessel*	26,000
FIXED COSTS (per year)	
Vessel loan repayments (11%) **	2,860
Vessel amortization over 10 yr.	2,600
Repairs & maintenance	2,000
Insurance (non-comprehensive 4.5%)	1,170
TOTAL FIXED COSTS (per year)	8,630
RUNNING COSTS (per trip)	
Crew payments	450
Fishing gear replacement	40
Fuel	75
Food, etc.	40
Bait (30 kg @ T$ 4.00/kg)	120
Ice (500 kg @ T$ 0.15/kg)	75
TOTAL RUNNING COSTS (per trip)	800
TOTAL RUNNING COSTS (per year***)	22,400
TOTAL ANNUAL COSTS (T$)	31,030

* vessel price subsidized by Tongan government
** all but 4 vessels believed to be currently repaying loans
*** based on 28 trips of 5 days duration (3 fishing days) per year

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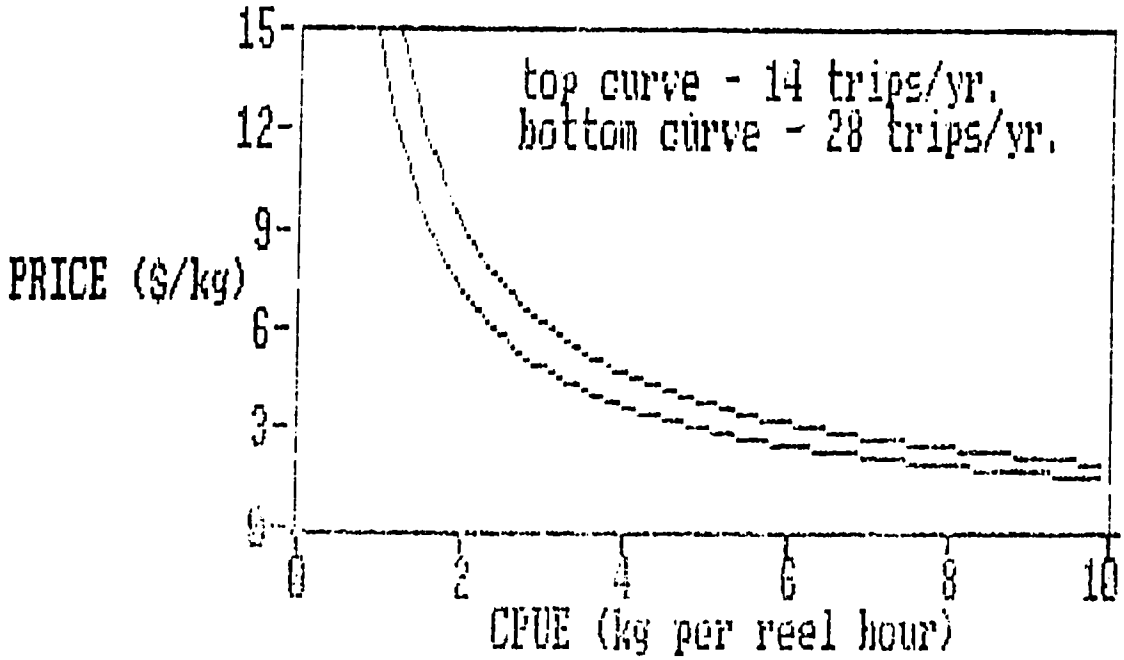
A notable point of Figure 3 is that the price curves rise steeply at lower catch rates. If fishing effort continues to increase, mean catch-rates will fall below levels at which fishermen can fish profitably at current fish prices.

The computer program BRAKEVEN used to generate Figure 3 was written while the author was in Tonga, and installed on the computer at the Fisheries Centre, Sopu. The program should be used to update financial analyses as new information becomes available.



for 28 trips/yr:

CPUE	$ PER kg	CPUE	$ PER kg
1.0	15.08	3.5	4.31
1.5	10.05	4.0	3.77
2.0	7.54	4.5	3.35
2.5	6.03	5.0	3.02
3.0	5.03	5.5	2.74

Figure 3. Preliminary breakeven curves for a typical snapper fishing vessel in Tonga. The curves show the relationship between catch rate (kg per reel hour) and fish price ($ per kg) required to just balance the cost of fishing. The lower curve and the table below the figure are based on an average of 28 fishing trips per vessel per year.

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6.0 A SIMULATION MODEL OF THE FISHERY

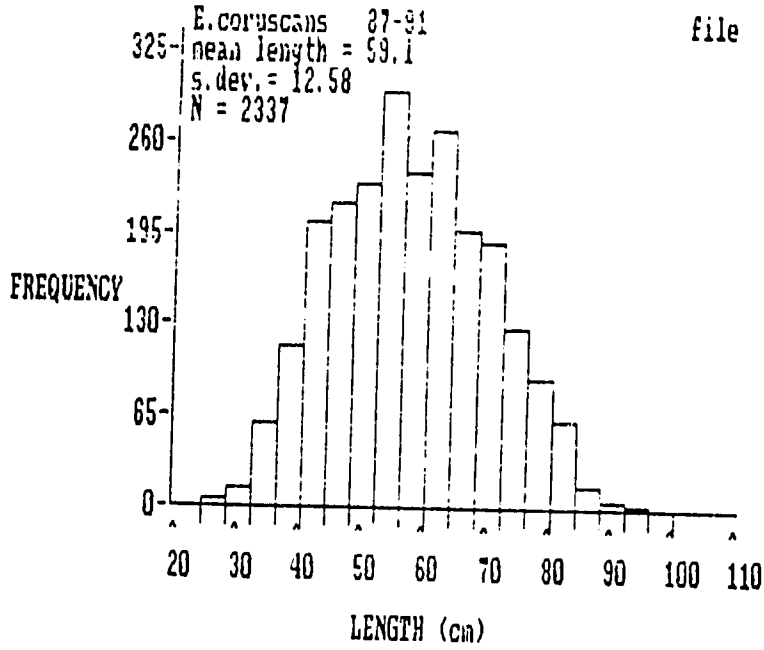
If extensive biological data are collected (or can be extrapolated from other fisheries) the application of simulation models is a useful method of assessing a fishery. Economic and stochastic factors can also be included in simulation models which can help in predicting the possible outcomes of various fishing levels and strategies.

Simulation models allow fisheries researchers and managers to deal with complex systems and "try out" various levels of fishing effort and management strategies. In a technique known as Monte Carlo modelling, simulations may be run repeatedly to estimate the probability of obtaining desirable outcomes (and the risk of undesirable ones!).

In the simulation model SNAPSIM, recruitment is related to stock size using Ricker's model on data provided in Latu & Tulua, 1991 (with the restriction that the curve is forced through a recruitment value that replaces numbers lost through natural mortality). A sample output from a long-run (25 year) simulation program based on snapper data from Tonga is shown in Figure 4.

The program is stochastic in that recruitment is allowed to vary randomly (within a given standard deviation) about the predicted level, and the catchability coefficient is allowed to vary randomly by plus or minus 10%

Figure 4. The output from a simulation model (SNAPSIM) of the deep-water snapper fishery in Tonga for 10, 20, and 30 vessels (based on actual fishing hours/7 hours per day).



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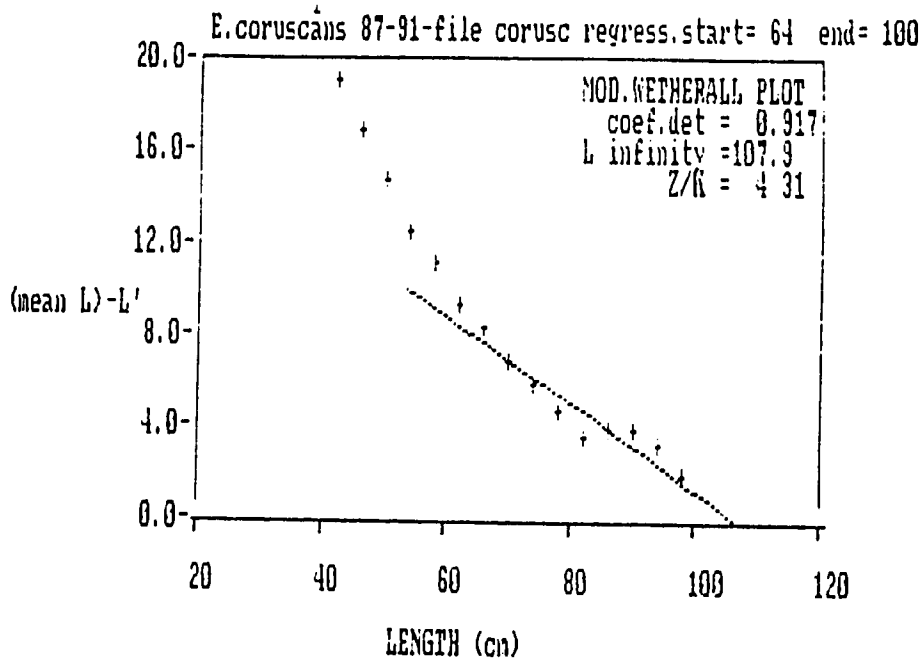

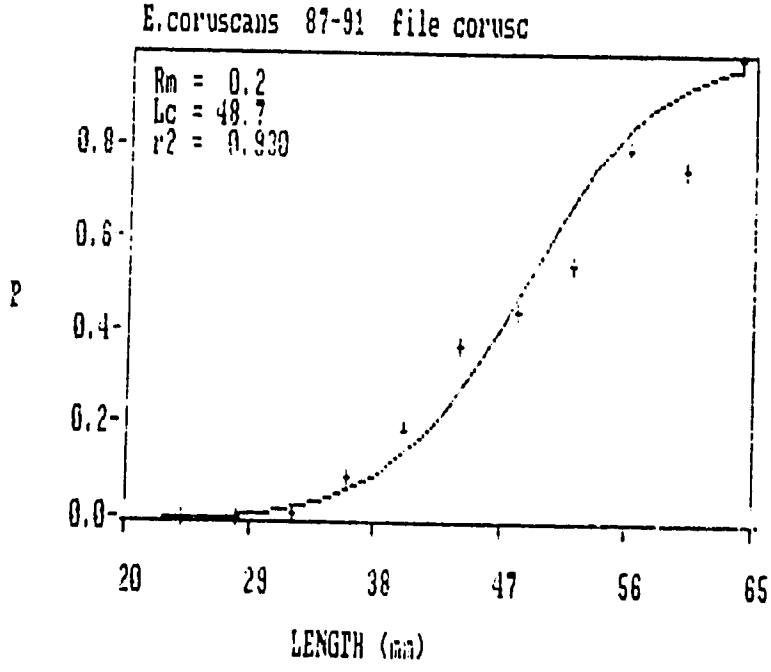

Fishing effort reduces the stock which stabilizes at new levels, depending on fishing effort. At the higher fishing effort level of 30 vessels, catch rates are reduced to 3.4 kg per actual reel-hour, at which point profits from the fishery are negative.

Figure 5 shows the output from the continuous simulation option of the program SNAPSIM, an additional vessel is added automatically for each simulation, and yields

are estimated. The figure shows that annual yields approach an asymtotic maximum at approximately 240 tons and 42,000 to 62,000 actual reel hours (equivalent to from 20 to 30 vessels). However, economic yield (returns minus costs) from the fishery are maximized at approximately 15,000 to 27,000 actual reel hours, equivalent to from 7 to 13 full-time fishing vessels. At the present levels of fishing effort in depths greater than 200 m, financial returns from the fishery are low.

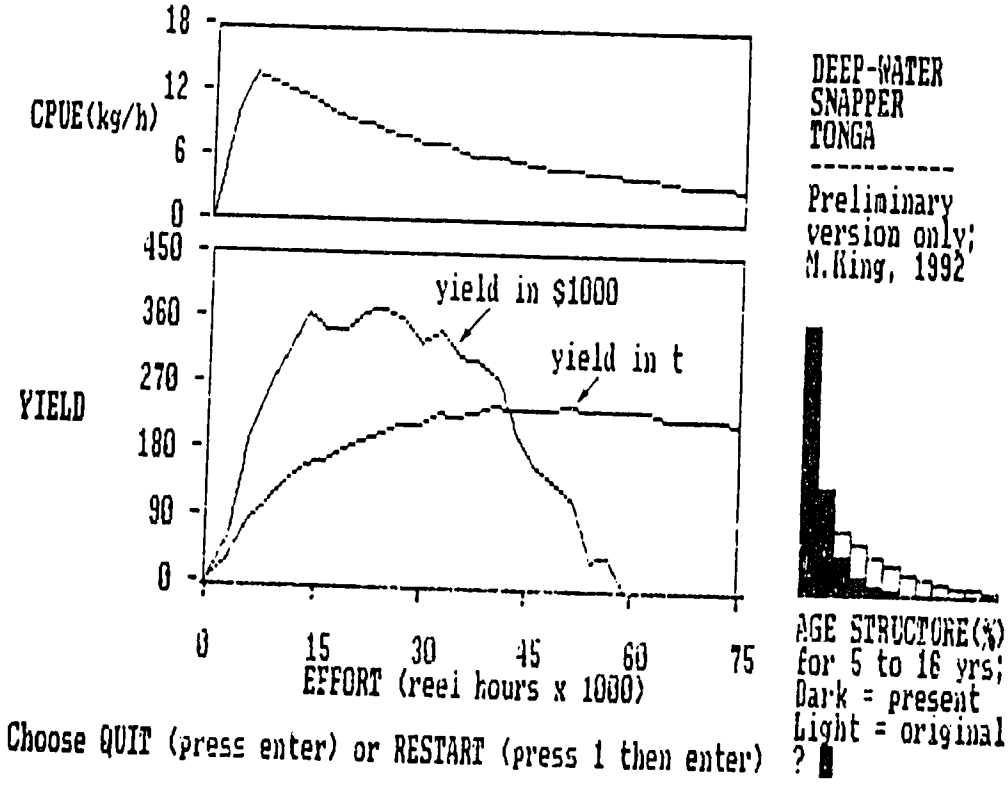

Figure 5. The output from a simulation model (SNAPSIM - continuous simulation option) of the deep-water snapper fishery in Tonga for fishing effort from 0 to 75,000 actual reel hours.

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7.0 MANAGEMENT OPTIONS

7.1 Quotas

Some countries, including Fiji (Lewis et al., 1988), have suggested the use of quotas (maximum permitted annual catches) to prevent the over-exploitation of deep-water snapper fisheries. This management measure presents considerable difficulties in policing the quotas, therefore is not recommended. A further problem is that fishermen would be tempted to under-report catches to the Fisheries Department.

7.2 Exclusion of foreign vessels

The government's present policy includes exclusion of foreign vessels. This policy should continue so that Tongan fishermen are not disadvantaged.

7.3 Boat-building subsidies

At present the government intends to build 10 additional vessels for sale to fishermen on favorable terms. If these vessels become engaged in the deep-water snapper fishery, fishing effort will increase by approximately 50%. Although there is a high level of uncertainty regarding estimates of sustainable yield, this action will undoubtedly result in lower mean catch rates per vessel, and reduced profitability.

It is recommended that plans for the construction and sale of vessels at subsidized prices for use in the deep-water snapper fishery be halted.

7.4 Limitations on the number of commercial vessels

Other Pacific Island countries have recommended restricting the number of boats allowed to fish for deep-water snapper in their EEZ (e.g., 8 vessels from 15-20 m in Fiji, Lewis etal., 1988)

The most common way of limiting vessel numbers is through a vessel registration and licensing system. This method may be considered as an option, as policing the management measure is unlikely to be onerous due to the limited number of landing sites and processors. A corollary of this management measure would be to make it illegal for processors to purchase deep-water snapper from unlicensed vessels. If profitability from the fishery is maximized, a nominal license fee may be imposed to amortise the costs of managing and policing the fishery.

REFERENCES

Allen, G. R. 1985 Snappers of the world. An annotated and illustrated catalogue of lutjanid species known to date. FAO Fisheries Synopsis (125)6:208 p.

Beddington, Jr. R., and J. G. Cooke 1983. The potential yield of fish stocks. FAO Fish. Tech. Pap. 242, 47 p.

Beverton, R.J.H. an S.J. Holt. 1957. On the dynamics of exploited fish populations. Fishery Invest., London, Ser. 2, 19. 533 p.

Brouard, F., and R. Grandperrin. 1985. Deep-bottom fishes of the outer reef slope in Vanuatu. South Pacific Commission Regional Technical Meeting on Fisheries, New Caledonia. Working Paper 12, 127 p.

Gulland, J.A. 1983. Fish stock assessment. A manual for basic methods. John Wiley & Sons, 223 p.

Langi, S.A., and V.A. Langi. 1988. Progress report on a programme to assess bottom fish stocks on seamounts in Tonga. South Pacific Commission Workshop on Pacific inshore fishery resources, New Caledonia. Background Paper 34, 15 p.

Pauly, D. 1983. Length-converted catch curves: a powerful tool for fisheries research in the tropics. Fishbyte 1(2):9-13.

Polovina, J.J. 1986. A variable catchability version of the Leslie model with application to an intensive fishing experiment on a multispecies stock. Fishery Bulletin, U.S. 84(2):423-428.

Polovina, J. J., and S. Ralston. 1986. An approach to yield assessment for unexploited resources with application to the deep slope fishes of the Marianas. Fishery Bulletin, U.S. 84:759-770.

Polovina, J. J., R. B. Moffitt, S. Ralton, P. M. Shiota, and H. A. Williams. 1985. Fisheries resource assessment of the Mariana Archipelago, 1982-85. Marine Fisheries Review., U.S. 47(4):19-25.

Ralston, S. 1982. Influence of hook size in the Hawaiian deep-sea handline fishery. Can. J. Fish. Aqua. Sci., 39:1297-1302.

Ralston, S., and H. A. Williams, 1988. Depth distributions, growth, and mortality of deep slope fishes from the Mariana Archipelago. National Oceanic and Atmospheric Administration (USA) Technical Memorandum 113, 47 p.

REFERENCES (Continued)

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can., Bull. 191, 382 p.

Wetherall, J. A. 1986. A new method for estimating growth and mortality parameters from length-frequency data. ICLARM Fishbyte 4(1):12-14.

APPENDICES

APPENDIX A

Two computer programs were developed, written and installed on the computer at the Fisheries Centre, Sopu. These are compiled programs (*.EXE files) and may be run by typing the program's name, then striking the enter key.

The program BRAKEVEN was used to generate Figure 3, and should be used to update financial analyses as new information becomes available.

The program SNAPSIM was used to generate Figures 4 and 5, and may be used to simulate the fishery with updated information as it becomes available.

APPENDIX B

Although analyses were conducted on data for most major component species, the examples shown on the following page are for the longtail snapper, *E. coruscans*. From the top, the graphs are:

1) Length-frequency data
2) Wetherall plot
3) Analysis of mean length at first capture