Estimation of Deepwater Snapper Yield from Tongan Seamounts

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Abstract

The data from two years' monitoring of the Tongan seamount fishery were analyzed. K.R. Allen's model was used to obtain estimates of catchability and recruitment and of a surplus production of 737 kg per nautical mile (nm) of 200 m contour. This compared reasonably well to total landings. Using this estimate, the annual surplus production for Tonga's 294 nm of 200 m contour is 217 t. The level of fishing mortality was found to be 0.3/year.

Introduction

In October 1986, the Fisheries Division, Tonga implemented a five- to seven-year resource assessment program on the commercial fisheries for deepwater snappers and groupers in Tonga.

In August 1987, the first nine months' data were taken to Dr. J. Polovina at the Southwest Fisheries Center, Honolulu Laboratory and analyzed in order to check sampling design and establish baseline parameters for the stocks (Langi and Langi 1987). A second visit was made in October 1988, whose purpose was to make a more detailed analysis of the data which now covered two years. It was hoped that some preliminary estimates of production levels could be made specifically for Tongan seamounts, and that current exploitation levels could be assessed so that advice for management and development of this fishery would be available. This report documents some of the findings.

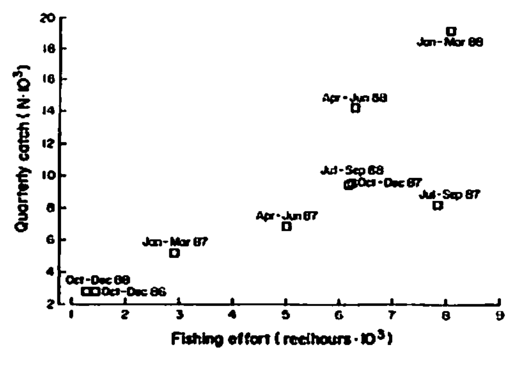

Fig. 1. *Quarterly catch vs. effort for all seamounts.*

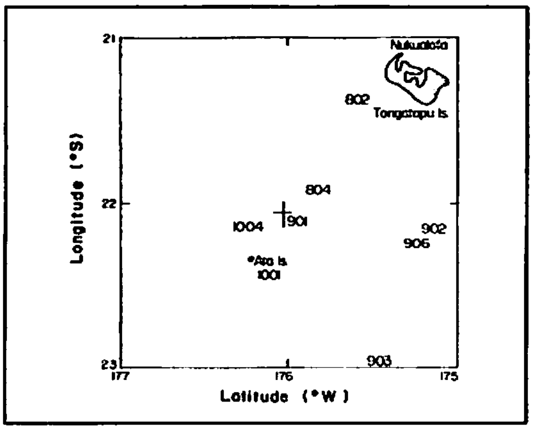

Fig. 2. *General locations of seamounts 802, 804, 901, 902, 903, 906, 1001 and 1004.*

Species

Six major species, comprising 80% of the total catch, are used in the analysis of the seamount fishery. The two main export species are *Pristipomoides filamentosus* and *Etelis coruscans*; of these, the former alone contributes 30% of the catch. The other four species are *P. flavipinnis*, *E. carbunculus*, *Epinephelus morhua* and *E. septemfasciatus*.

Fig. 1 shows a plot of total catch over total effort for all seamounts. If January 1988 is ignored (on the grounds that this represents unusually good weather conditions and a bumper harvest), the yield curve can be interpreted as plateauing out, i.e., increasing effort would not bring in substantially more fish.

Materials and Methods

In order to examine this, seamounts were chosen where coverage of the landings was complete and where the data covered a reasonable time span (Fig. 2). For each of these eight locations, catch per effort (C/f) was plotted over (a) time and (b) cumulative catch; except in the case of three seamounts, no depletion was apparent.

However, for these three seamounts, (1001, 1004, 901), (Figs. 3A, 3B and 3C), an initial sharp decline was followed by a period of constant C/f (Figs. 4A, 4B and 4C). Seamount 1004 showed the most dramatic decline from 4.3 to 1.0 fish per reelhour (rh).

In order to calculate catchability (q) and recruitment (R), a modification of Allen's model (Allen 1966) was fitted to the data from these seamounts; this model was derived by Sainsbury (1984) for an annual time series of catch and effort. We apply it to a monthly catch and effort series, where monthly catch (C_i) is expressed as a function of monthly effort (f_i), catchability (q) and monthly mean recruitment to the fishery and prior catch both adjusted for monthly natural mortality (M) as:

$$C_i = q\, f_i\,[(R/(1 - e^{-M})) - \sum_{j=1}^{i-1} C_j e^{-M(i-j)} - C_i/2]$$

By defining $A = q\,R/1 - e^{-M}$

and $$X_i = \sum_{j=1}^{i-1} C_j\, e^{-M(i-j)} + C_i/2$$

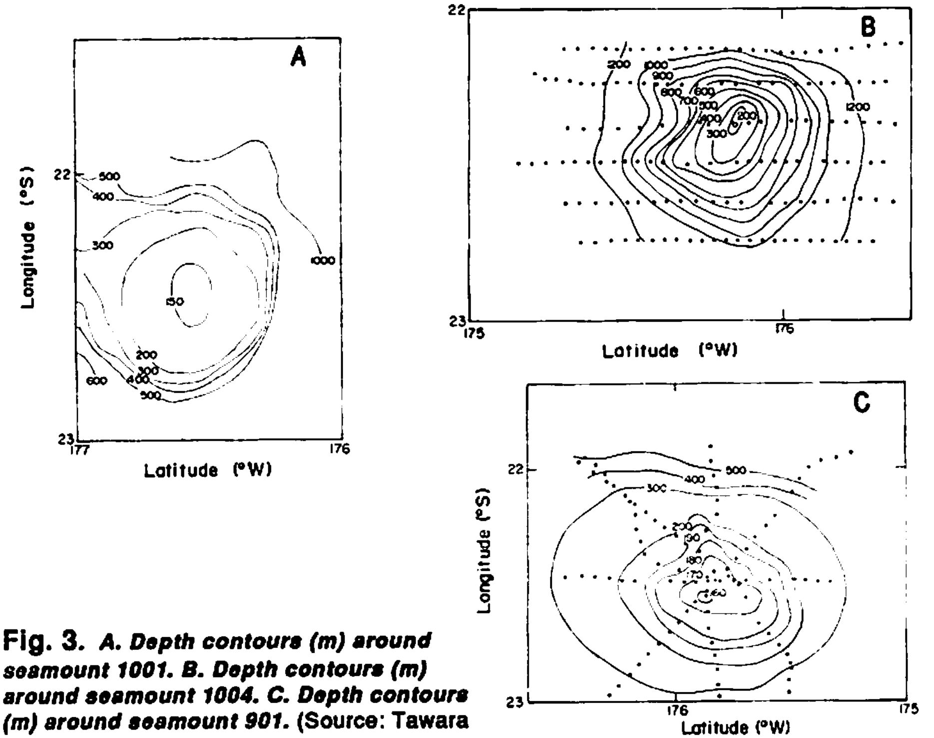

Fig. 3. ***A.* Depth contours (m) around seamount 1001. *B.* Depth contours (m) around seamount 1004. *C.* Depth contours (m) around seamount 901.** (Source: Tawara et al. 1987)

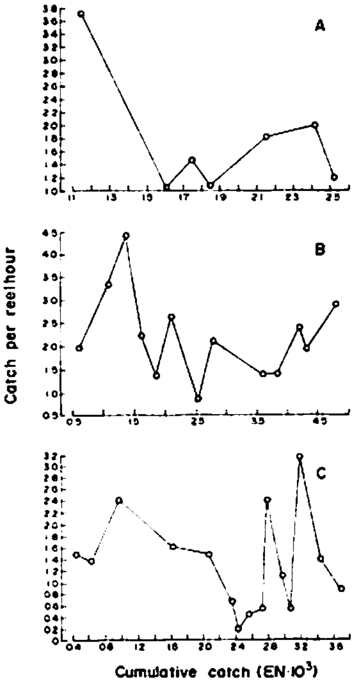

Fig. 4. ***CPUE x cumulative catch of major species at seamounts 1004(A), 1001(B), and 901(C).***

then assuming M is known, q and R can be estimated from the regression of monthly catch on f_i and X_i, as:

$C_i = A\ f_i - b\ X_i\ f_i$

where $q = b$ and $R = ((1 - e^{-M})/q)\ A$.

If there are months without any fishing, it is necessary to include a record of zero catch and effort in the time series so the natural mortality adjustments to prior monthly catches are correct. We have found that the model works best when there is a substantial decline in C/f early in the catch and effort time series.

Table 1. Values of q and R obtained from Allen's model.

Seamount	Length 200m	q	q/nm	R/month	R/nm/year	R^2
901	6.8	0.0009	0.006	131	231	0.88
1001	7.4	0.0002	0.0015	568	921	0.98
1004	1.2	0.002	0.0024	92.6	926	0.90

Average q/nm = 0.0033 Average R/nm/year = 693

Assumptions of the model are: M, q and R are constant.

An estimate of natural mortality of M = 0.04/month was used, as obtained by averaging estimates for the two main species obtained from the study in the Marianas (Polovina and Ralston 1986).

Results

The data showed a good fit, with R^2 = 0.88 to 0.98 (Figs. 5A, 5B and 5C). Table 1 gives the value of q and R obtained from Allen's model.

The sensitivity of the model to estimate natural mortality was tested by doubling its value. This led to q increasing by only 28%, implying the model was fairly robust. Thus we accept the estimates from Allen's model of q = .003/rh/nm, and the average R = 693 fish/nm/year; note, however, that this estimate of R represents short-term recruitment to the fishery and not necessarily long-term sustainable recruitment.

Using q = 0.003/rh/nm, fishing mortality was then calculated from F = qf. Fig. 1 shows that quarterly effort is approximately 7,000 rh, giving an annual effort of 28,000 rh. The approximate length of the 200 m contour isobath on seamounts is 300 nm. Thus:

f/nm = 28,000/300 = 93; F = 0.003 * 93 = 0.3/year.

Assuming M = 0.48/year, then F is about 0.6 times natural mortality. This is a conservative value, since at this level of F/M, when the size of entry exceeds the size of onset of maturity, the spawning stock biomass is about 50% of the level in the unexploited stock (Polovina 1987).

To calculate equilibrium or long-term surplus production, the following steps were taken; assuming q = 0.003:

Taking the average C/f on lightly fished seamounts of 2.3 fish/rh (Langi and Langi 1987), the standing stock (N) is 2.3/0.003 or 698 fish/nm. Using the average weight of 4.4 kg, estimated from catches of the six main species from 1987 when the seamounts were lightly exploited gives an unexploited biomass of 3,071 kg/nm.

The ratio of maximum sustainable production to unexploited biomass was then estimated with three different approaches for snappers and all approaches gave very similar estimates (Polovina and Ralston 1986). The mean of the estimates from the three methods for *Pristipomoides filamentosus* and *Etelis coruscans* gives an estimate of P/B = 0.24 (Polovina and Ralston 1986); thus

$$P = 0.24 * 3,071$$
$$= 737 \text{ kg/nm/year.}$$

When the stocks are being fished at MSY level, the mean weight of the fishes will be less than the 4.4 kg estimated at the unexploited level. If we assume the mean weight at MSY to be 2.0 kg, slightly below the current level of 2.4 kg, then the MSY translates into 369 fish/nm/year. This is the estimate of number of fish which can be harvested on a sustainable basis, with F_{MSY} = 1.0/year. Current F is about 0.3/year so current effort is considerably less than the effort which achieves MSY.

In order to compare this estimate of long-term surplus production with short-term catch rates, the data from three seamounts for the time period *after* initial depletion were examined. Here, catch/nm was plotted over annual effort/nm (Fig. 6A); also annual C/f was plotted over annual effort/nm (Fig. 6B).

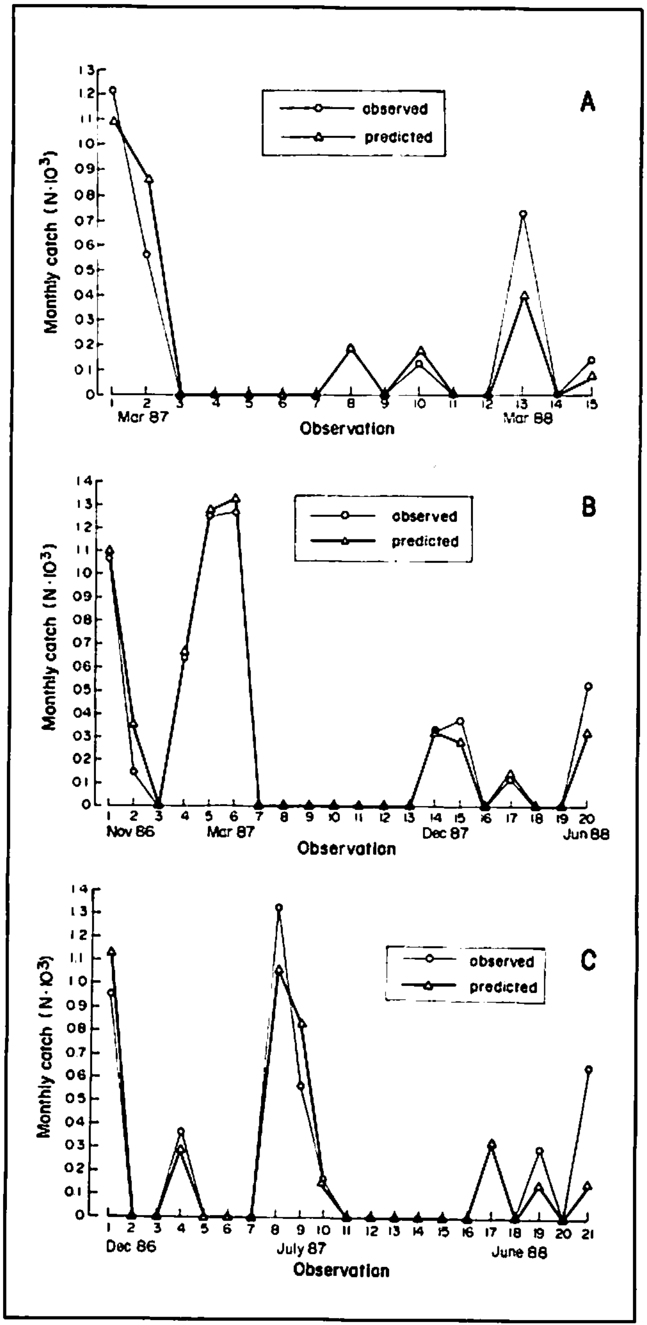

Fig. 5. *Allen's model fitted for seamounts 1004 (A), 1001 (B) and 901 (C).*

Fig. 6A shows the range of "sustainable" catch from 200 fish/nm to 1,100 fish, while Fig. 6B shows C/f ranging from 0.85 to 2.3 fish/rh and annual effort of up to 850 rh/nm.

At seamount 901, during the period of stable catches, an annual catch of 190 fish/nm of the main species were removed; since the species recorded contribute 80% to total catch, this brings the figure up to 237 fish/nm. Similarly, at 1001, 386 fish/nm were harvested. These two figures are fairly close to the above estimate of 369 fish/nm and therefore may be sustainable in the long term.

At seamount 1004, however, a very high figure of 1,403 fish/nm were harvested. On closer examination of 1004, the catches of *P. filamentosus* dropped considerably and did not recover, with the catches switching to other species, especially *E. coruscans* (Fig. 7). This switch in species coincided with effort occurring at greater depths. If the reason for this was the decline of *P. filamentosus*, then presumably the overall catch rate would not be sustainable in the long term, as each species would in turn be depleted.

This change in species composition may well be an indicator of excess fishing pressure.

Discussion

Using the surplus production estimate of 737 kg/nm/year, the 294 nmi of 200 m contour for all known seamounts in Tonga gives an annual yield of 217 t.

For the year 1987, an estimated 343 t were harvested from the seamounts; for the first six months of 1988, a further 363 t were landed. These levels are too high to be sustained in the long term if the fish on the seamounts are self-recruiting populations.

However, if fish simply recruit onto the seamounts from the larger banks, thus enabling us to think of the seamounts more as large fish aggregating "devices", then obviously much higher levels of catch could be taken from the seamounts if the spawning stock on the banks is protected. However, this question concerning recruitment onto the seamounts cannot yet be answered. Indeed, this question may remain open for a long time, because as catch rates on a particular seamount fall to uneconomic levels, the fishers move to other seamounts and no further catch data become available.

The estimate of 737 kg/nm/year for Tonga is about three times the yield estimates for the Hawaiian Archipelago and the Marianas. The average yield range for the Marianas was 165-279.6 kg. The lower bound estimate for the Hawaiian Archipelago was 272 kg. A second estimate of 286 kg was derived from an ecosystem model in the

North West Hawaiian islands (Ralston and Polovina 1982; Polovina 1984; Polovina and Ralston 1986).

Possible factors which may contribute to observed differences include:

- a) a longer time period is covered by the Tongan data than from the Marianas, thus enabling seasonal fluctuations and other short-term effects to be averaged out;
- b) the Hawaiian estimate did not include the recreational fishery and the total yield could be 2-3 times higher;
- c) the Tongan production estimates are for seamounts while the other estimates refer to larger banks and production per length of the 200-m isobath may not be comparable between seamounts and banks due to their different topographies; and
- d) the Tongan seamounts may simply be more productive.

Problems

Complete reliance on fishers for recording hours of effort, location and depth is a major constraint on accuracy (Langi 1988); however, excellent cooperation has been given by the Tongan fishers and we trust that our results do not suffer from major bias.

However, lack of accurate bathymetry for all but a few seamounts limits the number of locations where detailed analysis can be done. The estimate of 294 nm of 200 m contour for all Tonga's seamounts is also affected by this.

Despite these problems, this analysis of the seamount fishery has enabled catchability and hence surplus production estimates to be made using catch and effort data from Tonga. This suggests that the present sampling method is sufficient for monitoring the bottom fish stocks.

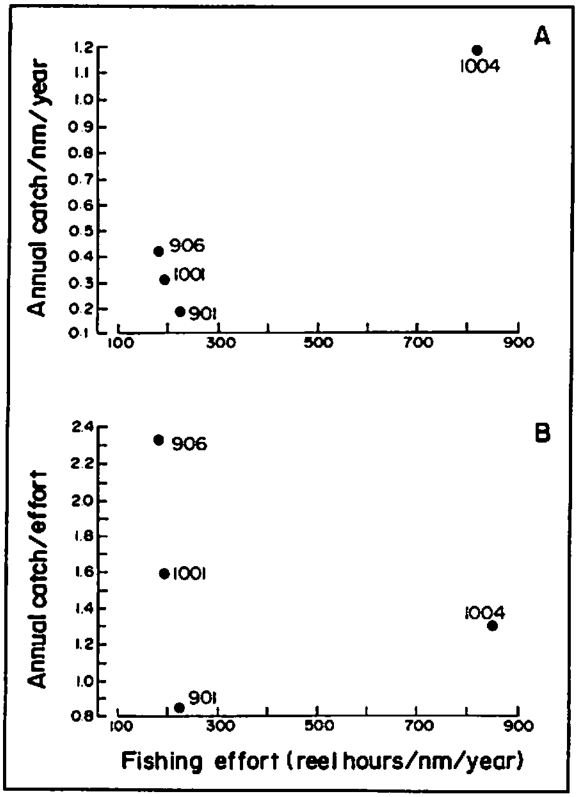

Fig. 6. *Average annual catch/nmi vs average annual fishing effort/nmi from October 1986 to September 1988 (A). Average annual catch/effort vs average annual fishing effort /nmi from October 1986 to September 1986 (B).*

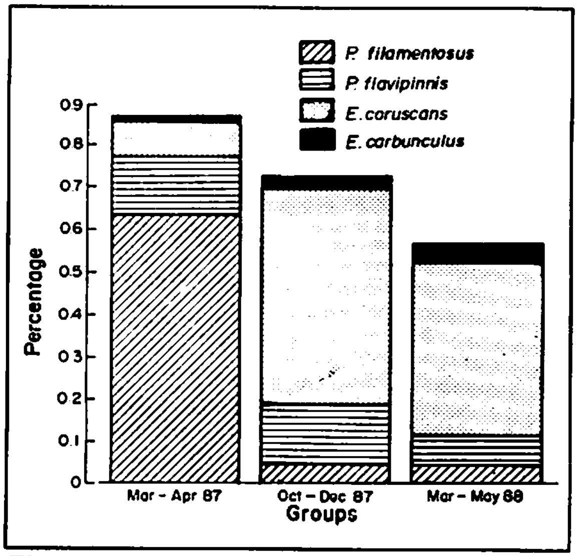

Fig. 7. *Changing species composition over time at seamount 1004.*

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