WP/12

Follow-up study on the stock status of bigeye tuna in the Pacific Ocean

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1. Introduction

Fisheries catching bigeye tuna in the Pacific appear to change quickly in the most recent years. Such changes can be seen in catch trend in Table 1. Whilst the Japanese longline fishery, which has accounted for more 80 % of total catch in the Pacific, declined its catch by 20 % from 1992 to 1994, Taiwanese longline catch and surface catch in the IATTC area has increased quickly during the same period. In addition, Mainland China took part in longline fishery at the same time. The increase of Taiwanese catch is not known but the increase of catch by the surface fishery in the IATTC area was caused by the change in mode of operation in the purse seiner fishery. Due to the strong pressure by the environmentalist, purse seiners in that area abandoned to fish on dolphin-associated school and changed to target schools associated with logs and other flotsam in order to reduce mortalities of dolphin. It is reported that the amount of small tunas caught by this type of operation were much higher than that by the dolphin set.

In this paper, production model analysis similar to last year's study (Miyabe 1994) was conducted. This year's study includes different stock structure assumption; whole Pacific, western and eastern Pacific. In addition to this, analysis done by IATTC was introduced here, since it has data to do for them and the results seem to be interesting to everyone who is working on this species.

2. Production model analysis

Stock structure

Two different stock hypotheses are assumed. One is whole Pacific-wide stock and the other is two stocks; one in the western Pacific and the other in the eastern Pacific. Although there is not much data which support this hypothesis, it was attempted to see the results as was the case of yellowfin tuna.

Data used

Catch in weight and effective fishing effort or abundance index are required for Production model analysis. Abundance index was developed from the catch and effort statistics of the same fleet , which is larger than 20 gross tonnage (GRT), compiled at the National Fisheries

Institute of Far Seas Fisheries (NRIFSF) for the years 1952 - 1994. 1994 data is provisional. Those basic data are aggregated by month and 5-degree square (latitude and longitude) for 1952 -1976 and by month, 5-degree square and number of hooks between floats for 1975 and thereafter.

Catch in weight used is the same as last year's dataset except updated figures. Under the assumption of two stocks, however, catch has to be separated between two areas. Unfortunately, this is not possible for some fisheries, so FAO statistics by area was used. FAO area codes 61, 71 and 81 are assumed to belong to the western stock and others (67,77 and 87) are to the eastern stock.

Estimation of Abundance Index

There are many factors which seem to affect CPUE such as biological (migration, reproduction, bait availability, etc.), environmental (water temperature, depth, salinity, current, season, etc.) and operational ones (kind of bait, gear, soaking time, target species, etc.). However, the data availability of such factors is normally limited, and here only some of them are incorporated into the analysis. General Linear Modelling (GLM) technique is used to account for such factors. Multiplicative model is used to model longline CPUE shown below.

$$\log(HR + 1.0) = \mu + Y_i + S_j + A_k + G_l + B_m + INTER + \varepsilon_{ijklm}$$

Here, log : natural logarithm,

- HR : hook rate of bigeye tuna per 100,000 hooks,
- μ : intercept,
- Y_i : effect of year i,
- S_j : effect of season j (month),
- A_k : effect of area k,
- G_l : effect of gear l (hooks between floats),
- B_m : effect of by-catch (other species, albacore and yellowfin),
- INTER : interaction term between effects,
- ε_{ijklm} : error term $N(0,\sigma)$.

Annual abundance is obtained from Y_i parameter.. As shown in above equation, factors included in the analysis are calendar year, month as season, area (as shown in Fig. 1), number of hooks between floats as gear, albacore and yellowfin as by-catch and two-way interactions between season, area and gear. Area division was made rather arbitrarily considering the major fishing grounds, fishing season and operational patterns. Areas 1, 3, 4, and 7 are waters covered by offshore license boats (< 120 GRT) and other areas are covered by distant water license boats (> 120 GRT - 500 GRT). Under the two stocks hypothesis, Areas 1, 3, 4, 7 and 10 are assigned to the western stock and the rest (Areas 2, 5, 6, 8 and 9) is assigned to the eastern stock.

The procedures of data setup are about the same as Miyabe (1994), however, the results of runs without weighting by the reciprocal of the number of observation (this was adopted to account for the concentration of fishing effort in higher CPUE within the GLM area) were added for the comparison. The final models are the same as those done in Miyabe (1994) as follows.

1952-1976 : $\log(HR + 1.0) = \mu + Y_i + S_j + A_k + ALB_l + YFT_m + S_j{*}A_k + \varepsilon_{ijklm}$

1975-1994 : $\log(HR + 1.0) = \mu + Y_i + S_j + A_k + G_l + ALB_m + YFT_n + S_j{*}A_k + S_j{*}G_l + A_k{*}G_l + \varepsilon_{ijklmn}$

where ALB and YFT are albacore CPUE and yellowfin CPUE, respectively. R squares are between 0.4 to 0.45 but in the cases of eastern stock they are much lower at about 0.15-0.20. Estimated CPUEs are shown in Fig. 2-4. All values are scaled to 1975.

Fitting ASPIC model

Surplus production model developed by Prager (1994) was applied to bigeye data. Two time frames (before and after 1975) used in the estimation of abundance index were kept separately. The reasons for this are 1) data set is different (no information on gear before 1975), 2)catchability might have changed through the time. The earlier data were not included in the analysis since very few data were in the data for the eastern stock and the fishery itself was in a developing stage.

The summary of results are tabulated in Table 2. The results under the assumption of single stock in the Pacific was similar to that of Miyabe (1994), although no meaningful solution was obtained when weighting by the number of observation was not included. The estimated MSYs under two stocks hypothesis were about 40,000 MT and 65,000 to 87,000 MT for western and eastern stocks, respectively. Relative benchmarks, B-ratio and F-ratio, are about at the MSY level for single stock hypothesis but they are in the side of overfishing for both of two stocks. Apparently current Pacific wide catch exceeded these estimated MSYs.

3. Analysis undertaken at IATTC

Summary of the analysis on bigeye tuna in the IATTC area taken from background paper presented at this year's Annual Meeting of the IATTC is attached as an Appendix I. It includes 1994 new data which recorded 28,500 MT of purse seine catch.

4. Discussion

The results of this paper are similar to last year's analysis. The general conclusion is that current catch or F is exceeding the catch or F which gives MSY, and that estimated current biomass is below or about the level which produces MSY. It was a matter of concern that CPUE from the Japanese longline fishery which covers about 80 % of total bigeye catch has continued to decrease. However, situations around bigeye tuna is different this year. As already noted in the introduction section, the catch of the Japanese longline fishery has declined whilst other longline catches of Taiwan, Mainland China and US and purse seine catch in the IATTC area showed quick increase. The large increase of small fish in the IATTC area is not included in this analysis. Taking all these information into consideration, it is urgently recommended that fishing mortality should not be increased. In order to set up efficient management of this species, management body which can deal with whole Pacific be formulated as soon as possible.

5. References

Miyabe, N. 1994. Assessment of bigeye tuna in the Pacific Ocean by production model analysis. The seventh meeting of the standing committee on tuna and billfish. Information paper 5.

Prager, M. H. 1994. A suite of extensions to a nonequilibrium surplus-production model. Fish. Bull. 92:374-389.

Table 1. Catch of bigeye tuna in the Pacific Ocean, from all data sources combined.

	Country													Surface fishery				
Year	Japan LL	Korea LL	Taiwan LL	Australia LL	F.S. Micronesia LL	Fiji LL	Mainland China LL	Marshall Is. LL	New Caledonia LL	Palau LL?	Solomon Is. LL	Tonga LL	USA LL	Japan PL	Japan PS	Japan Others	IATTC PS+PL	Total
55	39200													4009		342	117	43668
56	30700													4373		957	40	36070
57	64400													5198		435	68	70101
58	86500													4196		114	232	91042
59	79300													1729		74	150	81253
60	87600													1524		152	183	89459
61	132200													1837		111	213	134361
62	119800													824		213	328	121165
63	144400													1822		39	75	146336
64	99500													1142		260	68	100970
65	73500	700	2000											1254		231	118	77803
66	76900	2900	3500											1108		96	267	84771
67	77700	3200	3200											2803		314	1663	88880
68	63939	600	4000											2272		250	2559	73620
69	91885	2500	4600											1679		158	576	101398
70	71165		5000											1579		247	1332	79323
71	65059	4700	4300											931		218	2567	77775
72	82632	7800	3800											2364		781	2238	99615
73	90313	8900	3700								16			852		251	1978	106010
74	68730	14444	4420											729		456	889	89668
75	76913	15484	5348											3522		743	3722	105732
76	96816	21395	3114								25			7982		889	10185	140406
77	115833	17663	4507								34			5096		970	7054	151157
78	100557	8456	4402								36			3330	1438	549	11710	130478
79	104776	12804	4491								86			1967	892	347	7530	132893
80	96637	13975	4637								98			2205	908	113	15417	133990
81	78630	10608	3849								40			2357	1581	152	10089	107306
82	87571	10050	2111			8					23	18		4057	2325	191	4103	110457
83	91200	7706	3477			14			1		34	17		3847	2064	140	3260	111760

Table 1. Continued.

Year	Japan LL	Korea LL	Taiwan LL	Australia LL	F.S. Micronesia LL	Fiji LL	Mainland China LL	Marshall Is. LL	New Caledonia LL	Palau LL?	Solomon Is. LL	Tonga LL	USA LL	Japan PL	Japan PS	Japan Others	IATTC PS+PL	Total
	Country													Surface fishery				
84	83504	7478	2943			16			9		55	28		3447	1470	159	5853	104962
85	104208	10898	3031			133			15		46	15		2895	2256	289	4531	128317
86	123103	15927	2879			94			17		0	12		2227	2423	258	1979	148919
87	121386	19544	3280	33		49			33		259	14	756	1834	2506	261	771	150726
88	94666	13681	3610	24		18			18		1266	6	1823	2900	1694	303	1053	121062
89	103326	14180	2900	11		105			24		1095	12	1425	2472	2510	548	1470	130078
90	122059	20937	2900	13		27			54	1221	683	10	1675	1632	4855	104	4706	160876
91	107302	20345	2922	15		123	380		54	1190	1403	7	1517	1245	3553	354	3735	144145
92	93002	19800	16367	37	42	191	1226	5	110	1200	1200	13	1500	718	5714	593	5490	147208
93	79953	17317	18877	23	42	227	3131	31	95	1200	1000	10	2539	1114	4630	137	8055	138381
94																	28531	

Data source :

Japan LL > 20 GRT for 1955-1973 : From Kume (1979) and FAO (1974-1991).
Japan LL < 20 GRT for all years : From MAFFJ.
Japan surface fisheries catch : from MAFFJ.
Korea LL : FAO (1965-1991). All are assumed by LL.
Taiwan LL : FAO (1965-1991). Other nei A. All are assumed LL. Before 1965 data are from Kume (1979).
Australia : 1986-1992 from SPC (1993).
Solomon Is. : 1973-1980 from SPC, 1981- from FAO.
IATTC : Calkins et al. (1988), IATTC (1993), includes Bermuda, Ecuador, El Salvador, Mexico, Panama, USA, Venezuela and others.
New Caledonia : SPC (1993).
Tonga : SPC (1993).
Fiji : FAO for 1982-1989 : 1990-1992 from LL SPC (1993).
USA : PS in EPO from IATTC (1993), PS in WPO no estimate available.
USA : LL in central and western Pacific for 1987-1991 from FAO - IATTC

Table 2. Results of production model (ASPIC) analysis.

Stock hypothesis	Weight by Observation	Penalty on B1>K	MSY 1000 MT	K 1000 MT	r	B1	q1 1965-74	q2 1975-94	B-ratio	F-ratio
Total	Y	N	119	1516	0.31	1752	8.0E-04	8.4E-04	1.01	1.07
	Y	Y	120	1384	0.35	1452	9.1E-04	9.4E-04	0.99	1.09
	N	N	No meaningful solution was obtained.							
	N	Y	No meaningful solution was obtained.							
West	Y	N	39	226	0.70	205	6.5E-03	8.9E-03	0.73	1.57
	Y	Y	39	228	0.69	206	6.4E-03	8.7E-03	0.74	1.56
	N	N	40	214	0.74	166	7.4E-03	9.7E-03	0.75	1.53
	N	Y	40	213	0.74	166	7.4E-03	9.7E-03	0.75	1.53
East	Y	N	65	1464	0.18	2262	7.1E-04	6.3E-04	0.84	1.78
	Y	Y	76	987	0.31	1128	1.3E-03	9.9E-04	0.76	1.67
	N	N	84	808	0.42	1018	1.5E-03	1.5E-03	0.88	1.32
	N	Y	87	694	0.50	755	1.9E-03	1.7E-03	0.86	1.31

K : Carrying capacity

r : Intrinsic growth rate

B1 : Biomass at the beginning of the fishery (used in the fitting)

q1 : Catchability coefficient for fishery 1

q2 : Catchability coefficient for fishery 2

B-ratio : Relative ratio of current biomass to biomass which gives MSY, values less than 1.0 means overfishing.

F-ratio : Relative ratio of current fishing mortality rate (F) to F at MSY, values larger than 1.0 means overfishing.

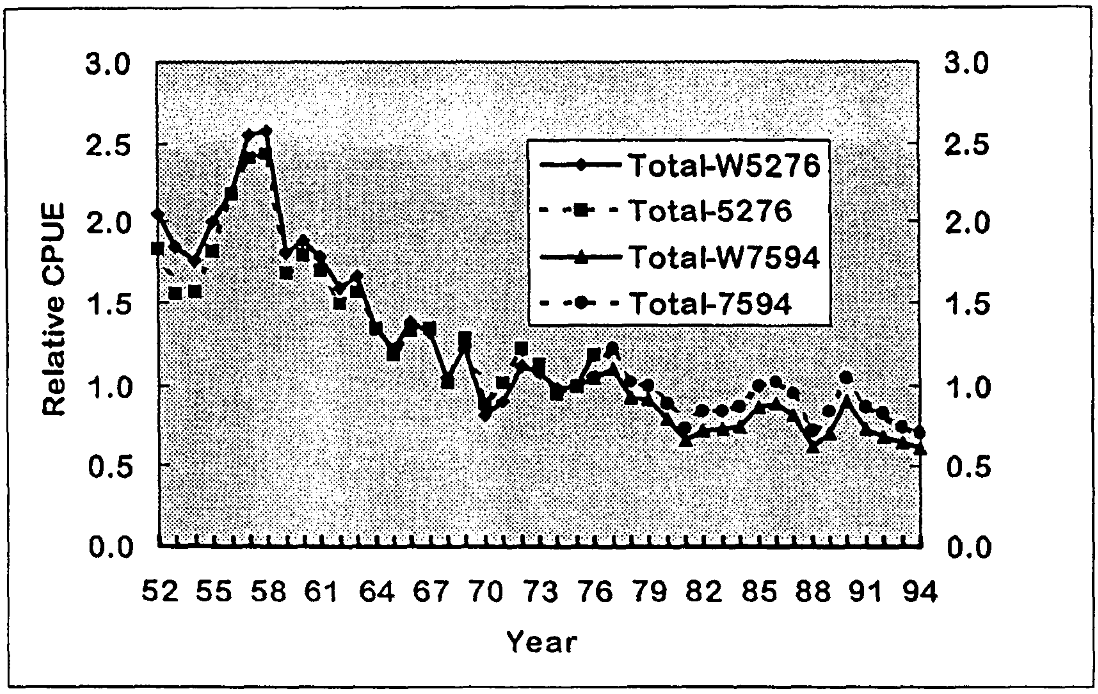

Fig. 2. Abundance indices estimated for bigeye tuna under single stock hypothesis in the Pacific.

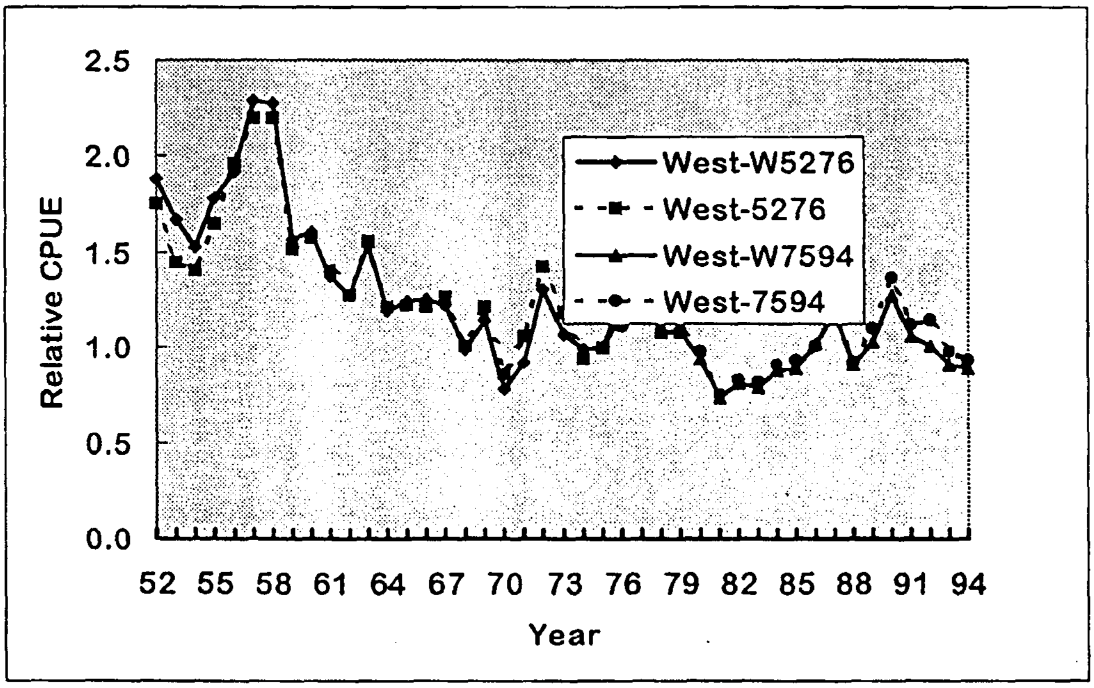

Fig. 3. Abundance indices estimated for bigeye tuna under two stocks hypothesis in the Pacific. Western stock.

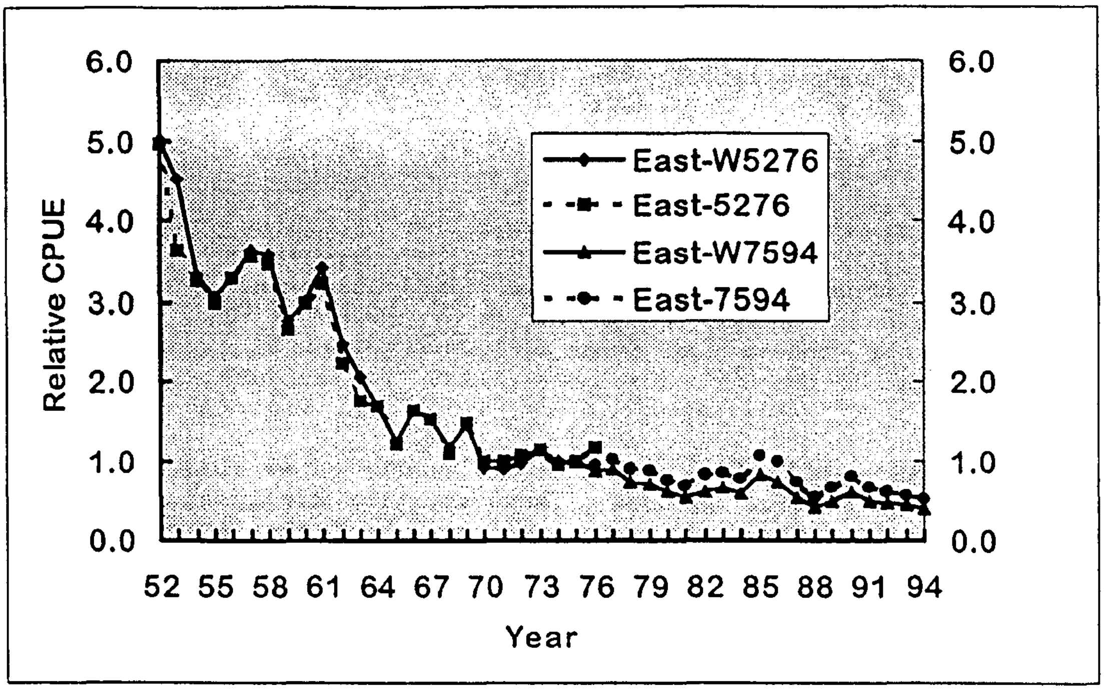

Fig. 4. Abundance indices estimated for bigeye tuna under two stocks hypothesis in the Pacific. Eastern stock.

Appendix I. Assessment of bigeye tuna in the IATTC area. Copied from Background paper 5. Presented to 55th Annual Meeting of the IATTC. June, 1995.

distribution of the fish caught by the longline fishery of 1988 through 1992 with a normal distribution. These data represent a catch of about 64 thousand tons of fish with an average weight of 127 pounds (58 kg).

The data shown in Figure 9 were used to calculate estimates of the catches at age by re-arranging the growth equation mentioned above and using it to assign the fish to age groups. The results are shown in Table 4, Columns 2-4. The values in column 5 of that table, the sums of those in columns 2 and 4, are typical of the fishery prior to 1994. The values in column 6 of the table, the sums of those in columns 3 and 4, represent what the catches would be if the increased purse-seine catches had no effect on the longline catches.

Cohort analyses were used to estimate the number of recruits needed to support the catches listed in Table 4. These analyses are based on the implicit assumption that the purse-seine and longline fisheries are exploiting the same stock(s) of bigeye. It is also necessary to assume that the fishery is in equilibrium, so that the within-year age structure is the same as the age structure of a cohort. The estimates of recruitment (Table 5) are those that would be obtained if the catch for each column in Table 4 came from a stock which was not affected by any other fishery. Column 5, with the combined purse-seine and longline catches for 1990-1992, is most representative of this assumption. If the recruitment estimated from column 2 is added to that from column 4, the result is similar to that obtained using the data in column 5 alone (Table 5). However, when the data in column 6 are used to estimate recruitment, the estimated recruitment is increased by 4 to 7 million fish, depending on the value of M. Similar results are obtained if columns 3 and 4 are used separately and the estimated recruitments are summed. Since column 5 corresponds to an observed condition and column 6 does not, it seems more likely that if the purse-seine fishery continues to catch 31 thousand tons of smaller bigeye the longline catch will decline to a level such that the combined catch from the purse-seine fishery (Table 4, Column 3) and the new level for the longline fishery would produce estimates of recruitment similar to those in column 5 of Table 5.

Simulating reduced longline catches with a size structure similar to that shown in Figure 9, combining these with 1994 purse-seine catch data, and then doing a cohort analysis until estimates of recruitment were similar to those in column 5 of Table 5 produced approximations of what might happen to the longline fishery. These approximations depend very strongly on the values of M used.

The simulations demonstrate that if M is 0.4 and the purse-seine fishery continues to catch around 31 thousand tons of smaller bigeye the longline catch will be reduced to less than 1 thousand tons per year. As can be seen in Table 5, when $M = 0.4$ all of the recruitment would be needed to support the purse-seine fishery (compare columns 3 and 5 in Table 5). If the value of M is 0.6 the longline catch would be reduced by about 50 percent, or about 32 thousand tons per year, as only about half of the recruits are needed to support the purse-seine fishery. Finally, if M is as high as 0.8 the longline catch would be reduced by about 25 percent, to about 48 thousand tons, and the purse-seine fishery would require about one third of the recruits.

It is also possible to estimate the yields per recruit which would result from the fisheries for bigeye as obtained from the data in Tables 4 and 5 and from the simulations. From the most realistic data set (Table 4, column 5), the catch of 68,700 tons would be obtained from recruitments of 4.4, 9.2, or 20.9 million fish, depending on *M* (Table 5). These correspond to yields per recruit of of 31.2 pounds (14.2 kg), 14.9 pounds (6.8 kg), and 6.6 pounds (3.0 kg), respectively. According to the simulations, with a catch of 31 thousand tons in the purse-seine fishery, the total catches would be approximately 32 thousand ($M = 0.4$), 63 thousand ($M = 0.6$), or 79 thousand ($M = 0.8$) tons, respectively. The last three catches correspond to yields per recruit of 14.5 pounds (6.6 kg), 13.7 pounds (6.2 kg), and 7.6 pounds (3.4 kg). Therefore, if the assumptions are fulfilled, the yield per recruit will be reduced if $M = 0.4$, stay about the same if $M = 0.6$, and increase slighcly if $M = 0.8$.

In the future, if the surface catch remains at about 30 thousand tons while the longline effort in the EPO remains the same, and the catch of bigeye declines significantly, the two fisheries are probably exploiting the same stock(s) and *M* is probably not much greater than 0.6. If, however, the longline catches do not decline the two fisheries are probably exploiting independent or semi-independent stocks or *M* is greater than 0.6 (or both).

NORTHERN BLUEFIN TUNA

Introduction

Northern bluefin tuna occur in both the Atlantic and Pacific Oceans. The world and Pacific Ocean catches of northern bluefin are much less than those of skipjack, yellowfin, bigeye, or albacore, but the fishery is still of considerable economic value. The annual catches of northern bluefin in the Pacific Ocean for the 1951-1994 period are shown in Table 6. Surface gear accounts for the majority of the catches in both the eastern Pacific Ocean (EPO) and the western Pacific Ocean (WPO). In the EPO the catches were below average during 1980-1984, about average during 1985 and 1986, and below average during 1987-1994. In the WPO the catches were well above average during 1978-1983 and about average during 1984-1992, except for 1988 and 1990, when the catches were well below average.

In the EPO nearly all of the catch of bluefin tuna is made by purse seiners fishing relatively close to shore off California and Baja California. The fishing season typically extends from May to October, although sporadic catches are made in other months. The 1994 catch of about 814 tons was the second-lowest of the 1951-1994 period. During 1994 logged catches of bluefin were made between 26°N and 33°N during late July through early October.

The staff of the IATTC has been studying bluefin tuna on a modest scale since 1958, when 122 purse seine-caught bluefin were tagged and released near Guadalupe Island, Mexico. Prior to 1979 the work consisted mostly of collection of logbook data and measurement of samples of fish caught by purse seiners in the EPO to estimate their length compositions. Since 1979, however, more has been done. In 1979 a review of information pertinent to stock assessment of this species was prepared (IATTC Internal Report 12). Also, data on the surface catches of bluefin in the EPO by area, date, vessel size class, size of school, type of school, *etc.*, were assembled, analyzed, and published in 1982 in IATTC Bulletin, Vol. 18, No. 2. In addition, purse seine-caught bluefin were tagged in the EPO in 1979 and 1980, and troll- and trap-caught bluefin were tagged in the WPO by IATTC employees who were stationed in Japan intermittently during 1980-1982. Also, research has been conducted on determination of the age and growth of bluefin from hard parts.

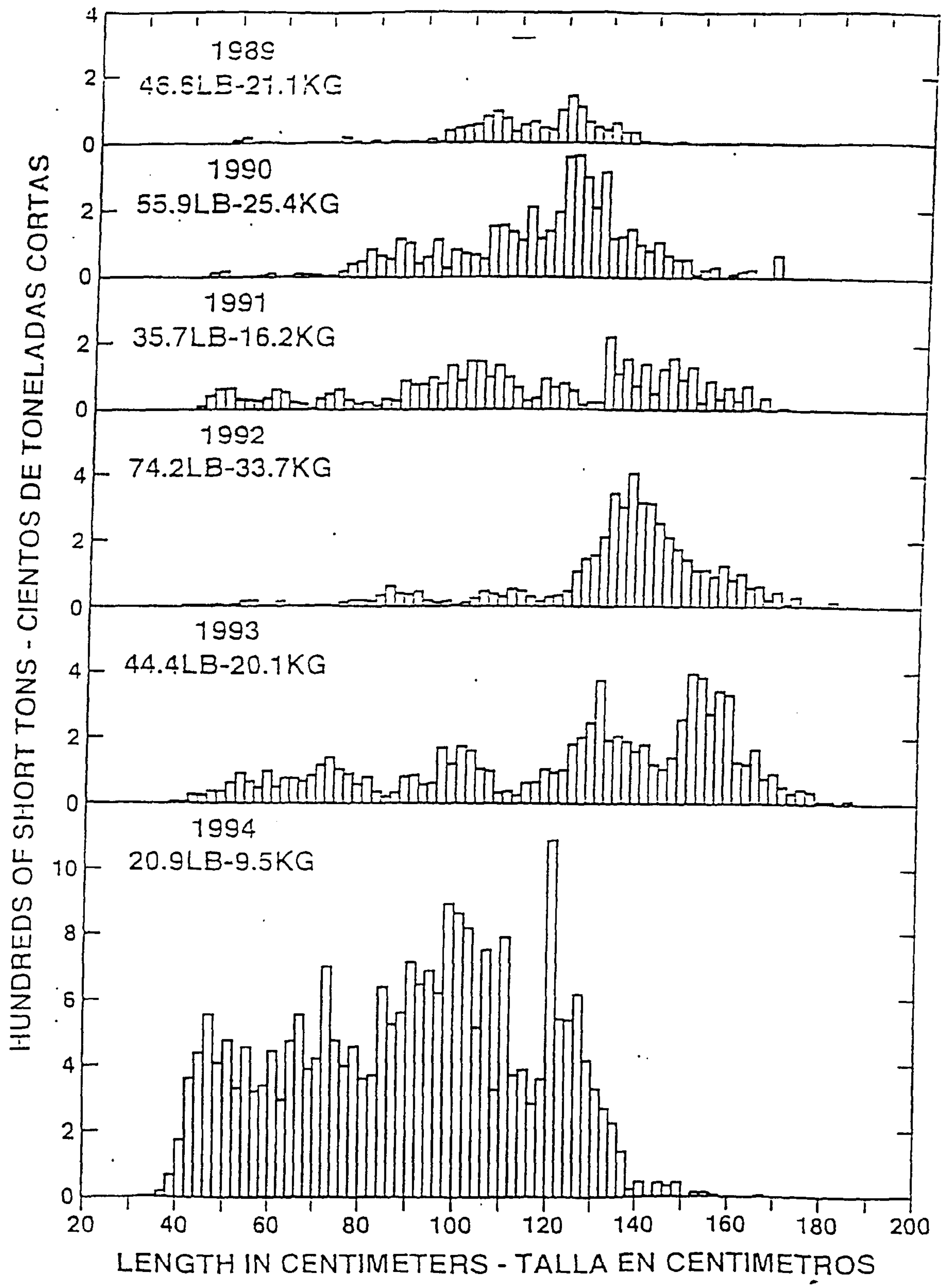

FIGURE 2. Estimated catches of bigeye by surface gear in the eastern Pacific Ocean. The values in the upper right corners of the panels are average weights.

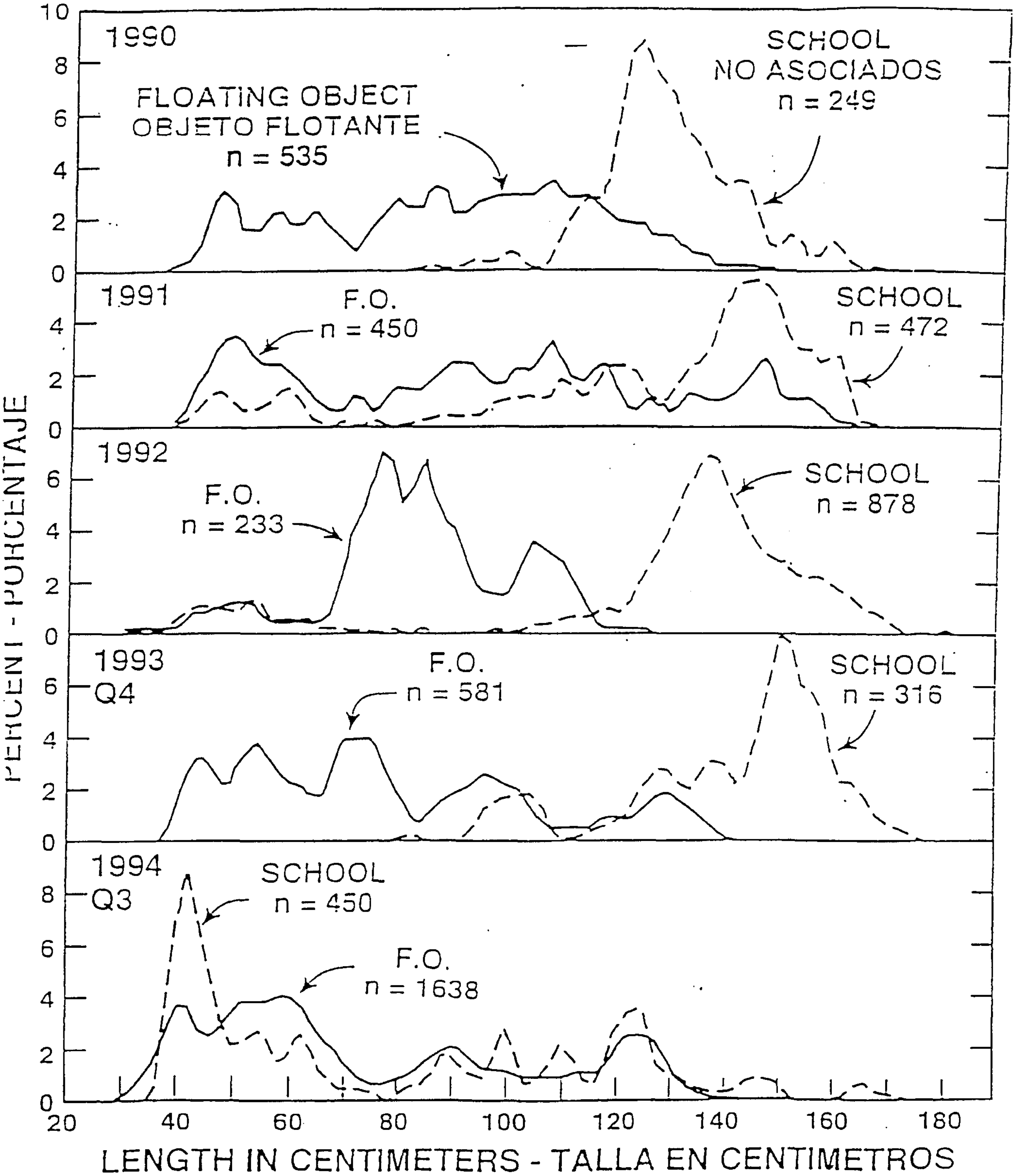

FIGURE 3. Smoothed length-frequency distributions for bigeye caught in sets made on schools of fish associated with floating objects and sets made on free-swimming schools of fish.

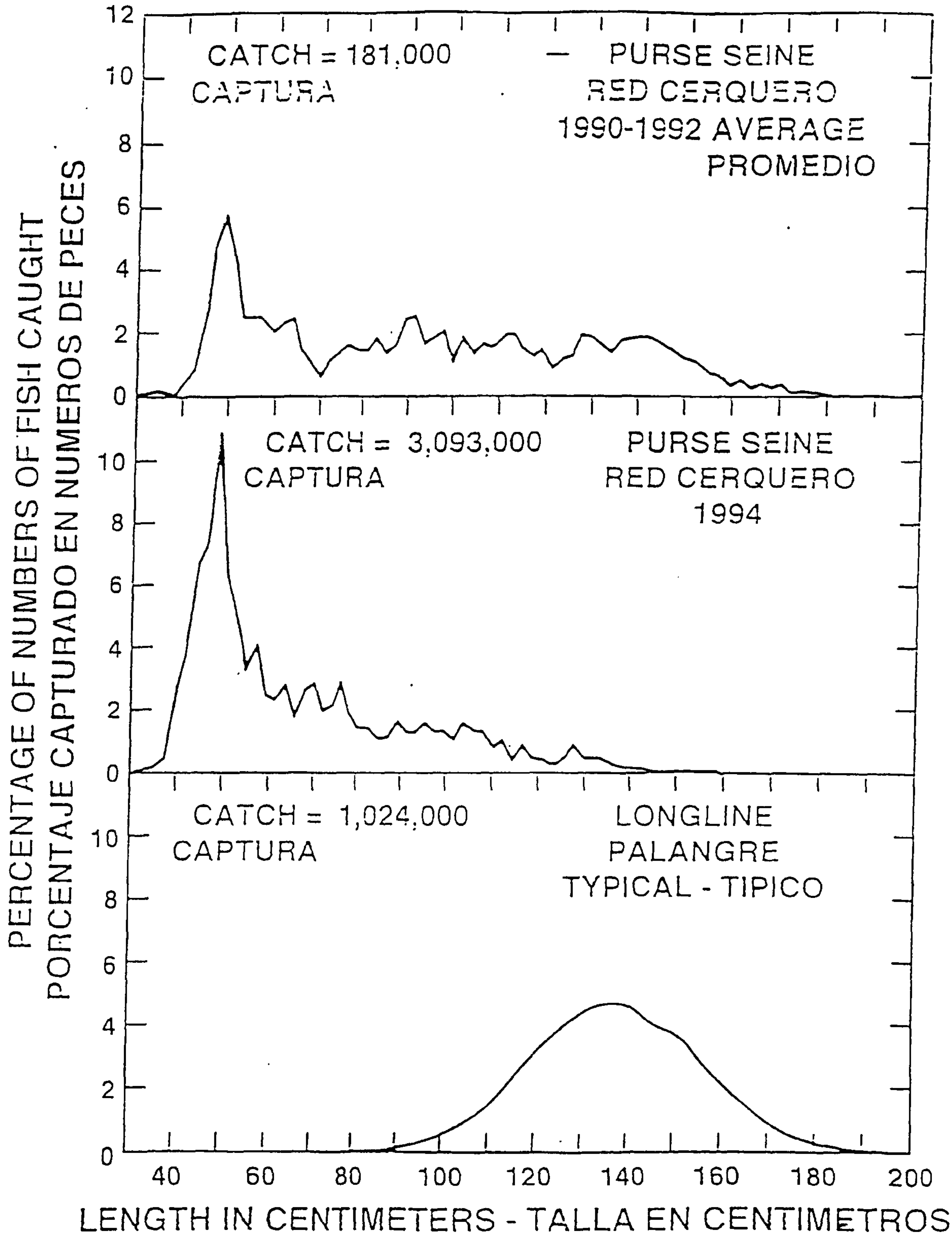

FIGURE 9. Catches of bigeye in the eastern Pacific Ocean and length-frequency distributions of the fish caught.

TABLE 4. Estimates of the catches at age of bigeye tuna calculated from the data in Figure 9.
TABLA 4. Estimaciones de las capturas a edad de atunes patudo, calculadas de los datos en la Figura 9.

Age	1990-1992 purse seine	1994 purse seine	Typical longline	1990-1992 ps + ll	1994 ps + ll
Edad	Cerco 1990-1992	Cerco 1994	Palangre típico	c + p 1990-1992	c + p 1994
0	63,813	2,013,726	0	63,813	2,013,726
1	52,739	828,686	35,991	88,730	864,677
2	35,525	227,127	368,943	404,468	596,070
3	24,371	23,319	430,577	454,948	453,896
4	4,107	554	146,047	150,154	146,601
5	814	76	32,719	33,533	32,795
6	45	0	8,045	8,090	8,045
7	0	0	1,507	1,507	1,507
8	0	0	314	314	314
9	0	0	159	159	159
Totals	181414	3093488	1024302	1205716	4117790

TABLE 5. Estimates of the numbers of recruits, in thousands, needed to support the catches of bigeye in Table 4.
TABLA 5. Estimaciones del número de reclutas, en miles, necesarios para sotener las capturas de patudos en la Tabla 4.

Natural mortality	1990-1992 purse seine	1994 purse seine	Typical longline	1990-1992 ps + ll	1994 ps + ll
Mortalidad natural	Cerco 1990-1992	Cerco 1994	Palangre típico	c + p 1990-1992	c + p 1994
0.4	390	4495	4024	4416	8622
0.6	627	5606	8579	9214	14383
0.8	1076	7186	19769	20859	27302