Korean Tuna Fisheries in the Western Pacific Ocean

National Fisheries Research and Development Agency

Fishing Vessel Specification

Longline [redacted] and purse seine fishing gears have been using in capture fisheries of Korea for tuna and tuna-like species in the Pacific Ocean. The longline fishery has commenced in 1975 mainly targeting such tunas as bigeye, yellowfin and albacore and purse seine for skipjack and somewhat small ~~bigeye~~ yellowfin in 1980 in this Ocean. Most of longliners are home-based vessels returning home port in a period between six and twelve months from finishing fishing, and some are based at foreign ports; Samoa and Guam of U.S.A. and Papeete of Tahiti. All purse seiners are Guam-based fishing vessels.

The vessel size of tuna longliners ranges from 200 to 700 gross tonnage (GRT) and number of vessels for the size of 400-500 GRT is prevalent. The size of purse seiners are in a range between 800 GRT and 2,000 GRT and among them, the vessels with the size of 1,000-2,000 GRT accounts for more than fifty percent.

Longliners are operating through the whole tropical areas in the Pacific Ocean and bigeye has been dominant in the longline catch. Purse seiners have been concentrating their fishing in the western Pacific through the year and skipjack has always prevailed.

Catch and Fishing Distribution

Longline fishery

A total of 154 longliners participated in fishing for tunas and billfished in the Pacific Ocean in 1995. The 1995 total catch of longline fishery in the SPC area from the vessels was estimated to be about 29,200 metric tons, a decrease of 12.4% over the previous year's catch (Table 1). From the annual catch of this fishery since 1989, a trend shows a two-year fluctuating cycle. For instance, annual total catch in 1990 was 35,660 tons but decreased to 25,060 tons in 1991.

Species composition of longline catch in 1995 consisted of 52.6%, 32.4%, 0.1% and 14.8% for bigeye, yellowfin, albacore and others, respectively (Table 2). Catch of bigeye decreased to 15,400 tons from 19,600 tons in 1994, whereas yellowfin catch remained at 9,500 tons showing nearly the same level over the previous year's volume.

Catch per unit effort (CPUE) of longline in 1995 was calculated to be 1.39 fish/100 hooks, a decrease of 3.5% from the 1994 figure (Table 2). CPUE's values by species showed that bigeye decreased to 0.61 fish/100 hooks from 0.86 fish/100 hooks in 1994 but yellowfin had a slight increase at 0.44 fish/100 hooks over the value of 0.37 fish/hooks in 1994.

Recent distribution maps of Korean tuna longline fishery in the Pacific Ocean from 1991 to 1994 are shown in Fig. 1. Fishing grounds were mainly distributed in the Central tropical area between 10°N and 10°S through the whole Pacific Ocean, showing dense distribution regions in the western Pacific (0-10°S, 170°E-180) and the eastern Pacific (5-15°N, 115-90°W).

Purse seine fishery

In 1995, thirty purse seiners operated around the SPC area for skipjack and yellowfin tuna (Table 1). The total catch of this fishery amounted to 175,500 metric tons, a decrease of 10.0% from the 1994 catch. Skipjack was dominant species in the catch composition as in the past years, accounting for 78.6% of the total catch (Table 3). Catch by species from this fishery during 1995 showed that skipjack was 137,800 metric tons, a 5.3% decrease over the 1994 volume and ~~bigeye~~ yellowfin was down 24.0% to 37,600 metric tons compared with the previous year's figure (Table 3).

The fishing grounds of Korean purse seine fishery were located in the SPC area, indicating good distribution pattern off waters south of Micronesia (Fig. 2). In recent years, however, the fishing areas extended eastward, reaching near Samoa Islands.

Research Activities

Data collection and compilation for catch and effort statistics on tuna longline and purse seine fisheries are being conducted under responsibility of the National Fisheries Research and Development Agency (NFRDA). Fishery statistics for longline data on catch and fishing effort by species, which compiled by the 5°x5° area, were provided to SPC until 1994 and the 1995 data are under processing in the same manner as previous years. On the other hand, purse seine statistics from 1980 to 1994 are compiled by the 1°x1° area and now are reviewing for publication.

Biological sampling was carried out at domestic sites once a month during 1995 to obtain size data and information on reproductive biology of yellowfin and skipjack from Korean purse seiners.

Table 1. Korean fisheries statistics for the Pacific tunas in the SPC area

Year	Vessel active			Catch (MT)		
	LL	PS	Total	LL	PS	Total
1975	253		253	33,262		33,262
1976	257		257	56,196		56,196
1977	217		217	50,863		50,863
1978	223		223	43,236		43,236
1979	216		216	52,045		52,045
1980	211	2	213	50,405	544	50,949
1981	209	3	212	35,582	2,044	37,626
1982	121	10	131	30,654	12,209	42,863
1983	102	11	113	23,086	16,216	39,302
1984	96	12	108	22,104	14,183	36,287
1985	94	11	105	40,012	11,279	51,291
1986	134	13	147	41,122	27,732	68,854
1987	138	20	158	38,590	58,752	97,342
1988	124	23	147	34,954	79,397	114,351
1989	152	30	182	25,134	115,754	140,888
1990	182	39	221	35,662	173,343	209,005
1991	220	36	256	25,056	227,518	252,574
1992	166	36	202	30,243	182,287	212,530
1993	148	34	182	25,735	126,648	152,383
1994	160	32	192	33,378	195,004	228,382
1995	154	30	184	29,232	175,464	204,696

LL : Longline, PS : Purse seine
LL and PS vessels are from the entire Pacific Ocean including SPC area. Longline catches are re-estimated by the National Fisheries Research and Development Agency (NFRDA) on the basis of data (statistical-sea block, 5° longitude x 5° latitude) compiled from Korean tuna vessels' logsheets.

Table 2. Catch and CPUE statistics for longliners of Korea in the SPC area

Year	Hooks	Albacore		Bigeye		Yellowfin		Others	Total	
		Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	Catch	CPUE
1975	57,102	6,261	0.19	13,543	0.70	9,529	0.39	3,929	33,262	1.44
1976	86,867	9,008	0.71	20,176	0.57	15,118	0.62	11,894	56,196	2.09
1977	92,492	11,454	0.70	15,978	0.62	16,179	0.85	7,252	50,863	2.31
1978	56,661	11,302	1.45	7,878	0.65	13,812	1.07	10,244	43,236	3.37
1979	90,883	11,046	0.72	12,448	0.51	18,421	0.98	10,130	52,045	2.33
1980	93,835	9,640	0.61	13,106	0.38	22,795	0.87	4,864	50,405	1.96
1981	96,735	13,153	0.89	7,838	0.26	10,245	0.37	4,346	35,582	1.64
1982	71,750	11,499	1.00	6,988	0.35	8,954	0.55	3,213	30,654	2.03
1983	45,162	6,997	1.17	5,923	0.46	8,445	0.78	1,721	23,086	2.52
1984	52,994	5,212	0.68	7,086	0.47	6,792	0.59	3,014	22,104	1.87
1985	90,521	12,935	0.79	10,022	0.52	10,047	0.60	7,008	40,012	2.02
1986	67,313	15,677	0.91	10,156	0.54	9,532	0.68	5,757	41,122	2.24
1987	68,239	6,921	0.35	15,119	0.70	10,059	0.70	6,491	38,590	1.79
1988	76,461	6,171	0.40	11,928	0.48	10,835	0.58	6,020	34,954	1.56
1989	66,546	3,905	0.15	9,774	0.42	7,841	0.49	3,614	25,134	1.14
1990	73,216	3,062	0.09	15,898	0.69	12,218	0.62	4,484	35,662	1.48
1991	53,452	1,224	0.15	12,103	0.88	8,247	0.55	3,482	25,056	1.60
1992	62,125	195	0.24	14,860	0.79	11,212	0.81	3,976	30,243	1.95
1993	56,190	79	0.11	12,580	0.77	8,118	0.61	4,958	25,735	1.60
1994	76,380	95	0.11	19,603	0.86	9,794	0.37	3,886	33,378	1.44
1995	81,831	39	0.19	15,389	0.61	9,483	0.44	4,321	29,232	1.39

Units : hooks in thousands, catch in MT and CPUE in numbers of fish per 100 hooks

1. Catches for 1975-1980 were detemined as follows : the numbes of fish caught in the SPC area, determined from logbook data aggregated by 5° ×5° by month published in NFRDA (1980, 1981, 1985), were multiplied by average weights and divided by coverage rates.
2. Catches for 1981-1995 were determined as follows : weights of fish caught in the SPC area, determined from logbook data aggregated by 5° ×5° , were divided by coverage rates. The average weights (kg) and coverage rates by species are presented in Table 4.

Table 3. Catch statistics for purse seiners of Korea in the SPC area

Year	Haul	Skipjack	Yellowfin	Bigeye	Others	Total
1980	34	476	68			544
1981	209	1,462	582			2,044
1982	568	10,167	2,042			12,209
1983	409	15,417	799			16,216
1984	767	13,767	416			14,183
1985	570	9,655	1,624			11,279
1986	883	25,305	2,427			27,732
1987	1,749	40,918	17,383	410	41	58,752
1988	1,900	64,032	15,365			79,397
1989	2,533	80,903	34,532	234	85	115,754
1990	4,187	138,460	34,765	118		173,343
1991	8,304	171,951	55,416	4	147	227,518
1992	7,502	115,290	66,982	15		182,287
1993	6,208	73,989	52,659			126,648
1994	6,352	145,541	49,463			195,004
1995	5,301	137,848	37,616			175,464

Table 4. Average weight and coverage rate by species for longliners of Korea in the SPC area

	Average weight (kg)				Coverage rate			
Year	Albacore	Bigeye	Yellowfin	Others	Albacore	Bigeye	Yellowfin	Others
1975	20.1	53.9	38.2	28.9	0.0291	0.1338	0.0761	0.0714
1976	18.6	45.7	37.0	35.3	0.2248	0.1989	0.2349	0.0940
1977	14.3	33.0	27.8	28.4	0.3422	0.5018	0.5702	0.2186
1978	15.1	34.6	30.9	27.6	0.6102	0.8979	0.7557	0.1880
1979	14.5	34.0	27.4	36.9	0.2711	0.4002	0.4189	0.1479
1980	17.3	36.5	30.7	32.7	0.6221	0.5903	0.6628	0.3820
1981					0.3700	0.4028	0.3252	0.3660
1982					0.4099	0.4958	0.5077	0.4473
1983					0.6627	0.5663	0.5815	0.5390
1984					0.6707	0.8203	0.7916	0.5590
1985					0.3807	0.8198	0.7020	0.2923
1986					0.2752	0.8123	0.7724	0.3101
1987					0.3860	0.8540	0.8228	0.4604
1988					0.5863	0.8904	0.8912	0.4707
1989					0.3127	0.9959	0.9213	0.5968
1990					0.2339	0.8957	0.8082	0.5035
1991					0.8828	0.9658	0.7956	0.5154
1992					-	0.7605	0.7255	0.4745
1993					-	0.8263	0.7778	0.4758
1994					-	0.4784	0.3147	0.3386
1995					0.8272	0.7567	0.5668	0.6257

- Impossible to estimate the coverage rate

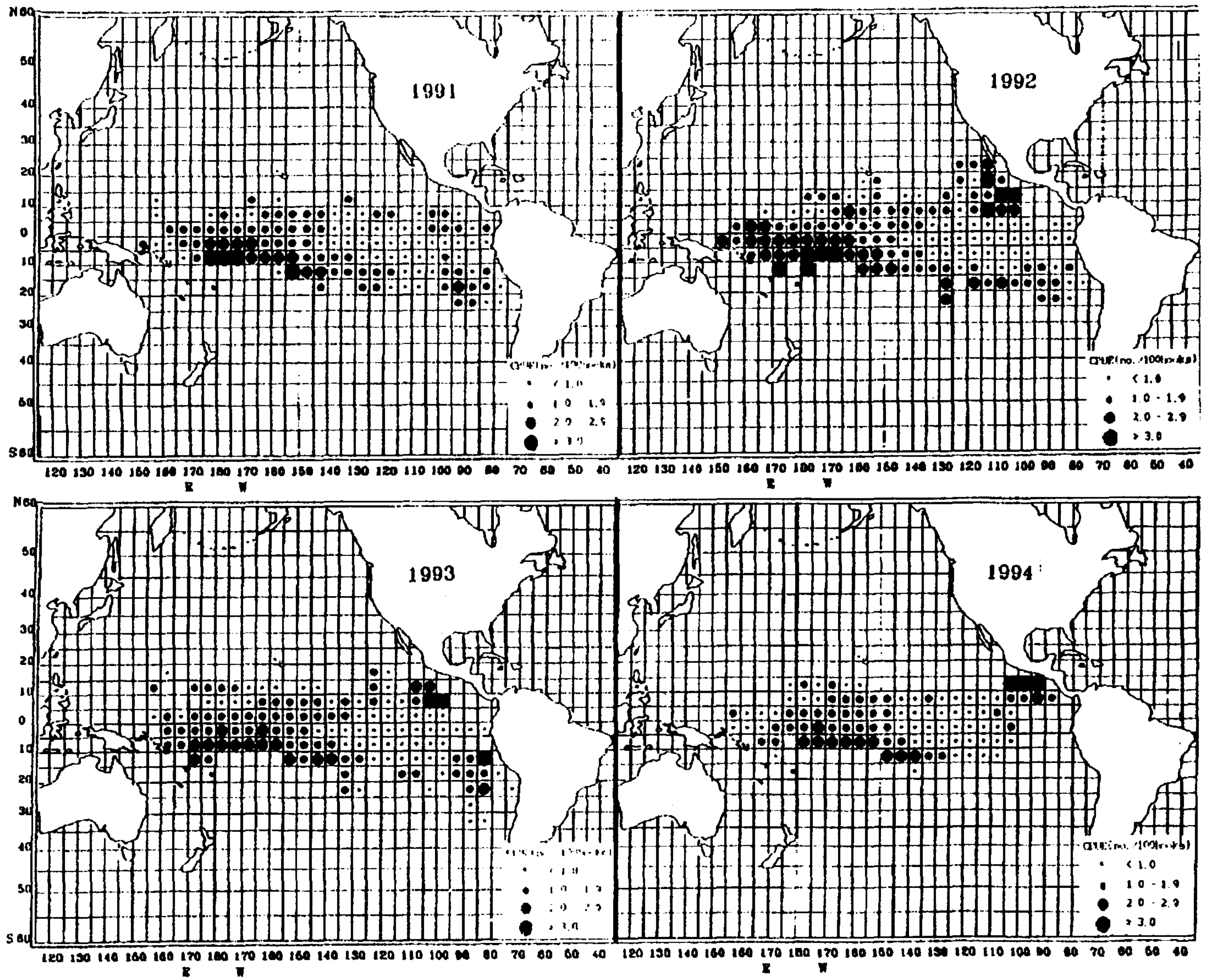

Fig. 1. Distribution of CPUE (fish per 100 hooks) for Korean tuna longline fishery in the Pacific Ocean during 1991-1994.

 3/3 "End"

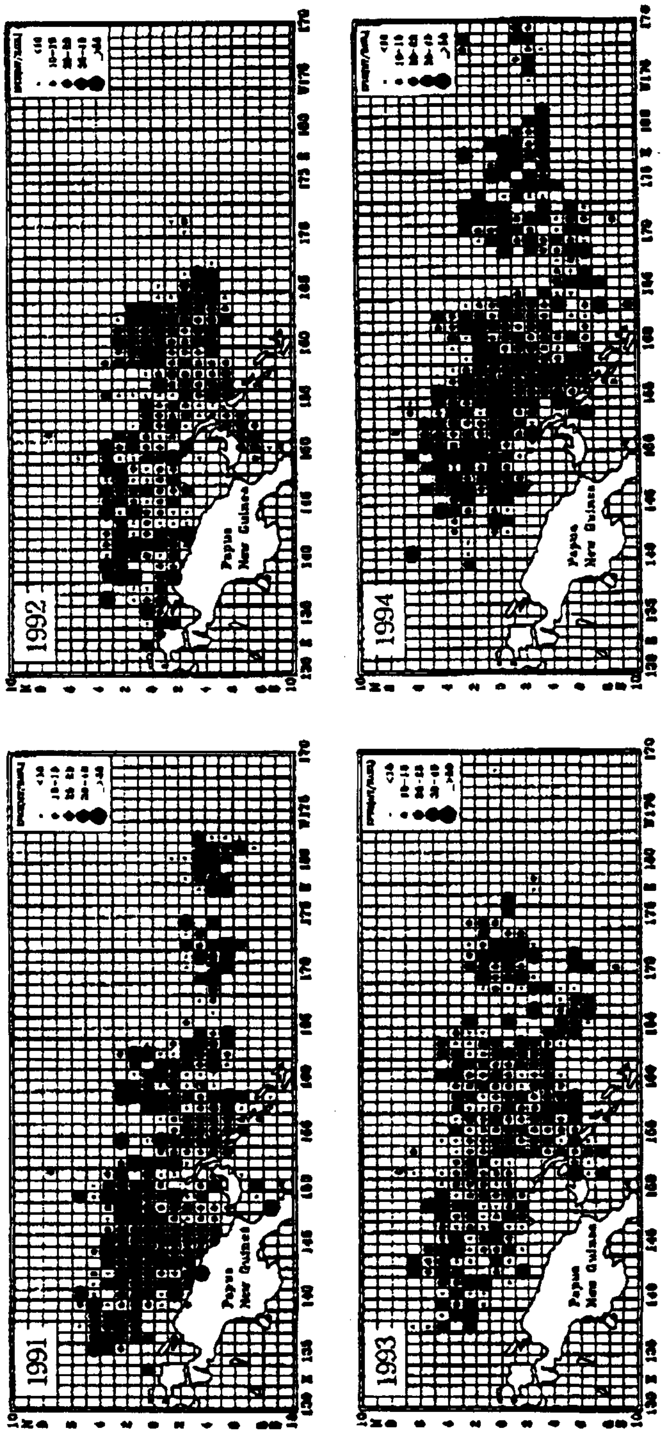

Fig. 2 Distribution of CPUE (tons per haul) for Korean purse seine fishery in the western Pacific Ocean during 1991-1994.

Stock assessment of the South Pacific albacore by using the Generalized Production Model, 1967-1991

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ABSTRACT

The maximum sustainable yield of albacore in the south Pacific Ocean was estimated by the generalized production model using 1967-1991 catch and effort data of Taiwanese, Japanese and Korean tuna longline fisheries. Catch rates were standardized by both the Honma's method and the Generalized Linear Modeling (GLM) method, respectively. The results revealed that (1) CPUE showed the comparable steady state in 1978-1987; (2) the MSY was about 31130 mt by the Honma's method and 31620 mt by the GLM method; (3) the results were very similar to those of Wang *et al.* (1988); (4) the effective efforts of recent years were closed to the optimum fishing effort level. However, they showed a little over exploitation according to the Honma's method and a little under exploitation by the GLM method. The strictly increasing or decreasing of south Pacific albacore tuna fisheries in recent years are not appreciable.

(Key words: South Pacific albacore, Honma's method, GLM, MSY)

INTRODUCTION

Albacore stocks in the Pacific Ocean were generally separated into two distinct stocks, one in the north Pacific Ocean and the other in the south Pacific Ocean (Koto, 1966; Suda, 1971; Wang *et al.*, 1988). Albacore (*Thunnus alalunga*) is an important tuna species in the south Pacific Ocean. In the south

Pacific Ocean, over 88% of the albacore stocks were exploited by Taiwanese, Japanese and Korean tuna longline fisheries. Only a few quantities of the South Pacific albacore were caught by surface fisheries in Chil and New Zealand. The U.S. South Pacific albacore fishery began in 1986 with two commercial troll vessels working along the Subtropical Convergence Zone (Laurs *et al.* 1987). Many papers were tried to estimate the maximum sustainable yield (Skillman 1975; Wetherall *et al.* 1979; Wetherall and Yong 1984, 1987; Wang, 1988). But those conclusions were drawn from the status of the South Pacific albacore before 1985 while surface fishery did not develop rapidly yet. Wang (1988) indicated that we should consider that the rapid development of surface fishery in recent years could affect the recruitment of longliners. Hence, this study tried to evaluate the current stock conditions based on the 1967-1991 catch and effort data of tuna longline fisheries.

The Honma's method (Honma, 1974) and the GLM method (Kimura, 1981) have been widely used to estimate effective fishing effort and indices of abundance of tunas. (Conser, 1984; Cramer and Eklund, 1991; Cramer *et al,*1991; Honma, 1974; Kimura, 1981; Miyabe, 1991; Punsly, 1987; Uozumi, 1993). The GLM method appeared to be preferable theoretically but the Honma 's method had some practical advantages when dealing with large and unbalanced data sets (Conser, 1984).

In this study, the Honma's method and the GLM method were used to estimate the effective fishing efforts. We were trying to compare the results through investigations of CPUE values adjusted. And the results were used to assess the status of the South Pacific albacore stocks based on the Generalized Production Model.

MATERIALS AND METHODS

Catch and effort data of the South Pacific albacore, compiled in 5-degree squares by month, of Taiwanese data (1967-1991), Japanese data (1967-1990) and Korean data (1975-1987), were used in this study.

The 1978-1987's data were adopted as the standard years in the Honma's method because of the consideration of the higher coverage rates, comparable steady state of fishery development, and the availability of the Korean data at that time.

Following Turner and Scott (1991), Cramer *et al.* (1991) and Uozumi (1993), year, quarters, and fishing area were used as the effective factors on catch rates, and adopted as the main effects in the GLM method. Based on the distributions of fishing effort and CPUE, the areas were separated into three subareas as in Fig. 1. Following model was used to estimate the effective fishing efforts:

$$Ln(cpue+1) = \mu + YR_i + QU_j + DN_k + QU_j * DN_k + \varepsilon_{ijk}$$

where,

Ln : natural logarithm ;

μ : overall mean ;

YR_i : effect of year i ;

QU_j : effect of quarter j ;

DN_k : effect of subarea k ;

$QU_j * DN_k$: interaction between quarter j and subarea k ;

ε_{ijk} : error term 。

The maximum sustainable yields of the South Pacific albacore stock were estimated by the generalized production model (Pella and Tomlinson, 1969) based on the effective efforts estimated by the above two methods. Since detail 5-degree square distributions of Korean data in 1967-1974 and 1988-1991, and

Japanese data in 1991 were not available, the CPUE and the effective index in these years were estimated by the moving average of the most recent five years. Then the nominal efforts were computed by the estimated CPUE. Finally, the effective efforts were estimated by multiplying the estimated effective index and the nominal fishing effort together.

RESULTS AND DISCUSSIONS

(1) Developments of south Pacific tuna longline fisheries.

As shown in Table 1, the South Pacific albacore were mainly exploited by Taiwanese, Japanese and Korean tuna longline fisheries. In 1967, Japan was the most important albacore tuna longline country. From 1968, Taiwan and Korea replaced Japan as the major countries for exploiting the South Pacific albacore stocks.

For Korean tuna longline fishery, catches in 1983 and 1984 dropped to a rather low level due to the retrenchment of fishing fleets. From 1987, they dropped again because of shifting the target species to yellowfin tuna and bigeye tuna (Park *et al.*, 1994).

For Taiwanese tuna longline fishery, the highest peak of the catch appeared in 1980. Then the total catch decreased year by year. In 1985, it was 6095 mt only. However, it increased to 14056 mt in 1988. Since, 1989, it was under ten thousand mt.

Overall the south Pacific Ocean, the highest peak of the total catch of the albacore stock was 47003 mt in 1973. Before 1980, the total catch varied in the ranges of 23-41 thousand metric tons. In 1981-1988, it decreased year by year, and varied in the ranges of 16-31 thousand mt. Since 1989, it showed a decreasing trend and was lower than twenty thousand mt.

Japanese longliners always embarked on the heaviest fishing efforts in the south Pacific Ocean. The next was Korean fisheries. However, they were not target on the South Pacific albacore stocks (Park and Kim, 1994) . Comparatively, the efforts of Taiwanese tuna longline fishery were in the lower level. But they were mainly target on the albacore (Wang *et. al*, 1988). The peak of Taiwanese fishing efforts was appearing in 1980. In 1986, it decreased to 11.7 million hooks only. From 1988, it maintained in the rather stable state and ranged in 31-37 million hooks.

(2) Estimating of the effective fishing efforts.

The analyses of variance for GLM (Table 2) indicated that all main effects of year, quarter, fishing area and the interaction between quarter and fishing area affected log(CPUE) significantly at the 0.1 % level. The variability of CPUE explained by the model (i.e. R-square) was obtained 0.53 for Taiwanese data, 0.49 for Japanese data and 0.65 for Korean data, respectively. The R-square value of Korean data was higher than those of the other two countries' data. The higher R-square of Korean data may be due to that all of the data which we used in this paper ranged in the standard years. Hence, the effects of year, quarter and fishing area were comparatively significant. The R-square of Taiwanese data was also larger than that of Japanese data. It reflected that Taiwanese longliners were target on albacore but Japanese longliners were not.

Fig. 2 shows the annual fluctuations of nominal efforts and effective efforts estimated by the Honma's and the GLM methods for Taiwanese, Japanese and Korean tuna longline fisheries, respectively.

Basically, the growth trend of Taiwanese tuna longline fishery was presented before 1974. In 1974-1980, fishing efforts fluctuated year by year. Clear reducing trends could be found in 1980 to 1983. In 1983-1987, a comparable steady-state but lower efforts were maintained. In 1986-1988, fishing intensities of Taiwanese tuna longliners showed the rapid increasing trend. After 1988, they maintained in higher level. The effective efforts showed the similar variations.

For Japanese tuna longline fisheries, the effective efforts fluctuated more moderately than the nominal efforts. This seems to reflect the fact that albacore was not the target species of Japanese longline fisheries. In the south Pacific Ocean, the effective fishing efforts estimated by GLM method revealed that they were in rather stable state since 1967. For Korean tuna longline fishery, the trends were similar to the results of Japanese longline fisheries.

The rationality of the above results supported that South Pacific albacore was the target species of Taiwanese tuna longline fisheries, but they were not the target species of Japanese and Korean tuna longline fisheries.

Annual fluctuations of the averages effective index of the Honma's method were shown in Fig 3. An slightly increasing trend of Taiwanese tuna longline fishery but decreasing trend of Japanese tuna longline fishery could be found in this Figure. It seems also to reflect the difference of target species.

Fig. 4 showed a rather stable trend of effective index of Taiwanese tuna longline fishery in the period of standard years in 1978-1987. Comparatively lower differences of effective index between the Honma's method and the GLM method implied that taking the period of 1978-1987 as the standard years was an acceptable assumption.

Fig. 5 showed the annual variations of nominal CPUE and the adjusted CPUEs both by the Honma's method and the GLM method, respectively. General speaking, they showed the similar trends for each country.

Taiwanese CPUE show a decreasing trend, especially before 1974. From 1974, a slightly increasing trend could be found. Comparative stable states were maintained since 1979. Both of the adjusted CPUE by the Honma's method and by the GLM method showed a significant deviation from the nominal CPUE.

For Japanese tuna longliners, the adjusted CPUE by the Honma's method also showed a decreasing trend in the early years since 1967. However, they almost maintained in the similar state since 1971. For Korean adjusted CPUE, no significant trend could be detected. Generally, the adjusted CPUE of Japanese and Korean data by GLM method deviated from the nominal CPUE and the adjusted CPUE by the Honma's method. But, the nominal CPUE were very consistent with the CPUE adjusted by the Honma's method.

It seems also to reflect the differences of the target species of the three main tuna longline countries. Japan and Korea were not target on albacore. So the effective factors were mainly depending on the fluctuation of the yellowfin tuna and/or bigeye tuna. It also implied that the Honma's method is dull of reflecting the difference of the target species. The GLM method are mainly reflecting the differences of the main effects of year, quarter and subarea of the target species, say, yellowfin tuna and bigeye tuna. But, the Honma's method are mainly reflecting the distribution of the albacore.

Fig. 6 showed the annual fluctuation of the overall effective efforts and adjusted CPUE both by the Honma's method and the GLM method. The trends of effective fishing efforts were similar. But, the trends of CPUE based on the Honma's method seem more moderate.

(3) Stock assessment of the South Pacific albacore.

Generalized production models (Pella and Tomlinson, 1969) were used to assess the South Pacific albacore stocks. The best fit obtained from these models appeared as setting the parameter m=2 and the significant year classes k=5. Fig. 7 showed the trends of the adjusted CPUE and the effective efforts estimated by the Honma's method and the GLM method, respectively. The correlation coefficient are very similar. Both are significant at 1 % level.

The derived production curves were given in Fig. 8. The maximum sustainable yields of the South Pacific albacore stocks was about 31130 mt based on the Honma's method and 31620 mt based on the GLM method. Both were consistent and very similar to the estimates by Wang et al (1988). The optimum fishing efforts were estimated as 140 million hooks by the Honma's method and 98 millions hooks by the GLM method.

Fig. 8 also revealed that it seems implying a slightly overfishing by the Honma's method, but underfishing by the GLM method in recent years. However, the deviations from the optimum fishing effort level of both methods were not so remarkable. A reasonable suggestion was considered that the present state of the utilization of the South Pacific albacore stock were closed to the optimum fishing effort level. Hence, any strictly increasing or decreasing of the fishing efforts are not appreciable. Moreover, it is rather difficult to know that which method is better for adjusting the effective fishing efforts. Although, the Honma's method was dull for reflecting the differences of the target species as stated above.

CONCLUSION

Recently, albacore is one of the by-catch species of Japanese tuna longline fisheries in the south Pacific Ocean. Japanese tuna longliners are target on yellowfin, bigeye and southern bluefin tunas. Korean tuna longliners shifted their target species to yellowfin tuna and bigeye tuna in recent year. However, the south Pacific albacore is still the target species of Taiwanese tuna longline fishery. Generally, the total catches of the South Pacific albacore revealed a decreasing trend since 1988.

The Honma's method and the GLM method are used to adjust the effective fishing effort. The adjusted CPUE revealed that the differences are mainly depending on the distinct target species. And comparatively, the Honma's method seems dull of reflecting the differences of the target species.

The maximum sustainable yield of the south Pacific albacore stocks was about 31130 mt based on the effective efforts estimated by the Honma's method and about 31620 mt by GLM method.

Conclusively, any strictly increasing or decreasing fishing intensities of the South Pacific albacore stocks are not appreciable in the future.

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Table 1 Annual albacore catches in weight and nominal effort in hooks of longline fisheries in the south Pacific Ocean.

Weight Unit: MT, Effort Unit: 1 million hooks

Year	Taiwan		Japan		Korea		other	total catch
	fishery countries							
	Catch	Effort	Catch	Effort	Catch	Effort	Catch	
1967	*14862	*17.7	*15146	*70.7	13717			43725
1968	11570	22.0	6717	65.9	10138			32425
1969	9948	15.5	5180	81.0	9963			25091
1970	14574	22.0	5377	69.1	11599			31550
1971	19677	35.3	3492	80.9	14482			37651
1972	21965	40.0	3093	79.6	14439			39497
1973	26795	53.4	2756	92.3	17452			47003
1974	19009	49.4	1931	83.9	12194			33134
1975	13343	33.8	1373	78.4	*8597	*40.4		23313
1976	18129	36.8	2138	113.0	11599	69.2		31866
1977	24620	46.3	2848	120.6	12882	65.8		40350
1978	18732	30.2	3351	112.0	11050	41.0		33133
1979	12376	28.8	2529	124.4	8678	57.3		23583
1980	27007	62.2	2229	168.6	10852	83.3		40088
1981	12041	37.6	4297	176.6	14914	100.0		31252
1982	10157	26.5	4961	156.7	12648	79.3	106	27872
1983	7822	17.4	5875	138.0	6807	45.3	155	20659
1984	6771	20.1	4410	131.8	5367	44.0	247	16795
1985	6095	13.8	4101	127.0	13363	83.8	305	23864
1986	6586	11.7	4758	165.1	18834	144.6	425	30603
1987	7428	16.2	4875	178.7	8632	126.0	1015	21950
1988	14056	33.4	7885	190.5	5600	ua	1026	28567
1989	8563	34.4	5495	147.0	3997	ua	1485	19540
1990	8486	31.3	6713	163.1	2586	ua	2210	19995
1991	9840	37.9	4616	ua	1225	ua	2007	17688

* Catches and efforts of Taiwanese tuna longliners in 1967 - 1991, Japanese longliners in 1967 - 1990 and Korean tuna longliners in 1975 - 1987 were recalculated from the annual report of catch statistics of tuna longliners of each country.

ua:unavailable.

Table 2 The ANOVA tables of the model used in GLM

1) Taiwanese longline fishery:

Source	D.F.	Sum of Squares	Mean Square	F Value	P(F)
Model	35	968.4175	27.6691	235.06	0.0001
YR	24	351.8073	14.6586	124.33	0.0001
QU	3	11.7252	3.9084	33.2	0.0001
DN	2	295.6096	147.8048	1255.66	0.0001
QU*DN	6	5.1722	0.8620	7.32	0.0001
Error	7233	851.4012	0.0077		
Corrected Total	7268	1819.8187			

R-square=0.5322

2) Japanese longline fishery:

Source	D.F.	Sum of Squares	Mean Square	F Value	P(F)
Model	34	8500.6012	250.0177	434.49	0.0001
YR	23	1032.2309	44.8796	77.99	0.0001
QU	3	577.5400	192.5134	334.56	0.0001
DN	2	5063.5500	2531.7750	4399.79	0.0001
QU*DN	6	227.1277	45.5210	79.11	0.0001
Error	15534	8938.7460	0.5754		
Corrected Total	15568	17439.3472			

R-square=0.4874

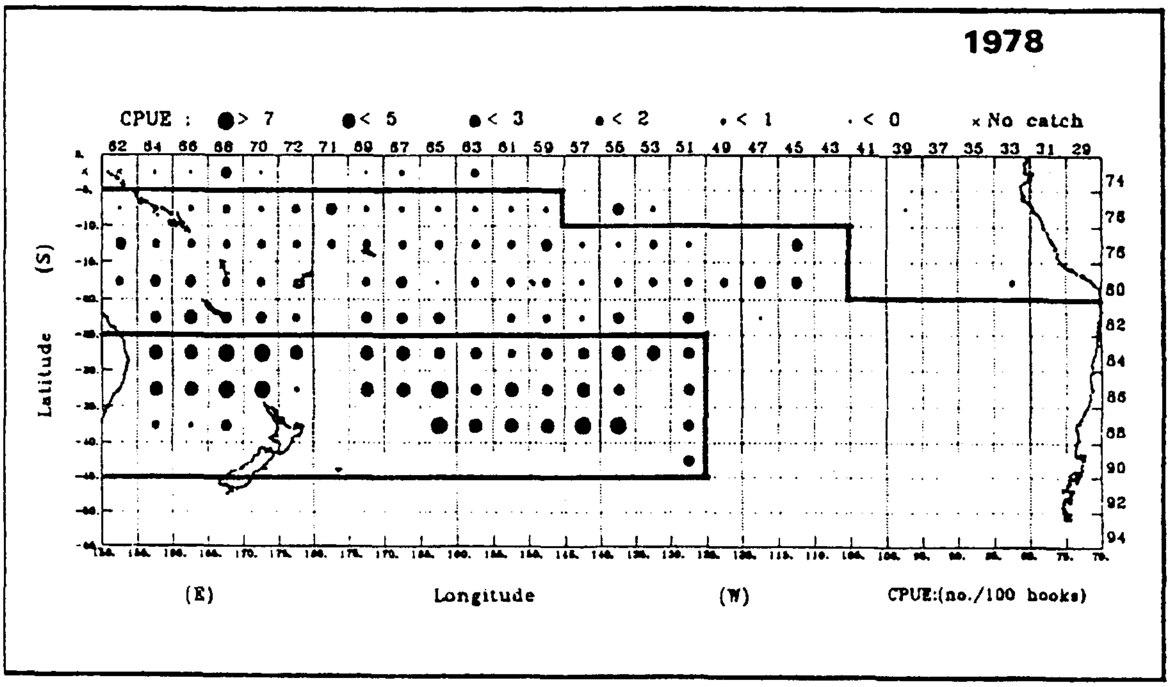
3) Korean longline fishery:

Source	D.F.	Sum of Squares	Mean Square	F Value	P(F)
Model	23	5632.2330	244.8797	499.72	0.0001
YR	12	160.4906	13.3742	27.29	0.0001
QU	3	81.2864	27.0955	55.29	0.0001
DN	2	3678.1964	1839.0982	3753	0.0001
QU*DN	6	54.5041	9.0840	18.54	0.0001
Error	6149	3013.2207	0.4900		
Corrected Total	6172	8645.4537			

R-square=0.6515

Table 3. Estimated effective fishing efforts, 1967-1991. Unit: 1000 H

	estimated by Honma method			estimated by GLM method		
YEAR	*Taiwan*	*Japan*	*Korea*	*Taiwan*	*Japan*	*Korea*
67	19248	60156	75300	18115	17908	17106
68	24461	44869	54885	22882	10849	12424
69	16858	39623	53686	17198	11363	12050
70	26456	35669	63661	28947	13376	14143
71	45329	55208	79200	55227	14881	18772
72	51531	44562	82480	63815	11490	18633
73	74210	51986	89268	98963	12670	19877
74	83111	56821	64789	103017	13543	13977
75	52873	36748	16258	62118	7401	3246
76	57666	52020	61245	70487	11106	18222
77	77541	36119	61418	75092	10461	11140
78	52735	42184	43187	59543	10051	9098
79	49909	52560	55728	48151	13575	10386
80	126328	63039	68991	122289	16710	11734
81	66508	90106	116638	71219	21429	19850
82	48960	91438	82819	45365	18376	19724
83	32598	81828	45606	30108	19337	9926
84	37229	67808	42548	41249	16513	8227
85	27387	69666	76246	23501	17378	15678
86	22860	87130	121158	23588	20845	33037
87	31419	75676	69921	37067	19196	12406
88	59637	119359	39700	69413	23592	8542
89	61921	92592	29761	72021	24188	6385
90	45501	95209	18625	58209	19959	-092
91	68004	73408	8655	69294	16947	1930



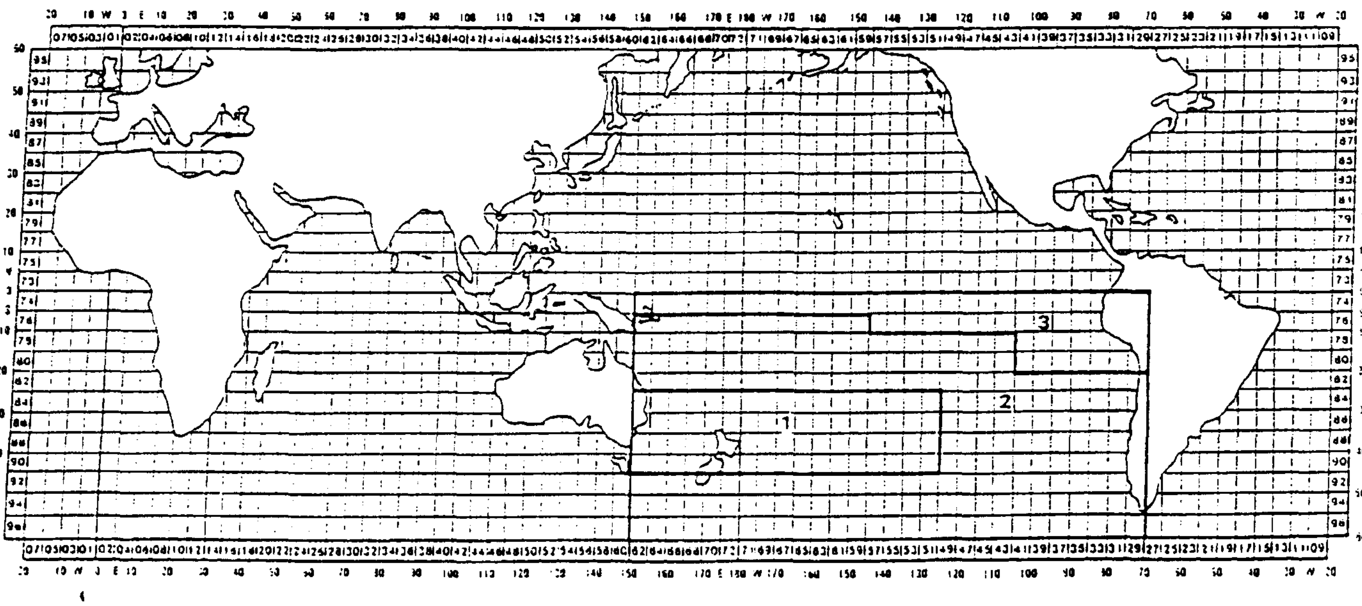


Fig. 1 3-Subareas of the south Pacific Ocean used in the GLM and the distribution of CPUE for Taiwanese tuna longline fishery (Ex. 1978).

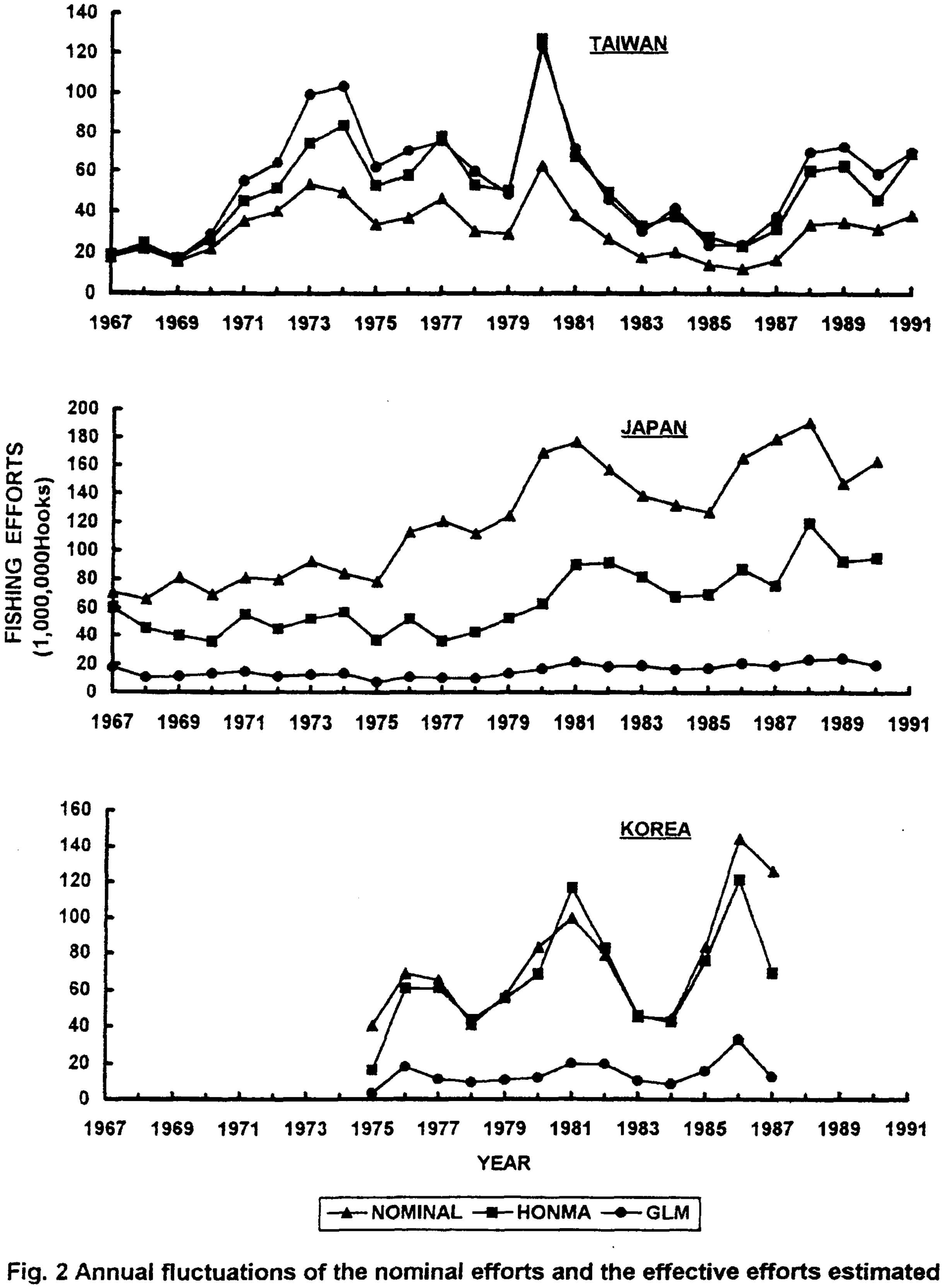


Fig. 2 Annual fluctuations of the nominal efforts and the effective efforts estimated by both of the Honma's method and the GLM method.

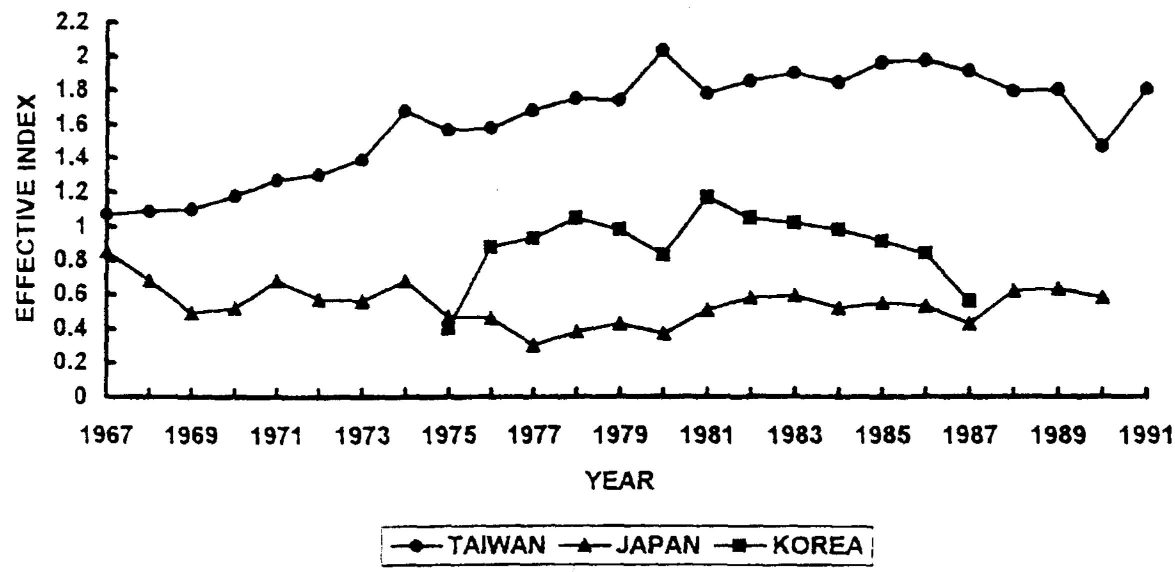


Fig. 3 Yearly average effective index of major longline fishery countries on albacore in the south Pacific Ocean estimated by the Honma method.

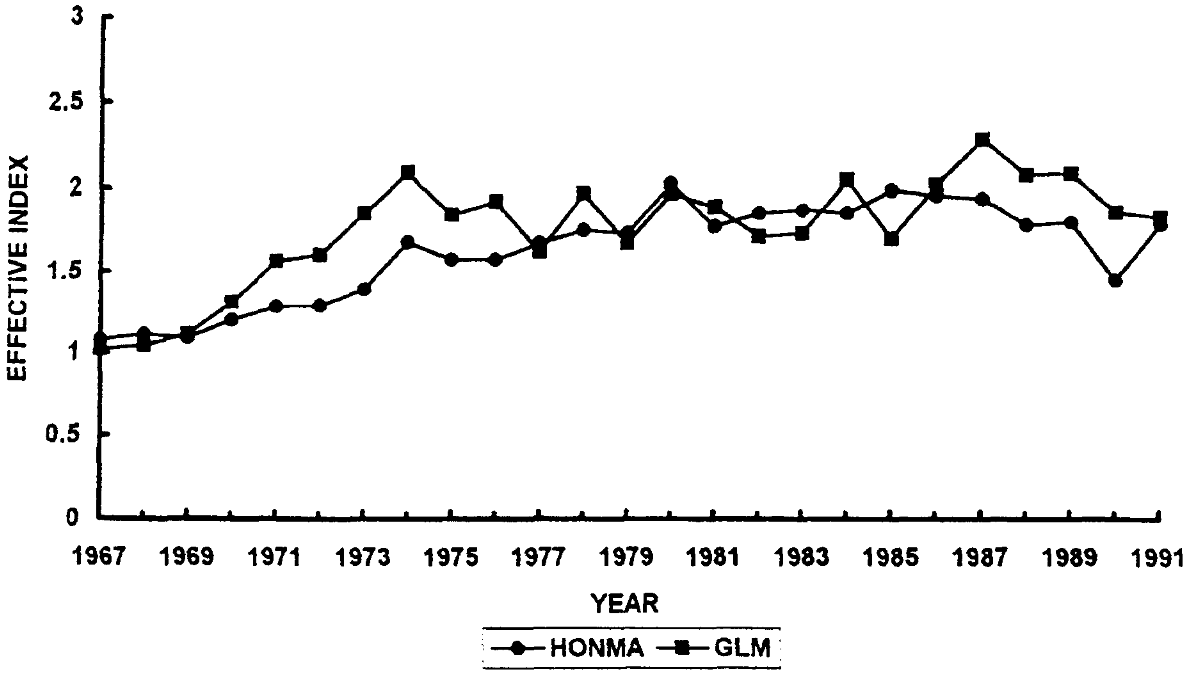


Fig. 4 Comparison of effective indices estimated by the Honma's and GLM methods of Taiwanese tuna longline fishery (1967-1991).

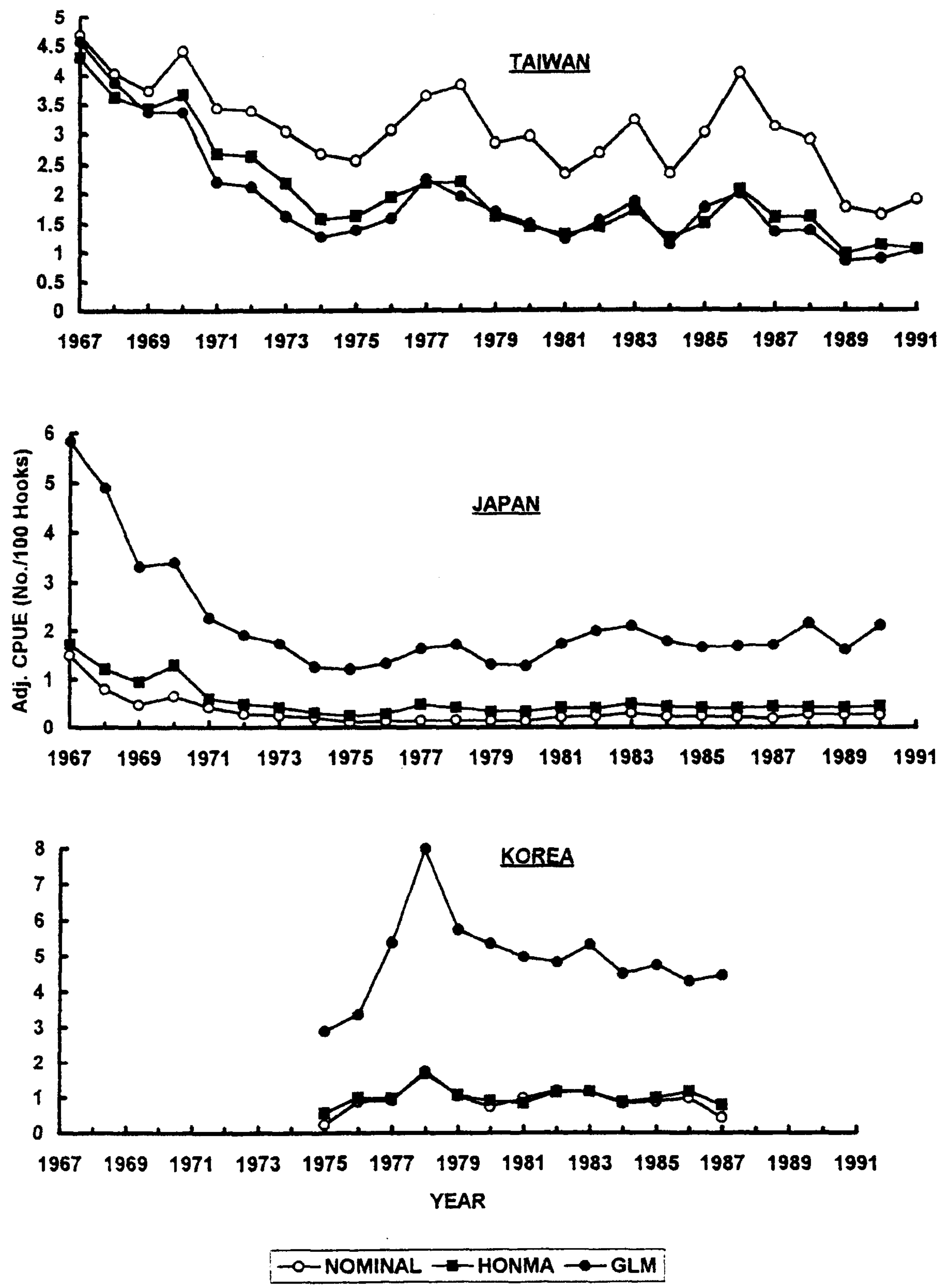
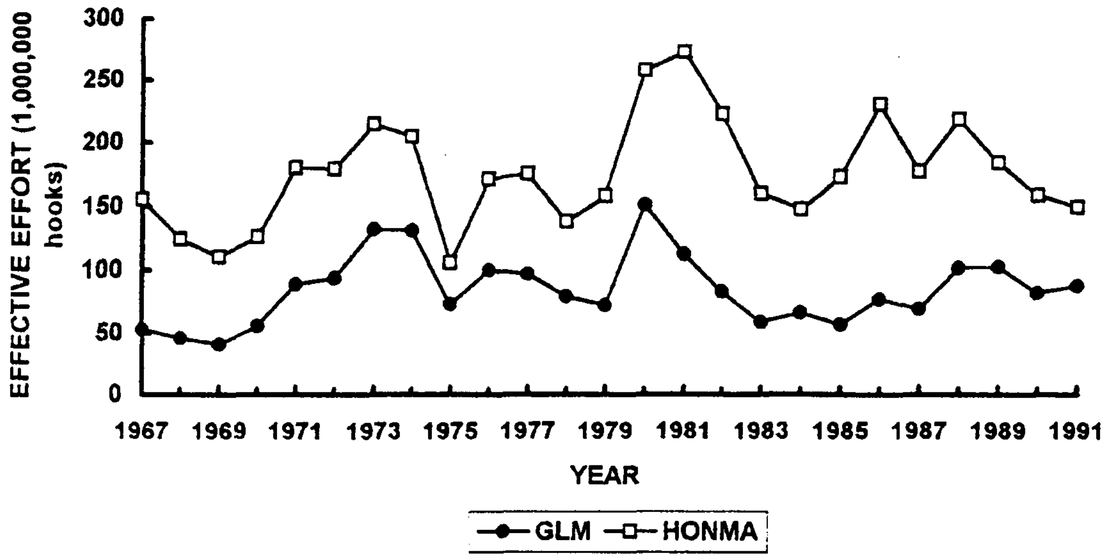


Fig. 5 Annual nominal CPUE and adjusted CPUE estimated by the Honma and GLM methods trends of longline fisheries on albacore in the south Pacific Ocean.



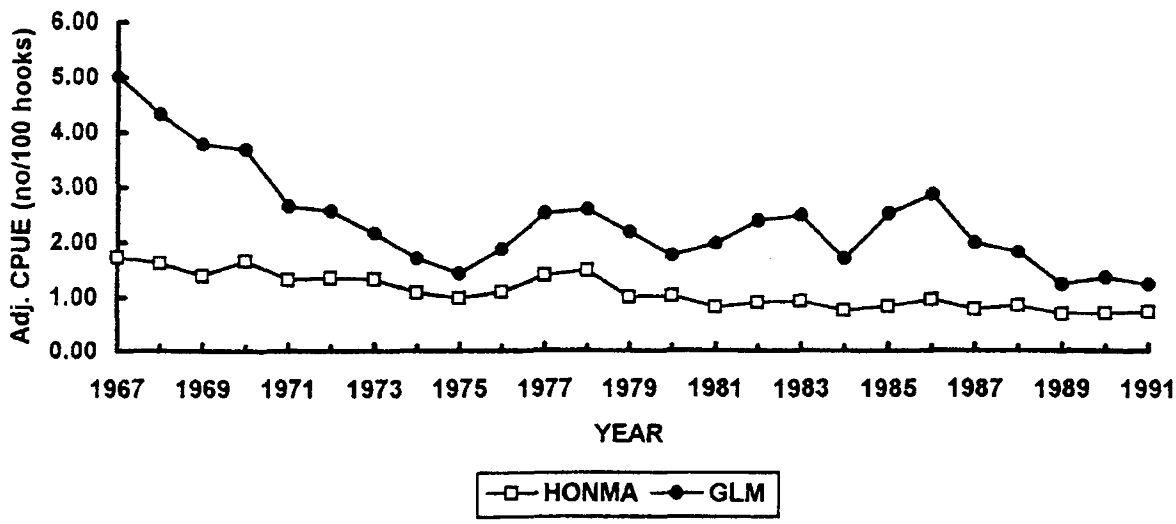


Fig. 6 Annual fluctuations of adjusted CPUE estimated by Honma and GLM methods of overall south Pacific Albacore tuna (1967-1991).

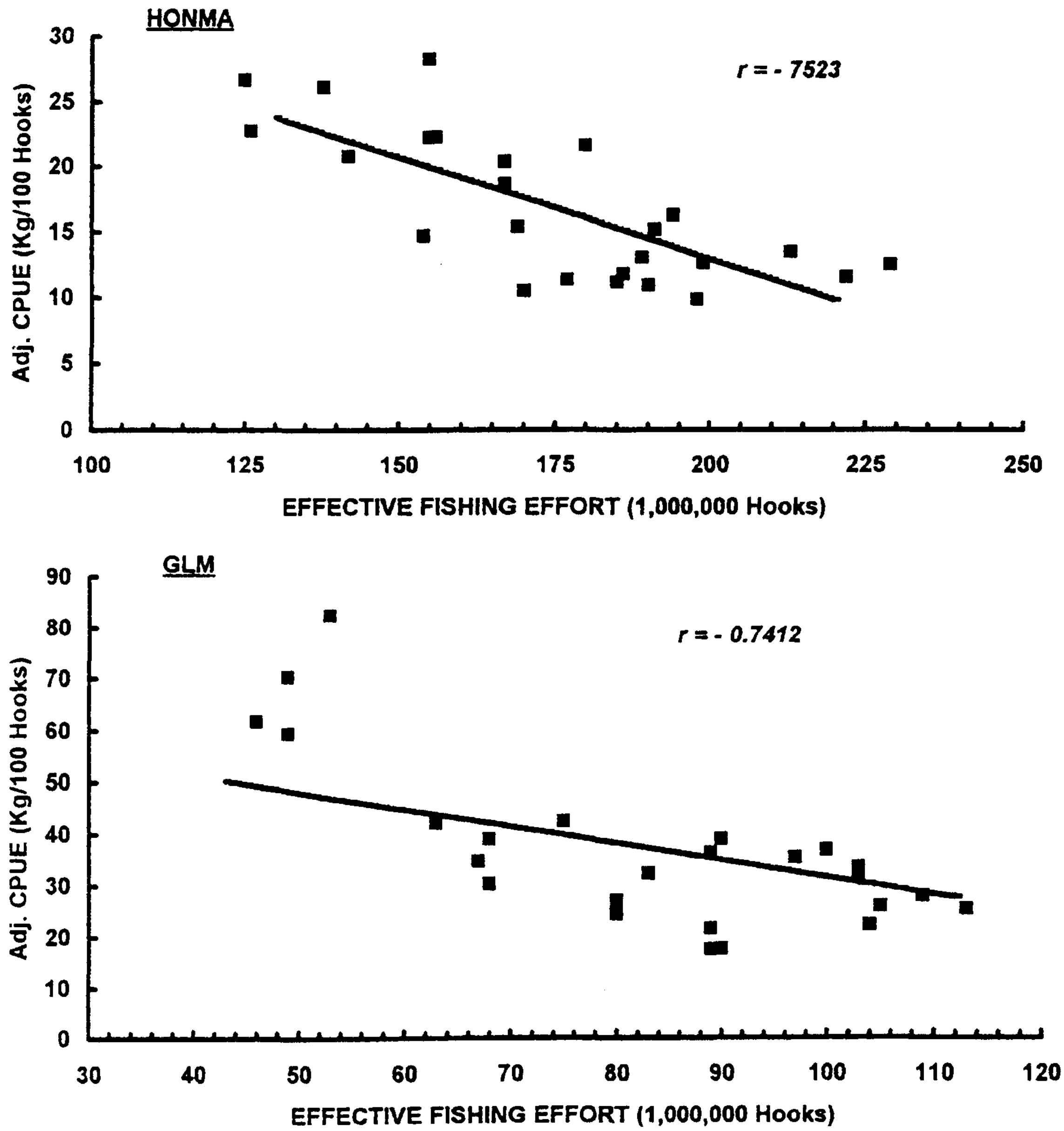
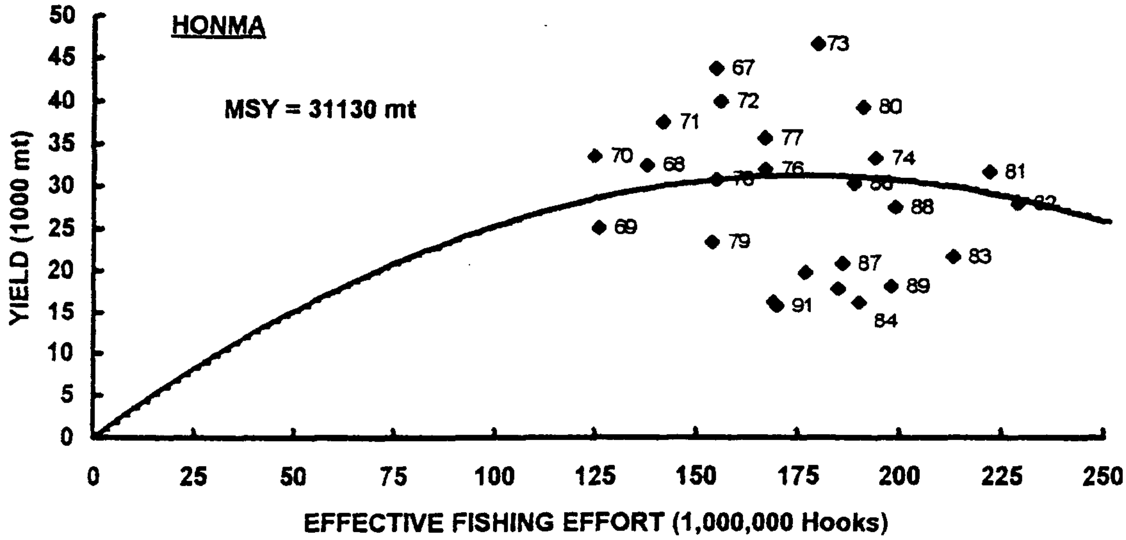


Fig. 7 Relationships between the adjusted CPUE and the effective fishing efforts based on the Honma's method and the GLM method of the South Pacific albacore.



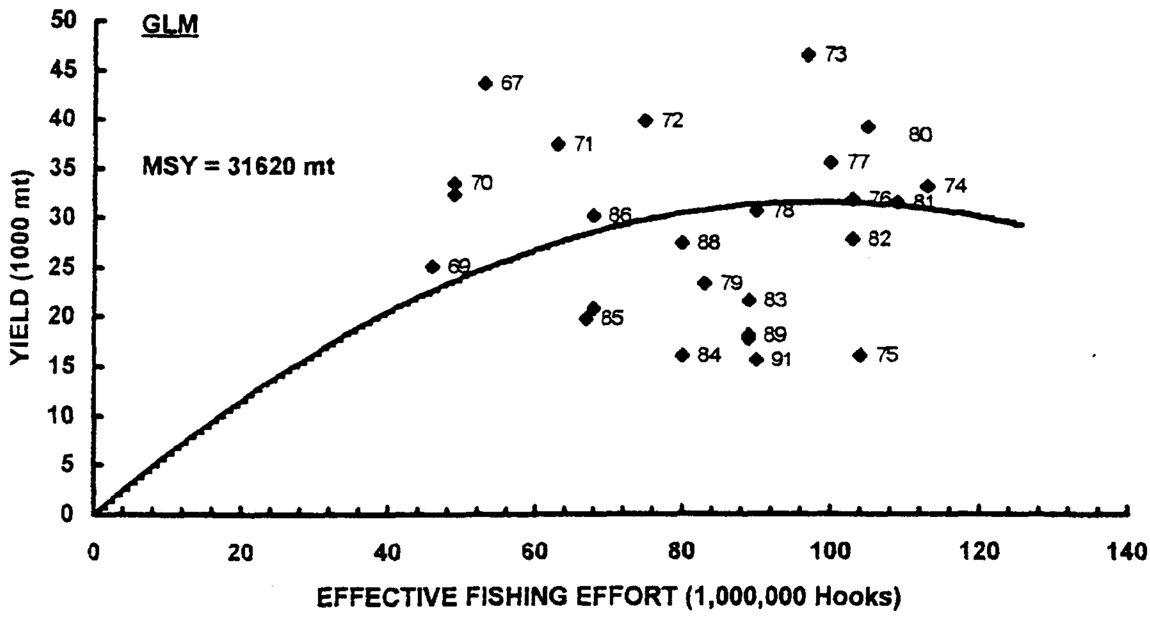


Fig. 8 Fitting the South Pacific albacore stocks by the Generalized Production Model.