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FURTHER INVESTIGATIONS ON THE POPULATION DYNAMICS OF THE SOUTH PACIFIC ALBACORE FISHERY[1]

By

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INTRODUCTION

In early 1974, I made an assessment of the South Pacific albacore fishery (Skillman, MS[2]) utilizing the generalized production model of Pella and Tomlinson (1969) in response to U.S. industry plans to expand cannery capacity in the South Pacific. Utilizing fishing effort measured both in hooks and days fished, the maximum sustainable "average" yield (MSAY) was estimated to be 33,000-35,000 metric tons (MT).

A number of simplifying assumptions were made regarding the validity of catch and catch per unit effort (CPUE) data in order to produce the assessment on a timely basis. In this report, I investigated the validity of the estimates of total catch for the South Pacific and the potential effect of changes in primary species sought as well as changes in nationality of the fleet operating out of American Samoa as these changes would affect the estimation of CPUE, total effective effort, and MSAY.

TOTAL CATCH

In Skillman (MS[2]), total catch estimates were compiled from cannery records for the operations in American Samoa, from various issues of the "Annual report on effort and catch statistics by area on Japanese tuna longline fishery" for Japanese catches made by vessels stations at foreign bases in the South Pacific (less Samoan catches) and by "home-based" vessels fishing in the South Pacific, and from various issues of reports by the Federation of Japan Tuna Fisheries Co-operative Associations and Japan Tuna Fishermen's Cooperative Association (referred to as the Asian Tuna Conference Proceedings in the remainder of this paper) for non-Samoan catches by Korean and Taiwanese vessels in the South Pacific. I considered the data from the first two sources as complete and accurate, but regarded data from the last source as approximate. In this paper, I investigated the effect of different estimates of non-Samoan catches of albacore by Korean and Taiwanese vessels on the estimation of MSAY.

In a previous study, non-Samoan catches of albacore by Korean and Taiwanese vessels were estimated from the Asian Tuna Conference Proceedings by incorporating the following assumptions:

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[2] Skillman, R. A. An assessment of the South Pacific albacore, Thunnus alalunga, fishery, 1953-72. Manuscript in preparation. Honolulu Laboratory, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.

1. That catches reported for the "Pacific" were entirely for the South Pacific;

2. That the reported catches were complete, that is, 100% of the actual landings for all foreign bases as well as for any home-based vessels;

3. That the proportion of albacore in the landings of a given nation for the entire "Pacific" applied to the total catch data given by foreign base but with no species breakdown;

4. That the reported or calculated albacore catches less known Samoan catches (NMFS data) equaled the catch in the remainder of the South Pacific.

In this paper, non-Samoan albacore catches were estimated using the reported number of vessels fishing by foreign base as given in the Asian Tuna Conference Proceedings. It was possible to use reported number of trips for Taiwan, but not for Korea. The following steps were followed:

1. Determined the error in reporting of vessels fishing in American Samoa for Korea and Taiwan and expressed this as a "raising factor;" the raising factor for Korean vessels for some years was less than 1;

2. Used the calculated raising factors to correct the reported number of Korean and Taiwanese vessels fishing out of other foreign bases;

3. Estimated catch per vessel for Korean and Taiwanese vessels based on NMFS' Samoan data;

4. Calculated estimated catch by foreign base for Korea and Taiwan using Samoan catch/vessel;

5. Summed estimates to obtain total albacore catch for the South Pacific.

These steps incorporated the following assumptions:

1. By using number of vessels as effort statistics, I assumed that the vessels at the different bases collectively had the same fishing power, which would be some mixture of fishing the same number of hooks per day per vessel, the same number of days per year, and the same species mixture as well as utilizing the same time-area fishing strategy;

2. That the number of vessels fishing out of American Samoa as determined from NMFS' records was exact;

3. That all South Pacific catches of albacore by Taiwan and Korea were made by vessels operating out of foreign bases;

4. That there existed the same degree of incorrect reporting of vessels fishing out of American Samoa as out of all other bases;

5. That catch/vessel by nation was identical for all foreign bases in the South Pacific.

When these new estimates for non-Samoan catches by Korea and Taiwan were combined with the remaining South Pacific catches, they compared with the total estimates from the first method as follows:

Year	First	Second	Percent difference	
1962	41,976	41,678	-0.7	Minimum
1963	39,020	38,412	-1.6	
1964	25,000	26,160	4.6	
1965	26,380	28,702	8.8	
1966	42,104	46,499	10.4	Maximum
1967	39,890	42,770	7.2	
1968	28,604	28,878	1.0	
1969	31,542	32,759	3.9	
1970	37,854	38,216	1.0	
1971	39,166	40,032	2.2	
			4.1	Average

These new estimates were used with the previously derived estimates of CPUE to calculate new estimates of total effective effort (Table 1). A generalized production model was then fitted to these new estimates of total catch and effective effort (Table 2). Results in this table, as well as in all subsequent tables of the generalized production model, were only for an averaging time of 3 years using Gulland's nonequilibrium adjustment technique, since this averaging time seemed to provide the best fit to the data.

The new estimates of MSAY (Table 2) were not significantly greater than the old estimates, though they were slightly larger. However, the shape of the sustained "average" yield curve changed drastically for the models using both effort in hooks and days fished. Using hooks fished, the sustainable yield curve changed from being nearly asymptotic to being skewed (Gompertz type). Using days fished, the sustainable yield curve changed from a skewed curve to a curve with an abruptly dropping right limb. Thus, these calculations indicate that the population is more sensitive to fishing beyond the optimum level than was the case in the initial analysis.

In order to further investigate the sensitivity of the production model to errors in estimating non-Samoan catches, I incorporated corrections for hypothetical underestimates of 10%, 25%, and 50% for Korea and Taiwan non-Samoan catches. Fitting the generalized production model to these data resulted in an increase in estimated MSAY of about 690, 1,800, and 3,700 MT, respectively (Table 3). The shape of the sustainable "average" yield curves did not change appreciably.

To summarize the results in this section, fitting the generalized production model to a new set of total catch data that incorporated new estimates of non-Samoan catches, plus data sets that represented increases of these non-Samoan catches of 10%, 25%, and 50% resulted in estimates of MSAY of 35,000-38,700 MT, while the original estimates were 33,000-35,000 MT. Thus, even substantial errors in the most likely segment of the total catch data resulted in only about a 10% increase in MSAY.

SPECIES MIXTURE

It is generally felt by people familiar with the South Pacific albacore fishery that yellowfin tuna has become increasingly important as a secondary target species in the fishery. If the fleet in American Samoa has changed its gear to take more yellowfin tuna, then the effort statistics must be adjusted in order to keep the same relationship between effort and fishing mortality, as it applies to the albacore. In this section, I investigated the possibility of a temporal change in species mixture in the Samoan segment of the fishery.

While the proportion of albacore to yellowfin tuna declined from 1962 to 1972 (Figure 1), the catch of both species increased over this same time period (Figure 2). Neither of these trends indicated whether or not the fleet changed its gear and therefore the species sought. The yearly trends in CPUE for albacore and yellowfin tuna (Figure 3) suggested that while CPUE for albacore declined with time, that for yellowfin tuna did not. When the CPUE for albacore and yellowfin tuna were compared directly, there seemed to be no relationship between them (Figure 4). If the 1962 value was included, there seemed to be a significant negative correlation for Japanese vessels; but when the 1962 and 1963 data points for Japan were dropped in order to coincide with the years available for Korea and Taiwan, a significant relationship did not exist for any single nation or for all nations pooled.

Therefore on a yearly basis, there was no evidence that the fishing fleet based in American Samoa had changed its gear in order to catch more yellowfin tuna. It caught more yellowfin tuna in the later years of the fishery because, as fishing effort increased, the catch rate for albacore declined markedly while that for yellowfin tuna remained stable. Hence, there was no need to standardize the effort statistics or to recalculate the generalized production model.

NATIONALITY OF THE FLEET

The national composition of the Samoan fleet has changed significantly over the history of the fishery. Japanese vessels were the first to enter, and they reached their greatest representation in 1963. They have now withdrawn from the Samoa-based fishery. Korean boats first entered the fishery in 1958 and Taiwan followed in 1964. Taiwanese vessels now dominate in numbers. There is the possibility that the fishing power of the fleet changed as inexperienced vessels entered the fishery and the veterans left. If this is true, pooling of the catch and effort data in order to calculate CPUE statistics would not be valid.

To investigate the possibility of differences in catch rate between nations, the yearly trends in CPUE given in Figure 3 (and others not included here) were studied for changes in the rank of one nation to another. No consistent trends were found between the various measures of CPUE. The CPUE statistics for Japan, Korea, and all nations pooled were so highly correlated (Table 4) that it should make no difference which statistic is used as the standard. CPUE for Taiwan was usually correlated with the other indexes but only at the 0.05 significance level; this was probably due to the first 3 years after Taiwan entered the fishery, at which time their catch rates did not agree well with those of the other nations.

Although the CPUE estimates were so highly correlated that it should have no significant influence on the estimation of MSAY, each of the national CPUE statistics was used as the standard in calculating the generalized production model. Table 5 gives the results of using the various estimates of CPUE with the original (A) and the new (B) estimates of total catch in the South Pacific. Some of the estimates of MSAY were less, some greater than those calculated using the pooled estimate of CPUE, but none were significantly different.

Therefore, the pooled estimate of CPUE as used in the initial assessment of the fishery provided nearly the same assessment of the stock as any other possible measure of CPUE based on nationality.

SEASONALITY

Since there is a marked seasonal trend in catch rate of albacore, it has been suggested that CPUE calculated over a time of peak catch rate may be a better measure of density or at least may provide a different picture of the state of the stock. Since June, July, and August are times of highest albacore catch rate, I calculated an average CPUE for each of these months. These averages were highly correlated with the yearly CPUE statistics ($r = 0.93^{**}$, d.f. = 8).

Hence, this peak season measure of CPUE did not show a different trend from any of the other measures of CPUE and should not lead to any significant differences in estimated MSAY (a generalized production model was not fitted to the data).

CONCLUSIONS

Having fitted generalized production models to two sets of total catch data utilizing different means of estimating non-Samoan catches of Korean and Taiwanese vessels, plus adding hypothetical 10%, 25%, and 50% corrections for underreporting of catches as well as investigating the use of nine different estimates of CPUE, and having determined thereby that there were no more than 2,000-4,000 MT differences in the estimation of MSAY, I have concluded that there is little to be gained by doing anymore generalized production model analyses. That is not to say that a yield per recruit analysis would not be beneficial, for example, in exploring the relatively low MSAY that has been predicted or in exploring ways of increasing the catch by manipulating the harvesting of specific age-classes. But I do not think that this kind of analysis is critical or urgent at this time.

LITERATURE CITED

Pella, J. J., and P. K. Tomlinson.
1969. A generalized stock production model. Inter-Am. Trop. Tuna Comm. Bull. 13:421-496.

Table 1.--Albacore catch in metric tons for the South Pacific Ocean. Estimates for non-Samoan catches were derived from the number of vessels reported in the Asian Tuna Conference Proceedings. Estimates of CPUE were calculated from all nations pooled in the fishery based in American Samoa.

		Catch in metric tons				Catch per unit effort		Estimated total effective effort	
Year	Category	Japan	Korea	Taiwan	Total	MT/10^3 hooks	MT/day fished	Hooks ($\times 10^3$)	Days
1962	Nation	28,352	--	--	28,352			19,067	17,334
	Am. Samoa	12,605	634	--	[1]13,326	1.4870	1.6356	8,962	8,147
	Grand total	40,957	634	--	41,678			28,029	25,481
1963	Nation	23,762	--	--	23,762			24,665	19,775
	Am. Samoa	12,907	1,660	--	[1]14,650	0.9634	1.2016	15,207	12,192
	Grand total	36,669	1,660	--	38,412			39,872	31,967
1964	Nation	14,136	1,233	--	15,369			18,233	13,705
	Am. Samoa	8,385	1,850	556	10,791	0.8429	1.1214	12,802	9,623
	Grand total	22,521	3,083	556	26,160			31,035	23,328
1965	Nation	10,871	2,373	--	13,244			17,096	12,776
	Am. Samoa	9,518	4,350	1,590	15,458	0.7747	1.0366	19,954	14,912
	Grand total	20,389	6,723	1,590	28,702			37,050	27,688
1966	Nation	16,534	3,152	1,243	20,929			23,946	19,635
	Am. Samoa	9,086	9,123	7,361	25,570	0.8740	1.0659	29,256	23,989
	Grand total	25,620	12,275	8,604	46,499			53,202	43,624
1967	Nation	9,670	3,257	1,532	14,459			19,710	15,091
	Am. Samoa	7,528	9,636	11,147	28,311	0.7336	0.9581	38,592	29,549
	Grand total	17,198	12,893	12,679	42,770			58,302	44,640
1968	Nation	5,413	2,570	3,172	11,155			20,216	15,707
	Am. Samoa	3,156	6,349	8,218	17,723	0.5518	0.7102	32,119	24,955
	Grand total	8,569	8,919	11,390	28,878			52,335	40,662
1969	Nation	4,489	2,645	6,894	14,028			24,211	17,800
	Am. Samoa	1,560	10,184	6,987	18,731	0.5794	0.7881	32,328	23,767
	Grand total	6,049	12,829	13,881	32,759			56,539	41,567
1970	Nation	5,598	2,506	6,236	14,340			25,207	16,626
	Am. Samoa	952	11,942	10,982	23,876	0.5689	0.8625	41,969	27,682
	Grand total	6,550	14,448	17,218	38,216			67,176	44,308
1971	Nation	6,437	2,491	8,910	17,838			32,634	24,844
	Am. Samoa	380	11,800	10,014	22,194	0.5466	0.7180	40,604	30,911
	Grand total	6,817	14,291	18,924	40,032			73,238	55,755

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[1] Includes undetermined nationality.

Table 2.--Generalized production model for South Pacific albacore using old and new catch estimates. $\bar{T}_i$ = 3 years.

Data	$\hat{\bar{m}}$	$\widehat{CPUE}_{opt}$	$\widehat{MSAY}$	$\hat{f}_{opt}$	MSQ
Days		MT/day	10^3 MT	10^3 days	10^{-1}
Old	1.62	0.791	33.072	41.801	0.0613
New	3.12	0.863	34.817	40.367	0.0541
Hooks		MT/10^3 hooks	10^3 MT	10^3 hooks	10^{-1}
Old	0.25	0.325	34.665	106.761	0.0769
New	1.27	0.570	34.277	60.152	0.0952

Table 3.--Generalized production model for South Pacific albacore fishery. Catch data incorporated +10%, +25%, +50% corrections for Korea and Taiwan using "new" catch estimates.

Data	$\hat{\bar{m}}$	$\widehat{CPUE}_{opt}$	$\widehat{MSAY}$	$\hat{f}_{opt}$	MSQ
Days		MT/day	10^3 MT	10^3 days	10^{-1}
"New"	3.12	0.863	34.817	40.367	0.0541
+10%	2.87	0.845	35.380	41.890	0.0574
+25%	2.53	0.816	36.307	44.489	0.0617
+50%	1.00	0.714	37.800	52.976	0.0567
Hooks		MT/10^3 hooks	10^3 MT	10^6 hooks	10^{-1}
"New"	1.27	0.570	34.277	60.152	0.0952
+10%	1.17	0.547	35.101	64.167	0.0952
+25%	1.03	0.513	36.464	71.145	0.0956
+50%	0.99	0.484	38.697	79.944	0.0966

Table 4.--Simple (above diagonal) and partial (below diagonal correlation coefficients for catch in metric tons per day for albacore and yellowfin tuna in the fishery based in American Samoa.

I. MT/day for albacore

	Japan	Korea	Taiwan	All
Japan		0.8608 **	0.7181 *	0.9601 **
Korea	-0.6174 NS		0.5931 NS	0.9533 **
Taiwan	0.2153 NS	-0.0576 NS		0.6797 NS
All	0.8800 *	0.8914 *	0.0287 NS	

II. MT/day for yellowfin tuna

	Japan	Korea	Taiwan	All
Japan		0.7001 *	0.2156 NS	0.6504 *
Korea	0.1462 NS		0.5895 NS	0.9027 **
Taiwan	-0.5338 NS	-0.2556 NS		0.7735 **
All	0.4396 NS	0.7111 NS	0.7621 NS	

Significance levels were tested at 0.05 and 0.01 and are indicated by * and **, respectively. NS = nonsignificance.

Table 5.--Comparison of the generalized production model using $\bar{T}_1$ = 3.0 years and different estimates of total effective effort based on estimates of CPUE by nation for the American Samoa fishery with A) total catch based on American Samoa, Japanese, and Asian Tuna Conference Proceedings (catch estimates) and B) total catch based on American Samoa, Japanese, and ATCP (number of vessels).

CPUE	$\hat{m}$	$\widehat{CPUE}_{opt}$	$\widehat{MSAY}$	$\hat{f}_{opt}$	MSQ
A. Catch estimates					
Days		MT/day	10^3 MT	10^3 days	10^{-1}
All nations	1.62	0.791	33.072	41.801	0.0613
Japan	2.10	0.924	32.915	35.630	0.0616
Korea	1.00	0.718	34.152	47.544	0.1776
Taiwan	5.20	0.836	34.443	41.219	0.0513
Hooks		MT/10^3	10^3 MT	10^6 hooks	10^{-1}
All nations	0.25	0.325	34.665	106.761	0.0769
Japan	0.71	0.458	34.075	74.379	0.0486
Korea	-----------------	-----------------No	solution-----------	-----------------	-----------------
Taiwan	0.03	1.377	33.026	23.981	0.0610
B. Number of vessels					
Days		MT/day	10^3 MT	10^3 days	10^{-1}
All nations	3.12	0.863	34.817	40.367	0.0541
Japan	3.10	0.958	34.704	36.243	0.0562
Korea	0.51	0.438	34.329	78.309	0.1163
Taiwan	-----------------	-----------------No	solution-----------	-----------------	-----------------
Hooks		MT/10^3	10^3 MT	10^6 hooks	10^{-1}
All nations	1.27	0.570	34.277	60.152	0.0950
Japan	1.75	0.573	34.721	60.574	0.0681
Korea	4.26	0.905	36.388	40.189	0.1430
Taiwan	0.21	0.211	37.653	17.881	0.0788

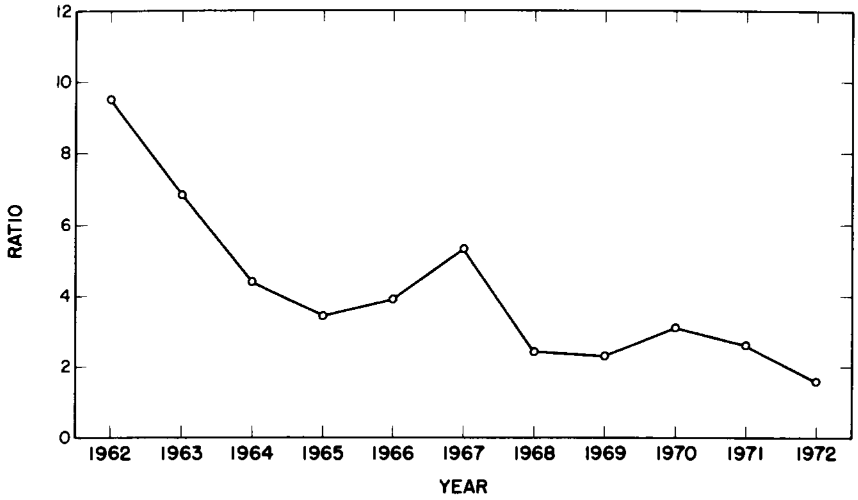

Figure 1.--Ratio of albacore to yellowfin tuna catches in metric tons for the fishery based in American Samoa.

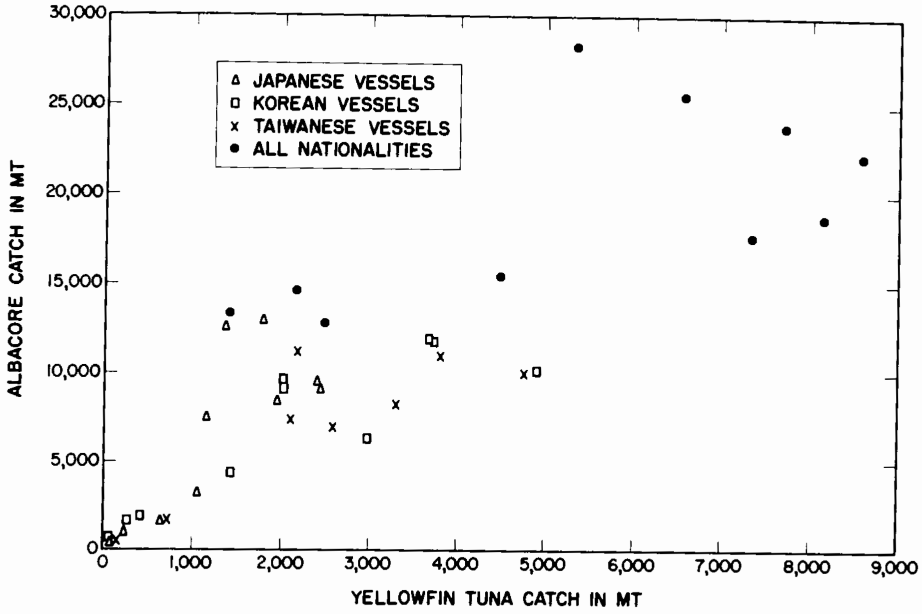

Figure 2.--Relationship between albacore and yellowfin tuna catches in metric tons for the fishery based in American Samoa. For catches made by Japanese, Korean, and Taiwanese vessels as well as vessels of all nationalities combined, the correlation coefficients are 0.80 ($P \leq 0.01$, d.f. = 8), 0.88 ($P \leq 0.01$, d.f. = 8), 0.84 ($P \leq 0.01$, d.f. = 6), and 0.65 ($P \leq 0.05$, d.f. = 8), respectively.

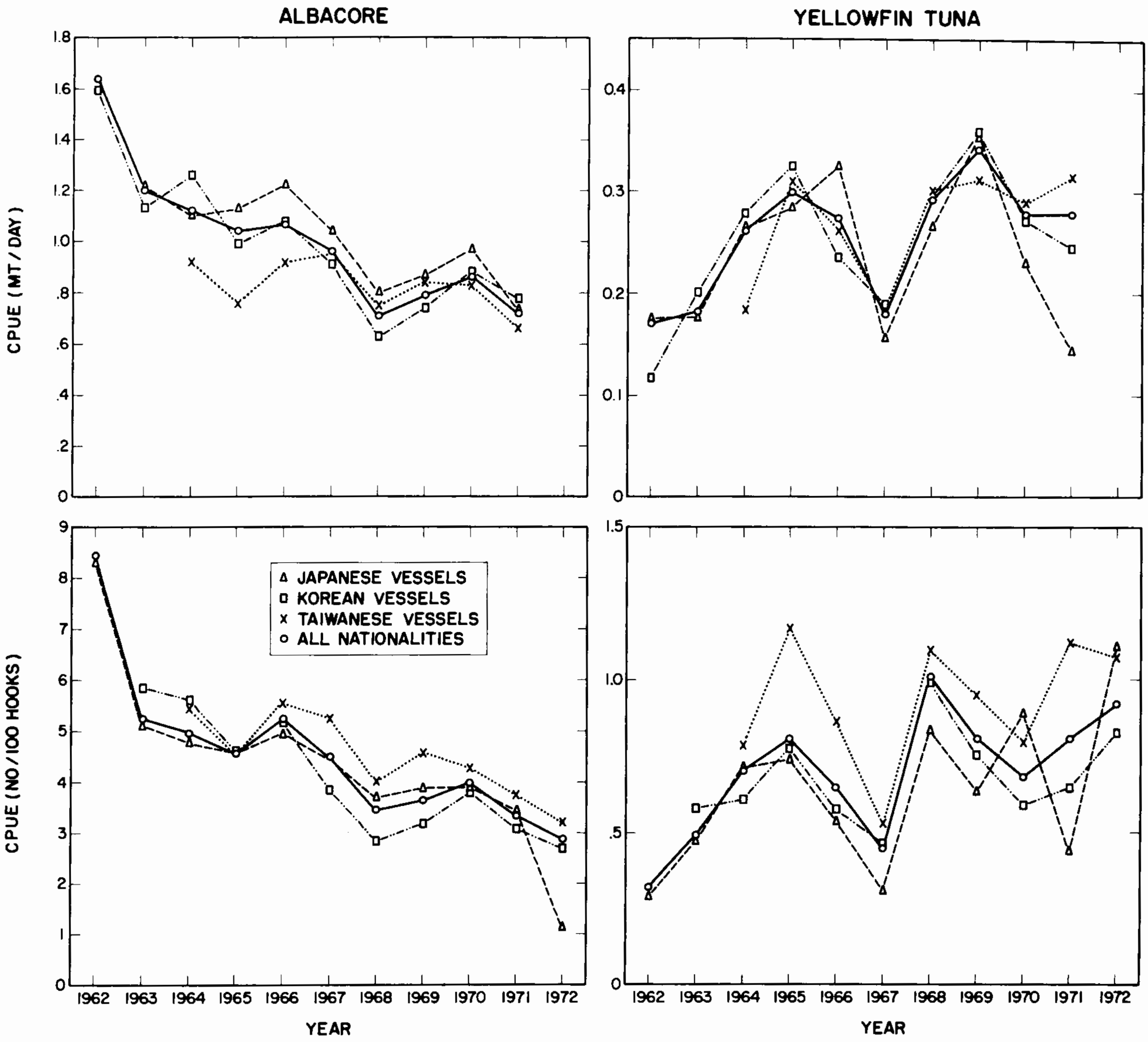

Figure 3.--Temporal trends in catch per unit effort (CPUE) for albacore and yellowfin tuna in the fishery based in American Samoa. No measurement of effort in hooks was obtained for Korea in 1962 even though they were fishing.

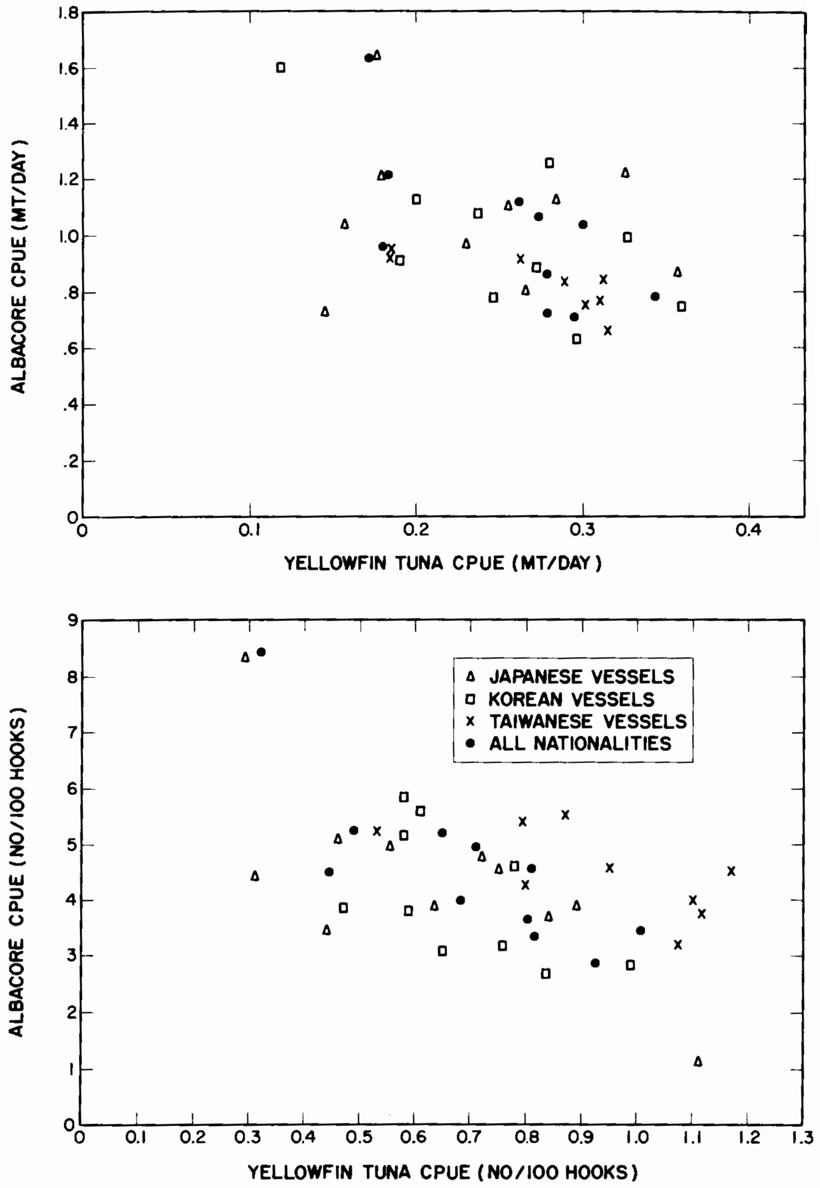

Figure 4.--Comparison of albacore and yellowfin tuna catch per unit effort (CPUE) for the fishery based in American Samoa.