SCB2 WP10

Preliminary analysis of fisheries and some inference on stock status for yellowfin tuna in the western Pacific

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1. Introduction

Stock status of yellowfin tuna in the western and central Pacific has been assessed mainly through longline statistics (e.g., Hayasi and Honma, 1971). This is mostly due to the fact that the longline fishery was an one dominant fishery for yellowfin tuna in the area with which relatively good statistics had been kept for a long time. Maximum sustainable yield (MSY), estimated in the past for the entire Pacific yellowfin tuna available to the longline fishery, ranges from 60,000 tons (Honma 1974a) to 100,000 tons (Suzuki 1986). Though the same estimates for the western Pacific have not been made, Suzuki (1988) suggested that the MSY available to the Japanese longline fishery in the western Pacific stock (west of 180°) would be somewhere between 40,000 and 50,000 tons. Regardless of the area and statistics dealt, it appears from the recent studies that the further increase of longline fishing effort would not be accompanied by any significant increase of the resultant catch.

The yellowfin production from the western tropical Pacific increased significantly in the turn of the 1980s by the development of purse seine fishing and various fisheries in coastal countries such as the Philippines and Indonesia (Table 1). By the middle of the 1980s, the purse seine fishing appears to have become the largest single fishing gear capturing yellowfin in the western Pacific replacing with the longlining, the former dominant gear.

In the wake of substantial changes in the yellowfin fishery, there has been a concern on the stock status as well as on interaction with other already existing fisheries in the areas with the consequence of the developing fisheries. However, it is difficult to evaluate the consequence for the western Pacific yellowfin stock, even preliminary one, due to lack of availability on basic statistics for major yellowfin fisheries and poor biological information necessary to the analysis. Despite the lack of relevant information, several attempts were made primarily aiming at analyzing interaction between fisheries, especially between the purse seine and the longline fisheries (SPC 1985, Suzuki 1986, SPC 1988). Although definite alarming phenomenum is not yet observed for the western Pacific yellowfin stock as of around 1985, the concern continues because of further development of the purse seine fishing. The present paper is an up-to-date study of the previous work (Suzuki 1986).

2. Materials and Methods

Materials

Catch and effort as well as size measurement statistics by areas form the basic data essential to the stock assessment in most cases. Unfortunately, those data are either unpublished or nonexistent for major yellowfin fisheries in the western Pacific.

Japan has large distant water fisheries for yellowfin tuna in this area including both traditional longline and developing purse seine fisheries. Therefore, the catch and effort statistics and size measurement data of Japan were extensively used as base data. Unpublished catch and effort statistics were used for the Japanese longline and purse seine fisheries along with the published longline catch and effort statistics during the period from 1962 to 1980 (Fisheries Agency of Japan, 1960-1982). All Japanese size measurement data used are unpublished ones. Strata of month-5° square and quarter-Lat 10° x Long 20° area were adopted for compiling the catch and effort and size measurement data, respectively.

Other than Japanese data, unpublished size measurement data for the Philippine fisheries were used. They were made available by courtesy of the Bureau of Fisheries and Aquatic Resource and Indo Pacific Tuna Development and Management Programme (IPTP). The size measurement data are in preliminary nature subject to revision and cover the catch in major unloading sites of the Philippines for the years from 1980 to 1987 compiled by gear, unloading site, statistical area and month. The Philippine size measurement data were combined to the Philippine national statistics (Bureau of Fisheries and Aquatic Resources 1980-1984, 1986, 1987) which specified the total catch by species, fishing gear and statistical area so that yellowfin catch by age by the Philippine fishery as a whole could be estimated. However, it should be noted that bigeye and yellowfin tuna are lumped in the Philippine catch statistics. Since very small amount of bigeye appears to have been caught in the Philippines and there are no clues to separate these two species at present, here the lumped yellowfin and bigeye catch statistics of the Philippine fishery were used as first appoximates of yellowfin catch of the country.

FAO Yearbook for Fishery Statistics and FAO (1980) were referred to in obtaining information of national yellowfin catch for the rest of the countries.

Methods

As previously stated, Japanese longline and purse seine fisheries were regarded as the base data. Generally speaking, purse seine and longline fisheries exploit juvenile and adult fish, respectively. Namely, catch rates and size of fish taken by the Japanese longline fishery was assumed to be the same with those by other foreign distant water longline fisheries. This assumption was also applied to the Japanese purse seine fishery with other foreign industrial purse seine fisheries. The Japanese longline catch and effort statistics covers yellowfin tuna taken by the boats larger than 20 gross tons. On the other hand, the Japanese purse seine statistics used in this study are for the boats, mainly composed of a size of 500 gross tons.

There are other Japanese longline and purse seine fisheries operated by coastal areas of Japan or by the small boats than the base fisheries.

However the amount of yellowfin catch by those fisheries is much smaller and the quality of statistics are poorer in general than those by the base fisheries. These two base statistics of Japan were used to describe historical trends of fishing performances such as catch, fishing effort, CPUE, and size of fish in the catch. This procedure will give a rough idea how the fisheries behaved and to some extent the stocks responded, one for juvenile and the other for adult segments of the yellowfin stock.

Following length-weight (Kamimura and Honma 1959) and age-length (Yabuta, Yukinawa and Warashina 1960) relationships were used throughout the study for conversion purpose :

$$W = 0.00000664 \times 1.15\ L^{3.1878}$$
$$L = 190\ (1-\exp\ (-0.33t))$$

were W, L, t denote live weight (kg), fork length (cm) and age (year), respectively. A factor of 1.15 was used to convert gilled and gutted weight to live weight (Morita 1973). In this paper, yellowfin tuna distributed in the Pacific west of 180° between 40°N and 40°S was assumed to form a single subpopulation as in the previous study (Suzuki 1986).

3. Result and discussion

(1) Catch and effort of Japanese fisheries

Longline

Fig. 1 shows the change of annual longline catch of yellowfin tuna in metric ton, number of nominal hooks used, average whole weight of fish caught and CPUE as nominal hook rate in % from the western Pacific, west of 180° and between 40°S and 40°N.

Efforts of Japanese longliners steadily increased during 1950s according to the development and expansion of the fishery. After that, effort level remained relatively stable with some fluctuations. The most recent increase and decrease in efforts roughly corresponded with the development of deep longlining since 1975 and the decline of use of conventional one as well as voluntary reduction of about 20% fishing vessels.

Annual catches showed the similar trend as that of efforts. So, CPUE of Japanese longliners remained more or less in a stable level except recent years when the drastic increase of 1977 and 1978 and the following steady decline occurred. It should be noted that this decline in CPUE started before the expansion of Japanese and US purse seiners in this area in 1981 and 1983, respectively. Average weight of fish caught by longline slightly increased during the same period.

Purse seine

Catch and effort of Japanese purse seine are shown in Fig. 2. In this Figure, the efforts are shown in nominal number of sets.

Total efforts of Japanese purse seine rapidly increased from 1980 through 1984 and showed some decrease in 1986. Catch of yellowfin tuna constantly increased during this period. CPUE increased steadily until 1981 maybe due to the development of new fishing grounds and the improvement of several fishing and searching devices. CPUE went down to low level in 1983 and 1984 and increased again after that. It has not been known whether this decline in CPUE has any relationship with El Nino and/or the drastic increase of US purse seine of 1983.

(2) Attempt to develop reliable CPUE.

Longline

Honma method (Honma 1974b) and general linear model (GLM) were applied. The former is powerful for unbalanced data but assumes, as one of critical ones, existence of a fixed pattern of CPUE distribution with respect to time and area in the whole data period analyzed, while the latter, statistical method, does not require that assumption and allows to include any factors which might affect CPUE significantly such as environmental conditions. Honma method was applied to the cases with or without adjustment for deep longlining which has become widely employed from 1975 (Suzuki, Warashina, Honma 1977). The period 1961-1976 was used to calculate average year distribution of CPUE. The deep and regular longlinings were defined operations with 10 or more and 4-6 branch lines, respectively. Ratio of hook rates by the deep over that of the regular is considered as an index of the fishing efficiency of the deep longline. Adjustment for the deep longlining was made on annual basis by multiplying fishing efficiency of the deep longlining over the regular one by the number of deep longline hooks used, thus converting number of the deep longline hooks to equivalent value with that of the regular longline hooks. The western Pacific was divided into 10 subareas in calculating the fishing efficiency of the deep longline. Longline CPUE trends, catch in number of fish per 100 effective hooks derived from Honma method are shown in Fig. 3. The trends of two indices, with and without adjustment for the deep longlining, are almost identical. They showed a moderate decline from around 1.5 in the 1950s to 0.8 in the early 1960s, then remained roughly in the same level from the early 1970s up to 1986 except few years with high CPUE. However, the CPUE in the latest three years from 1984 to 1986 is in the low level.

GLM used to examine CPUE trend includes the factors year (Y), quarter (Q), area (A) and hooks depth (H) and is applied for the years 1975 - 1986. The hook depth corresponds to the deep and regular longline operations defined previously. The area used for the calculation covers the western tropical Pacific, roughly between 15° N and 15° S and west of 180° with three subareas. Monthly data in a given quarter were regarded repitition for that quarter. Multiplicative type of the model was assumed and a constant of 1.0 was added to the observed CPUE. Other than four main factor terms, interaction factor terms between the two main factors were added in several models. The CPUE series thus calculated showed a very similar trend. In Fig. 3, shown is the case of the four main factors without interaction factor. Except for level of CPUE, the trends by Honma method and the GLM are quite similar.

Purse seine

In contrast to the longline fishery, fishing efficiency of the purse seine appears to have been improving. Some aspects of technical innovation are usages of radio buoys attached to the logs and bird radars which are very effective to locate bird flocks formerly out of detective range of optical binoculars. Therefore, it may be dangerous to interpret CPUE calculated from nominal fishing effort as that of abundance index of the stock. Three CPUE indices are shown in Fig. 4, i.e., catch per set (CPS), catch per days fished (CPD) and catch per days fished including searching days (CPDR). Searching day information started to be collected from 1983. The CPS and CPD and CPDR trends are similar. The CPS increased up to 1981 followed by decrease to 1984 and then recovered in 1986 to the highest 1983 level.

(3) Production curve for longline and purse seine fisheries

Shape of production curve for a specific fishery gives useful information on stock status if detailed history of the fishery is known simultaneously (Suzuki 1988). Figure 5 shows production curve for Japanese, Taiwanese and Korean longline fishery combined for the western Pacific. Overall catch and effort for three countries was obtained in the following manner. Japanese catch of yellowfin tuna in weight was estimated as a product of average weight and catch in number of fish basing on the time area stratum previously mentioned. For Taiwan and Korea, longline catch is assumed to be predominant in yellowfin catch. The Taiwanese catch was cited from the FAO (1980) for the period from 1952 to 1963 assuming the catch during this period came from the western Pacific since the distant water fleet of Taiwan had not operated in this early period. From 1964 up to 1986, Taiwanese catch was taken from FAO yearbook combining the catches from Areas 61 and 71. Country name 'Other nei' in the FAO yearbooks was assumed Taiwan. The Korean catch is referred from FAO yearbook combining the catches from Areas 61 and 71. Total effective effort was estimated using a ratio of total catch of the three longline countries to the Japanese catch and multiplying it with the Japanese effective effort.

The catch and effort relationship behaves fairly well in accordance with the production model. Therefore, generalized production model by Fox (1975) was applied with input parameter K (number of significant year class in the catch) of 3 and m (shape determinator of the production curve) of 0, 1.0, 2.0 and variable (estimated by the model). The results are :

	MSY (1000 MT)	Fopt (Million Hooks)	Fit index
m = 0 and estim.	112	--	0.68
m = 1	70	382	0.64
m = 2	68	300	0.60

The longline fishery in the western Pacific appears at present operating in the left hand side of the rim, i.e., a little bit below MSYL.

Plots of annual catch and effort for Japanese and US purse seine fleets combined were shown in Fig. 6. The combined effort was obtained with multiplying raising factor (combined catch / Japanese catch) by the Japanese nominal number of sets. No attempt was made to draw a equilibrium production curve for the purse seine fishery due to short time series as well as uncertainty of estimating effective fishing effort. It is not possible to infer future trend of the purse seine production curve whether the curve shows a continued increase or flat top of the catch with further increase of the fishing effort.

(4) Interaction between the purse seine and longline fisheries

Changes of in the longline CPUE by 5° square were compared for the periods before and after introduction of the purse seine fishery. The pattern of changes were different depending on the selection of the periods to be compared. At present, the study is being continued to determine which one is the most appropriate comparison and how to interpret the results due to complicating factors such as changes in fishing effort level as well as CPUE, regular to deep longlining and uncertainty of the population structure.

(5) Estimation of catch by age by major fisheries

Change in age composition is an important information on stock exploitation by fisheries. Three largest fisheries in terms of yellowfin catch in the western Pacific were selected: distant water purse seining (Japan plus U.S.A.), longlining (Japan, Taiwan and Korea combined) and the Philippine fishery. The Indonesian fishery was not considered due to lack of the relevant data despite of a significant contribution to the yellowfin catch in this areas. Age was assigned by back calculation of the age-length relationship (Yabuta et al. 1960) taking sampling season (quarter of the year) into account.

The result is shown in Table 2. The longline catch tended to increase nearly for all age classes from 1976 to the 1979-1981 period, then afterward showed a decreasing trend. Either age 2 or 3 is the most importnat segment in the catch, followed by age 4. Age composition of the longline fishery is rather constant after 1981. The catch of distant water purse seine has been increasing for all age classes with some sign of level off in the recent 1983 -1986 period. Age composition of the purse seine fishery appears fairly constant, i.e., age 1 fish is always most dominant followed by either age 0 or age 2. The data of the Philippine catch by age data was made available for the period from 1980 to 1986. Four segments of the Philippine fishery were classified, i.e., handline, ring net, purse seine and other gears. Estimation of catch by age were made by each gear, then summed to have catch by age of the entire Philippine fisheries. Since length measurement data of other gears were rather poor, the catch of the other gears were converted into ages using combined age composition of the other three gears. Age 1 and 2 are predominant. Age 4 fish were often caught more than age 3 fish. This is due to the fact handline fishery takes very young age 0 and 1 fishes as well as older fishes ranging 4-6 years old with intermediate age classes less represented. White (1982) estimated the 1980 length composition of yellowfin tuna caught by the Philippine fishery. The 1980 age composition shown in Table 2 is fairly close to that by Suzuki (1986) who converted the length data given by White (op. cit.) into age in the same manner described in this paper.

The age composition of the three fisheries combined shows big annual fluctuation during 1980-1986 without either apparent increasing or decreasing trend in any specific age classes except some increase in number of age 5 and 6+ in the early 1980-1983 period. For all fisheries combined there is also fairly good accordance in the 1980 age composition estimated by Suzuki (1986) and the present paper.

(6) Inference on stock status

The yellowfin catch in the recent years from 1983 to 1986 is fairly constant around 200,000-210,000 tons. Despite of increased catch by the industrial purse seine and the coastal fisheries during the recent years, longline CPUE remaines in the lowest level recorded in the period before development of these fisheries. Preliminary analysis of age composition of yellowfin tuna for the three largest fisheries suggests that the composition of all three fisheries combined did not change in a consistent way with respect to time although it did show big fluctuation in some years. This may explain rather sustained performance of the longline fishery in recent years. Therefore, it is inferred that the present level of the fishing pressure probably sustains about 200,000-210,000 tons of yellowfin tuna catch.

Future projection of production and stock size under various scenarios appears pointless due to preliminary nature on the catch by age data with a short time series. Suzuki (1986) made a projection using tentative data which reflected the age composition in 1980-1982 period estimated roughly the same way with the present study. It was suggested from the projection that increase of the distant water purse seine, under unchanged exploitation pattern of other fisheries, would double its catch but the total catch from the entire western Pacific would not increase significantly due to reduction of stock size available to the large fish fisheries. However, the total production from the entire stock has increased significantly in the recent years. Among several possible explanations for the discrepancy, change of the age composition in the Philippine fishery might be one of the cause because only one year data for 1980 which differ considerably from those in the rest of years (Table 2) were used in the previous study. Another problem which makes simple projection unrealistic is fluctuation of recruitment. Recent analysis for yellowfin in the eastern Pacific indicates very strong increasing tendency of the recruitment from 1983 to 1988(IATTC 1988). These information implies that the western Pacific yellowfin stock was far from being in equilibrium condition which was one of the critical assumption in the previous study.

Concl: Small fisheries not affecting [illegible], Jap. purse seine [illegible] catch

4. Conclusion

It appears that the fishing performance of the major yellowfin fisheries is fine or sustained in recent years. Although the stock status of this stock remains unclear, various circumstantial evidences indicate the stock is in a healthy condition. Interaction between the purse seine and the longline fisheries is not still appreciable up to 1986. However, since the longline CPUE is in the lowest level and fluctuation of the stock size may be caused not only by the fishing pressure but also by other biotic and abiotic factors, close monitoring of fishing performance for major fisheries as well as improvement of the quality and coverage of basic statistics for the fisheries in general are essential in the successful management of this stock.

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Table 1. Catch of yellowfin tuna by countries from the FAO Area 71 (Pacific, Central west).

Country (Gear)/Year	1971	1972	1973	1974	1975	1976	1977	1978
Fiji				12	11	74	151	540
Indonesia					11062	8037	10859	10601
Japan Total	23531	24315	29822	31670	33070	37813	50822	73080
Longline	22807	24021	29286		29528		41987	59044
Purse seine	379		481		2176		7159	7036
Baitboat	345	294	55		55		1676	769
Other								6231
Kiribati				25	25	25	2771	2930
Korea Rep.					259	3664	5462	5088
Papua New Guinea			1420	1420	1743	8563	3695	3115
Philippines			14900	51732	52793	44478	63059	47629
Solomon Is.								
U.S.A.								
Other				4229	4319	2510	2805	1870
Total	23531	24315	46142	89088	92209	105164	138904	144853
Japan/Total	1.00	1.00	0.65	0.36	0.36	0.36	0.37	0.50

Country (Gear)/Year	1979	1980	1981	1982	1983	1984	1985	1986
Fiji	361	240	846	1157	1586	1771	1128	995
Indonesia	14663	17550	21869	24340	20200	26450	31022	34140
Japan, Total	54789	75990	77145	72362	70682	61767	76513	73108
Longline	43488	55888	49003	38162	40193	28433	30766	24872
Purse seine	10528	9918	21827	28054	25567	32057	37523	42388
Baitboat	773	6143	2706	1531	1030	1275	3229	1827
Other		4041	3609	4014	3892	2	4995	4021
Kiribati	3000	3148	3000	3000	2135	4036	4844	1065
Korea Rep.	6881	7424	2712	2528	1156	1373	1893	3251
[redacted] New Guinea	2881	3019	3516	0	0	372	370	400
[redacted]	49224	48023	56176	51922	62036	58927	64293	59510
Solomon Is.	192	314	1167	2165	3328	2816	3698	2769
U.S.A.		772	12867	14345	51066	41455	28798	36520
Other	2084	2363	1444	1036	433	1031	1062	1009
Total	134075	158843	180762	172855	212622	199998	213621	212767
Japan/Total	0.41	0.48	0.43	0.42	0.33	0.31	0.36	0.34

Data from Suzuki (1984), FAO (1985-1988), Statistics and Information Division, Japanese Ministry of Agriculture, Forestry and Fisheries (1985-1988).

Table 2. Estimated catch by age of yellowfin tuna for three major fisheries, distant water longline ((A), Japanese, Korean and Taiwanese data combined), distant water purse seine ((B), Japanese plus U.S. data), the Philippine fishery (C) and the total (D) in the western Pacific.

A: Longline fishery — unit : 1000 fish

Year/Age	0	1	2	3	4	5	6+
1976		30	467	693	423	46	14
1977		49	1065	867	402	44	7
1978		26	1420	1499	329	42	3
1979		72	1063	1196	480	55	5
1980		150	1579	1265	425	32	3
1981		97	1650	920	415	45	6
1982		72	701	954	358	57	5
1983		57	635	1094	254	40	3
1984		33	543	800	324	25	3
1985		41	529	890	303	38	3
1986		34	512	634	344	49	5

B: Purse seine fishery

Year/age	0	1	2	3	4	5	6+
1976	105	747	183	25	4		
1977	161	1145	281	39	6	1	
1978	245	1742	427	59	8	1	
1979	343	2439	598	82	12	1	
1980	212	1502	368	51	7	1	
1981	701	4977	1220	169	24	3	
1982	1109	5132	894	452	119	20	2
1983	637	10331	2319	351	233	50	
1984	2698	9879	2537	524	110	47	7
1985	1647	9984	1162	373	229	27	5
1986	407	8338	3356	479	116	6	2

C: Philippine fishery

Year/age	0	1	2	3	4	5	6+
1980	12767	14459	169	305	384	35	1
1981	4978	5901	671	472	408	69	6
1982	5503	8418	394	268	396	83	12
1983	4353	9427	546	297	380	131	13
1984	2214	6893	720	271	360	127	7
1985	13412	20463	724	252	212	95	6
1986	3047	5840	464	391	404	128	14

D: Total.

Year/age	0	1	2	3	4	5	6+
1980	12979	16111	2116	1621	816	68	4
1981	5679	10975	3541	1561	847	117	12
1982	6612	13622	1989	1674	873	160	19
1983	4990	19815	3500	1742	867	221	16
1984	4912	16805	3800	1595	794	199	17
1985	15059	30488	2415	1515	744	160	14
1986	3454	14212	4332	1504	864	183	21

Fig. 1. Trends of catch, fishing effort, average weight of the catch and CPUE (catch in numbers of fish/100 nominal hooks) for yellowfin tuna caught by Japanese distant water longline fishery in the western Pacific(west of 180, south of 40°N and north of 40°S).

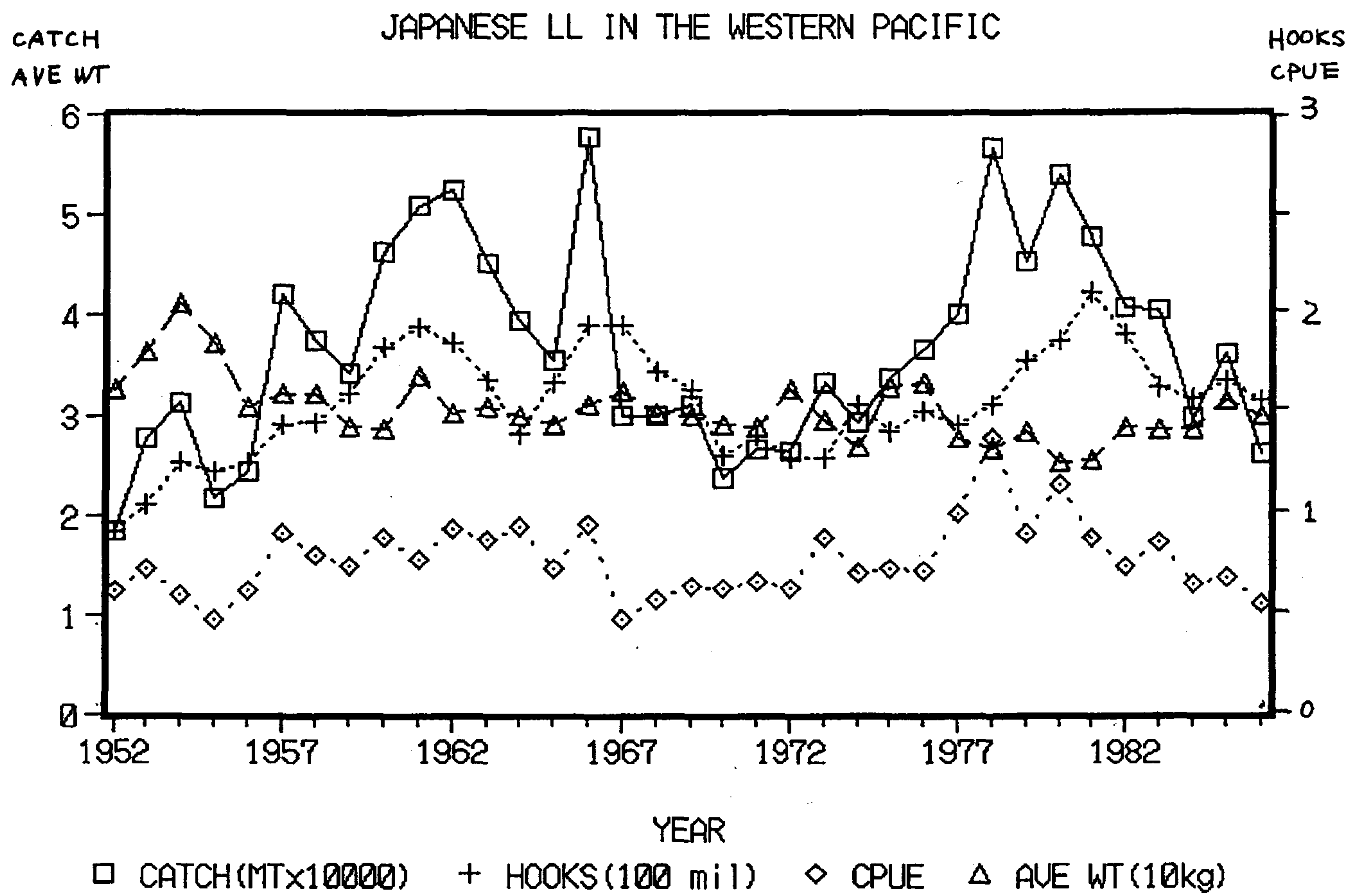
Fig. 2. Trends of catch, fishing effort, average weight of the catch and CPUE (catch in tons/set) for yellowfin tuna caught by Japanese distant water purse seine fishery in the western equatorial Pacific.

Fig. 3. Trends of CPUE (catch in number/100 hooks) estimated by Honma method and GLM for yellowfin tuna caught by the Japanese longline fishery in the western Pacific.

Fig. 4. Trends of CPUE calculated using various nominal fishing efforts for yellowfin tuna caught by the Japanese purse seine fishery in the western equatorial Pacific. CPS, CPD and CPDR indicate the catch in mt divided with number of sets, number of days fished, and number of days fished and searched, respectively.

Fig. 5. Catch and effort relationship for yellowfin caught by the Japanese, Taiwanese and Korean longline fisheries combined, from 1952 to 1986. Equilibrium curves calculated by Fox's production model are shown in the cases m = 2 and 0.

Fig. 6. Catch and effort relationship for yellowfin caught by the Japanese and U.S. purse seine fisheries combined, from 1976 to 1986.


JAPANESE LL IN THE WESTERN PACIFIC
CATCH
AVE WT
HOOKS
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6
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1952
1957
1962
1967
1972
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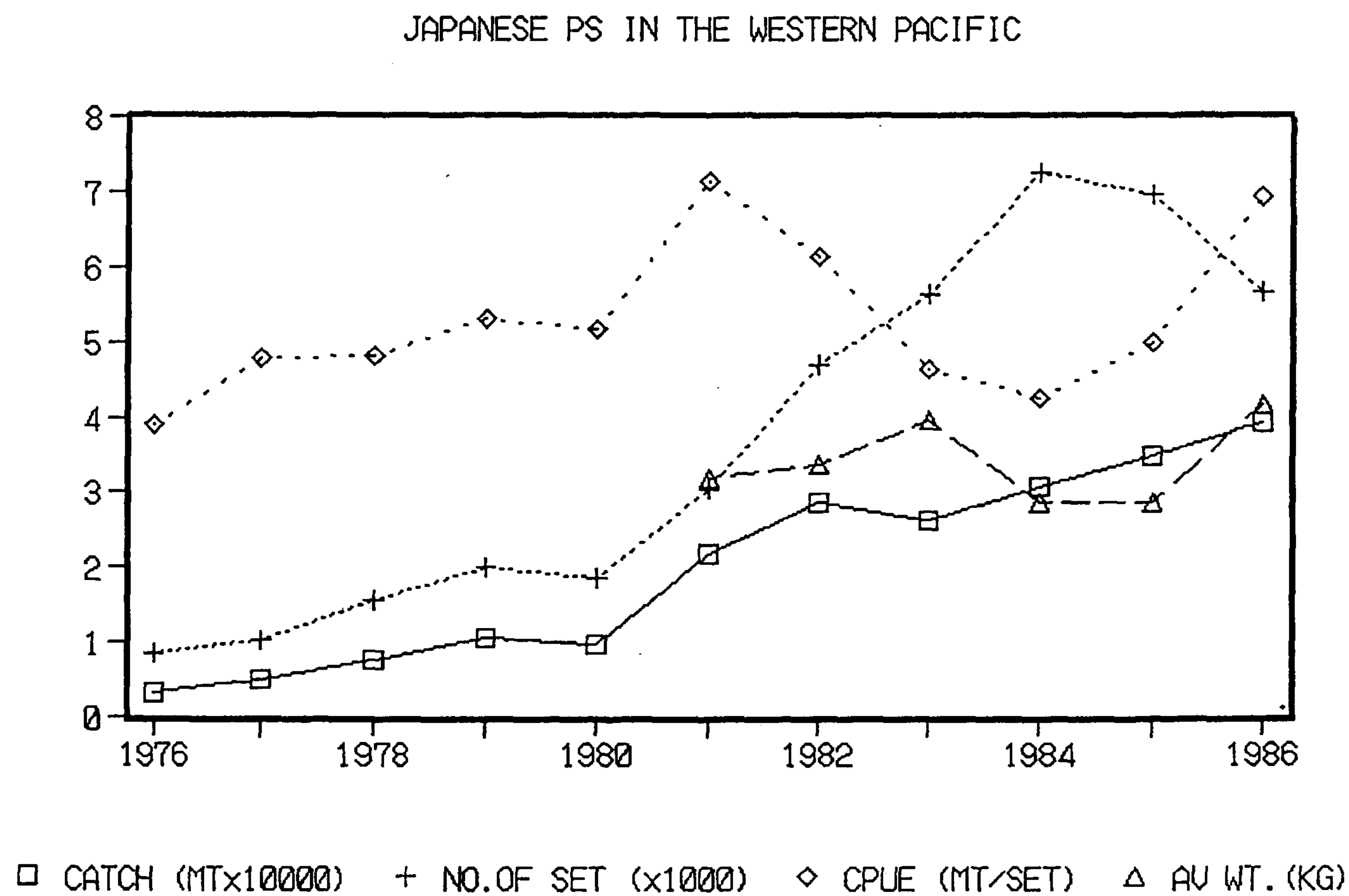
YEAR
CATCH(MTx10000)
HOOKS(100 mil)
CPUE
AVE WT(10kg)

Fig 1


JAPANESE PS IN THE WESTERN PACIFIC
8
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1976
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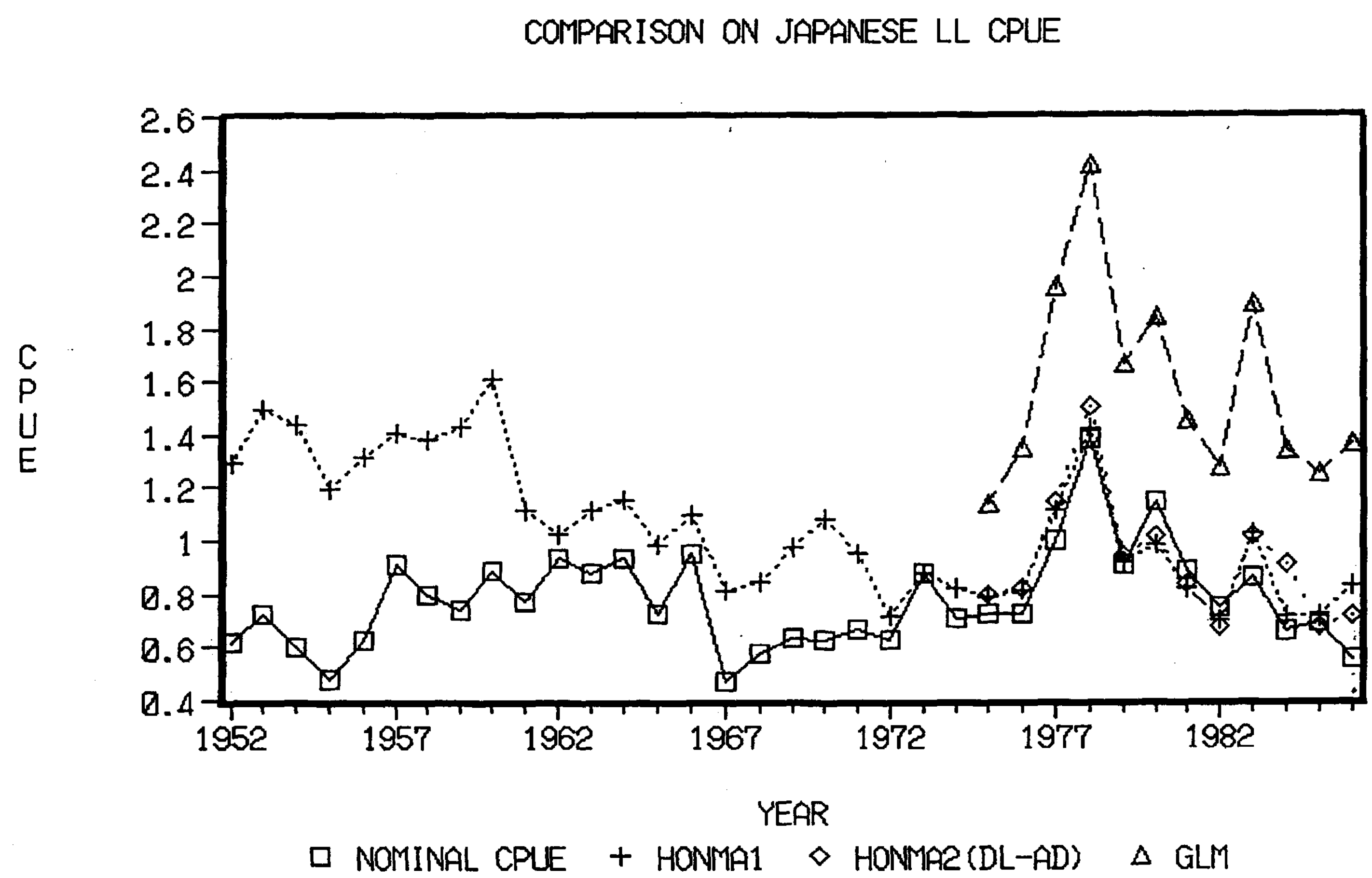
□ CATCH (MTx10000) + NO.OF SET (x1000) ◇ CPUE (MT/SET) △ AV WT.(KG)

Fig. 2.


COMPARISON ON JAPANESE LL CPUE
CPUE
2.6
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2
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1952
1957
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1982
YEAR
NOMINAL CPUE
HONMA1
HONMA2(DL-AD)
GLM

Fig 3

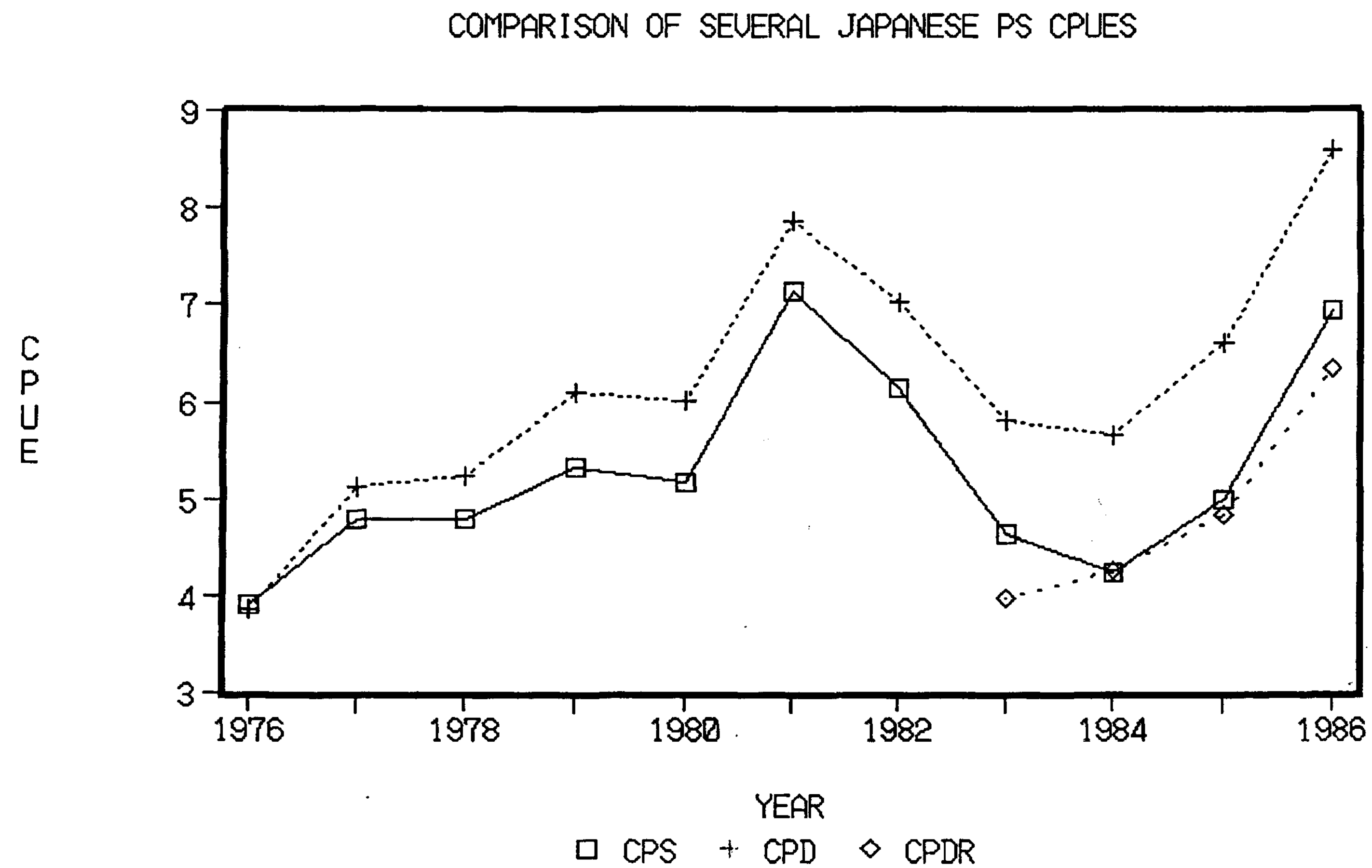

COMPARISON OF SEVERAL JAPANESE PS CPUES
CPUE
9
8
7
6
5
4
3
1976
1978
1980
1982
1984
1986
YEAR
CPS
CPD
CPDR

Fig 4

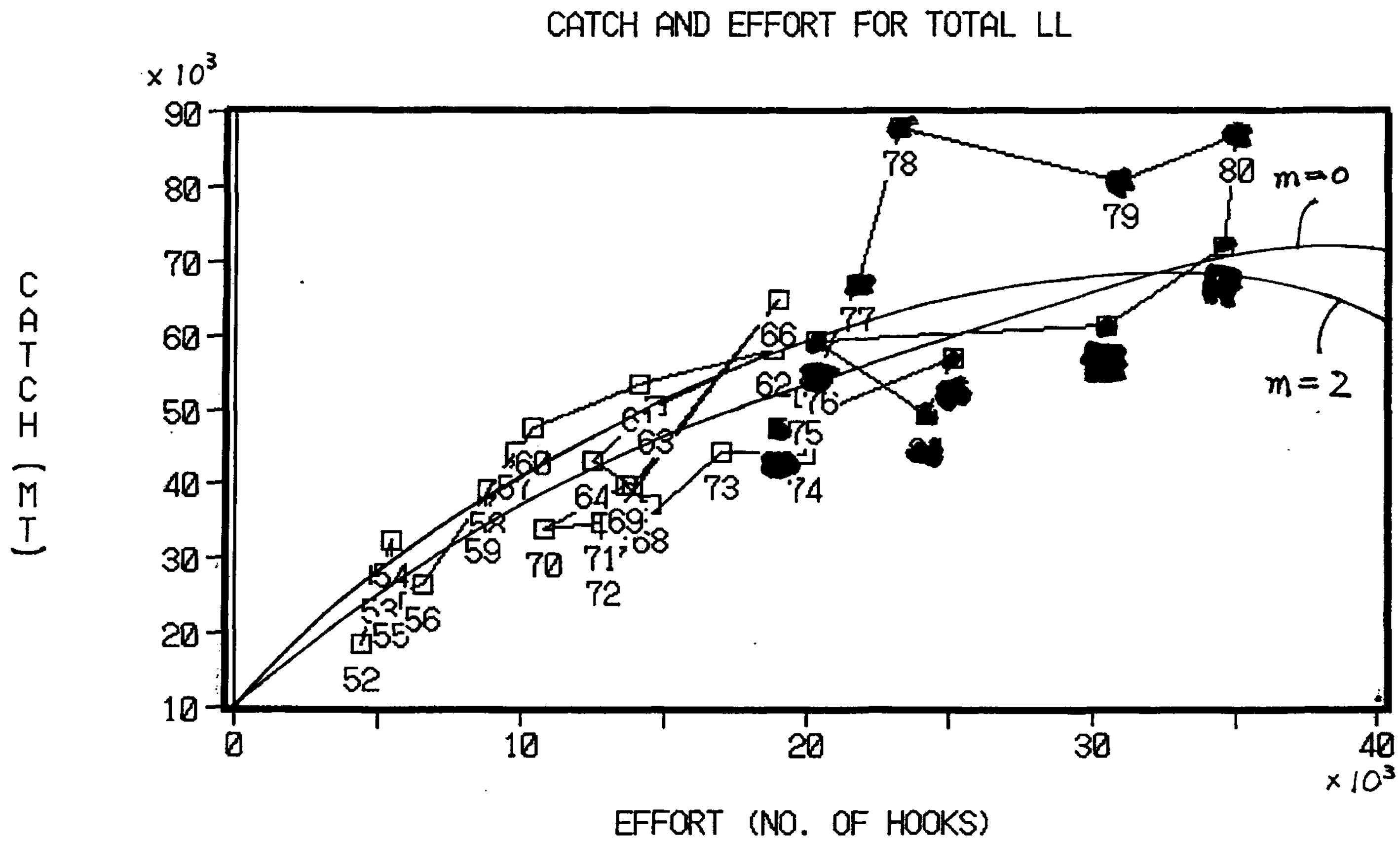
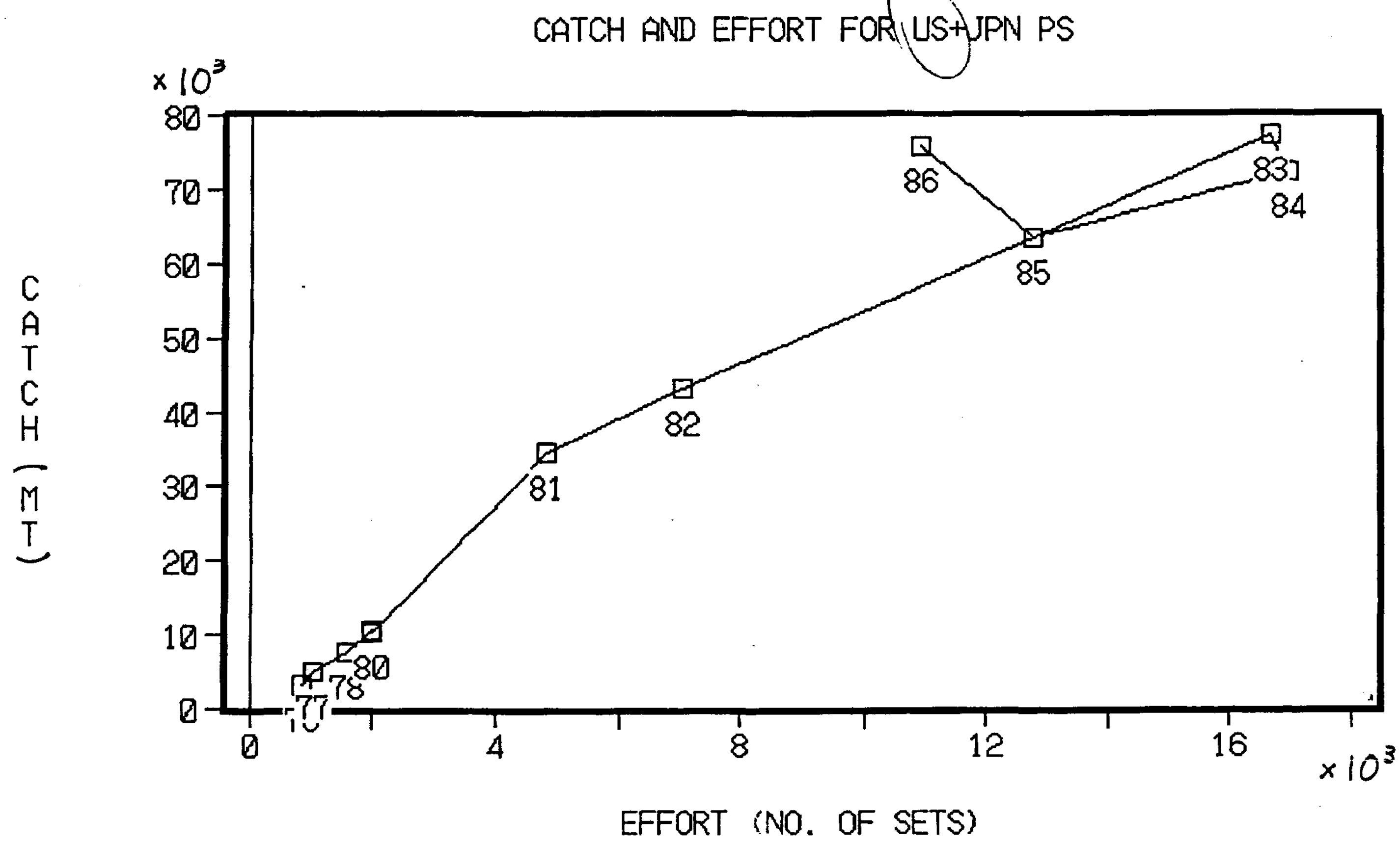

CATCH AND EFFORT FOR TOTAL LL
x 10^3
90
80
70
60
50
40
30
20
10
CATCH (MT)
0
10
20
30
40
x 10^3
EFFORT (NO. OF HOOKS)
m=0
m=2
52
53
54
55
56
57
58
59
60
61
62
63
64
66
68
69
70
71
72
73
74
75
76
77
78
79
80

Fig 5



CATCH AND EFFORT FOR US+JPN PS
CATCH (MT)
× 10³
80
70
60
50
40
30
20
10
0
0
4
8
12
16
× 10³
EFFORT (NO. OF SETS)
86
83
84
85
82
81
80
78
77

Fig. 6