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An Assessment of the South Pacific Albacore, *Thunnus alalunga*, Fishery, 1953-72

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ABSTRACT—As the amount of fishing effort expended in the South Pacific albacore, Thunnus alalunga *(Bonnaterre), fishery increased markedly from the mid-1960's through the early 1970's, measures of apparent abundance of albacore declined by more than 60%. Preliminary estimates of catch per unit effort for the first half of 1974 set new records, alarmingly low ones. Because of these factors and because of proposed further increases in harvesting pressure, an assessment of the fishery is needed. The albacore resource is assessed in this paper by using the generalized production model of Pella and Tomlinson. Using two measures of fishing effort, the maximum sustainable "average" yield is estimated to be 33,000-35,000 metric tons. Based on the generalized production model, a 25% increase in fishing effort over the 1971 level will result in a moderate increase in catch, 300 metric tons, or a substantial decline in catch, 6,700 metric tons, depending on the measure of fishing effort used.*

INTRODUCTION

The development of the South Pacific fishery for albacore, *Thunnus alalunga* (Bonnaterre), in its entirety and in particular that segment based in American Samoa has been described in detail by Otsu (1966) and Otsu and Sumida (1968). Their descriptions have been summarized and updated in the following paragraph.

Before the 1940's there was virtually no longline fishing in the South Pacific Ocean. After the ratification in April 1952 of the Peace Treaty between the United States and Japan, the Japanese began fishing in the western South Pacific near the Solomon Islands, principally for yellowfin tuna, *Thunnus albacares* (Bonnaterre). By late 1952, the Japanese had sent fishing expeditions as far south as lat. 15°S, and by 1953-54 they had extended their operations to lat. 25°S in the western Pacific. In 1953, a California tuna-packing firm bid for and obtained a lease from the U.S. Department of the Interior on a defunct cannery that had been built in Pago Pago, American Samoa in 1949 (Van Campen, 1954). In January 1954, seven Japanese tuna vessels began longline fishing in the vicinity of American Samoa to supply tuna for this cannery, thus establishing the albacore fishery in the South Pacific. This fishery has expanded over the years with the growth of the operations in American Samoa (Fig. 1), the increase in home-based fleets of Japan, Korea, and Taiwan, and the establishment of new bases in the South Pacific. A base was established at Espíritu Santo in the New Hebrides in 1958 and at Levuka in the Fiji Islands in 1963. Also in 1963, a second California tuna-packing firm began operations in American Samoa. The latest development occurred in 1971 when a transshipment base was established in Tahiti. Very small surface fisheries exist in Australia and New Zealand but were not considered in this paper.

In the Samoan fishery, the catch of yellowfin tuna slightly exceeded that of albacore in 1954 and 1955; thereafter, albacore has been dominant in the catch (Fig. 2). Albacore catches reached a peak in 1967 and have since declined. Catches of yellowfin tuna increased throughout the history of the fishery and remained second to albacore in all but 3 years. Catches of bigeye tuna, *Thunnus obesus* Lowe, reached a peak in 1967, when they exceeded yellowfin catches, and declined steadily through 1971. Catches of billfishes were never significant in

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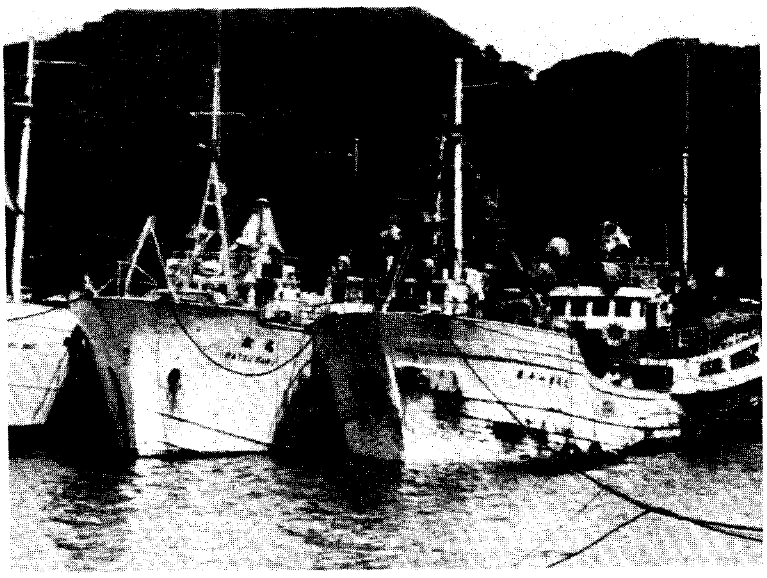


Pago Pago harbor and three typical Japanese longliners.

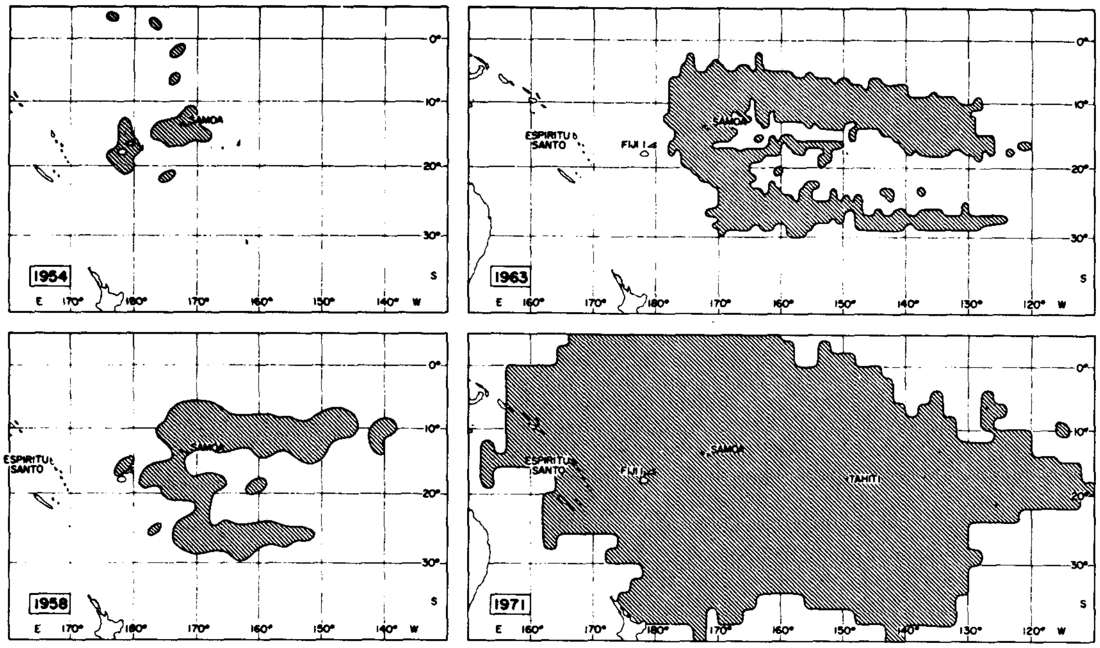


Figure 1.—Areas fished (hatched) by the longline fleet based in American Samoa in 1954, 1958, 1963, and 1971 as well as the location of longline bases (island names) in the South Pacific.

the Samoan fishery. The species trends shown in Figure 2 are not directly comparable because albacore were weighed in the round while yellowfin and bigeye tunas were weighed gilled and gutted and billfish weights were for fillets.

Other biological and fishery information relating to South Pacific albacore may be found in Isii and Inoue (1956), Koga (1961, 1962), Otsu and Hansen (1962), Yoshida and Otsu (1963), Yoshida (1965, 1971), Ishii (1967), Nakagome (1969), and Grandperrin and Legand (1971). A colorful description of the various fisheries in American Samoa, including the longline fishery for albacore, may be found in Otsu and Yoshida (1971).

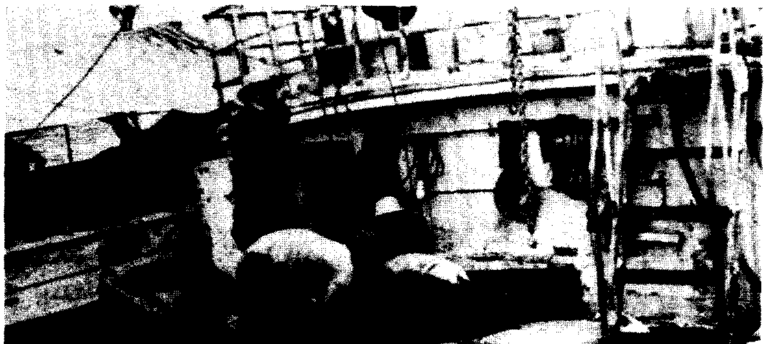
Plans to expand fishing operations in Tahiti and to establish a third cannery in American Samoa stimulated this production model assessment of: 1) the effects of the fishery on the albacore population and 2) the biological potential for expansion of the fishery. In order to produce this assessment on a timely basis, first approximations of total catch for the entire South Pacific were used and the effort statistics were treated in a cursory fashion.

Since total catch data for the entire South Pacific and appropriate effort data from the fishery in American Samoa were available from 1962 to 1971, the production model assessment was limited to those years. However, those statistics that were available through 1972 were included in the figures so that as current a picture of the fishery as possible could be presented.

SOURCE DATA

Fishing Effort

For the vessels based in American Samoa, fishing effort has been measured in terms of the number of vessels fishing, size of vessels, number of trips, number of days fished, and number of hooks fished. Each of these



Unloading operations on a small longliner. Here one deckhand unties a rope used to haul several frozen fish out of the hold while another lifts a large yellowfin tuna out by hand.

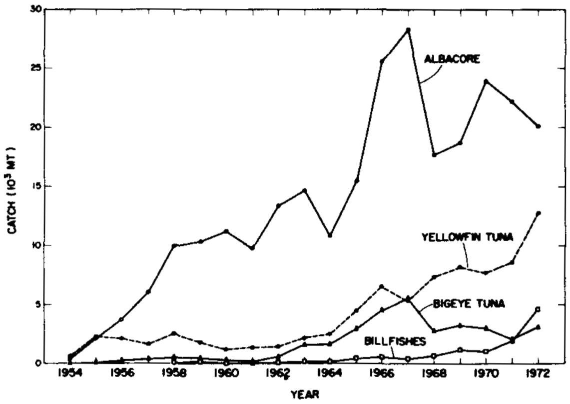


Figure 2.—Total catch in metric tons (MT) by species and by year of capture, 1954-72, for the fishery in American Samoa.

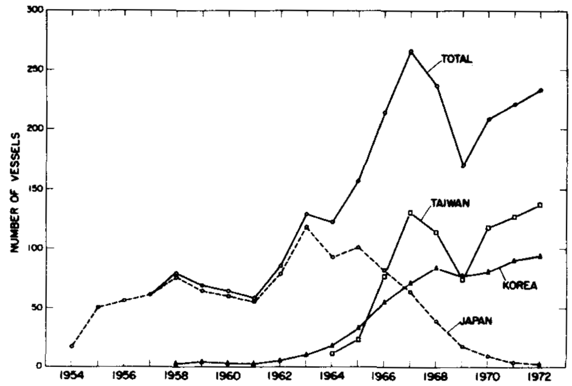


Figure 3.—The number of vessels, by nationality, fishing in the longline fishery based in American Samoa, 1954-72.

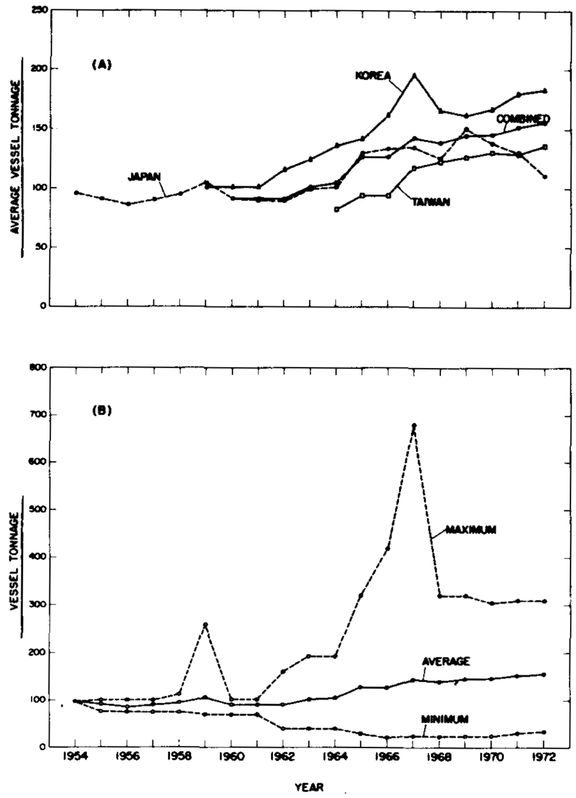


Figure 4.—Vessel tonnage for the fishery in American Samoa. A. Average vessel tonnage by nationality and for all nations combined (including those of undetermined nationality). B. Maximum, average, and minimum vessel tonnage for all nations combined (also including those of undetermined nationality).

measures will be presented to illustrate the historical development of the fishery while the latter two measures will also be used in the assessment of the effect of the fishery on the albacore population. Measures of fishing effort were available for home-based fleets of Japan, Korea, and Taiwan but were not used in this report because: 1) the percent of trips covered for some nations was low, 2) the time series was too short or interrupted for some nations, 3) albacore catches were usually incidental to fishing directed toward other tunas, and 4) these data would have had to be standardized to the Samoan data in any case.

Effort measured in number of vessels was obtained from cannery records and represents a complete sample of the fleet (Fig. 3). From a low of 18 vessels in the first year of the fishery, 1954, the number of vessels operating in the fishery increased steadily to a peak of 266 in 1967. This peak was a result of increasing representation of Korean and Taiwanese vessels and a fairly large component of Japanese vessels, although Japanese representation was actually decreasing at the time. The decline following 1967 resulted from the continued withdrawal of Japanese vessels and some contractual problems with the remaining vessels. In 1970-72, the number of vessels in the fleet again increased. In addition to this increase in number, the average size of vessels increased steadily from a low of 86 gross tons in 1956 to 156 gross tons in 1972 (Fig. 4). The maximum and minimum vessel tonnages have shown marked yearly fluctuations. The maximum increased from a low of 96 gross tons in 1954 to a peak of 680 gross tons in 1967 and stabilized at about 310 gross tons between 1968 and 1972.

Loading fish at a Samoan cannery.

The minimum decreased from a high of 96 gross tons in 1954 to a low of 20 in 1966.

The number of fishing trips made by the Samoan fleet was obtained from cannery records and represents a total sample of the fleet (Fig. 5). It has shown a highly oscillatory pattern over the history of the fishery. The number of trips made by Japanese vessels increased rapidly from 1954 to 1958, declined until 1961, increased to a peak in 1963, and declined steadily throughout the remaining years. Korea entered the fishery in 1958, but the number of fishing trips did not increase substantially until 1963. In 1964, Taiwan entered the fishery and has shown a rapid increase in fishing effort. The time trend for trips followed the same general pattern as that for number of vessels up to the peak in 1967. Trips by Taiwanese vessels showed the same decline in the late 1960's and rise in the early 1970's as the number of Taiwanese vessels; however, Korean trips showed a steady increase until 1969. The result was that the number of trips seemed to be stabilized whereas the number of vessels was increasing.

Data on the number of days spent fishing by each nation in the Samoan fleet (Fig. 6) from 1957 through part of 1972 were collected from cannery records. These data followed the same general trends shown by the other measures of effort, except for the last few years. This measure of fishing effort indicated that fishing intensity increased through 1972, when fishing effort exceeded that in the peak catch year 1967.

Because logbook records were obtained from a different proportion of the fleet each year, the number of hooks fished for 1960-72 was estimated from total catch, number of albacore per 100 hooks, and average weight of albacore in the fishery. Although it appeared that the Samoan fleet may have been directing an increasing amount of effort toward yellowfin tuna, fishing effort was not adjusted to take this potential effect into consideration. The numbers of hooks fished were at a low level in the early years but increased rapidly through 1967 (Fig. 7). The decline in number of hooks in 1968 resulted primarily from the withdrawal of Japanese vessels from the fishery. Following this decline, there seemed to be a leveling of effort at about 36 million hooks, which agrees with the trend shown by the number of trips but neither with the number of vessels nor with the number of days fished.

Total Catch

Catch data for the South Pacific longline fishery were obtained from cannery reports in American Samoa for 1954-72, from Fisheries Agency of Japan, Research Division (1965, 1966, 1967a, 1967b, 1968, 1969, 1970, 1971, 1972, 1973, 1974) for 1962-72, and from the Federation of Japan Tuna Fisheries Cooperative Associations and Japan Tuna Fishermen's Cooperative Association (1967-72) (hereafter referred to as the Asian Tuna Conference proceedings) for 1962-71. These data (Fig. 8) were used in the fitting of the generalized production model. Catch data for Japanese operations for the years 1953-59 and 1961 were obtained from Tuna Fishing (published monthly by the All Japan Investigative Conference of Tuna, Misaki Branch, c/o Kanagawa Prefectural Fisheries Experimental Station, Misakimachi, Miura-shi, Kanagawa, Japan) and presented in Figure 8 to give some idea of the trends in catches for that portion of the fishery not operating out of American Samoa. However, since these latter data were incomplete to an unknown degree, they were not used in fitting the generalized production model.

In order to convert catch reported in numbers to catch in weight, average weight was calculated using data from the Samoan fishery (Fig. 9). These averages were calculated in kilograms for 1962 through 1972 by "South Pacific Ocean Region" and "Eastern Pacific Ocean Region" as defined by the Fisheries Agency of Japan, and for the entire South Pacific (a weighted average). The average size of albacore has decreased in the "South Pacific Ocean Region" where most of the fishing effort has been expended, but this decrease in size may be due to the expansion of the fishery southward where small albacore occur. In the "Eastern Pacific Ocean Region" where the Samoan fleet fishes only seasonally and then only recently and where home-based foreign fleets fish mostly for yellowfin and bigeye tunas, the average weight showed no trend over years.

In the early years of the fishery up

Table 1.—Albacore catch in metric tons (MT) for the South Pacific Ocean. Catches in parentheses were estimated from 1970 catches (and 1971 average fish weights for Japan) because 1971 data were not available.

Year	Category	Catch (MT)				CPUE		Estimated total effective effort	
		Japan	Korea	Taiwan	Total	MT/10^3 hooks	MT/*day*	Hooks (× 10^6)	Days (× 10^3)
1962	Nation	28,352	—	298	28,650			19.267	17.517
	American Samoa				13,326	1.4870	1.6356	8.962	8.147
	Grand total				41,976			28.229	25.664
1963	Nation	23,762	—	608	24,370			25.296	20.281
	American Samoa				14,650	0.9634	1.2016	15.207	12,192
	Grand total				39,020			40.503	32.473
1964	Nation	14,136	—	73	14,209			16.857	12.671
	American Samoa				10,791	0.8429	1.1214	12.802	9.623
	Grand total				25,000			29.659	22.294
1965	Nation	10,871	—	50	10,921			14.097	10.535
	American Samoa				15,459	0.7747	1.0366	19.955	14.913
	Grand total				26,380			34.052	25.448
1966	Nation	16,534	0	0	16,534			18.918	15.512
	American Samoa				25,570	0.8740	1.0659	29.256	23.989
	Grand total				42,104			48.174	39.501
1967	Nation	9,670	1,306	604	11,580			15.785	12.086
	American Samoa				28,310	0.7336	0.9581	38.591	29.548
	Grand total				39,890			54.376	41.634
1968	Nation	5,413	1,262	4,206	10,881			19.719	15.321
	American Samoa				17,723	0.5518	0.7102	32.119	24.955
	Grand total				28,604			51.838	40.276
1969	Nation	4,489	4,924	3,398	12,811			22.111	16.256
	American Samoa				18,731	0.5794	0.7881	32.328	23.767
	Grand total				31,542			54.439	40.023
1970	Nation	5,598	4,673	3,707	13,978			24.570	16.206
	American Samoa				23,876	0.5689	0.8625	41.969	27.682
	Grand total				37,854			66.539	43.888
1971	Nation	(6,437)	(4,673)	5,863	16,973			31.052	23.639
	American Samoa				22,193	0.5466	0.7180	40.602	30.909
	Grand total				39,166			71.654	54.548

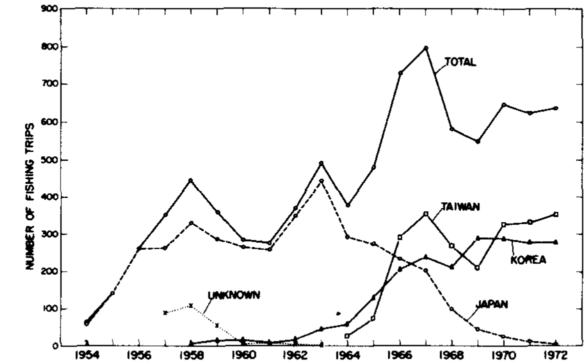


Figure 5.—Total number of fishing trips by nationality of vessels for the fishery based in American Samoa, 1954-72.

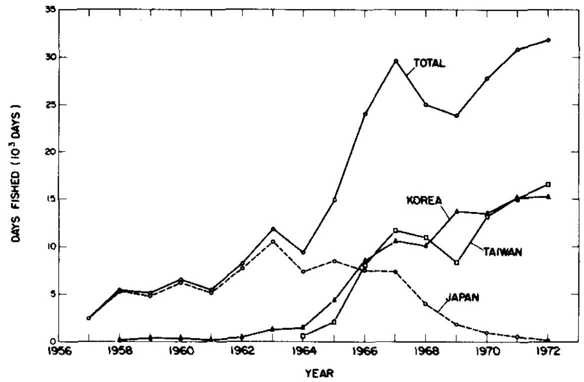


Figure 6.—Total number of days fished, by nationality of vessels, for the fishery based in American Samoa, 1957-72.

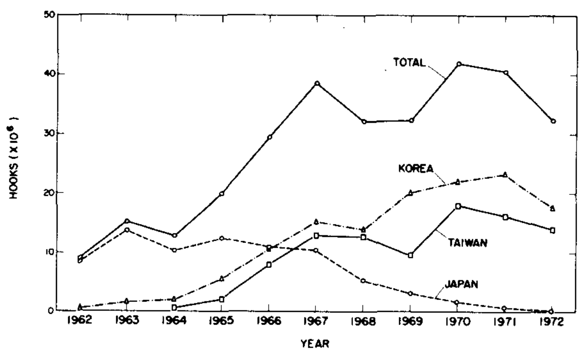


Figure 7.—Effort in hooks by nationality of vessel for the fishery based in American Samoa, 1960-72.

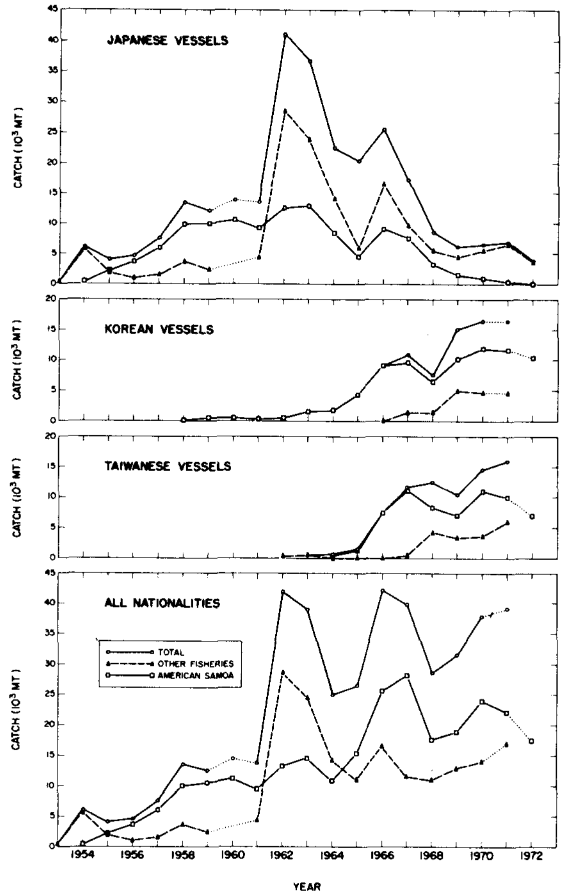


Figure 8.—Catch of albacore by nationality of vessels for the fishery in American Samoa and all other fisheries in the South Pacific. Dotted lines were used where data were missing or where catches were estimated from incomplete data.

through 1961, it appeared that the Samoan fishery constituted the major portion of the South Pacific albacore fishery (Fig. 8); however, these data were apparently incomplete and, therefore, not fully reliable. In 1962, when reliable data became available, the Samoan operations accounted for only 31.7 percent of the total catch. The actual catch and the proportion of the catch landed by the Samoan fleet increased steadily through 1964, when the proportion reached 58.6 percent, until 1967 when the fleet accounted for 71.0 percent of the catch. Following 1967, the Samoan operations accounted for about 60 percent of the total catch. This decrease in dominance of the Samoan fleet was due mainly to increased catches by other fleets.

Catches of albacore by Japanese vessels based in Samoa and elsewhere increased from 1953 through 1962, decreased through 1969 as the vessels withdrew from the albacore fishery. Incidental catches of albacore increased slightly in 1970-72. Catches of albacore by Korea and Taiwan seemed to have stabilized after an initial growth phase when they entered the fishery. For both nations, the operations based in American Samoa accoumted for the largest share of their albacore catches.

ANALYSIS

Index of Relative Abundance

Index of relative abundance or catch per unit of effort (CPUE) for the fishery based in American Samoa was calculated in terms of catch in numbers of albacore per 100 hooks

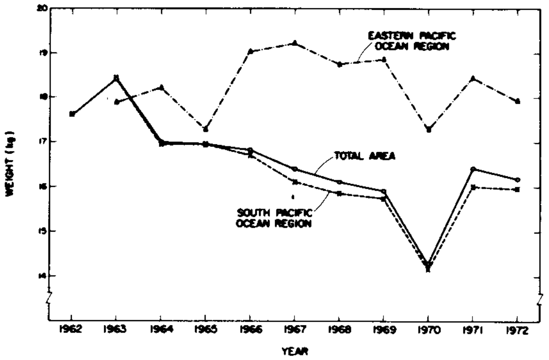


Figure 9.—Average weight of albacore for the year of capture by ocean area using data from the Samoan fishery. The 1971 and 1972 weights were estimated from actual length measures and historical trends in condition factor.

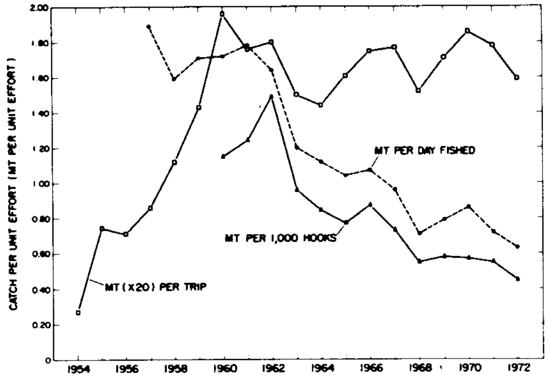


Figure 10.—Annual estimates of indexes of population abundance (CPUE) of albacore in terms of metric tons (MT) per trip, per day fished, and per 1,000 hooks as determined for the fishery based in American Samoa.

(converted to metric tons per 1,000 hooks), in metric tons per day fished (Table 1), and in metric tons per fishing trip. All indexes of relative abundance were calculated as ratio of averages estimators for each year (total catch divided by total effort).

CPUE in trips did not exhibit the same trend with time as the other indexes of abundance (Fig. 10) and was not, I felt, a valid measure of albacore abundance. The increasing CPUE in trips from 1954 through 1960 was probably due to an increase in days fished per trip as the fishery expanded into new grounds (Otsu and Sumida, 1968). Following 1965, at least until 1969, the fishery continued to expand but not as rapidly as in the preceding years (Yoshida[1]). Hence, the fluctuations seen over this time period were probably the result of a decreasing population density, a slight increase in the proportion of the population being harvested due to an expansion of the fishing grounds, a decrease in number of trips, and an increase in the number of days fished per trip. Because of these complications in the interpretation of the historical trend in these data, CPUE in trips was not used in fitting the generalized production model.

CPUE in days fished and CPUE in hooks fished followed similar trends with time, except in 1960-61. Differences in these early years were ascribed to errors in CPUE in hooks since this statistic was estimated from 2.5 percent and 8.1 percent of the total trips made by the fleet. Because of these differences and because CPUE in days fished was calculated from a complete sample of the fleet for all years, CPUE in days fished was considered the more accurate index of relative abundance. For comparative purposes, however, both of these indexes of abundance were used to estimate total effective effort and to calculate the generalized production model.

Total Effective Effort

The estimates of total effective effort, in terms of hooks and days fished by the Samoan fleet, expended in catching albacore in the South Pacific were calculated using total catch data and CPUE statistics derived in previous sections (Table 1). Since Samoan logbook records giving counts of hooks were a subsample of the whole Samoan fleet, estimates of effective effort were calculated for the Samoan fishery as well as for the catch outside the Samoan fishery. Total effective effort was obtained by summing these two estimates. Hence, by using the CPUE statistics calculated for the Samoan fishery, the effort expended by the Japanese, Korean, and Taiwanese fleets not based in Samoa was standardized in terms of the albacore fishery in American Samoa. Since Japanese vessels seemed to direct much of their effort toward southern bluefin tuna, *Thunnus maccoyii* (Castelnau), and bigeye tuna, the estimated number of hooks should have been much less than was actually fished. The same should have been true for Korean and Taiwanese data but to a lesser degree because a smaller proportion of their fishing seemed directed toward other species.

The amount of fishing effort expended by the non-Samoan fleet fluctuated from year to year but seemed to remain at about the same level from 1962 to 1970. In 1971, there may have been a trend upward in fishing effort. Over this same 10-year period, the effort expended by the Samoan fleet increased markedly (about 450 percent). The result of these two trends was that the total effective effort expended in the capture of albacore increased by about 250 percent.

Generalized Production Model

Although a wealth of biological knowledge on the South Pacific albacore does not exist and in particular information is lacking on mortality, individual growth, and recruitment that is required to use a dynamic pool model (Beverton and Holt, 1957; Ricker, 1958), there nonethless is a need to assess the state of the stock. Therefore, the generalized production model of Pella and Tomlinson (1969), requiring only catch and effort data, was used in this paper. However, this

[1]Yoshida, H. O. The American Samoa Longline Fishery, 1966-71. Manuscript.

model makes several assumptions regarding population processes and handling of effort data in order to allow for the simplification of certain dynamic processes of populations. These assumptions are as follows: 1) The population is a closed, distinct, self-sustaining unit. It is generally believed that there are separate albacore populations in the North and South Pacific for the following reasons: a) areas of high catches or catch rates do not straddle the equator, b). areas of peak catches in both the North and South Pacific occurring in their respective winter months are at the poleward extremes of the fishery and then tend to move to middle latitudes as "summer" approaches, c) albacore of all ages are apparently in both the North and South Pacific, d) spawning seems to occur in the North Pacific in areas and seasons that are distinct from spawning in the South Pacific, e) no albacore tagged in the North Pacific have ever been recaptured in the South Pacific. As on any question, there is no uniformity of opinion here. Grandperrin and Legand (1971) argued on the basis of limited experiments with deep-fishing vertical longline gear in waters near New Caledonia (lat. 12°-23°S) and in French Polynesia (lat. 10°-25°S) that it is possible for the exchange of small fish as well as large fish across the equator. Their hypothesis is based on high catch rates of large fish at 200-300 m (greater than in the traditional grounds above 150 m) and on the occurrence of two small albacore (4.0 and 9.5 kg) at these depths in the experiments near New Caledonia. More work needs to be done in this area (see also Saito, 1973). 2) The concept of equilibrium holds for the South Pacific albacore. I do not suggest that the population is necessarily in equilibrium but rather that the population always tends toward a stable population size in response to changes in mortality (primarily fishing effort). 3) Although I assume that the concept of equilibrium holds, I do not assume that equilibrium is reached instantaneously with changes in fishing effort. The age of maturity for albacore is sufficiently old and the albacore contributes significantly to the fishery for so long that I feel it is unreasonable to expect the population

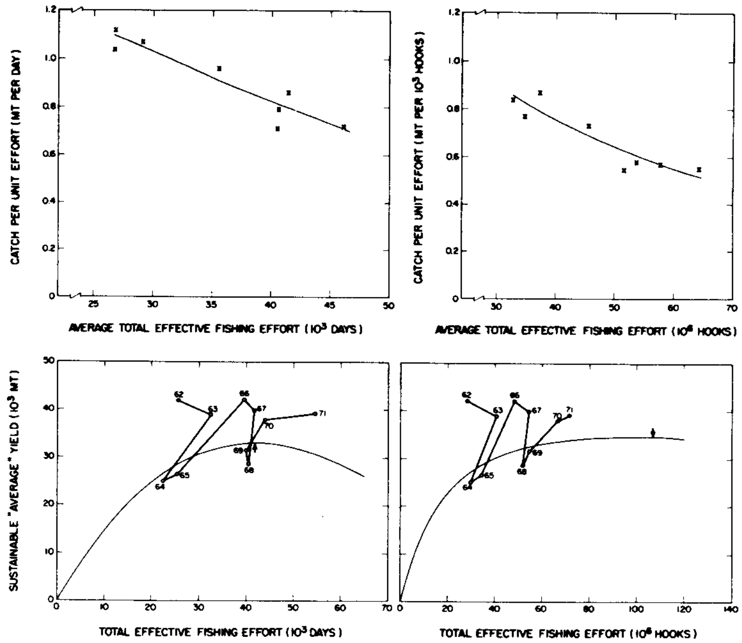


Figure 11.—Plots of catch and fishing effort data for the South Pacific albacore fishery showing the equilibrium relationship between CPUE and fishing effort and the relationship between sustainable "average" yield and fishing effort for the generalized production model with effort data in terms of number of days fished and number of hooks fished and with an averaging time ($\bar{T}_i$) equal to 3 years. Arrows indicate location of MSAY (Maximum Sustainable "average" yield) on the stock production curves.

to respond instantaneously to changes in fishing effort. Hence, Gulland's procedure (Gulland, 1969, p. 120), which averages fishing effort over some mean time period during which a year class contributes significantly to the catch, was used to adjust for non-instantaneous response of the population to changes in fishing effort. 4) I have assumed that the catchability coefficient, q, is constant. There is no evidence that any gear modification, change in the nationality of the fleet, or change in species sought has caused any change in q.[2] The possibility of changing q as the fishery has expanded into new grounds, some of which yield fish smaller than the average size in the fishery, has not been investigated. 5) Sufficient data are available over a time period when a large population change occurred (a reduction of 56-62 percent in relative abundance over an 11-year period) so that the parameters of the production model can be estimated efficiently.

The generalized production model of Pella and Tomlinson (1969) was obtained for the South Pacific albacore fishery by entering catch in metric tons and effort in both number of days fished and number of hooks fished into PRODFIT, a least squares nonlinear regression algorithm using Gulland's equilibrium approximation technique (Fox, 1972). Four parameters of management interest were derived from the model using PRODFIT, namely $\bar{m}$, $CPUE_{opt}$, f_{opt}, and MSAY. The phrase maximum sustainable "average" yield (MSAY) was substituted for the well-known phrase maximum sustainable yield (MSY) to denote that the sustainable yield will fluctuate even though fishing effort and the catchability coefficient remain constant. The least squares procedure finds a solution of the general production model, using CPUE as the dependent variable, that results in the smallest residual sum of squares compared to all other possible solutions. Thus, this solution is a measure of central tendency, but not a true average. Calculating the curve of

[2]Skillman, R. A. 1974. Further investigations on the population dynamics of the South Pacific albacore fishery. Unpublished report filed at the Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu Laboratory, Honolulu, HI 96812.

Table 2.—Generalized production model for the South Pacific albacore fishery, 1962-71.

$\bar{T}_i$	$\hat{m}$	$\widehat{CPUE}_{opt}$	$\widehat{MSAY}$	$\hat{f}_{opt}$	MSQ
	Model using fishing effort in days fished				
Years		MT/day	10^3 MT	10^3 DAYS	
2	2.24	0.825	35.385	42.900	0.1351
3	1.62	0.791	33.072	41.801	0.0613
4	0.61	0.584	33.473	57.291	0.1210
	Model using fishing effort in hooks fished				
$\bar{T}_i$	$\hat{m}$	$\widehat{CPUE}_{opt}$	$\widehat{MSAY}$	$\hat{f}_{opt}$	MSQ
Years		MT/10^3 hooks	10^3MT	10^6 hooks	
2	0.64	0.477	35.913	75.279	0.1588
3	0.25	0.325	34.665	106.761	0.0769
4	0.15	0.262	33.719	128.512	0.1351

sustainable "average" yields (SAY) from the above solution and finding the maximum of this curve produces an estimate of MSAY. The SAY curve may not appear to be the best possible fit to the observed yield/effort data because the curve represents equilibrium yield whereas the observed values represent transient yields (Fig. 11). In addition, the SAY/total effective effort curve is derived from the actual least squares solution of the production model. The other parameters are defined as follows: m describes the symmetry of the curve between SAY and fishing effort and the concavity of the curve between CPUE and effort, for example when $m = 0.0$, the SAY curve is asymptotic and the CPUE curve is markedly concave upwards, when $m \rightarrow 1$, the SAY curve is skewed (Gompertz model) and the CPUE curve is slightly concave upwards, and when $m = 2.0$, the SAY curve is symmetric (logistic or Schaefer model) and the CPUE curve is a straight line; and $CPUE_{opt}$ and f_{opt} are estimates of the index of population abundance in metric tons per unit effort and the amount of total effective fishing effort expended at the point of estimated MSAY.

Since no age or size group composition studies have been performed on the South Pacific albacore population, averaging times for the equilibrium approximation technique were based on the number of age groups present in the Japanese longline fishery for albacore in the North Pacific. Otsu and Uchida (1963) recognized six age groups, ages 2 to 7, in the North Pacific fishery with age group 2 comprising a small proportion of the catch; hence a year-class contributed significantly to the catch for approximately 5 years. Using this information, an averaging time ($\bar{T}_i$) of 2 or 3 years for Gulland's approximation seemed appropriate for the South Pacific fishery. For comparative purposes, an averaging time of 4 years was also included.

Results of the production model analysis are presented in Table 2 and Figure 11. On the basis of mean sum of squares (Table 2), an averaging time of 3 years resulted in the best fit with an averaging time of 4 years being second best for fishing effort in both days and hooks. From the distribution of the observed data points (averaged) relative to the fitted values (Figure 11), it is obvious that the generalized production model using $\bar{T}_i = 3$ years can be used for predictive purposes within the range of the observed fishing effort.

Since the production models for effort in both days and hooks fished indicated a MSAY of 33,000-35,000 metric tons, the major differences between the models was in the estimation of $CPUE_{opt}$ and $\hat{f}_{opt}$ and in the shape of the SAY and CPUE curves. It must be remembered that both $CPUE_{opt}$ and $\hat{f}_{opt}$ are in terms of the fleet based in American Samoa; therefore, the $CPUE_{opt}$ and f_{opt} estimates refer only to vessels fishing for albacore in the same manner as the Samoan fleet. In particular, the total amount of fishing effort expended in the South Pacific will be considerably in excess of the values used or predicted in this analysis because much of the fishing effort is directed towards yellowfin, bigeye, and southern bluefin tunas. If this were a management situation, $\hat{f}_{opt}$ would have to be partitioned and adjusted for each segment of the South Pacific longline fishery.

DISCUSSION

Based on the generalized production models given in Table 2 and Figure 11, it must be concluded that the South Pacific albacore fishery has reached or nearly reached the level of MSAY, given the current constitution of the fishery. Any further increase in fishing effort, deployed in the same manner as the present fishing effort, will result in a further decline in CPUE, without any significant increase in yield and probably a decrease. If the South Pacific fishing fleet were to change its fishing strategy, for example by harvesting different age groups at different intensities or possibly by fishing for adult fish at greater depths in the middle South Pacific latitudes, the estimated MSAY for the stock might change.

Because the shape of the SAY curve was different for the two models presented in this paper as well as for models not reported on here that used a slightly different estimate of total catch and different measures of CPUE, I do not have a great deal of confidence in the shape of the right-hand limb of the SAY curve. With the above statement in mind and using the two production models presented here, if a 25 percent increase in fishing effort over the 1971 level is hypothesized, the estimates of SAY would decrease to 27,900 metric tons (CPUE = 0.57 metric ton/day) from a 1971 SAY level of 30,800 metric tons for the model using effort in days fished, or increase to 34,300 metric tons (CPUE = 0.44 metric ton/10^3 hooks) from a 1971 SAY of about 34,000 metric tons for the model using effort in hooks fished. Based on this analysis, the SAY cannot be increased appreciably and might decline significantly with a 25 percent increase in effort.

While a number of assumptions regarding the use of the generalized production model and the handling of the catch and effort data have been made, none of these assumptions are regarded as being unreasonable. Nor would slight departures from any of the assumptions invalidate the results from this "first cut" analysis. If the biological information were available to verify the assumptions or to make adjustments to the data as called for, sufficient data would be present to apply a more sophisticated approach.

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