Stock Assessment of Indian Ocean Yellowfin Tuna *(Thunnus albacares)* Based on Data from a Sport Fishery

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Introduction

Formerly mainly a longline fishery, yellowfin tuna catches in the Indian Ocean increased dramatically with the advent of distant-water purse seiners in 1982, the expansion, from 3% of total catch in 1982 to 60% in 1984, being accompanied by worries of overexploitation. This paper presents a novel assessment of the Indian Ocean yellowfin tuna stock. Data from a well-documented sport fishery in the Pemba Channel off the Kenya-Tanzanian border are used in conjunction with commercial catch figures for the Indian Ocean.

Materials and Methods

From 1976 to 1986, the catch of 4245 yellowfin tuna by the seasonal (October-January) sport fishery at the Pemba Channel Fishing Club, Shimoni, Kenya, was carefully recorded; each tuna was weighed to the nearest kg. Fishing effort, which varied from year to year, was recorded as boat fishing days.

The sport fishery catch fell into three major groups by size, usually represented by separate modes in weight-frequency plots. Group A comprised tuna less than 10 kg, group B were approximately 15-30 kg, while group C were 35-50 kg: small numbers of larger tuna in the catch were excluded from this analysis. The weight-frequency distributions were dissected into normal components using mixture analysis (MacDonald and Pitcher 1979) and the proportions standardized across years by fishing effort. The standardized numbers are listed in Table 1 together with total catch in the sport and commercial fisheries.

Time-series cross-correlation analyses were carried out, using the standardized numbers, between groups A and B, and between B and C. For each analysis, the peak correlation occurred with a lag of one year. (Cohort A: lag of 0 years, $r^2 = 0.002$; 1, 0.544; 2, 0.130; 3, 0.132; 4; 0.006; 5, 0.005. Cohort B: lag 0 years, $r^2 = 0.031$; 1, 0.250; 2, 0.005; 3, 0.189; 4,

Table 1. Mortality rates of yellowfin tuna caught in the Pemba Channel sport fishery (values used in our best fishery assessment in bold). Numbers of fish in each cohort were derived from mixture analysis on the weight distributions standardized using fishing effort. The total commercial catch for the Indian Ocean was taken from FAO statistics (FAO 1985, 1986, 1987, 1988).

	Catch		Cohorts			Mortality		
	Commercial	Sport		Standardized no.			Annual Inst. Rate	
Year	t	no.	a	b	c	Z_{AB}	Z_{BC}	Z_{AV}
1976	30,090	503	377	29	6	-	-	-
1977	50,898	410	130	78	2	1.58	2.67	**2.12**
1978	44,683	325	64	33	9	1.37	2.16	**1.77**
1979	36,982	326	90	1	3	4.16	2.40	**3.28**
1980	34,064	551	148	11	1	2.10	0.00	**1.05**
1981	36,435	477	52	59	12	0.92	0.00	**0.46**
1982	46,828	418	31	40	24	0.26	0.90	**0.58**
1983	60,663	185	33	5	17	1.82	0.83	**1.34**
1984	93,503	126	23	1	12	**3.50**	0.00	1.75
1985	100,768	317	71	6	4	**1.34**	0.00	0.67
1986	114,243	465	20	88	2	0.00	**1.10**	1.10
1987	128,880	142	-	-	-	1.30	2.01	**1.66**

0.015; 5, 0.052.) We concluded that the groups represent tuna cohorts generated on an annual cycle.

The proportions of cohorts from mixture analysis can be used to calculate mortality (Koranteng and Pitcher 1987). Accordingly, we calculated annual instantaneous mortality rates for tuna in cohort A to cohort B in the following year (Z_{AB}); and from cohort B to cohort C (Z_{BC}, see Table 1). The average of these two rates, Z_{AV}, was generally taken as our best estimate of total tuna mortality. Where comparison of the numbers in a cohort produced zero or small increases, we took these as indicating low mortality estimated as zero. In 3 of the 22 estimates, large increases in the standardized cohort numbers occurred for one of the pair of cohort comparisons: in these instances, we took the mortality value from the other pair of comparisons. Our best values of mortality used in subsequent analysis are indicated in bold face in Table 1.

Following Csirke and Caddy's method (Csirke and Caddy 1983), the estimated mortality rates were plotted against total Indian Ocean catch and a symmetrical parabola fitted using least squares regression. In this method, the peak of the parabola indicates maximum sustainable yield, while its location on the mortality axis gives Z_{opt}. Its lower intercept with the mortality axis estimates natural mortality M. A negative estimate of M resulting from the initial fit was considered unacceptable, and so we constrained the origin of the parabola to a natural mortality rate of M = 0.25 year^{-1}.

Results and Discussion

Our best estimate for the long-term maximum sustainable yield (MSY) for Indian Ocean yellowfin tuna was around 113,000 tons per annum, to be achieved with a fishing mortality rate (F_{opt}) of 1.94 year^{-1} (Fig. 1). While wide statistical confidence limits can be attached to this estimate, we prefer to compare estimates using alternative mortality values in assessing the validity of the Csirke and Caddy value. Several alternative fits of the model, using other selections of mortality values, gave MSYs in the range 67-125,000 tons and F_{opt} from 1.9 to 2.6 year^{-1}.

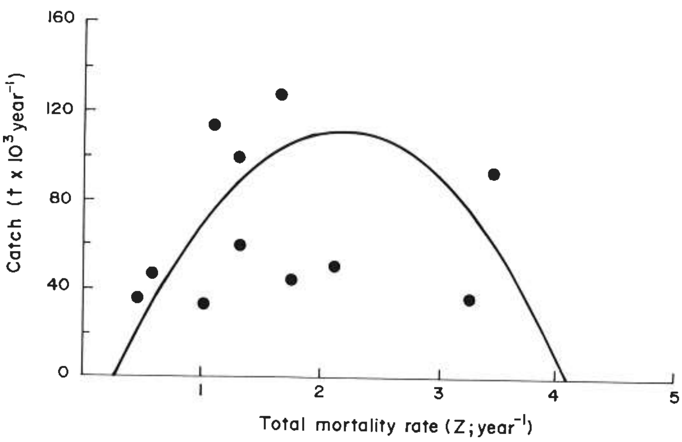

Fig. 1. Assessment of Indian Ocean yellowfin tuna stock total mortality rate, Z, estimated from annual sport fishery data from the Pemba Channel Fishing Club, Shimoni, Kenya, plotted against total Indian Ocean commercial catch. Caddy and Csirke parabola fitted by least squares: $Y = -30.31 + 131.12Z - 30.00Z^2$.

Our method assumes that changes in the Indian Ocean yellowfin tuna stock are reflected in the effort-standardized catches from the Pemba Channel sport fishery. This is tenable, provided that tuna caught by the sport fishery are unbiased by size. Although our catch data are standardized by boat-day effort, on any one day, smaller tuna are more voracious while larger fish take longer to subdue. A consequent overestimate of the numbers of smaller tuna would bias the mortality rates. A more important assumption of the method is that the documented catches are equilibrium values. However, this criticism applies to all methods used on this stock to date. Accordingly, we suggest that our results be viewed with caution.

Most Indian Ocean yellowfin tuna assessments have been made using only long-line data (MSY = 39-58,000 t, FAO 1980). The accuracy of this method has been questioned (Miyabe and Koido 1985), and Marcille (1985) guessed that the true MSY would be 3-5 times greater. For the Indian Ocean, our value of MSY is less than the lower end of Marcille's range but nearly twice as much as previous estimates. Marcille (1985) suggested that the purse seine fishery may exploit a different part of the yellowfin tuna stock from the longliners, and that it is difficult to conflate data from the two fisheries. Since most tuna in the Indian Ocean stock pass the Pemba Channel during the Southeast monsoon as part of their annual migration (Williams 1962; Morita and Koto 1971), our sport fishery data may permit a more accurate assessment to be made. Using Marcille's correction, the MSY of the Western Central Pacific yellowfin tuna is about 210,000 t (Susuki 1985), about the same as the current catch. In contrast, even a cautious interpretation of our results for the Indian Ocean stock suggests that catch levels now exceed MSY by a dangerous margin.

References

Csirke, J. and Caddy, J.F. 1983. Production modelling using mortality estimates. Can. J. Fish. Aquat. Sci. 40: 43-51.

FAO. 1980. State of selected stocks of tunas and billfish in the Pacific and Indian Oceans. Summary report of the workshop on assessment of selected tunas and billfish stocks in the Pacific and Indian Oceans, Honolulu Laboratory, Southwest Fisheries Center, NMFS and The Far Seas Fisheries Research

Laboratory of the Fisheries Agency of Japan, Shimizu, Japan. FAO Fish. Tech. Pap. 200:1-89.

FAO. 1985. Report on the expert consultation on the stock assessment of tunas in the Indian Ocean. IPTP/86/GEN/11

FAO. 1986. Indian Ocean fishery data summary for 1984. IPTP Data Summary No. 5.

FAO. 1987. Indian Ocean fishery data summary. IPTP Data Summary No. 7.

FAO. 1988. Indian Ocean and Southeast Asian tuna fisheries data summary for 1986. IPTP Data Summary No. 8.

Koranteng, K. and T.J. Pitcher. 1987. Population parameters, biannual cohorts and assessment in the *Pagellus bellottii* (Sparidae) fishery off Ghana. J. Cons. CIEM 43: 129-138.

MacDonald, P.D.M. and T.J. Pitcher. 1979. Age groups from size-frequency data: a versatile and efficient method of analyzing distribution mixtures. J. Fish. Res. Board Can. 36: 987-1001.

Marcille, J. 1985. Interaction between longline and surface fisheries for yellowfin tuna, p. 217-229. *In* Collective Volume of Working Documents presented at the expert consultation on stock assessment of tunas in the Indian Ocean, Colombo, Sri Lanka, December 1985, TWS/85/35.

Miyabe, N. and T. Koido. 1985. Production model analysis on bigeye and yellowfin tunas in the Indian Ocean, based on longline fishery data, p. 71-83. *In* Collective Volume of Working Documents presented at the expert consultation on stock assessment of tunas in the Indian Ocean, Colombo, Sri Lanka, December 1985, TWS/85/27.

Morita, Y. and T. Koto. 1971. Some considerations on the population structure of yellowfin tuna in the Indian Ocean based on the longline fishery. Bull. Far Seas Fish. Res. Lab. 4: 125-140.

Susuki, Z. 1985. Interaction study on yellowfin stock between longline and purse seine fisheries in the Western Pacific, p. 175-190. *In* Collective Volume of Working Documents presented at the expert consultation on stock assessment of tunas in the Indian Ocean, Colombo, Sri Lanka, December 1985, TWS/85/26.

Williams, F. 1962. The scombrid fishes of East Africa, p. 107-164. *In* Symposium of Scombrid Fishes. Part 1. Mar. Biol. Assoc., India.

Fisheries Development in the Kingdom of Tonga*

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Introduction

Reef and lagoon fish have been traditional sources of protein for the inhabitants of the Kingdom of Tonga (Halapua 1982). These inshore resources have become increasingly reduced and cannot keep pace with present rates of exploitation.

A major limitation facing most local fishermen is the lack of suitable vessels to fish beyond traditional inshore grounds (Ottesen 1984). This paper summarizes efforts by local and foreign organizations to improve artisanal fisheries in Tonga through the introduction of improved fishing vessels and associated training programs.

Demonstration Boat Program

The Tonga Ministry of Agriculture, Forestry and Fisheries (MAFF) in conjunction with Japanese Grant Aid and the United Nations Country Development Fund (UNCDF) implemented a boat building program in 1983 to develop crafts capable of exploiting the underutilized offshore resources of the Kingdom (MAFF 1984).

The principal aim of the demonstration boat plan was to train and financially prepare promising artisanal fishermen to purchase these MAFF/UNCDF vessels (Friedlander 1984).

A 6-m diesel vessel was purchased by the Foundation for the People of the South Pacific (FSP) and introduced to the island of 'Eua as part of the demonstration project. All of the existing fishing boats on the island were open 4-6 m locally-built dories with 15-25 horsepower outboard engines.