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PRELIMINARY YIELD ASSESSMENT FOR YELLOWFIN AND SKIPJACK TUNA STOCKS EXPLOITED BY SRI LANKA'S COASTAL AND OFFISHORE FLEETS

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Abstract

This preliminary assessment utilised monthly catch and fishing effort data available for 1994. Estimates were made for the biomass recruiting to the fishery in each month. These were in turn used within a Thompson and Bell type fishery model, to obtain predictions of the catches likely to result from increased fishing effort. The findings suggest that considerable scope exists to increase the catches of both yellowfin and skipjak. It was necessary to make assumptions concerning the number of zero age recruits, and the proportion of these subsequently entering the Sri Lankan fishery. The associated sensitivity analyses showed that the findings are only marginally affected by deviations from the assumptions.

Key words: Yellowfin tuna, skipjack tuna, yield assessment, Sri Lanka

1. Introduction

The fishery is based on the exploitation of migratroy resources of yellowfin and skipjack tunas, other smaller tunas, billfish and sharks. The coastal (within theshelf) component mostly involves the use of 1/2 ton boats, powered by in-board engines of 26-30 HP. There were 1,362 of these boats registered in 1995, which is about half the number recorded for 1984. Many have been converted for use in the offshore fishery, by lengthening and out-fitting with ice-boxes. In the coastal fishery, the boats are operated on a day-trip basis. Departure from port occurs at about midday, with the nets being set before dusk and recovered in the early morning. The outer extent of the fishing area is about 6 hours travel from port.

Drift gillnetting is the principal fishing method, usually accompanied by trolling, while fishing with pole and line and longlining are relatively unimportant. The soak-time for the nets is typically in the range from 6 to 8 hours. The number of nets per boat is about 20 to 3O pieces, with each piece being 150 m. in length.

During the monsoon period (May - October) the boats are engaged in more than 20 fishing trips per month, and about half this number in the remaining months. The production from the coastal fishery in 1994 was 20,217 in. ton from a fishing effort of about 200,000 boat-days (Williams, 1995).

The offshore fishery is an extension of the coastal fishery on the same resources. It commenced from the mid-1980s, following the success of demonstration fishing under the Northwest Coast Fishery Development Project, financed from the Abu Dhabi Fund (Joseph, 1994). About 1,400 boats are thought to have been operating during 1995. These are referred to as the multi- day boats, as fishing trips are typically of 6 to 9 days in duration. The majority, of the boats are 34 - 36 feet in length, and powered by inboards of 40 HP (Joseph et al. 1995).

The outer extent of the offshore fishing area is about 36 hours travel from port; although some boats are engaged in more distant waters. As in the coastal fishery, drift gillnets are the predominant fishing gear. Most boats are operated with about 40 nets, each of 150 m in length. Mesh sizes are in the range of 4 1/2" to 7" (stretched), with 6" mesh being by far the most common. The nets are set prior to dark and recovered in the early morning. The hauling of the nets is done manually. Increasingly, troll lines and longlines are being used in association with gillnetting. The estimated production from the offshore fishery in 1 994 is 54,704 m. ton from a fishing effort of about 250,000 boat-days (Williams. 1 995). The catches are stored on ice.

Tunas accounted for about 50% of the landings from both the coastal and offshore fisheries in 1994. Yellowfin and skipjack were the predominant species, especially in the offshore fishery where they were 46 % of the total, compared with 36 % in the coastal fishery. These were fish mostly in the 40 - 70 cm length range, The other important tunas were kawakawa and frigate tuna. Nearly 30% of the landings from offshore were shark This group is less important in the coastal fishery, where they accounted for 5 %. The other group of major importance were the billfish. contributing nearly 15 % of the landings from of Fshore 27 % of the coastal landings.

The offshore fishery has developed dramatically during the past decade, and is expecte, to expand further. The construction of additional boats is being encourage, through loans schemes and subsidies provided by the government. Plans for fishing harbour rehabilitation and construction are on the drawing board. As such, it has become increasingly important to assess whether the resources are able to sustain the anticipated increase in exploitation, and particularly to determine the likely trends in future catches and catch rates from increases in fishing effort. This could not be done from applying a production model, in the absence of a time series of annual catch and effort data. It was necessary to develop the less conventional approach described here.

2. Materials and Method

An improved system for monitoring the production from driftnets and pelagic long lines was introduced from January 1994. This was done through assistance to the National Aquatic Resources Agency (NARA) from the FAO Technical Cooperation Programme (FI:TCP/SRL/2251). Estimates of landings, fishing efforts and catch rates resulting from this work are given in Williams (1995). These estimates were used as inputs in the analyses. Separate analyses were undertaken in respect to the yellowfin and skipjack, and for each of the coastal and offshore components of the fishery. The method has five parts general desciptions of these are provided below. More detailed information is given in the works depicted in Table1,2 and 3. These include the values used for the inputs, and the operative equations.

Estimation of annual recruit biomass:

The objective of this first part was to obtain estimates for the mean biomass of the yellowfin and skipjack stocks being recruited annually into the Sri Lankan fishery. The worksheet depiction of this and the next part are given in Table 1. The starting procedure in respect to yellowfin was to assume the number of zero aged fish which recruit to the Indian Ocean stock. The alternative value of 60, 90 and 120 million were chosen as being representative of low,intermediate and high levels of recruitment. They are from the sequential population analysis (SPA) reported in Anonymous (1992). No indicators of the annual recruit numbers for skipjack, were found in the literature. As such, it was necessary to 'back-calculate' these, on the assumption that the fishing mortality coefficients (front exploitation in the Sri Lankan fishery) were the same as for the yellowfin.

Table 1: Estimation of exploied srock stock biomass.

Imputs		Equations
Stock no at zero age-yellowfin	Noy =	90,000 '000
Stock no. at zero age - skipjack	Nos =	609.675 '000
Area occupied by stock - yelowfin	ASy =	5,600 '000 km^2
Area occupied by stock - skipjack	ASs =	4,800 '000 km^2
Area of fishing ground - offishore	Ao =	340 '000 km^2
Area of fishing ground - coastal	Ac =	57 '000 km^2
Natural mortality coef - yellowfin	My =	0.6 /yr.
Natural mortality coef - skipjack	Ms =	0.8 /yr.
Fishing mortality (pre-recruit) - yellowfin	F1y =	0.0 /yr
Fishing mortality (pre-recruit) - Skipjack	F1s =	0.0 /yr
Av. indiv. weight (age 1) -yellowfin	Wy =	5.0 kg
Av. indiv. weigth (age 2) - skipjack	Ws =	3.0 kg

B4 = No. exp(-(M+F1).t).w.A/AS
F2 = Y/B4
q = F2 X
B4 = Y'(X'.q)
Nos = (sum(Y's)/(F2y)(exp(-Fis-Ms).t ws. A/ASs

when F1 is the fishing mortality coef. prior to petering the Sri Lankan Fishery, and it is the mean age for the fish entering the fishery. the F2 is the fishing mortality coef. applying within the fishery.

Note: Stock no. for skipjack is estimated, on assumption that F2y = F2s.

			Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	sums/means
Observations:															
Fishing efforts	X' =	boat-days					(Offshore fishery - 1994)								
Catch weights - yellowfin	Yy' =	metric ton	20,179	16.613	22,553	18,992	22,553	22,553	23,740	22.553	16,618	17,805	24,927	21,366	250,457
Catch weights - skipjack	Ys' =	mertic ton	972	513	667	353	423	1,437	565	795	974	741	967	832	9,239
Catch rates - yellowfin	CPUEy'=	kg/day	879	925	955	815	1,614	4,777	1,770	664	585	794	1,247	1,092	16,117
Catch rates - skipjack	CPUEs' =	kg/day	48.2	30.9	29.6	18.6	18.8	63.7	23.8	35.3	58.6	41.6	38.8	38.9	36.9
			43.6	55.7	42.3	42.9	71.6	211.8	74.6	29.4	35.2	44.6	50.0	51.1	64.4
Fishing efforts							(Coastal Fishery - 1994)								
Catch weights - yellowfin	X' =	boat-days	11.844	10,660	11,844	9,870	14,312	19,740	15.101	18,358	21,714	24,675	21,220	22,010	201,348
Catch weights - skipjack	Yy' =	metric ton	197	50	143	46	53	228	93	300	193	28	312	219	1,862
Catch rates - yellowfin	Ys' =	merric ton	233	504	463	211	316	740	938	854	354	211	87	519	5,430
Catch rates - skipjack	CPUEy'=	kg/day	16.6	4.7	12.1	47	3.7	11.6	6.2	16.3	8.9	1.1	14.7	10.0	9.2
Estimates:	CPUEy'=	kg/day	19.7	47.3	39.1	21.4	22.1	37.5	62.1	46.5	16.3	8.6	4.1	23.6	27.0
Est. biomass (age 1) - yellowfin	By4 =	14,994 metirc ton													
Est. biomass (age 2) - skipjack	Bs4 =	26,157 metric ton													
Est. fishing mort. coef. - yellowfin	F2y =	0.616					(Offshore Fishery - 1994)								
Est. fishing mort. coef. - skipjack	F2s =	0.616													
Est. catchability coef. - yellowfin	qy =	2,460E -05													
Est. catchability coef. - skipjak	qs =	2,460E -06	Jan	Feb	Mar.	Apr.	May	Jun	Jul	Aug	Sep	Oct.	Nov.	Dec	
Est. monthly exploited biomass- yellowfin	By4' =	metric ton	19,579	12,548	12,021	7,555	7,624	25,899	9,674	14,328	23,824	16,917	15,769	15,828	
Est. monthly exploited biomass - skipjack	Bs4' =	metric ton	17,706	22,625	17,212	17,443	29,089	86,097	30,306	11,967	14,309	18,126	20,334	20,775	
Est. biomass (age 1) - yellowfin	By4 =														
Est. biomass (age 2) - skipjack	Bs4 =	2,514 metric ton					(Coastal Fishery - 1994)								
Est. fishing mort. coef. - yellowfin	F2y =	4,385 metric ton													
Est. fishing mort. coef. - skipjack	F2s =	0.741													
Est. catchability coef - yellowfin	qy =	3,679 -06													
Est. catchability coef - skipjack	qs =	6,150 -06	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Est. monthly exploited biomass - yellwfin	By4'=	metric ton	4,521	1,275	3,282	1,267	1,007	3,140	1,674	4,442	2,416	308	3,997	2,705	
Est. monthly exploited biomass - skipjack	Bs4'	metric ton	3,199	7,688	6,356	3,476	3,590	6,096	10,100	7,564	2,651	1,390	667	3,834	

Literature values for the natural mortality rates were then applied to determine the numbers of these fish surviving to the mèan age at which they are exploited off Sri Lanka. The fishing mortalities applying, prior to exploitation off Sri Lanka, were assumed to be zero. The mean ages were taken as 1 year for yellowfin and two years for skipjack; based on the observed size compositions of the fish in the catches and published growth rates. Next, the area of the Sri Lankan fishing ground was determined as a proportion of the area occupied by each stock (Figure 1,2 and 3). The same proportions were used to estimate the numbers of fish recruiting to the Sri Lankan fishery, on the assumption that the fish were evenly distributed across the ocean. The products of the estimated numbers and the observed mean individual weights provided the required estimates for the mean recruit biomass (annual).

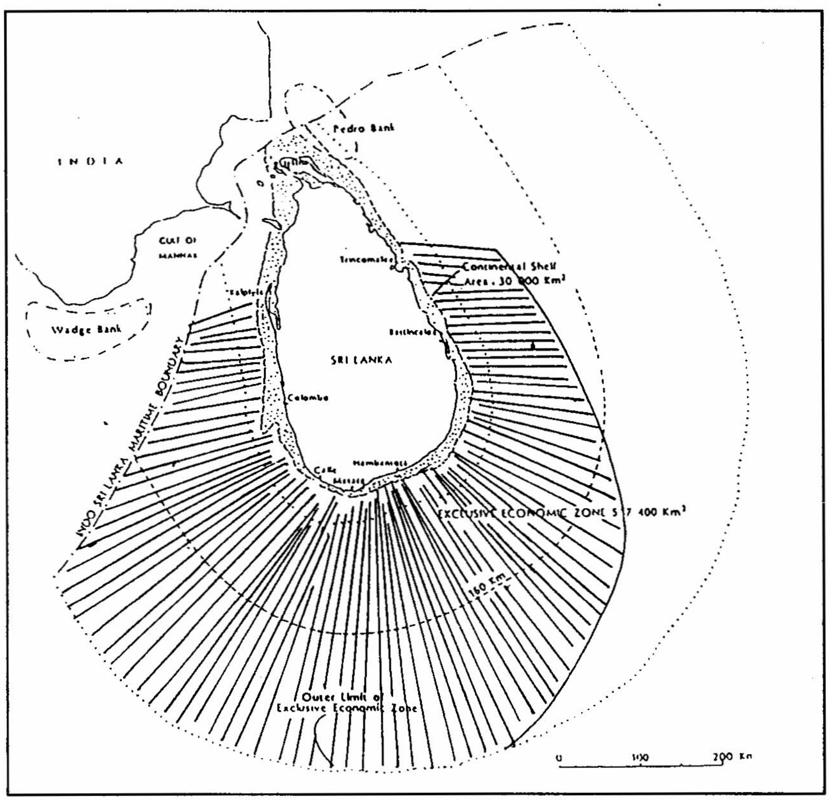

Fig 1. Depiction of the Coastal and Offshore fishing ranges used in the model.

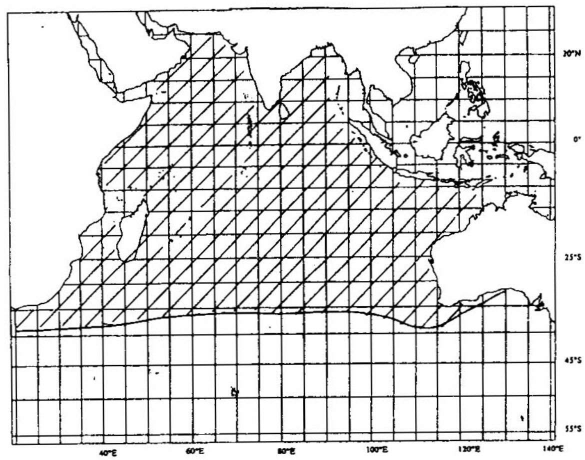

Figure 2. Distribution of yellowfin tuna in the Indian Ocean

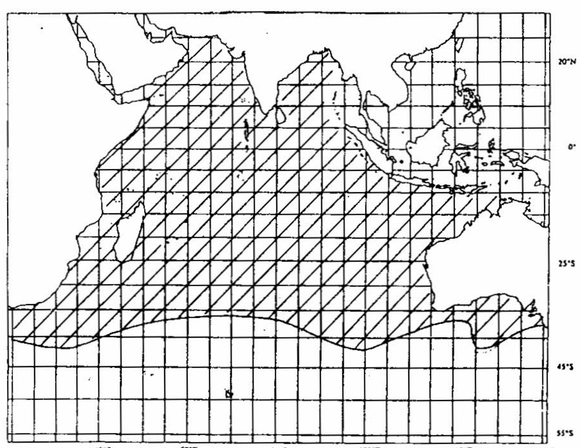

Fig 3. Distribution of skipjack tuna in the Indian Ocean

Estimation of mean exploited biomass in each month

The data required for this part were the observed monthly catch weights and fishing efforts for the Sri Lankan fishery. Values for 1994 were provided by the National Aquatic Resources Agency (NARA) bised on the work of Williains (1995). The annual catch weights,divided by the estimates for the annual mean recruit biomass (from 2.1), provided estimates of the fishing mortality, coefficient (annual) for each species. These annual mortalities were then distributed between the months in proportion to the monthly fishing efforts (assuming the relationship between fishing mortality and fishing effort remained coiistaiit). Estimates for the mean biomass present in each month, were then estimated by dividing the monthly catch weights by the respective monthly fishing mortality coefficients.

Estimation of net recruitment of biomass for each month:

Here the initial procedure was to plot the monthly estimates for the mean biomass against the mid-point of each month. and to 'read' from the plots the associated values for the biomass at the beginning and end of each month. This was done electronically by cubic spline fitting as describbed Hamming (1973). Next, estimates were obtained for each month of treat weight of biomass dying as the consequence of natural mortality. These were determined as the products of the mean biomass for each month and the respective monthly Value for the natural mortality coefficient. The net recruitment of biomass in each month was then estimated from the difference between the biomass at the beginning and end of each month, after accounting for the losses from capture and natural mortality. The worksheet depiction of this part is shown in Table 2.

Table 2: Estimation of monthly net recruit biomass.

Month	Start biomass -yellowfin	Start biomass -skipjack	End biomass -yellowfin	End biomass skipjack	Mean biomass -yellowfin	Mean biomass -skipjack	Catch weight -yellowfin	Catch weight -skipjack	Natural death weight -yellowfin	Natural death weight -skipjack	Net recruit biomass -yellowfin	Net rectuit biomass -skipjack
	(Metric ton)											
	By1'	By1'	By3'	By3'	By4'	By4'	Yy'	Ys'	Dy'	Ds'	By2'	Bs2'
	(Offishore fishery - 90 mill wero mill. zero age recruits)											
Jan.	17,789	19,014	15,822	20,879	19,579	17,706	972	879	979	1,180	-16	3,924
Feb.	15,822	20,879	11,923	20,164	12,548	22,625	513	925	627	1,508	-2,759	1,718
Mar.	11,923	20,164	10,514	17,390	12,021	17,212	667	955	601	1,147	-141	-672
Apr.	10,514	17,390	4,823	16,373	7,555	17,443	353	815	378	1,163	-4,960	961
May.	4,823	16,373	18,572	63,811	7,624	29,089	423	1,614	381	1,939	14,553	50,991
Jun.	18,572	63,811	19,423	65,512	25,899	86,097	1,437	4,777	1,295	5,740	3,583	12,218
Jul.	19,423	65,512	8,755	13,930	9,674	30,306	565	1,770	484	2,020	-9,619	-47,792
Aug.	8,755	13,930	20,781	12,853	14,328	11,967	795	664	716	798	13,537	385
Sep.	20,781	12,853	21,135	16,257	23,824	14,309	974	585	1,191	954	2,519	4,943
Oct.	21,135	16,257	15,570	19,411	16,917	18,126	741	794	846	1,208	-3,978	5,156
Nov.	15,570	19,411	15,511	21,061	15,769	20,334	967	1,247	788	1,356	1,696	4,253
Dec.\	15,511	21,061	17,789	19,014	15,828	20,775	832	1,092	791	1,385	3,901	430
Sums							9,239	16,117	9,078	20,399	18,317	36,516

Note: The values in the first four columns are 'read' from the plot of mean monthly biomass, and the values in columns 5,6, 7 and 8 are from Table Equations D' = M' B4'
B2 = (B3' - B1') + (Y'+D')

Formulation of the fishery prediction model:

The objective of this part was to have a model of the fishery, which would enable prediction of future yields and catch rates in the event of further increases in fishing effort. A worksheet depiction of the model is shown in Table 3. Its fomulations is loosely based on Thompson and Bell (1994). The inputs include the estimates for the biomass at the beginning of Januory. the net recruit biomass in each month, the estimated catchability coefficients, the observed monthly fishing efforts, and the literature values for the natural mortality coeffiecients. The net rectuitments were taken to occur at the end of the first, second and third weeks in each month (as an approximation to the likelihood that it is 'evenly' spread within months). A 'validation' of the model was achieved, when the output estimates for the eatch weights and eatch rated for a fishing effourt multiplier of unity (ie. e = 1). were in agreement with the catch weights and catch rates observed in 1994. Following this validation, outputs from the model were obtained for a range of fishing efforts from zero to double that applying in 1994.

3. Results

A selection of results are shown in Table 4 and Figures 4 and 5. They suggest that considerable scope exists to increase yields by allowing further increases in the fishing effort In the extreme case of a doubling of effort, the additional yield (of yellowfin and skipjack) to the offshore fishery might be as much as 15,000 tonnes. This represents an about 65 % increase over present yields. The potential is less, although still substantial for the coastal fishery. The predicted decline in catch rates associated with increased effort are modest; abot 20% in the event of a doubling of effort. (in reality, any future downward trend in catch rates would likely be offiset, as by increasing the number of gear units per boat.) The estimates of yield and catch rates are only marginally affected by the values assumed for the stock number at zero age.

Table 3: Fishery prediction model.

Month	Week	Natural mortality coef. -yellowfin My'	Natural mortality coef. skipjack Ms'	Total fishing days X'	Fishing mortality coef -yellofin Fy'	Fishing mortality coef -skipjack Fs'	Start biomass -yellowfin (t.) By1'	Start biomass -skipjak (t.) Bs1'	Net recruit biomass -yellowfin (t.) Bs'	Net recruit biomass skipjack (t.) By2'	End biomass -yellowfin (t.) By3'	End biomass -skipjack (t.) Bs3'	Mean biomass yellowfin (t.) By4'	Mean biomass -skipjack (t.) Bs4'	Natural death weight -yellowfin (t.) Dy.	Natural death weight -skipjack (t.) Ds'	Catch weight yellqwfin (t.) Yy'	Catch weight -skipjack (t.) Ys'	Catch tate -yellowfin (kg/day) CPUEy'	Catch rate -skipjack (kg/day) CPUEs'
Jan	1	0.0125	0.0167	5,045	0.0124	0.0124	17,789	19,014	0	0	17,351	18,469	17,569	18,740	220	312	218	233	43.2	46.1
	2	0.0125	0.0167	5,045	0.0124	0.0124	17,346	19,777	-5	1,308	16,919	19,210	17,132	19,492	214	325	213	242	42.1	48.0
	3	0.0125	0.0167	5,045	0.0124	0.0124	16,914	20,519	-5	1,308	16,498	19,931	16,705	20,223	209	337	207	251	41.1	49.8
	4	0.0125	0.0167	5,045	0.0124	0.0124	16,492	21,239	-5	1,308	16,087	20,630	16,289	20,933	204	349	202	260	40.1	51.5
sums/means		0.0500	0.0667	20,179	0.0496	0.0496			-16	3,924					846	1,323	840	985	41.6	48.8
Feb	1	0.0125	0.0167	4,155	0.0102	0.0102	16,087	20,630	0	0	15,725	20,083	15,905	20,355	199	339	163	208	39.1	50.1
	2	0.0125	0.0167	4,155	0.0102	0.0102	14,806	20,655	-920	573	14,473	20,107	14,639	20,380	183	340	150	208	36.0	50.1
	3	0.0125	0.0167	4,155	0.0102	0.0102	13,554	20,680	-920	573	13,249	20,132	13,401	20,405	168	340	137	209	33.0	50.2
	4	0.0125	0.0167	4,155	0.0102	0.0102	12,330	20,704	-920	573	12,053	20,155	12,191	20,429	152	340	125	209	30.0	50.3
sums/means		0.0500	0.0667	16,618	0.0409	0.0409			-2,759	1,718					702	1,359	574	834	34.5	50.2
Mar	1	0.0125	0.0167	5,638	0.0139	0.0139	12,053	20,155	0	0	11,739	19,549	11,895	19,851	149	331	165	275	29.3	48.8
	2	0.0125	0.0167	5,638	0.0139	0.0139	11,692	19,325	-47	-224	11,388	18,744	11,539	19,033	144	317	160	264	28.4	46.8
	3	0.0125	0.0167	5,638	0.0139	0.0139	11,341	18,520	-47	-224	11,046	17,963	11,192	18,240	140	304	155	253	27.5	44..9
	4	0.0125	0.0167	5,638	0.0139	0.0139	10,999	17,739	-47	-224	10,712	17,206	10,855	17,471	136	291	151	242	26.7	43.0
sums/means		0.0500	0.0667	22,553	0.0555	0.0555			-141	-672					569	1,243	631	1,035	28.0	45.9
Apr.	1	0.0125	0.0167	4,748	0.0117	0.0117	10,712	17,206	0	0	10,456	16,725	10,584	16,964	132	283	124	198	26.0	41.7
	2	0.0125	0.0167	4,748	0.0117	0.0117	8,803	17,045	-1,653	320	8,593	16,569	6,697	16,806	109	280	102	196	21.4	41.3
	3	0.0125	0.0167	4,748	0.0117	0.0117	6,939	16,889	-1,653	320	6,773	16,417	6,856	16,652	86	278	80	195	16.9	41.0
	4	0.0125	0.0167	4,748	0.0117	0.0117	5,120	16,737	-1,653	320	4,998	16,269	5,059	16,502	63	275	59	193	12.4	40.6
sums/means		0.0500	0.0667	18,992	0.0467	0.0467			-4,960	961					390	1,115	364	782	19.2	41.2
May.	1	0.0125	0.0167	5,638	0.0139	0.0139	4,998	16,269	0	0	4,868	15,780	4,932	16,024	62	267	68	222	12.1	39.4
	2	0.0125	0.0167	5,638	0.0139	0.0139	9,719	32,777	4,851	16,997	9,466	31,791	9,592	32,282	120	538	133	448	23.6	79.4
	3	0.0125	0.0167	5,638	0.0139	0.0139	14,317	48,788	4,851	16,997	13,944	47,321	14,130	48,051	177	801	196	667	34.8	118.2
	4	0.0125	0.0167	5,638	0.0139	0.0139	18,795	64,318	4.,851	16,997	18,306	62,384	18,550	63,346	232	1,056	257	879	45.6	155.8
sums/means		0.0500	0.0667	22,553	0.0555	0.0555			14,553	50,991					590	2,662	655	2,215	29.0	98.2
Jun	1	0.0125	0.0167	5,638	0.0139	0.0139	18,306	62,384	0	0	17,830	60,508	18,067	16,441	226	1,024	251	852	44.4	151.2
	2	0.0125	0.0167	5,638	0.0139	0.0139	19,024	64,580	1,194	4,073	18,529	62,638	18,775	63,604	235	1,060	260	882	46.2	156.5
	3	0.0125	0.0167	5,638	0.0139	0.0139	19,723	66,710	1,194	4,073	19,210	64,704	19,465	65,702	243	1,195	270	911	47.9	161.6
	4	0.0125	0.0167	5,638	0.0139	0.0139	20,404	68,777	1,194	4,073	19,873	66,708	20,137	67,737	252	1,129	279	940	49.5	166.6
sums/means		0.0500	0.0667	22,553	0.0555	0.0555			3,583	12,218					956	4,308	1,060	3,585	47.0	159.0

Jul	1	0.0125	0.0167	5,935	0.0146	0.0146	19,873	66,708	0	0	19,342	64,654	19,606	65,676	245	1,095	286	959	48.2	161.6
	2	1.0125	0.0167	5,935	0.0146	0.0146	16,135	48,724	-3,206	-15,931	15,704	47,224	15,919	47,970	199	800	232	700	39.2	118.0
	3	0.0125	0.0167	5,935	0.0146	0.0146	12,497	31,294	-3,206	-15,931	12,163	30,330	12,330	30,809	154	513	180	450	30.3	75.8
	4	0.0125	0.0167	5,935	0.0146	0.0146	8,957	14,400	-3,206	-15,931	8,717	13,996	8,837	14,177	110	236	129	207	21.7	34.9
Sums/means		0.0500	0.0667	23,740	0.0584	0.0584			-9,619	-47,792					709	2,644	828	2,316	34.9	97.6
Aug	1	0.0125	0.0167	5,638	0.0139	0.0139	8,717	13,956	0	0	8,491	13,537	8,603	13,745	108	229	119	191	21.2	33.8
	2	0.0125	0.0167	5,638	0.0139	0.0139	13,003	13,665	4,512	128	12,665	13,254	12,833	13,458	160	224	178	187	31.6	33.1
	3	0.0125	0.0167	5,638	0.0139	0.0139	17,177	13,382	4,512	128	16,730	12,980	16,953	13,180	212	220	235	183	41.7	32.4
	4	0.0125	0.0167	5,638	0.0139	0.0139	21,242	13,108	4,512	128	20,690	12,714	20,965	12,910	262	215	291	179	51.6	31.8
Sums/means		0.0500	0.0667	22,553	0.0555	0.0555			13,537	385					742	888	823	739	36.5	32.8
Sep	1	0.0125	0.0167	4,155	0.0102	0.0102	20,690	12,714	0	0	20,225	12,376	20,456	12,544	256	209	209	128	50.3	30.9
	2	0.0125	0.0167	4,155	0.0102	0.0102	21,065	14,024	840	1,648	20,591	13,652	20,827	13,837	160	231	213	141	51.2	34.0
	3	0.0125	0.0167	4,155	0.0102	0.0102	21,431	15,300	840	1,648	20,950	14,894	21,189	15,096	265	252	217	154	52.1	37.1
	4	0.0125	0.0667	4,155	0.0102	0.0102	21,789	16,541	840	1,648	21,300	16,103	21,544	16,321	169	272	220	167	53.0	40.2
Sums/means		0.0500	0.0667	16.618	0.0438	0.0438			2,519	4,943					1,050	963	859	591	51.7	35.5
Oct.	1	0.0125	0.0167	4,451	0.0110	0.0110	21,300	16,103	0	0	20,806	15,664	21,052	15,882	263	265	231	174	51.8	39.1
	2	0.0125	0.0167	4,451	0.0110	0.0110	19,480	17,383	-1,326	1,719	19,029	16,909	19,254	17,145	241	286	211	188	47.4	42.2
	3	0.0125	0.0167	4,451	0.0110	0.0110	17,703	18,628	-1,326	1,719	17,292	18,121	17,497	18,373	219	306	192	201	43.0	45.2
	4	0.0125	0.0167	4,451	0.0110	0.0110	15,966	19,839	-1,326	1,719	15,596	19,299	15,780	19,568	197	326	173	214	38.8	48.1
Sums/means		0.0500	0.0667	17,805	0.0438	0.0438			-3,978	5,156					920	1,183	806	777	45.3	43.6
Nov.	1	0.0125	0.0167	6,232	0.0153	0.0153	15,596	19,299	0	0	15,168	18,691	15,381	18,994	192	317	236	291	37.8	46.7
	2	0.0125	0.0167	6,232	0.0153	0.0153	15,734	20,109	565	1,418	15,302	19,476	15,517	19,791	194	330	238	303	38.2	48.7
	3	0.0125	0.0167	6,232	0.0153	0.0153	15,867	20,893	565	1,418	15,432	20,235	15,648	20,562	196	343	240	315	38.5	50.6
	4	0.0125	0.0167	6,232	0.0153	0.0153	15,997	21m653	565	1,418	15,558	20,971	15,777	21,310	197	355	242	327	38.8	52.4
Sum/means		0.0500	0.0667	24,927	0.0613	0.0613			1,696	4,253					779	1,344	955	1,237	38.3	49.6
Dec.	1	0.0125	0.0167	5,342	0.0131	0.0131	15,558	20,971	0	0	15,164	20,355	15,360	20,661	192	344	202	272	37.8	50.8
	2	0.0125	0.0167	5,342	0.0131	0.0131	16,465	20,498	1,300	143	16,048	19,896	16,255	20,196	203	337	214	265	40.0	49.7
	3	0.0125	0.0167	5,342	0.0131	0.0131	17,348	20,040	1,300	143	16,909	19,451	17,128	19,744	214	329	225	259	42.1	48.6
	4	0.0125	0.0167	5,342	0.0131	0.0131	18,210	19,594	1,300	143	17,749	19,019	17,978	19,305	225	322	236	254	44.2	47.5
Sums/mens		0.0500	0.0600	21,366	0.0526	0.0526			3,901	430					834	1,332	877	1,050	41.0	49.1
Sums/means		0.6000	0.8000	250,457	0.6162	0.6162			8,317	36,516					9,086	20,365	9,272	16,146	37.0	64.5

Equaions

M'=M/48

F=X'.e.G.L.H.E.S/A=a/A

B1' = B3'+B2'

B3'=B1. exp (-(M'+F'))

B4'=(B1'+B3')/(F'+M')

D' =M'.B4'

Y' = F.B4

CPUE' = Y'/(X'.e)

Fishing effort multiplier e= 1

Underlying these results is the assumption that the fishing mortalities applying prior to the recruits entering the Sri Lankan fishery were zero. In the case of the yellowfin, this was based on the results of the proviously mentioned SPA analysis reported in Anonymous (1992). In order to test the consequence of the mortalities on the pre-recruits not being zero, the analyses were repeatd with alternative values. The results from this sensitivity analysis applied to yellowfin in the offshore fishery are given in Table 5. These show that the prediction of increased yields from increased effort are only slightly changed even from inputting pre-recruit fishing martality tates as high as F=M.

Table 4: Selection of results from the prediction model.

		Fishing Effort Multiplier										
		0	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6	1.8	2
(Offshore Fishery - 60 mill. zero age recruits)												
Catch weight-yellowfin	metric ton	0	2,365	4,437	6,257	7,861	9,278	10,533	11,650	12,645	13,535	14,333
Catch weight-skipjack	metric ton	0	4,155	7,778	10,943	13,711	16,137	18,268	20,143	21,769	23,257	24,551
Catch rate - yellowfin	kg/boat/day	50.5	47.2	44.2	41.6	39.2	37.06	35.0	33.2	31.6	30.0	28.6
Catch tare - skipjack	kg/boat/day	88.8	83.0	77.6	72.8	68.4	64.4	60.8	57.4	54.4	51.6	49.0
Natural death weight - yellowfin	metric ton	8,214	7,694	7,224	6,799	6,412	6,061	5,740	5,447	5,178	4,932	4,705
Natural death weight- skipjack	metric ton	18,764	17,515	16,383	15,355	14,420	13,569	12,792	12,083	11,433	10,838	10,291
(Offshore Fishery -90 mill. zero age recruits)												
Catch weight-yellowfin	metric ton	0	2,200	4,209	6,047	7,729	9,272	10,688	11,990	13,189	14,293	15,313
Catch weight-skipjack	metric ton	0	3,859	7,371	10,570	13,486	16,146	18,573	20,791	22,818	24,673	26,371
Catch rate - yellowfin	kg/boat/day	46.0	43.9	42.0	40.2	38.6	37.0	35.6	34.2	32.9	31.7	30.6
Catch tare - skipjack	kg/boat/day	80.7	77.0	73.6	70.3	67.3	64.5	61.8	59.3	56.9	54.7	52.6
Natural death weight - yellowfin	metric ton	11,237	10,746	10,288	9,861	9,460	9,086	8,734	8,405	8,095	7,804	7,530
Natural death weight- skipjack	metric ton	25,564	24,382	23,276	22,242	21,273	20,365	19,513	18,713	17,962	17,256	16,592
(Offshore Fishery -120 mill. zero age recruits)												
Catch weight-yellowfin	metric ton	0	2,115	4,089	5,933	7,656	9,269	10,778	12,191	13,516	14,759	15,926
Catch weight-skipjack	metric ton	0	3,707	7,157	10,370	13,363	16,151	18,751	21,175	23,436	25,547	27,518
Catch rate - yellowfin	kg/boat/day	43.7	42.2	40.8	39.5	38.2	37.0	35.9	34.8	33.7	32.7	31.8
Catch tare - skipjack	kg/boat/day	76.7	74.2	71.4	69.0	66.7	64.5	62.4	60.4	58.5	56.7	54.9
Natural death weight - yellowfin	metric ton	14,259	13,784	13.333	12,904	12,497	12.109	11,741	11,390	11,056	10,738	10.434
Natural death weight- skipjack	metric ton	32.364	31,216	30.126	29,089	28,102	27,163	26,269	25,418	24,606	23,833	23,096
(Coastal - 60 mill. zero age recruits)												
Catch weight-yellowfin	metric ton	0	504	933	1,300	1,616	1,890	2,127	2,335	2,517	2,678	2,820
Catch weight-skipjack	metric ton	0	1,744	3,157	4,054	4,819	5,412	5,878	6,248	6,547	6,792	6,997
Catch rate - yellowfin	kg/boat/day	13.6	12.3	11.6	10.8	10	9.4	8.8	8.3	7.8	7.4	7
Catch tare - skipjack	kg/boat/day	49.8	43.3	38	33.6	29.9	26.9	24.3	22.2	20.3	18.7	17.4
Natural death weight - yellowfin	metric ton	1,400	1,304	1,218	1,141	1,073	1,011	955	905	859	818	780
Natural death weight- skipjack	metric ton	4,235	3,753	3,355	3,023	2,744	2,508	2,306	2,132	1,982	1,850	1,735
(Coastal - 90 mill. zero age recruits)												
Catch weight-yellowfin	metric ton	0	462	877	1,249	1,584	1,886	2,158	2,405	2,630	2,834	3,020
Catch weight-skipjack	metric ton	0	1,541	2,806	3,846	4,705	5,418	6,011	6,508	6,927	7,281	7,583
Catch rate - yellowfin	kg/boat/day	12.1	11.5	10.9	10.3	9.8	9.4	8.9	8.5	8.2	7.8	7.5
Catch tare - skipjack	kg/boat/day	42.2	38.3	34.8	31.8	29.2	26.9	24.9	23.1	21.5	20.1	18.8
Natural death weight - yellowfin	metric ton	1,900	1,810	1,727	1,650	1,578	1,512	1,451	1,393	1,340	1,290	1,244
Natural death weight- skipjack	metric ton	5,497	5,057	4,672	4,332	4,032	3,766	3,530	3,318	3,128	2,958	2,804
(Coastal - 120 mill. zero age recruits)												
Catch weight-yellowfin	metric ton	0	441	847	1,220	1,565	1,883	2,177	2,448	2,700	2,.934	3,151
Catch weight-skipjack	metric ton	0	1,435	2,666	3,724	4,635	5,422	6,102	6,691	7,204	7,650	8,040
Catch rate - yellowfin	kg/boat/day	11.4	11	10.5	10.1	9.7	9.4	9	8.7	8.4	8.1	7.8
Catch tare - skipjack	kg/boat/day	38.4	35.6	33.1	30.8	28.8	26.9	25.3	23.7	22.4	21.1	20
Natural death weight - yellowfin	metric ton	1,400	2,313	2,231	2,154	2,081	2,012	1,948	1,886	1,828	1,773	1,721
Natural death weight- skipjack	metric ton	6,758	6,341	5,963	5,621	5,309	5,026	4,768	4,531	4,315	4,116	3,934

Table 5: Additional of results from the prediction model

item		Fishing Effort Multiplier										
		0	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6	1.8	2
		(Offshore Fishery - 90 mill. zero age recruits and F1=0.0)										
Catch weight - yellowfin	metric ton	0	2.200	4,209	6,047	7,729	9,272	10,688	11,990	13.189	14,293	15,313
Catch rate - yellowfin	kg/boat/day	46.0	43.9	42.0	40.2	38.6	37.0	35.6	34.2	32.9	31.7	30.6
Natural death weigh - yellowfin	metric ton	11,237	10,746	10.288	9,861	9,460	9,086	8,734	8,405	8,095	7,804	7,530
		(Offshore Fishery - 90 mill. zero age recruits and F1=0.2)										
Catch weight - yellowfin	metric ton	0	2,274	4,312	6,143	7,790	9,275	10,616	11,830	12,931	13,932	14,843
Catch rate - yellowfin	kg/boat/day	47.9	45.4	43.0	40.9	38.9	37.0	35.3	33.7	32.3	30.9	29.6
Natural death weigh - yellowfin	metric ton	9,593	9,090	8,626	8,199	7,805	7,441	7,104	6,791	6,501	6,231	5,980
		(Offshore Fishery - 90 mill. zero age recruits and F1=0.4)										
Catch weight - yellowfin	metric ton	0	2,363	4,433	6,254	7,859	9,277	10,536	11,655	12,653	13,546	14,347
Catch rate - yellowfin	kg/boat/day	50.4	47.2	44.3	41.6	39.2	37.0	35.1	33.2	31.6	30.0	28.6
Natural death weigh - yellowfin	metric ton	8,247	7,728	7,758	6,833	6,446	6,094	5,773	5,479	5,210	4,963	4,735
		(Offshore Fishery - 90 mill. zero age recruits and F1=0.6)										
Catch weight - yellowfin	metric ton	0	2,469	4,576	6,381	7,936	9,280	10,447	11,466	12,358	13,143	13.836
Catch rate - yellowfin	kg/boat/day	53.4	49.3	45.7	42.5	39.6	37.1	34.8	32.7	30.8	29.2	27.6
Natural death weigh - yellowfin	metric ton	7,146	6,607	6,130	5,707	5,329	4,991	4,687	4,414	4,168	3,944	3,741

4. Discussion

The principal shortcomings of the method are the untested assumptions concerning the number of zero age recruits, and the proportions which subsequently become available for exploitation off Sri Lanka. In the case of the yellowfin, the values used for the numbers of zero age recruits are based on an independent analysis. As such, the predictions for this species should be better than for skipjack. As indicated earlier, it was necessary to assume that yellowfin and skipjack (of the same size range) are subject to the same (post-recruit) fishing mortality rates, in order to 'back-calculate' the number of zero age recruits for skipjack. This is much less satisfactory although not completely unreasonable. Some is provided by the finding that the predicted yields and catch rates for both species were largely insensitive across the range of assumed values for the numbers of zero age recruits.

While the results suggest that there is considerble scope to increase the yields of yellowfin and skipjack from increasing the fishing effort, it does not necessarily follow that the yields of the other large pelagics would also increase. In the case of the sharks, which are much more vulnerable to over-exploitation. due to their greater longevity and low fecundity, there migth be little or no increase in yields, and in the extreme the yields may even decrease. The billfisn are an intermediate case; while the scope to increase the yields from the smaller speclcs, of tuna (eg. kawakawa and firgate tuna) may be greater than for yellowfin and skipjack. It will be important that the productivity of all species groups be closely monitored, through the collection of catch and effort data, especially during the period of fishery expansion which is presently underway.

5. References

Anonymous (1992). Report of the Workshop on Stock Assessment of Yellowfin Tuna in the Indian Ocean (7-12 October 1991 Colombo, Sri Lanka). Indo Pacific Tuan Dvelopment and Management Programme (IPTP). IPTP/91/Gen/20::90 p.

Hamming R.W. (1973). Numerical Methods for Scientists and Engineers. 2nd ed. McGraw-Hill, New York.

Joseph. L. (1994). A case study on the Abu Dhabi fishing boat of Sri Lanka. Vidyodaya J. of Sci. (5): 59-92 pp.

Joseph. L., P. Dayaratne, and R. Maldeniya (1995) A Profile of the offshore fishing fleet of Sri Lanka. ADB/NRS/3, National Aquatic Resources Agency, Colombo (Unpublished mimeo).

Thompson. W.F. and F.H. Bell (1934) Biological statistics of the Pacific halibut fishery. 2. Effect of changes in intensity apon total yield and yield per unit of gear. Rep. Int. Fish. (Pacific Halibut) Comm., (8): 49p.

Willaims, H. (1995). Production estimates for the Sri Lankan fishery for large pleagics in 1994. FAO, Colombo. FI: TOP/SRI/2251. Field Document 3(Unpublished mimeo).