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OBSERVATIONS ON THE PURSE-SEINE FISHERY FOR TROPICAL TUNAS IN THE EASTERN PACIFIC OCEAN

by

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INTRODUCTION

Yellowfin tuna, Thunnus albacares, and skipjack tuna, Katsuwonus pelamis, are caught in the eastern Pacific Ocean by fishermen based in the Americas by two methods, bait fishing and purse-seining. Bait fishing was the dominant method until 1960-1961. During 1948-1957 about 80 percent of the yellowfin and 90 percent of the skipjack landed by California-based vessels, which make up the majority of the fleet, were caught by bait vessels (Anonymous 1967:Table 4). In 1957 conversion of bait vessels to purse-seine vessels was begun, and most of the fleet had been converted by the end of 1961. The details of this conversion are discussed by Orange and Broadhead (1959), Broadhead and Marshall (1961), and McNeely (1961). During 1963-1966 about 90 percent of the yellowfin and 85 percent of the skipjack landed by the California-based fleet were caught by purse-seine vessels (Anonymous, 1967:Table 4).

Several studies have been made of the purse-seine fishery for yellowfin and skipjack tuna. Orange, Schaefer, and Larmie (1957) studied the incidence of pure yellowfin, pure skipjack, and mixed yellowfin-skipjack schools in the catches, and the weights of the catches made in individual sets. Their data were for 1946-1955, when the purse-seine fishery was less important than the bait fishery, and conducted mostly north of 20°N. Broadhead and Orange (1960) conducted the same type of study for 1956-1958, when the spatial and temporal extent of the fishery was much more extensive. In addition, they compared the length-frequency distribution of yellowfin and skipjack tuna from pure and mixed schools of yellowfin and skipjack. Broadhead (1962) compared the catches per unit of effort by bait and purse-seine vessels to standardize the effort by purse-seine vessels to the fishing power of a Class-4 baitboat (201-300 short tons capacity). Calkins (1963) examined the "concentration indices," i.e., indices of the degree of concentration of the fishing effort in the areas where the catch per unit of effort was highest, for purse-seine vessels for 1951-1961. Calkins (1965) made a study of the size composition of yellowfin tuna within individual purse-seine sets. Green and

Broadhead (1965) made an economic study of the purse-seine fishery for tropical tunas.

One of the Inter-American Tropical Tuna Commission's most important investigations is a continuing study of the relationship among catch, effort, and catch per unit of effort of yellowfin and skipjack tuna (Shimada and Schaefer 1956; Schaefer 1957). An estimate of the total effort in the eastern Pacific Ocean is obtained by dividing the total catch of all vessels by the catch per unit of effort of as many bait and purse-seine vessels as possible standardized to the fishing power of a Class-4 baitboat. To accomplish the standardization, it is necessary to have as thorough an understanding as possible of the schooling habits of the fish, the nature of the purse-seine fishery, and the relationships between them. This report constitutes a contribution to this end.

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DATA AND METHODS

Three species of tropical tunas, yellowfin, skipjack, and bigeye, Thunnus obesus, are caught by the purse-seine vessels of the tropical tuna fleet of the eastern Pacific Ocean. In addition, at the northern and southern ends of the range of the tropical tunas these vessels catch bluefin tuna, T. thynnus, albacore tuna, T. alalunga, bonito, Sarda velox, and S. chiliensis, mackerels, Scomber japonicus and Trachurus symmetricus, and yellowtail, Seriola dorsalis.

For this report, the eastern Pacific Ocean has been divided into the five areas shown in Figure 1. This division is made because of differences in the species composition of the catches, the habits of the fish, and the methods of fishing at different latitudes. The vessels have been assigned to the following size classes, in accordance with their capacities in short tons: 1, 1-50; 2, 51-100; 3, 101-200; 4, 201-300; 5, 301-400; 6, greater than 400. This was done by Shimada and Schaefer (1956) because they suspected that the fishing powers differed among vessels of different sizes.

The data on which this study is based were obtained from information in the logbooks of the purse-seine vessels. Data from the logbooks of vessels based in Canada, Mexico, Peru, Puerto Rico, and the United States were used. The information in the logbooks includes records of the date of each set, the location where it was made, the type of school, the weight in short tons of each species caught, and a notation as to whether or not assistance was received from an airplane or helicopter in locating and setting the net around the school of fish. Information on the capacity and speed of each vessel and the length and depth of its net were collected from various sources, and these were also used in the analysis.

The following data were analyzed in this report: catch per day of fishing; catch per set; catch per successful set; ratio of successful to total sets; sets per day of fishing. The first statistic, catch per day of fishing, which is presently used as an index of the abundance of the fish, is the product of the last three statistics. It is thus likely that study of these three statistics will provide a greater understanding of the usefulness of catch per day of fishing as an index of abundance of the fish. The catch per successful set is the product of the sizes of the schools and the fractions of the schools which are caught, but since neither of these can be measured, the catch per successful set must be used. The catch per set is studied only because it is necessary to use this statistic, in conjunction with the catch per day of fishing, to estimate the sets per day of fishing.

The data were abstracted from the logbooks and punched on two sets of computer cards, one with the fishing effort in days and the other with the effort in sets. From these cards summaries have been made for various purposes. The analyses in the present report were prepared mostly from these summaries, but also partly from the original computer cards and partly from new cards prepared from the original ones, but with additional information added to them.

The data were not used to calculate the catch per day of fishing in the following cases:

1. If the total weight logged for the trip did not agree within 25 percent of the weight of fish unloaded, none of the data for this trip were used.

2. If the weight of yellowfin and skipjack combined was less than two-thirds of the total weight of fish unloaded, none of the data for that trip were used. If the weight of yellowfin and skipjack was two-thirds or more of the total weight, however, all the effort for that trip was assumed to have been directed toward yellowfin and skipjack.

The data were not used to calculate the catch per set, catch per successful set, or ratio of successful to total sets in the following cases:

1. If the total weight logged for the trip did not agree within 25 percent of the weight of fish unloaded, none of the data for that trip were used.

2. If it was not reasonably certain that the vessel was fishing for yellowfin or skipjack, rather than for some other species, the data for those days were not used.

3. If the catch was recorded for several sets combined instead of individually, the data for those sets were not used. If this occurred frequently in the logbook record of a trip, none of the data for that trip were used.

The catch data were recorded in short tons, and the catches of fractions of tons were reduced to the nearest whole number. Thus 0 tons was recorded for the sets in which $\frac{1}{4}$ to $\frac{1}{2}$ ton was caught. These were considered to be successful sets, however, as were all the sets in which $\frac{1}{4}$ ton or more of yellowfin and/or skipjack was caught.

In some cases, when a school consisted of many fish of one species and only a few of the other, the school was recorded in the vessel's logbook as being a pure school. This is not believed to be an applicable source of error for the present analysis, however.

The data are summarized in Tables 1-6 and 22-26. The catches are recorded in short tons in all the tables in this report. The species of fish were not recorded in the logbooks in some cases. For the catch-per-unit-of-effort data in Tables 1 and 22, the data for all fish of the species in question, whether caught in pure schools or in schools mixed with the other species, were used. The catches which were not recorded by species were prorated in accordance with the species composition of the catches by all vessels for which logbook data were available for the same 1-degree area, year, and quarter. For the catch-per-set data in Tables 2 and 23, all the data were used except those for the sets for which the species was not recorded. In other words, the total catches recorded as the species in question, whether the fish were caught in pure or mixed schools, were divided by the numbers of sets, exclusive of those for which the species of fish caught was not recorded. For the catch-per-successful-set data in Tables 3, 4, and 24 only the data for the sets in which only the species in question were caught were used. For the ratio-of-successful-to-total-sets data in Tables 5 and 25, the data for all the sets were used, and all those in which $\frac{1}{4}$ ton of yellowfin and/or skipjack or unidentified fish believed to have been yellowfin and/or skipjack were caught, were considered to have been successful. For this reason, the numbers of sets are usually slightly higher in Tables 5 and 25 than in Tables 2 and 23. For the sets-per-day-of-fishing data in Table 6 and Table 26, the numbers of days of fishing and the numbers of sets were taken from Tables 1 and 2 and Tables 22 and 23, respectively.

In Tables 7 and 27 are shown the logged catches of skipjack and yellowfin (i.e., those for which logbook data were obtained) and the total catches of skipjack and yellowfin in the eastern Pacific Ocean for 1961 through 1966. It can be seen from these tables that the majority of the logged catches of skipjack in Areas 3, 4, and 5 are included in Tables 1, 2, and 3 and that the majority of the logged catches of yellowfin in Area 2 are included in Table 24. A minority of the logged catches of skipjack in Area 1 appears in Table 4, however; this is because a large portion of the skipjack in this area is taken in schools of mixed yellowfin and skipjack.

Most of the calculations were performed on the CDC 3600 computer at the University of California at San Diego and the IBM 7094 and IBM 360 computers at the University of California at Los Angeles. The following computer programs were used in the analyses:

Multiple-classification analysis of variance--BMD 02V (Dixon 1965), BMD 05V (Dixon 1965);

Single-classification analysis of variance--G4 UTEX SCANOVA (Veldman 1962);

Analysis of covariance--BIMD 20 (Dixon 1961);

Simple correlation--Weighted Linear Regression for Two Variables (Paulik and Gales 1965), BMD 03R (Dixon 1965);

Multiple correlation--BMD 03R (Dixon 1965).

ASSUMPTIONS

As mentioned previously, the vessels of the tropical tuna fleet fish for several species. The problem of separating the effort according to the species toward which it is directed is a formidable one. On most trips the vessels do not catch bluefin, albacore, bonito, mackerel, or yellowtail, nor do they fish in water of the temperatures where these species occur. When they do catch these species, the criteria described in the preceding section are probably adequate for assigning the effort as to whether it is directed toward these species or toward the tropical tunas. This leaves the effort directed toward yellowfin, skipjack, and bigeye to be separated. According to the procedures described in the preceding section, the data for a trip in which the catch consisted of 50 percent yellowfin and 50 percent bigeye would not be used to calculate the catch per day of fishing, but those for a trip in which the catch consisted of 50 percent yellowfin and 50 percent skipjack would be used for this purpose. This seems illogical, since the bigeye is a tropical tuna and occurs within the geographic ranges of the yellowfin and skipjack. The error resulting from this procedure is minor, however, since bigeye tuna are rarely caught in sufficient quantities to cause the data for a trip not to be used to calculate the catch per day of fishing.

The problem thus consists almost entirely of separating the effort directed toward yellowfin and skipjack. The sets in which only yellowfin or only skipjack are caught can be considered as being directed toward whichever of these species was caught (and possibly toward the other species too), and those in which both species were caught can be considered as being directed toward both. A considerable portion of the sets catch no fish, however, and there are no notations in the logbooks to tell which species the fishermen thought were in the schools when the sets were begun. Shimada and Schaefer (1957), considered all effort assigned as being directed toward yellowfin or skipjack to be directed toward yellowfin. Yellowfin occur throughout the range of the tropical tuna fishery (Alverson 1963), and are favored by the fishermen because they can be sold for a higher price. Therefore, any vessel fishing in the area where tropical tunas are caught could be assumed to be searching for yellowfin, except possibly when it is in an area where there are known to be large schools of skipjack and few yellowfin. Skipjack, on the other hand, do not occur in all areas of the range of the tropical tuna fishery, nor do they occur at all times of the year in the areas where they are found (Alverson 1963). Recognizing this, Joseph (unpublished manuscript) has defined an area off central Mexico where relatively few skipjack are caught, and considered all effort except that in this area to be directed toward skipjack. This area shifts slightly from year to year, probably due to differences in oceanographic conditions, but corresponds fairly well to Area 2.

The great majority of the skipjack catch is made in Area 5, and this catch is considerably greater than that of yellowfin in the same area (Tables 7 and 27). Thus it is assumed that all the effort in this area is directed toward skipjack. Therefore only this area is considered for the analysis of the catch per day of fishing, catch per set, ratio of successful to total sets, and sets per day of fishing for skipjack. The catches of yellowfin are substantial in Area 2, while those of skipjack are quite low in that area (Tables 7 and 27). Thus it is assumed that all the effort in this area is directed toward yellowfin, and only data for this area are used for the analyses of yellowfin in this report.

The ratio of successful to total sets in each stratum is calculated by dividing the number of sets in which at least $\frac{1}{4}$ ton of yellowfin and/or skipjack was caught by the total number of sets. The assumption that the ratio of successful to total sets is the same for schools of yellowfin, skipjack, and mixed yellowfin and skipjack is implicit in this procedure. It is not believed that this assumption is valid, but the procedure must be used until some way has been found to determine toward which species the unsuccessful sets were directed.

Results

The differences among years, quarters, and size classes of the values of catch per day of fishing, catch per set, catch per successful set, ratio of successful to total sets, and sets per day of fishing were tested by analysis of variance to determine if they were significant. For this purpose the model was assumed to be

$$x_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha_i \beta_j + \alpha_i \gamma_k + \beta_j \gamma_k + \epsilon_{ijk}$$

where

x_{ijk} = value (catch per day of fishing, catch per set, catch per successful set, ratio of successful to total sets, or sets per day of fishing) for size class k in quarter j of year i,

μ = overall mean,

α_i = mean effect of year at level i,

β_j = mean effect of quarter at level j,

γ_k = mean effect of size class at level k,

$\alpha_i \beta_j$, $a_i \gamma_k$, and $\beta_j \gamma_k$ = mean effects of the two-way interactions at their respective levels, and

ϵ_{ijk} = error term.

For this model the following assumptions are made:

1. Any factors other than year, quarter, or size class which affect the values are distributed randomly among the year, quarter, and size-class strata.

2. There is no three-way interaction among years, quarters, and size classes.

3. The experimental error is distributed normally, with its mean equal to 0 and its variance equal to σ^2.

Because of limitations in the capacities of the available computer programs, it was necessary to use the means instead of the individual values for each stratum in the multiple-classification analyses of variance, and this made it impossible to test whether three-way interactions existed. In some of these tests it may be noted that F values of less than 1 were obtained, and especially in these cases the possibility of the existence of three-way interactions should be recognized. Since all the available data were used in these problems, all three factors are assumed to be fixed.

In the analyses which involve Area 5 (catch per day of fishing, catch per set, ratio of successful to total sets, and sets per day of fishing) and Areas 3, 4, and 5 combined (catch per successful set) only data for Class-4, Class-5, and Class-6 vessels are considered, since vessels of the other size classes fish only infrequently in those areas. In the analyses involving Area 1 (catch per successful set) only data for the third and fourth quarters and for Class-3, Class-4, and Class-5 vessels are used since few skipjack are caught in that area in the first two quarters and since vessels of the other size classes fish there only infrequently.

Catch per day of fishing

In Table 1 are shown the catches, days of fishing, and catches per day of fishing in Area 5 by year, quarter, and size class for 1961 through 1966. In Table 8 are shown the results of an analysis of variance to determine if there were significant differences among years, quarters, or size classes in the catch per day of fishing. The data for 1961 were omitted because there were insufficient data for the first quarter of that year. The results indicate significant differences for all three factors and for the year-quarter interaction.

Catch per set

In Table 2 are shown the catches, sets, and catches per set in Area 5 by year, quarter, and size class for 1962 through 1966. There were no data available for 1961 on the total number of sets, so the catches per set could not be calculated for that year. In Table 9 are shown the results of an analysis of variance to determine if there were significant differences among years, quarters, or size classes in the catch per set. The results indicate significant differences for all three factors and for the year-quarter interaction.

Catch per successful set

As mentioned previously, skipjack are caught infrequently in an area off central Mexico. Though it shifts slightly from year to year, this area corresponds fairly well to Area 2. The interchange of fish between Area 1 and Areas 3, 4, and 5 is slight (Schaefer, Chatwin, and Broadhead 1961). Accordingly, in this report the fish of Area 1 are considered to belong to a northern group and those of Areas 3, 4, and 5 to a southern group. The fish caught in Area 2 probably belong to both groups, so they are not considered for this analysis.

In Tables 3 and 4 are shown the catches, successful sets, and catches per successful set for the southern and nothern groups, respectively, by year, quarter, and size class for 1961 through 1966. The catches per successful set are so much greater for the southern than for the northern group that no statistical test is needed to determine the significance of these differences.

Southern group

In Table 10 are shown the results of an analysis of variance to determine if there were significant differences among years, quarters, or size classes in the catch per successful set. The data for 1961 were omitted because there were insufficient data for the first quarter of that year. The results indicate significant differences for all three factors and for the year-quarter interaction.

A similar analysis of variance was conducted using only data for Area 5. The results were the same as those for Areas 3, 4, and 5 combined except that for Area 5 the difference among years was significant at the 1-percent instead of the 5-percent level.

Northern group

In Table 11 are shown the results of an analysis of variance to determine if there were significant differences among years, quarters, or size classes in the catch per successful set. It was arbitrarily decided not use the data for any stratum for which there were less than five successful sets; three strata were in this category. With BMD 05V, the computer program used for this analysis, it is not necessary to have data for all the cells, so substitute values for these strata were not calculated. The results indicate significant differences for the years, quarters, and quarter-size class interaction. This result is in contrast to that obtained for the southern group, for which there were found significant differences for the years, quarters, size classes, and year-quarter interaction.

Ratio of successful to total sets

In Table 5 are shown the ratios of successful to total sets in Area 5 by year, quarter, and size class for 1962 through 1966. There were no data available for 1961 on the total number of sets, so the ratios of successful to total sets could not be calculated for that year. In Table 12 are shown the results of an analysis of variance to determine if there were significant differences among years, quarters, or size classes in the ratios of successful to total sets. As the range of values is 0.329 to 0.776, with only 2 of the 60 values above 0.700, no transformation of the data is needed (Steel and Torrie 1960:158). The results indicate significant differences for the years, quarters, and year-quarter interaction. In contrast to the catch per day of fishing, catch per set, and catch per successful set, however, there was no significant difference among size classes in the ratios of successful to total sets.

Sets per day of fishing

In Table 6 are shown the sets, days of fishing, and sets per day of fishing in Area 5 by year, quarter, and size class for 1962 through 1966. The data were taken from Tables 1 and 2. It is evident from the Data and Methods section that different criteria were used to determine whether or not the available logbook data were used for these tables. In most cases more data were usable for Table 1 than for Table 2, as can be seen by the fact that the catches in Table 1 are in most cases higher than those in the equivalent strata of Table 2. Therefore the numbers of sets in Table 2 were adjusted to correct for this discrepancy. This adjustment was made by multiplying the numbers of sets for each stratum by the ratio of the catch in Table 1 to the catch in Table 2 for that stratum. The adjusted numbers of sets are shown in Table 6. In Table 13 are shown the results of an analysis of variance to determine if there were significant differences among years, quarters, or size classes in the numbers of sets per day of fishing. The results indicate significant differences for the years, quarters, and year-quarter interaction. Thus they are similar to the results for the ratio of successful to total sets, but in contrast to those for catch per day of fishing, catch per set, and catch per successful set.

Aircraft assistance

Airplanes and helicopters are sometimes used to search for schools of tuna for purse-seine vessels, and to direct the fishing operations. The airplanes are based on shore, while the helicopters are based on the fishing vessels. The airplanes operate independently of the vessels, and the pilots assist any vessel in its fishing operations for a share of the value of the catch of the sets for which assistance was furnished. The helicopter pilot's first responsibility is to the vessel on which the helicopter is based, but when that vessel is not searching for fish (i.e. engaged in bringing the fish aboard the vessel after making a set, returning to port fully loaded, etc.) he may furnish assistance to other vessels. In such cases his remuneration is made in the same manner as that of the airplane pilots. Helicopters have been used much less frequently than airplanes for assistance in fishing.

Catch per successful set

To determine the effect of aircraft assistance on the catch per successful set, the data were examined for each year-quarter-size class stratum for which there were at least 10 successful sets for which the vessels were assisted by aircraft and 10 for which they did not receive such assistance. Airplanes and helicopters were not separated from one another, since there were so few data for helicopters. The distribution of the weights of skipjack in purse-seine sets is reverse J-shaped (Orange, Schaefer, and Larmie 1957:Figure 9; Broadhead and Orange 1960: Figure 5) so the logarithmic transformation of Bartlett (1947) to make the frequency distribution more nearly normal is appropriate. This was accomplished by $x' = \log_{10}(x + 1)$, where x = catch per successful set. Single-classification analyses of variance were made for each stratum to determine if there were significant differences between the assisted and non-assisted sets. The results are summarized in Table 14. Of the 22 tests, seven showed the catch per successful set to be greater at the 5-percent level for aircraft-assisted sets and 15 showed no significant difference. The results of the 22 tests were combined, using the method of Winer (1962:44-45). For this it is necessary to assume that aircraft assistance has the same effect on the catch per successful set in each year-quarter-size class stratum. The values of t for Winer's equation are the square roots of the values of F in Table 14. The value of z for the combined data is 3.56, which indicates at the 1-percent level that assistance by aircraft increases the catch per successful set.

Ratio of successful to total sets

In Table 15 are shown the ratios of successful to total sets by year, quarter, and whether or not assistance was received from aircraft. In Table 16 are shown the results of an analysis of variance to determine if there were significant differences among years or whether or not assistance was received from aircraft. Because of the shortage of data for aircraft-assisted sets, the data for 1964 are omitted and the data for the different quarters and size classes are combined. The arcsine transformation described by Bartlett (1947) was used for the data, as two of the eight values are greater than 0.700 (Steel and Torrie 1960:158). The results indicate a significant difference between the assisted and non-assisted sets, the ratio of successful to total sets being higher for the former. However, the airplane pilots do not receive any remuneration for the sets in which no fish are caught, and it is known that often when no fish are caught the fact that assistance was received from an airplane is not recorded in the logbooks. Thus the difference between the ratios of successful to total sets by vessels assisted by aircraft and those not receiving such assistance is less than indicated in Table 15, and may be non-existent.

Time consumed in making sets

An index of abundance of a species of fish is obtained from the catch per unit of effort. For a species which is fished by purse-seines, this should be the ratio of the catch to the time spent searching for fish. For skipjack (and yellowfin) the catch per unit of effort is presently defined as the ratio of the catch to the days of fishing. A portion of the days of fishing is devoted to making sets, rather than to searching for fish, and if this time is subtracted from the days of fishing, there will be obtained an estimate of the time spent searching for fish, which is a better measure of the fishing effort. As a first step in determining whether it is worthwhile to make this correction, it is necessary to determine the time consumed in making sets in which various quantities of fish are caught.

For this purpose it is assumed that the relationship between the time consumed in making a set and the quantity of fish in that set is linear, and thus of the form

$$y_{ij} = a + bx_{ij}$$

where

y_{ij} = time spent making a set in quarter j of year i,

x_{ij} = quantity of fish caught in that set, and

a and b = constants.

Data on sets in which pure skipjack were caught and on unsuccessful sets were used for this study. These were obtained from the abstracts made by Tuna Commission personnel of the fishermen's logbooks. The catches in short tons for the successful sets were tabulated at intervals of 5 tons, i.e. catches of 0.1 to 4.9 tons were tabulated as 2.5 tons, catches of 5.0 to 9.9 tons were tabulated as 7.5 tons, etc., and the times of the sets were tabulated in minutes. The data were not used when the times of the sets were not recorded in the logbooks. The data were tabulated by year and quarter of landing, which correspond fairly closely to the years and quarters in which the fish were actually caught. They were not tabulated by area or size class, however. If there were usable data for more than 50 sets for a given interval for a given year, the data for only 50 of them were used. These were distributed approximately equally among the four quarters and among the vessels which had usable data in their logbooks.

In Table 17 are shown the numbers of sets for which data were obtained for each quarter and year and the estimates of the values of the constants in the regressions. Analyses of covariance were conducted to determine if the slopes or levels of the regression differed among quarters within years or among years without regard to quarters. The results are shown in Table 18. The differences among quarters are significant in only two of the six years, and in neither case is the significance high. The difference among years is highly significant, however. It is apparent from Figure 2 that the time required to make a set has been reduced considerably during the 1961-1966 period.

Discussion and conslusions

Differences among years

Significant differences among years were found for the catch per day of fishing, catch per set, catch per successful set, ratio of successful to total sets, and sets per day of fishing. The first two factors are functions of the last three, whereas the last three may be related to the abundance of the fish. It is thus of interest to compare each of the last three factors to indices of abundance of the fish. For this purpose the following indices were chosen: logged catch in Area 3 or in Areas 3, 4, and 5 combined (Table 7); total catch (Table 7); catches in pounds per day of fishing in the entire eastern Pacific Ocean standardized to Class-3 purse-seine vessels, which were as follows: 1961, 3286; 1962, 5252; 1963, 7299; 1964, 4852; 1965, 5451; 1966, 4715 (Anonymous 1965:Table 4; Anonymous 1967:Table 6; unpublished data of the Inter- American Tropical Tuna Commission).

The catch per successful set might be related to the techniques of fishing, to the sizes of the schools, or to some behavior characteristic of the fish which influences what portions of the schools are caught. It is unlikely that the first is the case, as the catches per successful set, though they differed significantly among years during 1961-1966, do not appear to have increased during that period. These were the first years of purse-seining for most of the fishermen, and they would be expected to have learned much about handling the gear during that period, but apparently they did not learn anything which enabled them to increase the catch per successful set. If the second or third is the case, it is worthwhile to compare the catches per successful set with the indices of abundance of the fish to see if they are related, since the sizes of the schools and/or the behavior of the fish may in turn be related to the abundance. For this purpose, the catches per successful set in Areas 3, 4, and 5 combined (Table 3) were used. The product-moment correlation coefficients for the catches per successful set with the three indices of abundance of the fish were calculated, with the following results:

	Correlation coefficient	Degrees of freedom	Probability
logged catch in Areas 3, 4, and 5 combined-catch per successful set	-0.028	4	>0.10
total catch and catch per successful set	0.204	4	>0.10
catch per day of fishing and catch per successful set	0.026	4	>0.10

From these data there is no evidence that the catch per successful set is related to the abundance of the fish, and it can be inferred that the size of the schools and the behavior characteristic mentioned above (if it exists) are not related to the abundance. However, it is stated by some fishermen that in years when skipjack are abundant, very large schools of them occur in Area 5, and they sometimes have to avoid these large schools and set on smaller ones because they cannot handle the very large schools. It is not known if this occurs frequently enough to invalidate the above inference.

The ratio of successful to total sets might be related to the techniques of fishing or to some behavior characteristic which influences the ease with which the schools (or portions of them) can be caught. If the latter is the case, it is worthwhile to compare the ratios of successful to total sets with the indices of abundance of the fish to see if they are related, since the behavior of the fish may in turn be related to the abundance. For this purpose, the ratios of successful to total sets for Area 5 (Table 5) were used. The product-moment correlation coefficients for the ratios of successful to total sets with the three indices of abundance of the fish were calculated, with the following results:

	Correlation coefficient	Degrees of freedom	Probability
logged catch in Area 5-ratio of successful to total sets	-0.662	3	>0.10
total catch-ratio of successful to total sets	-0.798	3	>0.10
catch per day of fishing-ratio of successful to total sets	-0.712	3	>0.10

From these data there is no evidence that the ratio of successful to total sets is related to the abundance of the fish, and it can be inferred that the behavior characteristic (if it exists) which influences the ease with which the schools of fish may be caught is not related to the abundance. The increase in the ratios of successful to total sets in 1966 is believed to be due chiefly or entirely to improved techniques in capturing yellowfin tuna schooled with propoises. The ratio of successful to total sets increased much more in Area 2 (Tables 25 and 34) where the proportion of yellowfin in the catches is higher and where more porpoises occur, than in Area 5.

The sets per day of fishing might be related to the technique of fishing or to the numbers of schools of fish in the area. If the latter is the case, it is worthwhile to compare the number of sets per day of fishing with the indices of abundance of the fish to see if they are related, since the numbers of schools of fish in the area may in turn be related to the abundance. For this purpose the sets per day of fishing for Area 5 (Table 6) were used. The product-moment correlation coefficients for the sets per day of fishing with the three indices of abundance of the fish were calculated, with the following results:

	Correlation coefficient	Degrees of freedom	Probability
logged catch in Area 5-sets per day of fishing	0.852	3	<0.10
total catch-sets per day of fishing	0.626	3	>0.10
catch per day of fishing-sets per day of fishing	0.573	3	>0.10

From these data there is some evidence that the number of sets per day of fishing is related to the abundance of the fish, and it can be inferred that when the fish are more abundant there are more schools of fish in the area.

In summary, it appears that when the fish are more abundant there are more schools of fish, but that the schools are about the same size as when the fish are less abundant. The same conclusion was reached by Broadhead and Orange (1960) for yellowfin tuna. More investigation of this is needed, however, when more data are available.

Differences among quarters

Significant differences among quarters were found for the catch per day of fishing, catch per set, catch per successful set, ratio of successful to total sets, and sets per day of fishing for Area 5 or for Areas 3, 4, and 5 combined. The catch per successful set has tended to be higher in the second and third quarters, while the ratio of successful to total sets and the sets per day of fishing were usually higher during the first and second quarters. The greatest difference among quarters was in the catch per successful set, which caused the catch per set and the catch per day of fishing also to be higher in the second and third quarters.

The differences in the catch per successful set, ratio of successful to total sets, and sets per day of fishing in different quarters could be due to differences in the abundance of the fish or to differences in their behavior. There appears to be no point in pursuing this further until more is known of the biology of the skipjack.

Year-quarter and quarter-size class interactions

Significant year-quarter or quarter-size class interactions were found for the catch per day of fishing, catch per set, catch per successful set, ratio of successful to total sets, and sets per day of fishing for Area 5, or for Areas, 3, 4, and 5 combined. This means that the ratios among quarters within the years or among size classes within the quarters for these factors differed among the years or quarters involved. There appears to be no point in pursuing this further until more is known of the biology of the skipjack.

Differences among vessel size classes

It is evident from the foregoing analyses that in Area 5 the larger vessels do not make more sets per day than do the smaller ones, nor do they have higher ratios of successful to total sets. They catch greater amounts of fish per successful set, however, and for this reason make higher catches per set and higher catches per day of fishing. Actually there is a nearly-significant difference in the number of sets per day made by the larger vessels (Table 13), and this might become significant when data for more years are obtained. Thus the differences in the catches per day of fishing by the larger vessels may be due partly to their making more sets per day of fishing, but they are due chiefly to their catching greater amounts of fish per successful set.

It is of interest to determine whether the larger vessels make greater catches per successful set than do the smaller ones because the former set on larger schools of fish or because they catch larger portions of the schools that they set on. Examination of other characteristics of the vessels and gear is appropriate for this purpose. Data on the vessel speeds and the net lengths and depths are available for most of the vessels in the purse-seine fleet. These data, and data on the vessel capacities, are summarized in Table 19.

Product-moment correlation analyses were conducted to determine the relationships of each of these factors with the vessel capacities. The actual capacities, rather than the size classes, were used for this purpose. In Table 20 are shown the coefficients of correlation with vessel capacity for each factor for 1961 through 1966. All the coefficients are high, with probability levels of less than 1 percent, indicating that each of these factors is strongly correlated with vessel capacity.

Next the catches per successful set were correlated with the vessel capacities, vessel speeds, net lengths, and net depths. For this purpose the data used for Tables 3 and 4 were employed except that the data for the few vessels for which there were no data for the vessel and net characteristics were omitted, as were the data for the few sets in which the vessels were assisted by an airplane or helicopter. The latter were omitted because, as was shown previously, aircraft assistance tended to result in slightly higher catches per successful set, and such assistance may not have been randomly distributed among vessels of different characteristics. The logarithmic transformation described previously was used for the data in this analysis. The results are summarized in Table 21. The correlation coefficients for all the strata combined were calculated by the method of Fisher (1958:204); these are also shown in Table 21. For this it is necessary to assume that the correlations are equal for each stratum. The catch per successful set is correlated about equally with each of the four factors. However, the correlations are much lower than those among the vessel and net characteristics, and most of them for the individual strata are not significant. Also shown in Table 21 are coefficients of multiple correlation involving all four vessel and net characteristics. The number of significant correlations is about the same for the multiple correlations as for each of the single correlations. This is not surprising, since the data in Table 20 indicate that the vessel and net characteristics are strongly correlated with one another. There is no way to ascertain from these data which of these factors, if any, is most influential in affecting the catch per successful set. The most conspicuous feature of the data is the low correlation of the catch per successful set with the vessel and net characteristics.

The above analyses have accomplished very little, except to demonstrate the low correlation of the catch per successful set with the vessel and net characteristics and to show that there would apparently be little or no advantage to substituting some other vessel or net characteristic for vessel capacity in studies involving the catch per unit of effort.

It will be noted that the larger vessels catch more fish per successful set when fishing on the southern group (Table 10), but not the northern group (Table 11), and that the catch per successful set is much higher in the south (Tables 3 and 4). The latter is probably because the schools are larger in the south than in the north. It appears that the vessels in the north (Size classes 3, 4, and 5) all set on schools of equal size and are able to catch equal portions of these schools. In the south, however, the larger vessels catch more fish per successful set, either because they set on larger schools of fish or because they catch larger portions of the schools they set on. If the latter is the case, it may be because the larger vessels are equipped with longer and/or deeper nets. This is merely speculation, however, and better data would be needed for verification.

It was indicated previously that a nearly-significant difference was found in the sets per day made by vessels of different size classes (Table 13). The larger vessels tend to be faster (Table 20), which may enable them to make more sets per day. It would be worthwhile to examine the correlation between sets per day and vessel speed, but data for this purpose are not available.

It is the desire of the fishermen to achieve the highest possible earnings per year, of course, rather than the highest possible catch per successful set. Larger vessels make considerably higher catches per year than do the smaller ones, even though the catches per successful set and the catches per day of fishing in the same areas are nearly the same. When fishing in the same area, the larger vessels catch more fish per year because they spend less time travelling to and from port and unloading their catches. In addition, it is feasible for the larger vessels to travel to areas which are further from port and where the catches per unit of effort are higher. The economic merits of vessels of different sizes are discussed in detail by Green and Broadhead (1965).

Time consumed in making sets

In 1966 the average vessel capacity was 325 short tons (Table 19). From data in Tables 1, 3, 5, and 17 it is calculated that such a vessel fishing exclusively for skipjack in Area 5 on a single trip might have had the following results:

days of fishing - 40;

successful sets - 22, with 15 tons of fish in each set;

unsuccessful sets - 13;

total time required for the successful sets - 45 hours;

total time required for the unsuccessful sets - 19 hours.

Thus 64 hours (2-2/3 days) should be subtracted from the 40 days of fishing to get the time actually spent searching for fish. The amount of time to be subtracted in each case would depend on the numbers of successful and unsuccessful sets made and the distribution of the amounts of fish caught in the successful sets. If some of the effort was devoted to yellowfin instead of skipjack there would be introduced a considerable further complication. It is beyond the scope of this report to suggest procedures for subtracting the time consumed in making the sets.

Results

The differences among years, quarters, and size classes of the values of catch per day of fishing, catch per set, catch per successful set, ratio of successful to total sets, and sets per day of fishing were tested by analysis of variance to determine if they were significant. The model was assumed to be the same as that described for skipjack on pages 7-9.

Only the data for the first, second, and fourth quarters and for Class-3, Class-4, and Class-5 vessels are considered, since little fishing occurs in Area 2 in the third quarter and since vessels of the other size classes fish there only infrequently.

Catch per day of fishing

In Table 22 are shown the catches, days of fishing, and catches per day of fishing in Area 2 by year, quarter, and s ze class for 1961 through 1966. In Table 28 are shown the results of an analysis of variance to determine if there were significant differences among years, quarters, or size classes in the catch per day of fishing. The results indicate significant differences for all three factors and for the year-quarter interaction.

Catch per set

In Table 23 are shown the catches, sets, and catches per set in Area 2 by year, quarter, and size class for 1962 through 1966. There were no data available for 1961 on the total number of sets, so the catches per set could not be calculated for that year. In Table 29 are shown the results of an analysis of variance to determine if there were significant differences among years, quarters, or size classes in the catch per set. The results indicate significant differences for all three factors and for the year-quarter interaction.

Catch per successful set

In Table 24 are shown the catches, successful sets, and catches per successful set in Area 2 by year, quarter, and size class for 1961 through 1966. In Table 30 are shown the results of an analysis of variance to determine if there were significant differences among years, quarters, or size classes in the catch per successful set. The results indicate significant differences for all three factors and for the year-quarter interaction.

Ratio of successful to total sets

In Table 25 are shown the ratios of successful to total sets in Area 2 by year, quarter, and size class for 1962 through 1966. There were no data available for 1961 on the total number of sets, so the ratios of successful to total sets could not be calculated for that year. In Table 31 are shown the results of an analysis of variance to determine if there were significant differences among years, quarters, or size classes in the ratios of successful to total sets. As the range of values is 0.378 to 0.745, with only 3 of the 45 values above 0.700, no transformation of the data is needed (Steel and Torrie 1960:158). The results indicate significant differences for the years and size classes. In contrast to the catch per day of fishing, catch per set, and catch per successful set, however, there were no significant differences for the quarters and year-quarter interaction.

Sets per day of fishing

In Table 26 are shown the sets, days of fishing, and sets per day of fishing in Area 2 by year, quarter, and size class for 1962 through 1966. The data were taken from Tables 22 and 23. It is evident from the Data and Methods section that different criteria were used to determine whether or not the available logbook data were used for these tables. In most cases more data were usable for Table 22 than for Table 23, as can be seen by the fact that the catches in Table 22 are in most cases higher than those in the equivalent strata of Table 23. Therefore the numbers of sets in Table 23 were adjusted to correct for this discrepancy. This adjustment was made by multiplying the numbers of sets for each stratum by the ratio of the catch in Table 22 to the catch in Table 23 for that stratum. The adjusted numbers of sets are shown in Table 26. In Table 32 are shown the results of an analysis of variance to determine if there were significant differences among years, quarters, or size classes in the numbers of sets per day of fishing. The results indicate significant differences for the years, size classes, and year-size class interaction. Thus they are similar to the results for the ratio of successful to total sets except for the year-size class interaction, but in contrast to those for the catch per day of fishing, catch per set, and catch per successful set.

Types of schools

The four principal types of schools of yellowfin are recognized by the fishermen, those in which the fish are schooled with porpoises, those which are caught in sets made at night, those which are caught in sets made around floating objects, and those which do not fit into any of the other three categories. The last are termed "school fish." In Tables 33, 34, and 35 are shown the catch per set, catch per successful set, and ratio of successful to total sets for each of these types of school. The values in these tables are less than those in Tables 23, 24, and 25 because the types of schools the vessels set on were sometimes not specified in the logbooks, and the data for such sets are omitted from Tables 33, 34, and 35. In addition, the sets made with the assistance of aircraft are omitted from these tables.

The average catch per successful set is considerably higher for school fish than for porpoise fish, but the opposite is true for the ratio of successful to total sets, and the result is that the catch per set is about the same for school fish and propoise fish. The average catch per successful set is intermediate for the night sets, but the ratio of successful to total sets is very high, which results in the highest catch per set.

About 60 percent of the yellowfin caught in Area 2 are caught in schools mixed with porpoises. The catch per set, catch per successful set, and ratio of successful to total sets were calculated by year, quarter, and size class for fish schooled with porpoises only, and analyses of variance were conducted to determine if significant differences existed among the above factors. The results were quite similar to those for all schools combined (Tables 29, 30, and 31), differing only as follows for the catch per set: year-quarter interaction significant at the 1-percent instead of the 5-percent level; quarter-size class interaction significant at the 1-percent level.

Aircraft assistance

The use of airplanes and helicopters to search for schools of tuna for purse-seine vessels, and to direct the fishing operations, is discussed on page 11.

Catch per successful set

To determine the effect of aircraft assistance on the catch per successful set, the data were examined for each year-quarter-size class stratum for which there were at least 10 successful sets for which the vessels were assisted by aircraft and 10 for which they did not receive such assistance. Airplanes and helicopters were not separated from one another, since there were so few data for helicopters. The distribution of the weights of yellowfin in purse-seine sets is reverse J-shaped (Orange, Schaefer, and Larmie 1957;Figure 9; Broadhead and Orange 1960:Figure 5) so the logarithmic transformation of Bartlett (1947) to make the frequency distributions more nearly normal is appropriate. This was accomplished by $\underline{x}' = \log_{10}(\underline{x} + 1)$, where $\underline{x}$ = catch per successful set. Single-classification analyses of variance were made for each stratum to determine if there were significant differences between the assisted and non-assisted sets. The results are summarized in Table 36. Of the eight tests, six showed the catch per successful set to be greater at the 5-percent level for aircraft-assisted sets and two showed no significant difference. The results of the eight tests were combined, using the method of Winer (1962: 44-45). For this it is necessary to assume that aircraft assistance has the same effect on the catch per successful set in each year-quarter-size class stratum. The values of $\underline{t}$ for Winer's equation are the square roots of the values of $\underline{F}$ in Table 36. The value of $\underline{z}$ for the combined data is 5.85, which indicates at the 1-percent level that assistance by aircraft increases the catch per successful set.

Ratio of successful to total sets

In Table 37 are shown the ratios of successful to total sets by year, quarter, and whether or not assistance was received from aircraft. In Table 38 are shown the results of an analysis of variance to determine if there were significant differences among quarters or whether or not assistance was received from aircraft. Because of the shortage of data for aircraft-assisted sets, the data for the fourth quarter are omitted and the data for the different years and size classes are combined. The arcsine transformation described by Bartlett (1947) was used for the data, as one of the four values is greater than 0.700 (Steel and Torrie 1960: 158). The results indicate no significant difference between the assisted and non-assisted sets.

Time consumed in making sets

The purpose of investigating the time consumed in making sets for skipjack, and the model and procedures employed, are described on pages 12 and 13. The purpose, model, and procedures are the same for yellowfin.

In Table 39 are shown the numbers of sets for which data were obtained for each quarter and year and the estimates of the values of the constants in the regressions. Analyses of covariance were conducted to determine if the slopes or levels of the regressions differed among quarters within years or among years without regard to quarters. The results are shown in Table 40. The differences among quarters are significant in five of the six years. The difference among years is also significant, and is greater than those among quarters. It is apparent from Figure 3 that the time required to make a set has been reduced considerably during the 1961-1966 period.

Discussion

Differences among years

Significant differences among years were found for the catch per day of fishing, catch per set, catch per successful set, ratio of successful to total sets, and sets per day of fishing. The first two factors are functions of the last three, whereas the last three may be related to the abundance of the fish. It is thus of interest to compare each of the last three factors to indices of abundance of the fish. For this purpose the following indices were chosen: logged catch in Area 2 (Table 27); total catch (Table 27); catches in pounds per day of fishing in the entire eastern Pacific Ocean standardized to Class-3 purse-seine vessels, which were as follows: 1961, 10,590; 1962, 6,277; 1963, 6,421; 1964, 9,407; 1965, 7,507; 1966, 9,168 (Anonymous 1965: Table 4; Anonymous 1967: Table 6; unpublished data of the Inter-American Tropical Tuna Commission).

The catch per successful set (Table 24) might be related to the techniques of fishing, to the sizes of the schools, or to some behavior characteristic of the fish which influences what portions of the schools are caught. It is unlikely that the first is the case, as the trend is downward, and the fishermen have not been compelled by law to reduce the efficiency of their gear. If the second or third is the case, it is worthwhile to compare the catches per successful set with the indices of abundance of the fish to see if they are related, since the sizes of the schools and/or the behavior of the fish may in turn be related to the abundance. The product-moment correlation coefficients for the catches per successful set with the three indices of abundance of the fish were calculated, with the following results:

	Correlation coefficient	Degrees of freedom	Probability
logged catch in Area 2-catch per successful set	0.572	4	> 0.10
total catch and catch per successful set	0.381	4	> 0.10
catch per day of fishing-catch per successful set	0.098	4	> 0.10

From these data there is no evidence that the catch per successful set is related to the abundance of the fish, and it can be inferred that the size of the schools and the behavior characteristic mentioned above (if it exists) are not related to abundance.

The ratio of successful to total sets (Table 25) might be related to the techniques of fishing or to some behavior characteristic which influences the ease with which the schools (or portions of them) can be caught. If the latter is the case, it is worthwhile to compare the ratios of successful to total sets with the indices of abundance of the fish to see if they are related, since the behavior of the fish may in turn be related to the abundance. The product-moment correlation coefficients for the ratios of successful to total sets with the three indices of abundance of the fish were calculated, with the following results:

	Correlation coefficient	Degrees of freedom	Probability
logged catch in Area 2-ratio of successful to total sets	-0.279	3	> 0.10
total catch-ratio of successful to total sets	0.501	3	> 0.10
catch per day of fishing-ratio of successful to total sets	0.719	3	> 0.10

From these data there is no evidence that the ratio of successful to total sets is related to the abundance of the fish, and it can be inferred that the behavior characteristic (if it exists) which influences the ease with which the schools of fish may be caught is not related to the abundance. The increase in this ratio during the 1962-1966 period is due entirely to improved techniques in capturing yellowfin tuna schooled with porpoises, as can be seen from Table 35.

The sets per day of fishing (Table 26) might be related to the techniques of fishing or to the numbers of schools of fish in the area. If the latter is the case, it is worthwhile to compare the number of sets per day of fishing with the indices of abundance of the fish to see if they are related, since the numbers of schools of fish in the area may in turn be related to the abundance. The product-moment correlation coefficients for the sets per day of fishing with the three indices of abundance of the fish were calculated, with the following results:

	Correlation coefficient	Degrees of freedom	Probability
logged catch in Area 2-sets per day of fishing	0.809	3	< 0.10
total catch-sets per day of fishing	0.520	3	> 0.10
catch per day of fishing-sets per day of fishing	0.744	3	> 0.10

From these data there is some evidence that the number of sets per day of fishing is related to the abundance of the fish, and it can be inferred that when the fish are more abundant there are more schools of fish in the area.

In summary, it appears that when the fish are more abundant, there are more schools of fish, but that the schools are about the same size as when the fish are less abundant. The same conclusion was reached by Broadhead and Orange (1960). More investigation of this is needed, however, when more data are available.

Differences among quarters

Significant differences among quarters were found for the catch per day of fishing, catch per set, and catch per successful set, but not for the ratio of successful to total sets or sets per day of fishing. The catch per successful set has tended to be highest in the second quarter and lowest in the fourth quarter, which results in the same pattern for the catch per day of fishing and the catch per set. In Table 34 it can be seen that the catches per successful set are also highest in the second quarter and lowest in the fourthquarter for the porpoise and night schools. The differences could be due to differences in the abundance of the fish or to differences in their behavior. There appears to be no point in pursuing this further until more is known of the biology of the yellowfin.

Year-quarter and year-size class interactions

Significant year-quarter or year-size class interactions were found for the catch per day of fishing, catch per set, catch per successful set, and sets per day. This means that the ratios among quarters within years or among the size classes within the years differed among the years. There appears to be no point in pursuing this further until more is known of the biology of the yellowfin.

Differences among vessel size classes

It is evident from Tables 24 and 25 that in Area 2 the larger vessels catch more fish per successful set and have higher ratios of successful to total sets than do the smaller ones. For this reason, they make higher catcher per set and higher catches per day of fishing. The number of sets per day of fishing is about the same for all size classes of vessels, however (Table 26).

It is of interest to determine whether the larger vessels make greater catches per successful set than do the smaller ones because the former set on larger schools of fish or because they catch larger portions of the schools that they set on. Examination of other characteristics of the vessels and gear is appropriate for this purpose. Data on the vessel speeds and the net lengths and depths are available for most of the vessels in the purse-seine fleet. These data, and data on the vessel capacities, are summarized in Table 19.

Product-moment correlation analyses were conducted to determine the relationships of each of these factors with the vessel capacities. The actual capacities, rather than the size classes, were used for this purpose. In Table 20 are shown the coefficients of correlation with vessel capacity for each factor for 1961 through 1966. All the coefficients are high, with probability levels of less than 1 percent, indicating that each of these factors is strongly correlated with vessel capacity.

Next the catches per successful set were correlated with the vessel capacities, vessel speeds, net lengths, and net depths. For this purpose the data used for Table 24 were employed except that the date for the few vessels for which there were no data for the vessel and net characteristics were omitted, as were the data for the sets in which the vessels were assisted by an airplane or helicopter. The latter were omitted because, as was shown previously, aircraft assistance tended to result in higher catcher per successful set, and such assistance may not have been randomly distributed among vessels of different characteristics. The logarithmic transformation described previously was used for the data in this analysis. The results are summarized in Table 41. The correlation coefficients for all the strata combined were calculated by the method of Fisher (1958:204); these are also shown in Table 41. For this it is necessary to assume that the correlations are equal for each stratum. The catch per successful set is correlated most strongly with vessel capacity. However, all the correlations are much lower than those among vessel and net characteristics, and most of them for the individual strata are not significant. Also shown in Table 41 are coefficients of multiple correlation involving all four vessel and net characteristics. The number of significant correlations is about the same as for each of the single correlations. This is not surprising, since the data in Table 20 indicate that the vessel and net characteristics are strongly correlated with one another. There is no way to ascertain from these data which of these factors, if any, is most influential in affecting the catch per successful set. The most conspicuous feature of the data is the low correlation of the catch per successful set with the vessel and net characteristics.

The above analyses have accomplished very little, except to demonstrate the low correlation of the catch per successful set with the vessel and net characteristics and to show that there would apparently be little or not advantage to substituting some other vessel of net characteristics for vessel capacity in studies involving the catch per unit of effort.

The larger vessels catch more fish per successful set either because they set on larger schools of fish or because they catch larger portions of the schools they set on. If the latter is the case, it may be because the larger vessels are equipped with longer and/or deeper nets. This is merely speculation, however, and better data would be needed for verification. The higher ratios of successful to total sets attained by the larger vessels are believed to be the result of their employment of better equipment for capturing yellowfin schooled with porpoises.

Time consumed in making sets

It can be seen from Figures 2 and 3 that the time consumed in making sets for skipjack and yellowfin is about the same. It is fortunate that this is so, because if it were not, when both species are caught in a single trip, as is usually the case, it would be more difficult to subtract the time consumed in making sets from the days of fishing to find the time actually spent searching for fish.

CONCLUSIONS

The catch per day of fishing is probably the best available index of the abundance of skipjack and yellowfin, since it is a function of both the size of the schools and the number of schools in the area. (It is a function also of the portions of the schools which are caught and the ease with which these portions are captured. These, however, are manifestations of the vulnerability of the fish to capture and the techniques of fishing rather than the abundance.)

Two corrections should be applied to the effort (days of fishing) data, however, before dividing it into the catch to obtain the catch per day of fishing. First, a method should be devised to determine toward which species the unsuccessful sets are directed. The method used in the present report, for which it is assumed that the ratios of successful to total sets for each species is the same in a given stratum, is considered to be unsatisfactory. If and when such a method is obtained, the days of fishing in each stratum should be assigned as skipjack, yellowfin, and bigeye days, in accordance with the portions of the total sets directed toward each of these species. Second, the days of fishing should be adjusted by subtracting the time actually spent making the sets. When the remainder is divided into the catch, the new index of abundance might be called the "catch per day of searching."

The catch per day of fishing, catch per set, and catch per successful set differ in most cases among years, quarters, and size classes of vessels. The difference among the size classes are so slight for skipjack, however, that perhaps they can be ignored. The ratio of successful to total sets and the sets per day of fishing differ among years for both yellowfin and skipjack, among quarters but not size classes for skipjack, and among size classes but not quarters for yellowfin. Significant differences exist among many of the interactions.

The use of aircraft for assistance in finding schools of fish and setting upon them increases the catch per successful set slightly, and may also increase the ratio of successful to total sets. The data for the sets for which such assistance was received and those for the sets for which such assistance was not received were not separated in the summaries on which most of the analyses in this report were based. This is probably of no consequence, since assistance was received for so few sets. It would be advisable in the future to separate the data for the aircraft-assisted sets from the other, however, since the use of aircraft may increase, and such assistance is not likely to be randomly distributed in time and space.

It appears that when the fish are more abundant, the numbers of schools are greater but the sizes of the schools are about the same. It is necessary that this be true if the model of Paloheimo and Dickie (1964) is to be used with these data. Therefore, this should be investigated further.

There is no evidence that any of the following has increased for skipjack in Area 5 during the 1962-1966 period: catch per successful set (Table 3); ratio of successful to total sets (Table 5); sets per day of fishing (Table 6). It is therefore concluded that the fishing power of the vessel for skipjack has probably not increased during this period either. For yellowfin in Area 2 during the same period neither the catch per successful set (Table 24) nor the sets per day of fishing (Table 26) has increased. The ratio of successful to total sets has increased for porpoise schools, however, (Table 35), and thus the fishing power of the vessels has increased for yellowfin.

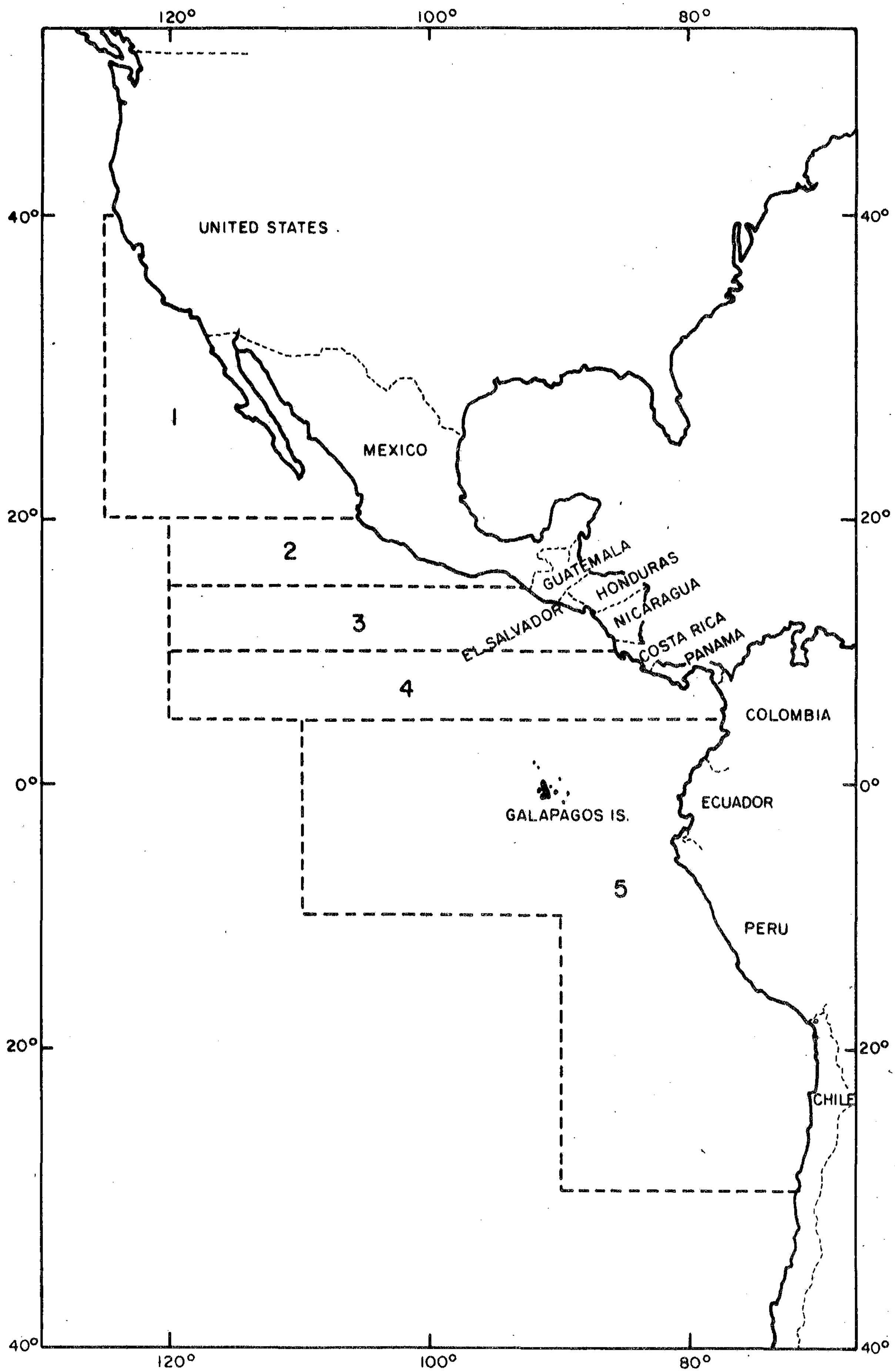

FIGURE 1. Map of the eastern Pacific Ocean, showing the areas used for the present study

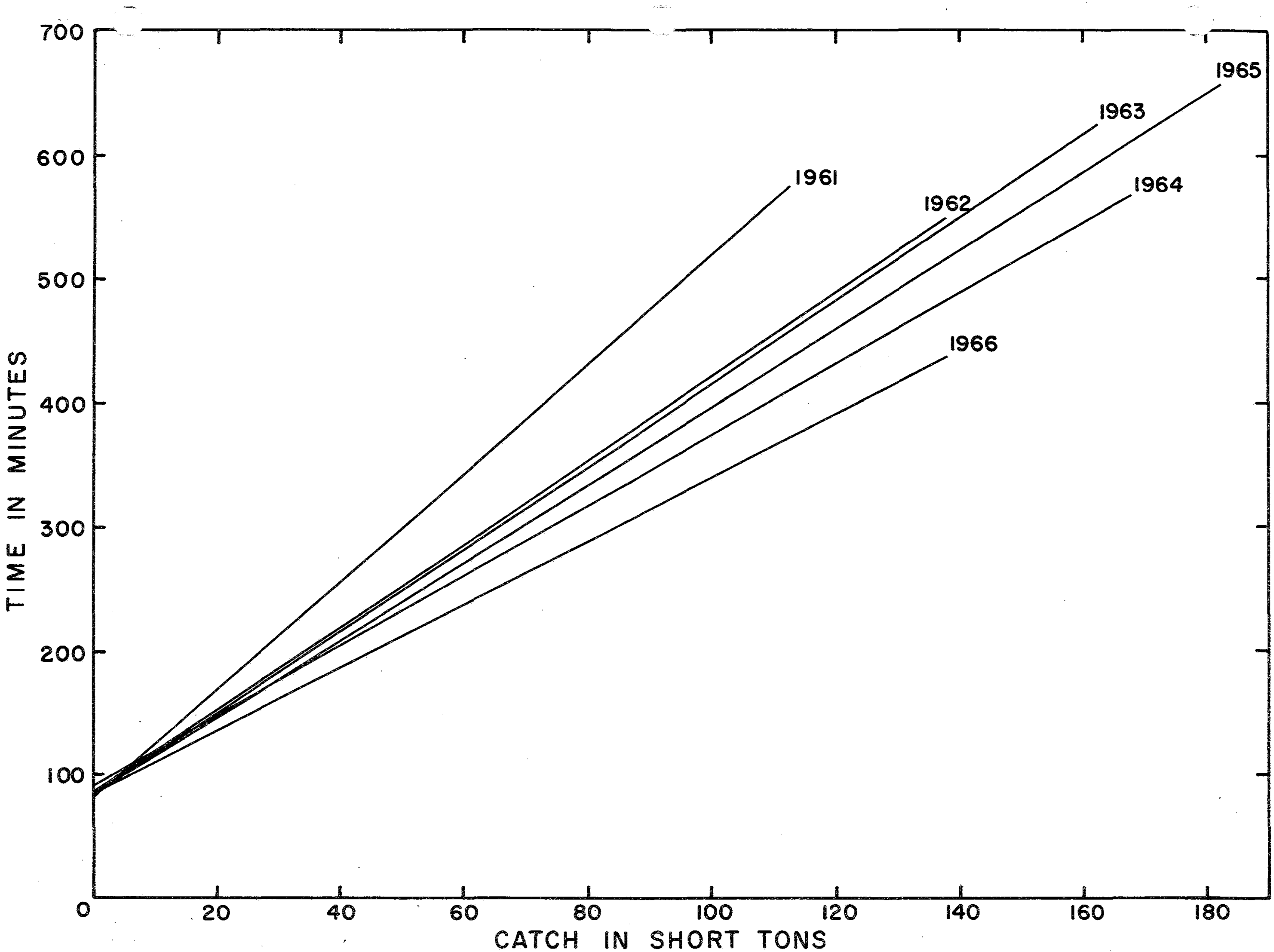

FIGURE 2. Regressions of the times of the sets on the quantities of fish caught in them for pure skipjack schools

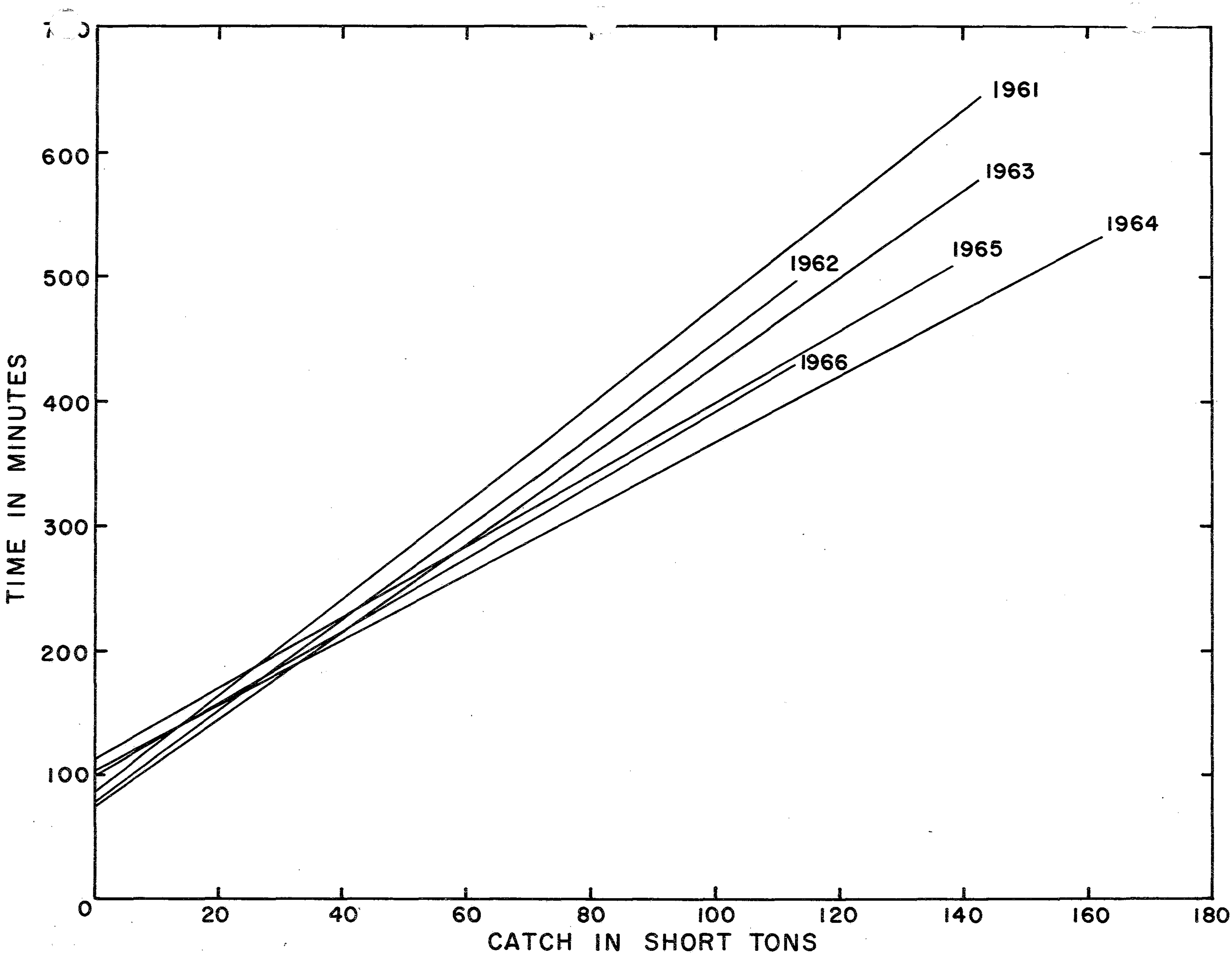

FIGURE 3. Regression of the times of the sets on the quantities of fish caught in them for pure yellowfin schools

TABLE 1. Catch of skipjack tuna per day of fishing in Area 5. The three columns under each size class refer to catch, days of fishing, and catch per day of fishing, respectively.

Year	quarter	Size Class 4			5			6			TOTAL		
1961	1	142	22.0	6.5	0	0.0	-	0	0.0	-	142	22.0	6.5
	2	3353	164.0	20.4	4018	187.0	21.5	1059	48.0	22.1	8430	399.0	21.1
	3	424	120.0	3.5	532	139.0	3.8	645	54.0	11.9	1601	313.0	5.1
	4	1234	165.5	7.5	2357	279.5	8.4	1396	126.0	11.1	4987	571.0	8.7
	Total	5153	471.5	10.9	6907	605.5	11.4	3100	228.0	13.6	15160	1305.0	11.6
1962	1	1063	269.5	3.9	1978	285.5	6.9	1548	202.5	7.6	4589	757.5	6.1
	2	2696	375.0	7.2	2967	393.5	7.5	3535	349.0	10.1	9198	1117.5	8.2
	3	5289	511.0	10.3	4044	411.5	9.8	4258	370.0	11.5	13591	1292.5	10.5
	4	780	308.0	2.5	1424	594.0	2.4	1206	378.5	3.2	3410	1280.5	2.7
	Total	9828	1463.5	6.7	10413	1684.5	6.2	10547	1300.0	8.1	30788	4448.0	6.9
1963	1	3469	416.5	8.3	4217	554.0	7.6	4230	405.0	10.4	11916	1375.5	8.7
	2	4593	372.5	12.3	6023	473.0	12.7	8596	449.0	19.1	19212	1294.5	14.8
	3	1839	126.0	14.6	1856	241.0	7.7	5849	383.0	15.3	9544	750.0	12.7
	4	850	355.0	2.4	3140	864.5	3.6	3214	679.5	4.7	7204	1899.0	3.8
	Total	10751	1270.0	8.5	15236	2132.5	7.1	21889	1916.5	11.4	47876	5319.0	9.0
1964	1	1332	225.5	5.9	1969	239.0	8.2	3356	437.0	7.7	6657	901.5	7.4
	2	1017	165.0	6.2	579	172.0	3.4	4073	610.0	6.7	5669	947.0	6.0
	3	494	144.0	3.4	1070	186.0	5.8	3050	379.0	8.0	4614	709.0	6.5
	4	1028	188.0	5.5	812	58.0	14.0	5863	594.0	9.9	7703	840.0	9.2
	Total	3871	722.5	5.4	4430	655.0	6.8	16342	2020.0	8.1	24643	3397.5	7.3
1965	1	1193	230.0	5.2	1798	200.0	9.0	5062	535.5	9.5	8053	965.5	8.3
	2	3216	271.0	11.9	2094	215.0	9.7	8878	677.0	13.1	14188	1163.0	12.2
	3	3389	367.0	9.2	5457	466.0	11.7	6667	597.0	11.2	15513	1430.0	10.8
	4	875	253.0	3.5	1030	308.0	3.3	4644	780.5	5.9	6549	1341.5	4.9
	Total	8673	1121.0	7.7	10379	1189.0	8.7	25251	2590.0	9.7	44303	4900.0	9.0
1966	1	1629	485.0	3.4	2536	620.5	4.1	4008	641.5	6.2	8173	1747.0	4.7
	2	2791	399.5	7.0	3888	418.0	9.3	6350	554.5	11.5	13029	1372.0	9.5
	3	1475	233.5	6.3	3028	393.5	7.7	4690	629.5	7.5	9193	1256.5	7.3
	4	646	202.0	3.2	152	92.5	1.6	2958	435.0	6.8	3756	729.5	5.1
	Total	6541	1320.0	5.0	9604	1524.5	6.3	18006	2260.5	8.0	34151	5105.0	6.7

Table 1 (page 2)

Year quarter	Size Class 4			5			6			TOTAL		
1	8828	1648.5	5.4	12498	1899.0	6.6	18204	2221.5	8.2	39530	5769.0	6.9
2	17666	1747.0	10.1	19569	1858.5	10.5	32491	2687.5	12.1	69726	6293.0	11.1
1961- 3	12910	1501.5	8.6	15987	1837.0	8.7	25159	2412.5	10.4	54056	5751.0	9.4
1966 4	5413	1471.5	3.7	8915	2196.5	4.1	19281	2993.5	6.4	33609	6661.5	5.0
Total	44817	6368.5	7.0	56969	7791.0	7.3	95135	10315.0	9.2	196921	24474.5	8.0

TABLE 2. Catch of skipjack tuna per set in Area 5. The three columns under each size class refer to catch, sets, and catch per set, respectively.

Year	quarter	Size Class 4			Size Class 5			Size Class 6			TOTAL		
	1	963	370	2.6	1892	366	5.2	1344	289	4.7	4199	1025	4.1
	2	1788	314	5.7	2769	380	7.3	3414	490	7.0	7971	1184	6.7
1962	3	4237	507	8.4	3761	398	9.4	4330	457	9.5	12328	1362	9.1
	4	640	231	2.8	1360	531	2.6	1242	342	3.6	3242	1104	2.9
	Total	7628	1422	5.4	9782	1675	5.8	10330	1578	6.5	27740	4675	5.9
	1	1760	333	5.3	4079	636	6.4	4136	542	7.6	9975	1511	6.6
	2	2997	421	7.1	5819	681	8.5	8464	692	12.2	17280	1794	9.6
1963	3	621	36	17.2	1516	196	7.7	6106	482	12.7	8243	714	11.5
	4	752	292	2.6	2987	1009	3.0	3193	690	4.6	6932	1991	3.5
	Total	6130	1082	5.7	14401	2522	5.7	21899	2406	9.1	42430	6010	7.1
	1	1296	259	5.0	1857	338	5.5	3311	594	5.6	6464	1191	5.4
	2	945	145	6.5	472	111	4.3	3760	607	6.2	5177	863	6.0
1964	3	410	99	4.1	899	180	5.0	2917	344	8.5	4226	623	6.8
	4	1003	134	7.5	708	54	13.1	5834	532	11.0	7545	720	10.5
	Total	3654	637	5.7	3936	683	5.8	15822	2077	7.6	23412	3397	6.9
	1	1010	224	4.5	1812	256	7.1	5040	679	7.4	7862	1159	6.8
	2	2538	298	8.5	1705	323	5.3	8907	943	9.4	13150	1564	8.4
1965	3	2945	247	11.9	5323	519	10.3	6701	605	11.1	14969	1371	10.9
	4	958	340	2.8	984	333	3.0	4416	850	5.2	6358	1523	4.2
	Total	7451	1109	6.7	9824	1431	6.9	25064	3077	8.1	42339	5617	7.5
	1	1362	492	2.8	2258	677	3.3	4240	948	4.5	7860	2117	3.7
	2	2373	423	5.6	3444	555	6.2	6426	950	6.8	12243	1928	6.4
1966	3	1518	188	8.1	1899	300	6.3	5054	870	5.8	8471	1358	6.2
	4	645	159	4.1	123	37	3.3	2920	412	7.1	3688	608	6.1
	Total	5898	1262	4.7	7724	1569	4.9	18640	3180	5.9	32262	6011	5.4
	1	6391	1678	3.8	11898	2273	5.2	18071	3052	5.9	36360	7003	5.2
	2	10641	1601	6.6	14209	2050	6.9	30971	3682	8.4	55821	7333	7.6
1962-	3	9731	1077	9.0	13398	1593	8.4	25108	2758	9.1	48237	5428	8.9
1966	4	3998	1156	3.5	6162	1964	3.1	17605	2826	6.2	27765	5946	4.7
	Total	30761	5512	5.6	45667	7880	5.8	91755	12318	7.4	168183	25710	6.5

TABLE 3. Catch of skipjack tuna per successful set in Areas 3, 4, and 5 combined. The three columns under each size class refer to catch, successful sets, and catch per successful set, respectively.

Year	quarter	Size Class 4			5			6			TOTAL		
	1	255	8	31.9	25	1	25.0	0	0	-	280	9	31.1
	2	3188	122	26.1	4520	178	25.4	1508	55	27.4	9216	355	26.0
1961	3	1499	95	15.8	2028	110	18.4	877	58	15.1	4404	263	16.7
	4	2106	174	12.1	2862	173	16.5	1589	87	18.3	6557	434	15.1
	Total	7048	399	17.7	9435	462	20.4	3974	200	19.9	20457	1061	19.3
	1	1960	180	10.9	1729	128	13.5	954	84	11.4	4643	392	11.8
	2	2105	108	19.5	3613	155	23.3	3377	181	18.7	9095	444	20.5
1962	3	4421	221	20.0	4522	212	21.3	4017	205	19.6	12960	638	20.3
	4	1522	97	15.7	1241	111	11.2	1261	88	14.3	4024	296	13.6
	Total	10008	606	16.5	11105	606	18.3	9609	558	17.2	30722	1770	17.4
	1	2198	182	12.1	3967	216	18.4	3345	185	18.1	9510	583	16.3
	2	3332	201	16.6	6207	317	19.6	8129	271	30.0	17668	789	22.4
1963	3	590	16	36.9	1494	53	28.2	6094	195	31.3	8178	264	31.0
	4	1028	117	8.8	2965	264	11.2	2700	173	15.6	6693	554	12.1
	Total	7148	516	13.9	14633	850	17.2	20268	824	24.6	42049	2190	19.2
	1	1254	89	14.1	1781	118	15.1	2993	141	21.2	6028	348	17.3
	2	948	43	22.0	1343	80	16.8	3844	224	17.1	6135	347	17.7
1964	3	665	51	13.0	1597	118	13.5	2668	87	30.7	4930	256	19.3
	4	1145	44	26.0	1267	51	24.8	5461	166	32.9	7873	261	30.2
	Total	4012	227	17.7	5988	367	16.3	14966	618	24.2	24966	1212	20.6
	1	1086	65	16.7	1781	88	20.2	4725	201	23.5	7592	354	21.4
	2	2976	132	22.5	2077	119	17.5	8792	318	27.6	13845	569	24.3
1965	3	2827	93	30.4	5234	233	22.5	6492	233	27.9	14553	559	26.0
	4	917	87	10.5	953	90	10.6	3865	243	15.9	5735	420	13.7
	Total	7806	377	20.7	10045	530	19.0	23874	995	24.0	41725	1902	21.9
	1	1269	124	10.2	2117	167	12.7	4193	324	12.9	7579	615	12.3
	2	2107	120	17.6	2719	173	15.7	5901	271	21.8	10727	564	19.0
1966	3	1285	67	19.2	1803	104	17.3	4234	213	19.9	7322	384	19.1
	4	494	32	15.4	123	9	13.7	2646	107	24.7	3263	148	22.0
	Total	5155	343	15.0	6762	453	14.9	16974	915	18.6	28891	1711	16.9

Table 3 (page 2)

Year quarter	Size Class 4			5			6			TOTAL		
1	8022	648	12.4	11400	718	15.9	16210	935	17.3	35632	2301	15.5
2	14656	726	20.2	20479	1022	20.0	31551	1320	23.9	66686	3068	21.7
1961- 3	11287	543	20.8	16678	830	20.1	24382	991	24.6	52347	2364	22.1
1966 4	7212	551	13.1	9411	698	13.5	17522	864	20.3	34145	2113	16.2
Total	41177	2468	16.7	57968	3268	17.7	89665	4110	21.8	188810	9846	19.2

TABLE 4. Catch of skipjack tuna per successful set in Area 1. The three columns under each size class refer to catch, successful sets, and catch per successful set, respectively.

Year quarter	Size Class 3			4			5			TOTAL		
3	419	69	6.1	191	33	5.8	91	7	13.0	701	109	6.4
1961 4	468	53	8.8	333	39	8.5	15	6	2.5	816	98	8.3
Total	887	122	7.3	524	72	7.3	106	13	8.2	1517	207	7.3
3	455	65	7.0	611	82	7.5	392	57	6.9	1458	204	7.1
1962 4	99	12	8.3	92	14	6.6	21	3	-	212	29	7.3
Total	554	77	7.2	703	96	7.3	413	60	6.9	1670	233	7.2
3	1283	117	11.0	1063	92	11.6	1444	111	13.0	3790	320	11.8
1963 4	1036	103	10.1	824	67	12.3	319	30	10.6	2179	200	10.9
Total	2319	220	10.5	1887	159	11.9	1763	141	12.5	5969	520	11.5
3	766	84	9.1	993	127	7.8	389	45	8.6	2148	256	8.4
1964 4	238	26	9.2	39	3	-	127	16	7.9	404	45	9.0
Total	1004	110	9.1	1032	130	7.9	516	61	8.5	2552	301	8.5
3	747	102	7.3	459	65	7.1	311	26	12.0	1517	193	7.9
1965 4	534	46	11.6	233	22	10.6	157	18	8.7	924	86	10.7
Total	1281	148	8.7	692	87	8.0	468	44	10.6	2441	279	8.7
3	749	78	9.6	297	38	7.8	154	16	9.6	1200	132	9.1
1966 4	13	6	2.2	21	10	2.1	0	0	-	34	16	2.1
Total	762	84	9.1	318	48	6.6	154	16	9.6	1234	148	8.3
1961- 3	4419	515	8.6	3614	437	8.3	2781	262	10.6	10814	1214	8.9
1966 4	2388	246	9.7	1542	155	9.9	639	73	8.8	4569	474	9.6
Total	6807	761	8.9	5156	592	8.7	3420	335	10.2	15383	1688	9.1

TABLE 5. Ratios of successful to total sets in Area 5. The three columns under each size class refer to successful sets, total sets, and ratio of successful to total sets, respectively.

Year	Quarter	Size class 4			5			6			Total		
1962	1	191	376	0.508	193	369	0.523	183	319	0.574	567	1064	0.533
	2	193	319	0.605	231	389	0.594	296	498	0.594	720	1206	0.597
	3	256	508	0.504	216	401	0.539	267	458	0.583	739	1367	0.541
	4	155	245	0.633	345	536	0.644	212	350	0.606	712	1131	0.630
	Total	795	1448	0.549	985	1695	0.581	958	1625	0.590	2738	4768	0.574
1963	1	200	335	0.597	330	643	0.513	289	552	0.524	819	1530	0.535
	2	200	421	0.475	350	682	0.513	329	692	0.475	879	1795	0.490
	3	20	36	0.556	68	196	0.347	209	483	0.433	297	715	0.415
	4	119	300	0.397	468	1023	0.457	294	692	0.425	881	2015	0.437
	Total	539	1092	0.494	1216	2544	0.478	1121	2419	0.463	2876	6055	0.475
1964	1	178	259	0.687	231	338	0.683	373	594	0.628	782	1191	0.657
	2	63	145	0.434	52	115	0.452	294	609	0.483	409	869	0.471
	3	38	99	0.384	108	184	0.587	191	346	0.552	337	629	0.536
	4	76	134	0.567	29	54	0.537	280	535	0.523	385	723	0.533
	Total	355	637	0.557	420	691	0.608	1138	2084	0.546	1913	3412	0.561
1965	1	101	224	0.451	143	256	0.520	366	679	0.539	610	1159	0.526
	2	130	298	0.436	167	324	0.515	450	943	0.477	747	1565	0.477
	3	129	248	0.520	277	520	0.533	304	606	0.502	710	1374	0.517
	4	112	340	0.329	133	336	0.396	314	851	0.369	559	1527	0.366
	Total	472	1110	0.425	720	1436	0.501	1434	3079	0.466	2626	5625	0.467
1966	1	261	493	0.529	393	679	0.579	594	948	0.627	1248	2120	0.589
	2	329	424	0.776	394	555	0.710	643	951	0.676	1366	1930	0.708
	3	119	188	0.633	185	302	0.613	514	872	0.589	818	1362	0.601
	4	96	161	0.596	23	37	0.622	262	414	0.633	381	612	0.623
	Total	805	1266	0.636	995	1573	0.633	2013	3185	0.632	3813	6024	0.633
1962-1966	1	931	1687	0.552	1290	2285	0.565	1805	3092	0.584	4026	7064	0.570
	2	915	1607	0.569	1194	2065	0.578	2012	3693	0.545	4121	7365	0.560
	3	562	1079	0.521	854	1603	0.533	1485	2765	0.537	2901	5447	0.533
	4	558	1180	0.473	998	1986	0.503	1362	2842	0.479	2918	6008	0.486
	Total	2966	5553	0.534	4336	7939	0.546	6664	12392	0.538	13966	25884	0.540

TABLE 6. Sets per day of fishing in Area 5. The three columns under each size class refer to adjusted sets, days of fishing, and sets per day, respectively.

Year	Quarter	Size class 4			Size class 5			Size class 6			Total		
1962	1	407	269.5	1.51	384	285.5	1.35	332	202.5	1.64	1123	757.5	1.48
	2	474	375.0	1.26	407	393.5	1.03	510	349.0	1.46	1391	1117.5	1.24
	3	634	511.0	1.24	430	411.5	1.04	448	370.0	1.21	1512	1292.5	1.17
	4	282	308.0	0.92	558	594.0	0.94	332	378.5	0.88	1172	1280.5	0.92
	Total	1797	1463.5	1.23	1779	1684.5	1.06	1622	1300.0	1.25	5198	4448.0	1.17
1963	1	656	416.5	1.58	655	554.0	1.18	553	405.0	1.37	1864	1375.5	1.36
	2	644	372.5	1.73	708	473.0	1.50	706	449.0	1.57	2058	1294.5	1.59
	3	107	126.0	0.85	239	241.0	0.99	463	383.0	1.21	809	750.0	1.08
	4	330	355.0	0.93	1059	864.5	1.22	697	679.5	1.03	2086	1899.0	1.10
	Total	1737	1270.0	1.37	2661	2132.5	1.25	2419	1916.5	1.26	6817	5319.0	1.28
1964	1	267	225.5	1.18	358	239.0	1.50	600	437.0	1.37	1225	901.5	1.36
	2	157	165.0	0.95	137	172.0	0.80	656	610.0	1.08	950	947.0	1.00
	3	119	144.0	0.83	214	186.0	1.15	361	379.0	0.95	694	709.0	0.98
	4	137	188.0	0.73	62	58.0	1.07	532	594.0	0.90	731	840.0	0.87
	Total	680	722.5	0.94	771	655.0	1.18	2149	2020.0	1.06	3600	3397.5	1.06
1965	1	264	230.0	1.15	253	200.0	1.26	679	535.5	1.27	1196	965.5	1.24
	2	378	271.0	1.39	397	215.0	1.85	943	677.0	1.39	1718	1163.0	1.48
	3	284	367.0	0.77	535	466.0	1.15	599	597.0	1.00	1418	1430.0	0.99
	4	309	253.0	1.22	350	308.0	1.14	892	780.5	1.14	1551	1341.5	1.16
	Total	1235	1121.0	1.10	1535	1189.0	1.29	3113	2590.0	1.20	5883	4900.0	1.20
1966	1	590	485.0	1.22	758	620.5	1.22	901	641.5	1.40	2249	1747.0	1.29
	2	499	399.5	1.25	627	418.0	1.50	940	554.5	1.70	2066	1372.0	1.51
	3	182	233.5	0.78	477	393.5	1.21	809	629.5	1.29	1468	1256.5	1.17
	4	159	202.0	0.79	46	92.5	0.50	416	435.0	0.96	621	729.5	0.85
	Total	1430	1320.0	1.08	1908	1524.5	1.25	3066	2260.5	1.36	6404	5105.0	1.25
1962-1966	1	2184	1626.5	1.34	2408	1899.0	1.27	3065	2221.5	1.38	7657	5747.0	1.33
	2	2152	1583.0	1.36	2276	1671.5	1.36	3755	2639.5	1.42	8183	5894.0	1.39
	3	1326	1381.5	0.96	1895	1698.0	1.12	2680	2358.5	1.14	5901	5438.0	1.09
	4	1217	1306.0	0.93	2075	1917.0	1.08	2869	2867.5	1.00	6161	6090.5	1.01
	Total	6879	5897.0	1.17	8654	7185.5	1.20	12369	10087.0	1.23	27902	23169.5	1.20

TABLE 7. Logged catches of skipjack in each area, and total catches of skipjack in the eastern Pacific Ocean, for 1961-1966. The data were obtained from Anonymous (1967: Table 3) and unpublished data of the Inter-American Tropical Tuna Commission.

Area	1961	1962	1963	1964	1965	1966
1	6,600	5,200	10,100	5,500	9,300	5,300
2	700	1,800	4,100	7,900	1,700	1,500
3	12,600	7,100	7,100	5,700	2,100	400
4	3,300	9,400	1,700	1,100	1,700	3,800
5	24,700	35,200	51,000	26,500	47,200	38,600
Total logged catch	48,000	58,700	74,000	46,700	62,200	49,500
Total catch	76,400	78,400	106,100	65,300	86,100	66,800

TABLE 8. Analysis of variance for the catch per day of fishing by years, quarters, and size classes for Area 5.

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F	Degrees of freedom	Probability
Years (Y)	4	106.15	26.54	8.14	4,24	<0.01
Quarters (Q)	3	241.30	80.43	24.66	3,24	<0.01
Size classes (S)	2	77.77	38.88	11.92	2,24	<0.01
Y x Q	12	262.22	21.85	6.70	12,24	<0.01
Y x S	8	25.38	3.17	0.97	8,24	>0.05
Q x S	6	14.98	2.50	0.77	6,24	>0.05
Residual	24	78.27	3.26			
Total	59	806.08				

TABLE 9. Analysis of variance for the catch of skipjack per set by years, quarters, and size classes for Area 5.

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F	Degrees of freedom	Probability
Years (Y)	4	54.30	13.58	4.73	4,24	<0.01
Quarters (Q)	3	160.28	53,43	18.60	3,24	<0.01
Size classes (S)	2	25.30	12.65	4.40	2,24	<0.05
Y x Q	12	202.51	16.88	5.88	12.24	<0.01
Y x S	8	15.03	1.88	0.65	8.24	>0.05
Q x S	6	23.50	3.92	1.36	6,24	>0.05
Residual	24	68.93	2.87			
Total	59	549.86				

TABLE 10. Analysis of variance for the catch of skipjack per successful set by years, quarters, and size classes for Areas 3, 4, and 5 combined.

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F	Degrees of freedom	Probability
Years (Y)	4	215.04	53.76	4.12	4,24	<0.05
Quarters (Q)	3	596.95	198.98	15.24	3,24	<0.01
Size classes (S)	2	229.90	114.95	8.81	2,24	<0.01
Y x Q	12	925.27	77.11	5.91	12,24	<0.01
Y x S	8	112.60	14.07	1.08	8,24	>0.05
Q x S	6	70.61	11.77	0.90	6,24	>0.05
Residual	24	313.32	13.06			
Total	59	2463.69				

TABLE 11. Analysis of variance for the catch per successful set by years, quarters, and size classes for Area 1.

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F	Degrees of freedom	Probability
Years (Y)	5	133.08	26.62	5.95	5,7	<0.05
Quarters (Q)	1	21.92	21.92	4.90	1,7	<0.05
Size classes (S)	2	3.07	1.54	0.34	2,7	>0.05
Y x Q	5	64.85	12.97	2.90	5,7	>0.05
Y x S	10	15.81	1.58	0.35	10,7	>0.05
Q x S	2	48.69	24.35	5.44	2,7	<0.05
Residual	7	31.32	4.47			
Total	32	220.02				

TABLE 12. Analysis of variance for the ratio of successful to total sets by years, quarters, and size classes for Area 5.

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F	Degrees of freedom	Probability
Years (Y)	4	0.2325	0.0581	24.02	4,24	<0.01
Quarters (Q)	3	0.0219	0.0073	3.02	3,24	<0.05
Size classes (S)	2	0.0014	0.0007	0.28	2,24	>0.05
Y x Q	12	0.1680	0.0140	5.79	12,24	<0.01
Y x S	8	0.0153	0.0019	0.79	8,24	>0.05
Q x S	6	0.0029	0.0005	0.20	6,24	>0.05
Residual	24	0.0580	0.0024			
Total	59	0.5000				

TABLE 13. Analysis of variance for the sets per day of fishing by years, quarters, and size classes for Area 5.

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F	Degrees of freedom	Probability
Years (Y)	4	0.3553	0.08882	3.74	4,24	<0.05
Quarters (Q)	3	1.9383	0.64611	27.20	3,24	<0.01
Size classes (S)	2	0.1614	0.08069	3.397	2,24	>0.05
Y x Q	12	1.0392	0.08660	3.65	12,24	<0.01
Y x S	8	0.3576	0.04470	1.88	8,24	>0.05
Q x S	6	0.0986	0.01643	0.69	6,24	>0.05
Residual	24	0.5701	0.02375			
Total	59	4.5204				

TABLE 14. Analyses of variance for the catch per successful set for the sets by vessels assisted by aircraft and by those not receiving such assistance.

Group	Year	Quarter	Size class	Aircraft assistance	Geometric mean of catch per successful set plus 1	Sample size	F	Degrees of freedom	Probability
Southern	1961	4	4	no	7.6	161			
				yes	6.8	13	0.13	1,172	>0.05
				total	7.5	174			
	1961	4	5	no	9.4	163			
				yes	4.6	10	3.73	1,171	<0.05
				total	9.0	173			
	1962	1	4	no	6.6	163			
				yes	10.8	17	3.58	1,178	>0.05
				total	6.9	180			
	1962	2	4	no	11.1	96			
				yes	15.0	12	0.65	1,106	>0.05
				total	11.5	108			
	1962	2	5	no	14.2	138			
				yes	14.4	17	0.00	1,153	>0.05
				total	14.2	155			
	1963	1	4	no	7.9	162			
				yes	8.9	20	0.25	1,180	>0.05
				total	8.0	182			
	1963	1	5	no	11.0	202			
				yes	11.8	13	0.05	1,213	>0.05
				total	11.1	215			
	1963	1	6	no	10.7	162			
				yes	12.2	23	0.27	1,183	>0.05
				total	10.9	185			
	1963	2	5	no	12.1	284			
				yes	19.8	33	7.15	1,315	<0.01
				total	12.7	317			

Table 14 (Page 2)

Group	Year	Quarter	Size class	Aircraft assistance	Geometric mean of catch per successful set plus 1	Sample size	F	Degrees of freedom	Probability
Southern	1963	2	6	no	18.3	246			
				yes	32.4	25	6.56	1,269	<0.05
				total	19.4	271			
	1964	2	4	no	13.8	33			
				yes	7.6	10	1.80	1,41	>0.05
				total	12.0	43			
	1964	2	5	no	9.6	60			
				yes	15.8	20	4.02	1,78	<0.05
				total	10.9	80			
	1964	2	6	no	9.9	213			
				yes	7.5	12	0.70	1,223	>0.05
				total	9.7	225			
	1965	2	5	no	10.6	104			
				yes	11.9	15	0.14	1,117	>0.05
				total	10.8	119			
	1965	2	6	no	14.7	273			
				yes	26.6	45	10.72	1,316	<0.01
				total	16.0	318			
	1966	1	5	no	7.7	157			
				yes	14.6	10	3.67	1,165	>0.05
				total	8.0	167			
	1966	1	6	no	7.9	303			
				yes	16.5	21	11.01	1,322	<0.01
				total	8.2	324			
	1966	2	6	no	14.6	258			
				yes	19.1	13	0.93	1,269	>0.05
				total	14.8	271			
Northern	1963	3-4	3-5	no	7.9	479			
				yes	10.5	41	3.34	1,518	>0.05
				total	8.1	520			
	1964	3-4	3-5	no	6.5	271			
				yes	9.6	30	6.41	1,299	<0.05
				total	6.8	301			

Table 14 (Page 3)

Group	Year	Quarter	Size class	Aircraft assistance	Geometric mean of catch per successful set plus 1	Sample size	F	Degrees of freedom	Probability
Northern	1965	3-4	3-5	no	6.0	251			
				yes	9.4	28	5.78	1,277	<0.05
				total	6.3	279			
	1966	3-4	3-5	no	5.2	123			
				yes	7.6	25	3.27	1,146	>0.05
				total	5.5	148			

TABLE 15. Ratios of successful to total sets in Area 5, according to whether the vessels were assisted by aircraft. The three columns under each category refer to successful sets, total sets, and ratio of successful to total sets, respectively.

Year	Quarter	Not assisted by aircraft			Assisted by aircraft			Total		
	1	558	1052	0.530	9	12	0.750	567	1064	0.533
	2	690	1166	0.592	30	40	0.750	720	1206	0.597
1962	3	733	1359	0.539	6	8	0.750	739	1367	0.541
	4	697	1103	0.632	15	28	0.536	712	1131	0.630
	Total	2678	4680	0.572	60	88	0.682	2738	4768	0.574
	1	764	1466	0.521	55	64	0.859	819	1530	0.535
	2	807	1676	0.482	72	119	0.605	879	1795	0.490
1963	3	297	713	0.417	0	2	0.000	297	715	0.415
	4	881	2015	0.437	0	0	-	881	2015	0.437
	Total	2749	5870	0.468	127	185	0.686	2876	6055	0.475
	1	779	1188	0.656	3	3	1.000	782	1191	0.657
	2	406	866	0.469	3	3	1.000	409	869	0.471
1964	3	337	629	0.536	0	0	-	337	629	0.536
	4	385	723	0.533	0	0	-	385	723	0.533
	Total	1907	3406	0.560	6	6	1.000	1913	3412	0.561
	1	600	1146	0.524	10	13	0.769	610	1159	0.526
	2	656	1435	0.457	91	130	0.700	747	1565	0.477
1965	3	710	1374	0.517	0	0	-	710	1374	0.517
	4	559	1527	0.366	0	0	-	559	1527	0.366
	Total	2525	5482	0.461	101	143	0.706	2626	5625	0.467
	1	1187	2043	0.581	61	77	0.792	1248	2120	0.589
	2	1321	1874	0.705	45	56	0.804	1366	1930	0.708
1966	3	810	1353	0.599	8	9	0.889	818	1362	0.601
	4	364	589	0.618	17	23	0.739	381	612	0.623
	Total	3682	5859	0.628	131	165	0.794	3813	6024	0.633
	1	3888	6895	0.564	138	169	0.817	4026	7064	0.570
	2	3880	7017	0.553	241	348	0.693	4121	7365	0.560
1962-	3	2887	5428	0.532	14	19	0.737	2901	5447	0.533
1966	4	2886	5957	0.484	32	51	0.627	2918	6008	0.486
	Total	13541	25297	0.535	425	587	0.724	13966	25884	0.540

TABLE 16. Analysis of variance for the ratio of successful to total sets in Area 5 by years and whether the vessels were assisted by aircraft.

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F	Degrees of freedom	Probability
Years	3	0.02578	0.00859	4.88	3,3	>0.05
Aircraft	1	0.07466	0.07466	42.42	1,3	<0.01
Residual	3	0.00527	0.00176			
Total	7	0.10573				

TABLE 17. Constants in the regressions of the times of the sets on the quantities of fish caught in them.

Year	Quarter	Sample size	a	b	Year	quarter	Sample size	a	b
1961	1	-	-	-	1964	1	159	91.2	2.784
	2	73	84.9	4.400		2	152	88.9	3.111
	3	178	81.3	4.488		3	131	90.7	2.668
	4	139	85.2	3.909		4	135	105.2	2.754
	Total	390	82.1	4.359		Total	577	93.8	2.830
1962	1	150	88.3	3.613	1965	1	170	75.2	3.467
	2	137	97.6	2.475		2	157	88.0	2.915
	3	212	70.1	3.679		3	225	79.2	3.158
	4	94	84.4	3.461		4	150	85.0	3.105
	Total	593	83.7	3.387		Total	702	81.9	3.156
1963	1	123	84.1	3.856	1966	1	103	86.8	2.224
	2	212	95.2	2.920		2	137	89.8	2.315
	3	238	69.4	3.660		3	161	78.2	2.755
	4	76	75.1	3.383		4	87	95.8	2.472
	Total	649	83.3	3.336		Total	528	84.6	2.565

TABLE 18. Comparisons by analysis of covariance of the regressions of the times of the sets on the quantities of fish caught in them. The significance of the F values is indicated as follows: **, <1 percent; *, 1-5 percent.

		Slope		Elevation	
Comparison	Year	F	Degree of freedom	F	Degreed of freedom
Quarters within years	1961	0.77	2,384	0.41	2,386
	1962	3.75*	3,585	-	-
	1963	3.33*	3,641	-	-
	1964	0.73	3,569	1.42	3,572
	1965	1.20	3,694	0.28	3,697
	1966	0.75	3,520	0.50	3,523
Years		16.26**	5,3427	-	-

TABLE 19. Summary of the characteristics of the purse-seine vessels of the tuna fleet of the eastern Pacific Ocean. The vessel capacities are expressed in short tons, the vessel speeds in knots, and the net lengths and net depths in fathoms.

Year	Number of vessels	Vessel capacity		Vessel speed		Net length		Net depth	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
1961	122	240	35-725	9.8	8.0-14.6	432	260-550	41	31-52
1962	121	272	100-750	10.0	8.0-14.6	447	370-550	42	31-52
1963	126	303	103-1023	10.1	8.0-14.6	455	370-590	43	31-54
1964	123	314	103-1068	10.2	8.3-14.6	459	370-590	43	31-54
1965	119	318	103-1068	10.2	8.3-14.6	460	370-590	43	31-54
1966	115	325	103-1097	10.1	8.0-14.6	471	370-600	44	31-58

TABLE 20. Coefficients of correlation for vessel speed, net length, and net depth with vessel capacity.

		COEFFICIENTS OF CORRELATION		
Year	Number of vessels	Vessel speed with vessel capacity	Net length with vessel capacity	Net depth with ves. cap.
1961	122	0.788	0.829	0.728
1962	121	0.786	0.772	0.654
1963	126	0.825	0.814	0.679
1964	123	0.831	0.790	0.670
1965	119	0.834	0.794	0.678
1966	115	0.753	0.751	0.534
Mean		0.803	0.792	0.657

TABLE 21. Coefficients of correlation for catch per successful set with vessel capacity, vessel speed, net length, and net depth. The significance of the coefficients of correlation is indicated as follows: **, <1 percent; *, 1-5 percent.

Area	Year	Quarter	Sample size	Vessel capacity	Vessel speed	Net length	Net depth	Multiple
5	1961	2	341	-0.052	-0.053	-0.095	-0.063	0.107
		3	251	-0.026	0.009	-0.049	-0.003	0.077
		4	398	0.081	0.162**	-0.019	0.053	0.257**
	1962	1	371	0.021	0.043	-0.013	-0.054	0.084
		2	404	-0.056	-0.023	-0.057	-0.039	0.062
		3	624	-0.017	0.022	0.015	0.013	0.058
		4	284	-0.076	-0.040	-0.178**	-0.106	0.196*
	1963	1	526	0.064	0.087*	0.020	0.089*	0.158*
		2	725	0.185**	0.163**	0.130**	0.140**	0.202**
		3	264	-0.077	-0.047	-0.068	-0.041	0.083
		4	552	0.155**	0.152**	0.144**	0.152**	0.193**
	1964	1	348	0.099	0.105*	0.091	0.121*	0.148
		2	304	0.077	-0.009	0.082	0.108	0.121
		3	256	0.350**	0.290**	0.229**	0.153*	0.367**
		4	261	0.097	0.095	0.127*	0.141*	0.144
	1965	1	346	0.080	0.082	0.066	0.105*	0.118
		2	477	0.153**	0.140**	0.088	0.068	0.174**
		3	509	0.031	-0.033	0.011	0.031	0.125
		4	402	0.146**	0.143**	0.149**	0.054	0.196**
	1966	1	562	0.064	0.071	0.098*	0.042	0.106
		2	522	0.135**	0.058	0.072	-0.003	0.170**
		3	377	0.019	0.065	0.077	0.069	0.127
		4	136	0.066	0.083	0.037	0.027	0.100
1	1961	3-4	206	-0.007	-0.079	0.060	0.175*	0.189
	1962	3-4	226	-0.028	-0.076	-0.048	0.046	0.140
	1963	3-4	479	0.118**	0.086	-0.003	0.012	0.174**
	1964	3-4	271	0.084	-0.002	0.030	0.124*	0.160
	1965	3-4	247	0.121	0.157*	0.074	0.070	0.159
	1966	3-4	123	0.032	0.058	-0.012	0.095	0.158
Total			10792	0.078**	0.067**	0.045**	0.054**	

TABLE 22. Catch of yellowfin tuna per day of fishing in Area 2. The three columns under each size class refer to catch, days of fishing, and catch per day of fishing, respectively.

Year	Quarter	Size Class 3			4			5			Total		
1961	1	4372	696.5	6.3	4830	478.0	10.1	2416	201.5	12.0	11618	1376.0	8.4
	2	2276	507.5	4.5	2111	357.0	5.9	1318	170.0	7.8	5705	1034.5	5.5
	4	1464	511.0	2.9	1193	333.0	3.6	331	160.5	2.1	2988	1004.5	3.0
	Total	8112	1715.0	4.7	8134	1168.0	7.0	4065	532.0	7.6	20311	3415.0	5.9
1962	1	1056	446.0	2.4	595	232.0	2.6	242	94.5	2.6	1893	772.5	2.5
	2	2120	492.0	4.3	2846	309.0	9.2	759	150.0	5.1	5725	951.0	6.0
	4	648	208.5	3.1	955	233.0	4.1	631	106.5	5.9	2234	548.0	4.1
	Total	3824	1146.5	3.3	4396	774.0	5.7	1632	351.0	4.6	9852	2271.5	4.3
1963	1	1620	448.0	3.6	1470	340.0	4.3	2061	270.5	7.6	5151	1058.5	4.9
	2	2715	396.5	6.8	2659	273.0	9.7	1399	214.5	6.5	6773	884.0	7.7
	4	466	225.0	2.1	555	387.0	1.4	580	184.5	3.1	1601	796.5	2.0
	Total	4801	1069.5	4.5	4684	1000.0	4.7	4040	669.5	6.0	13525	2739.0	4.9
1964	1	2022	462.5	4.4	4198	750.5	5.6	4751	566.5	8.4	10971	1779.5	6.2
	2	2546	316.5	8.0	5560	477.0	11.7	4502	356.0	12.6	12608	1149.5	11.0
	4	684	189.5	3.6	2253	529.5	4.3	1103	293.5	3.8	4040	1012.5	4.0
	Total	5252	968.5	5.4	12011	1757.0	6.8	10356	1216.0	8.5	27619	3941.5	7.0
1965	1	1326	452.5	2.9	1524	429.5	3.5	934	220.5	4.2	3784	1102.5	3.4
	2	760	221.0	3.4	2472	431.5	5.7	788	192.5	4.1	4020	845.0	4.8
	4	256	142.5	1.8	1199	398.5	3.0	182	101.0	1.8	1637	642.0	2.5
	Total	2342	816.0	2.9	5195	1259.5	4.1	1904	514.0	3.7	9441	2589.5	3.6
1966	1	1081	353.5	3.1	1552	444.5	3.5	41	71.0	0.6	2674	869.0	3.1
	2	510	102.0	5.0	386	106.0	3.6	369	84.0	4.4	1265	292.0	4.3
	4	336	139.5	2.4	468	123.5	3.8	62	25.0	2.5	866	288.0	3.0
	Total	1927	595.0	3.2	2406	674.0	3.6	472	180.0	2.6	4805	1449.0	3.3
1961-1966	1	11477	2859.0	4.0	14169	2674.5	5.3	10445	1424.5	7.3	36091	6958.0	5.2
	2	10927	2035.5	5.4	16034	1953.5	8.2	9135	1167.0	7.8	36096	5156.0	7.0
	4	3854	1416.0	2.7	6623	2004.5	3.3	2889	871.0	3.3	13366	4291.5	3.1
	Total	26258	6310.5	4.2	36826	6632.5	5.6	22469	3462.5	6.5	85553	16405.5	5.2

TABLE 23. Catch of yellowfin tuna per set in Area 2. The three columns under each size class refer to catch, sets, and catch per set, respectively.

Year	Quarter	Size Class 3			4			5			Total		
1962	1	984	306	3.2	712	166	4.3	242	54	4.5	1938	526	3.7
	2	2201	388	5.7	2865	268	10.7	752	81	9.3	5818	737	7.9
	4	398	113	3.5	790	161	4.9	788	126	6.3	1976	400	4.9
	Total	3583	807	4.4	4367	595	7.3	1782	261	6.8	9732	1663	5.9
1963	1	1518	396	3.8	1448	257	5.6	1956	264	7.4	4922	917	5.4
	2	2379	443	5.4	2529	314	8.1	1375	170	8.1	6283	927	6.8
	4	413	249	1.7	509	266	1.9	578	166	3.5	1500	681	2.2
	Total	4310	1088	4.0	4486	837	5.4	3909	600	6.5	12705	2525	5.0
1964	1	1863	476	3.9	3967	882	4.5	4631	748	6.2	10461	2106	5.0
	2	2238	412	5.4	5598	712	7.9	4302	543	7.9	12138	1667	7.3
	4	682	207	3.3	2038	564	3.6	1085	307	3.5	3805	1078	3.5
	Total	4783	1095	4.4	11603	2158	5.4	10018	1598	6.3	26404	4851	5.4
1965	1	1230	408	3.0	1382	416	3.3	919	195	4.7	3531	1019	3.5
	2	721	233	3.1	2293	388	5.9	773	130	5.9	3787	751	5.0
	4	251	51	4.9	1170	291	4.0	174	51	3.4	1595	393	4.1
	Total	2202	692	3.2	4845	1095	4.4	1866	376	5.0	8913	2163	4.1
1966	1	858	325	2.6	1519	454	3.3	40	17	2.4	2417	796	3.0
	2	557	148	3.8	556	130	4.3	369	46	8.0	1482	324	4.6
	4	331	133	2.5	426	110	3.9	61	18	3.4	818	261	3.1
	Total	1746	606	2.9	2501	694	3.6	470	81	5.8	4717	1381	3.4
1962-1966	1	6453	1911	3.4	9028	2175	4.2	7788	1278	6.1	23269	5364	4.3
	2	8096	1624	5.0	13841	1812	7.6	7571	970	7.8	29508	4406	6.7
	4	2075	753	2.8	4933	1392	3.5	2686	668	4.0	9694	2813	3.4
	Total	16624	4288	3.9	27802	5379	5.2	18045	2916	6.2	62471	12583	5.0

TABLE 24. Catch of yellowfin tuna per successful set in Area 2. The three columns under each size class refer to catch, successful sets, and catch per successful set, respectively.

Year	Quarter	Size class 3			Size class 4			Size class 5			Total		
1961	1	4422	332	13.3	4533	260	17.4	2527	138	18.3	11482	730	15.7
	2	2200	158	13.9	2017	152	13.3	1202	70	17.2	5419	380	14.3
	4	1378	166	8.3	1151	138	8.3	331	58	5.7	2860	362	7.9
	Total	8000	656	12.2	7701	550	14.0	4060	266	15.3	19761	1472	13.4
1962	1	984	122	8.1	712	94	7.6	203	34	6.0	1899	250	7.6
	2	2196	160	13.7	2742	146	18.8	639	30	21.3	5577	336	16.6
	4	323	43	7.5	773	89	8.7	788	79	10.0	1884	211	8.9
	Total	3503	325	10.8	4227	329	12.8	1630	143	11.4	9360	797	11.7
1963	1	1415	194	7.3	1271	130	9.8	1878	157	12.0	4564	481	9.5
	2	2024	202	10.0	2409	164	14.7	1265	86	14.7	5698	452	12.6
	4	305	63	4.8	411	73	5.6	513	58	8.8	1229	194	6.3
	Total	3744	459	8.2	4091	367	11.1	3656	301	12.1	11491	1127	10.2
1964	1	1686	195	8.6	3470	388	8.9	3803	363	10.5	8959	946	9.5
	2	1943	181	10.7	4578	346	13.2	3836	289	13.3	10357	816	12.7
	4	682	96	7.1	1821	258	7.1	1059	138	7.7	3562	492	7.2
	Total	4311	472	9.1	9869	992	9.9	8698	790	11.0	22878	2254	10.1
1965	1	1085	200	5.4	1343	247	5.4	919	127	7.2	3347	574	5.8
	2	696	129	5.4	2193	239	9.2	681	81	8.4	3570	449	8.0
	4	209	25	8.4	954	129	7.4	161	31	5.2	1324	185	7.2
	Total	1990	354	5.6	4490	615	7.3	1761	239	7.4	8241	1208	6.8
1966	1	524	121	4.3	822	179	4.6	33	8	4.1	1379	308	4.5
	2	504	84	6.0	509	66	7.7	369	29	12.7	1382	179	7.7
	4	329	67	4.9	423	79	5.4	61	13	4.7	813	159	5.1
	Total	1357	272	5.0	1754	324	5.4	463	50	9.3	3574	646	5.5
1961-1966	1	10116	1164	8.7	12151	1298	9.4	9363	827	11.3	31630	3289	9.6
	2	9563	914	10.5	14448	1113	13.0	7992	585	13.7	32003	2612	12.3
	4	3226	460	7.0	5533	766	7.2	2913	377	7.7	11672	1603	7.3
	Total	22905	2538	9.0	32132	3177	10.1	20268	1789	11.3	75305	7504	10.0

TABLE 25. Ratios of successful to total sets in Area 2. The three columns under each size class refer to successful sets, total sets, and ratio of successful to total sets, respectively.

Year	Quarter	Size Class 3			4			5			Tôtel		
1962	1	125	306	0.408	94	166	0.566	39	54	0.722	258	526	0.490
	2	163	389	0.419	156	268	0.582	34	81	0.420	353	738	0.478
	4	52	113	0.460	108	161	0.671	87	129	0.674	247	403	0.613
	Total	340	808	0.421	358	595	0.602	160	264	0.606	858	1667	0.515
1963	1	209	398	0.525	139	257	0.541	171	267	0.640	519	922	0.563
	2	233	451	0.517	176	314	0.561	97	171	0.567	506	936	0.541
	4	95	251	0.378	114	266	0.429	76	166	0.458	285	683	0.417
	Total	537	1100	0.488	429	837	0.513	344	604	0.570	1310	2541	0.516
1964	1	237	478	0.496	458	887	0.516	444	757	0.587	1139	2122	0.537
	2	217	412	0.527	445	712	0.625	356	552	0.645	1018	1676	0.607
	4	114	207	0.551	309	564	0.548	183	312	0.587	606	1083	0.560
	Total	568	1097	0.518	1212	2163	0.560	983	1621	0.606	2763	4881	0.566
1965	1	223	412	0.541	259	416	0.623	127	195	0.651	609	1023	0.595
	2	136	234	0.581	255	388	0.657	87	131	0.664	478	753	0.635
	4	35	51	0.686	164	294	0.558	32	51	0.627	231	396	0.583
	Total	394	697	0.565	678	1098	0.617	246	377	0.653	1318	2172	0.607
1966	1	198	336	0.589	301	454	0.663	11	17	0.647	510	807	0.632
	2	93	148	0.628	74	130	0.569	29	46	0.630	196	324	0.605
	4	70	133	0.526	82	110	0.745	13	18	0.722	165	261	0.632
	Total	361	617	0.585	457	694	0.659	53	81	0.654	871	1392	0.626
1962-1966	1	992	1930	0.514	1251	2180	0.574	792	1290	0.614	3035	5400	0.562
	2	842	1634	0.515	1106	1812	0.610	603	981	0.615	2551	4427	0.576
	4	366	755	0.485	777	1395	0.557	391	676	0.578	1534	2826	0.543
	Total	2200	4319	0.509	3134	5387	0.582	1786	2947	0.606	7120	12653	0.563

TABLE 26. Sets per day of fishing in Area 2. The three columns under each size class refer to adjusted sets, days of fishing, and sets per day, respectively.

		Size Class											
Year	Quarter	3			4			5			Total		
1962	1	327	446.0	0.73	139	232.0	0.60	54	94.5	0.57	520	772.5	0.67
	2	372	492.0	0.76	265	309.0	0.86	82	150.0	0.55	719	951.0	0.76
	4	184	208.5	0.88	195	233.0	0.84	101	106.5	0.95	480	548.0	0.88
	Total	883	1146.5	0.77	599	774.0	0.77	237	351.0	0.68	1719	2271.5	0.76
1963	1	424	448.0	0.95	262	340.0	0.77	277	270.5	1.02	963	1058.5	0.91
	2	505	396.5	1.27	330	273.0	1.21	173	214.5	0.81	1008	884.0	1.14
	4	281	225.0	1.25	290	387.0	0.75	166	184.5	0.90	737	796.5	0.93
	Total	1210	1069.5	1.13	882	1000.0	0.88	616	669.5	0.92	2708	2739.0	0.99
1964	1	519	462.5	1.12	935	750.5	1.25	770	566.5	1.36	2224	1779.5	1.25
	2	470	316.5	1.48	705	477.0	1.48	570	356.0	1.60	1745	1149.5	1.52
	4	207	189.5	1.09	626	529.5	1.18	313	293.5	1.07	1146	1012.5	1.13
	Total	1196	968.5	1.23	2266	1757.0	1.29	1653	1216.0	1.36	5115	3941.5	1.30
1965	1	441	452.5	0.97	458	429.5	1.07	199	220.5	0.90	1098	1102.5	1.00
	2	245	221.0	1.11	419	431.5	0.97	133	192.5	0.69	797	845.0	0.94
	4	52	142.5	0.36	297	398.5	0.75	54	101.0	0.53	403	642.0	0.63
	Total	738	816.0	0.90	1174	1259.5	0.93	386	514.0	0.75	2298	2589.5	0.89
1966	1	410	353.5	1.16	463	444.5	1.04	17	71.0	0.24	890	869.0	1.02
	2	136	102.0	1.33	90	106.0	0.85	46	84.0	0.55	272	292.0	0.93
	4	136	139.5	0.97	121	123.5	0.98	18	25.0	0.72	275	288.0	0.95
	Total	682	595.0	1.15	674	674.0	1.00	81	180.0	0.45	1437	1449.0	0.99
1962-1966	1	2121	2162.5	0.98	2257	2196.5	1.03	1317	1223.0	1.08	5695	5582.0	1.02
	2	1728	1528.0	1.13	1809	1596.5	1.13	1004	997.0	1.01	4541	4121.5	1.10
	4	860	905.0	0.95	1529	1671.5	0.91	652	710.5	0.92	3041	3287.0	0.93
	Total	4709	4595.5	1.02	5595	5464.5	1.02	2973	2930.5	1.01	13277	12990.5	1.02

TABLE 27. Logged catches of yellowfin in each area, and total catches of yellowfin in the eastern Pacific Ocean, for 1961-1966. The data were obtained from Anonymous (1967: Table 3) and unpublished data of the Inter-American Tropical Tuna Commission.

Area	1961	1962	1963	1964	1965	1966
1	14,500	14,300	14,700	14,000	16,200	10,500
2	22,200	11,300	15,100	30,800	10,700	5,800
3	48,500	10,900	13,100	18,400	24,400	10,200
4	11,300	13,200	1,800	3,500	16,700	26,500
5	6,800	18,500	13,800	18,300	12,600	29,300
Total logged catch	103,300	68,200	58,500	85,000	80,600	82,300
Total catch	115,400	87,000	72.700	101,900	90,000	90,900

TABLE 28. Analysis of variance for the catch per day of fishing by years, quarters, and size classes for Area 2.

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F	Degrees of freedom	Probability
Years (Y)	5	99.90	19.98	9.62	5,20	<0.01
Quarters (Q)	2	110.28	55.14	26.56	2,20	<0.01
Size classes (S)	2	22.69	11.35	5.47	2,20	<0.05
Y x Q	10	107.20	10.72	5.16	10,20	<0.01
Y x S	10	17.64	1.76	0.85	10,20	>0.05
Q x S	4	8.62	2.16	1.04	4,20	>0.05
Residual	20	41.52	2.08			
Total	53	407.85				

TABLE 29. Analysis of variance for the catch per set by years, quarters and size classes for Area 2.

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F	Degreed of freedom	Probability
Years (Y)	4	22.36	5.69	5.95	4,16	<0.01
Quarters (Q)	2	77.06	38.53	40.29	2,16	<0.01
Size classes (S)	2	29.08	14.54	15.20	2,16	<0.01
Y x Q	8	28.23	3.53	3.69	8,16	<0.05
Y x S	8	4.75	0.59	0.62	8,16	>0.05
Q x S	4	9.41	2.35	2.46	4,16	>0.05
Residual	16	15.30	0.96			
Total	44	186.60				

TABLE 30. Analysis of variance for the catch per successful set by years, quarters, and size classes for Area 2.

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F	Degrees of freedom	Probability
Years (Y)	5	299.79	59.96	22.13	5,20	<0.01
Quarters (Q)	2	279.65	139.83	51.62	2,20	<0.01
Size classes (S)	2	45.73	22.86	8.44	2,20	<0.01
Y x Q	10	204.18	20.42	7.54	10,20	<0.01
Y x S	10	13.84	1.38	0.51	10,20	>0.05
Q x S	4	30.93	7.73	2.85	4,20	>0.05
Residual	20	54.18	2.71			
Total	53	928.30				

TABLE 31. Analysis of variance for the ratio of successful to total sets by years, quarters, and size classes for Area 2.

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F	Degrees of freedom	Probability
Years (Y)	4	0.0946	0.0236	5.79	4,16	<0.01
Quarters (Q)	2	0.0006	0.0003	0.07	2,16	>0.05
Size classes (S)	2	0.0707	0.0353	8.66	2,16	<0.01
Y x Q	8	0.0761	0.0095	2.33	8,16	>0.05
Y x S	8	0.0286	0.0036	0.88	8,16	>0.05
Q x S	4	0.0118	0.0030	0.73	4,16	>0.05
Residual	16	0.0653	0.0041			
Total	44	0.3476				

TABLE 32. Analysis of variance for the sets per day of fishing by years, quarters, and size classes for Area 2.

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F	Degrees of freedom	Probability
Years (Y)	4	1.6486	0.4122	14.87	4,16	<0.01
Quarters (Q)	2	0.1934	0.0967	3.49	2,16	>0.05
Size classes (S)	2	0.3131	0.1566	5.65	2,16	<0.05
Y x Q	8	0.5690	0.0711	2.57	8,16	>0.05
Y x S	8	0.5864	0.0733	2.64	8,16	<0.05
Q x S	4	0.0988	0.0247	0.89	4,16	>0.05
Residual	16	0.4436	0.0277			
Total	44	3.8529				

TABLE 33. Catch of yellowfin tuna per set by school type in Area 2. The three columns under each size class refer to catch, sets, and catch per set, respectively.

TYPE OF SCHOOL

	"School Fish"			Porpoise			Night			Floating object		
1962	954	223	4.3	3665	692	5.3	3614	412	8.8	57	3	19.0
1963	2212	498	4.4	4513	1112	4.1	3177	420	7.6	0	5	0.0
1964	3934	804	4.9	13237	2755	4.8	1780	411	4.3	38	8	4.8
1965	450	175	2.6	5134	1389	3.7	1351	212	6.4	27	11	2.5
1966	518	156	3.3	1879	824	2.3	633	203	3.1	6	7	0.9
Total	8068	1856	4.3	28428	6772	4.2	10555	1658	6.4	128	34	3.8

TABLE 34. Catch of yellowfin tuna per successful set by school type in Area 2. The three columns under each size class refer to catch, successful sets, and catch per successful set, respectively.

TYPE OF SCHOOL

Year	Quarter	"School fish"			Porpoise			Night			Floating object			Totel		
1962	1	136	16	8.5	646	122	5.3	905	69	13.1	0	0	-	1687	207	8.1
	2	599	37	16.2	2987	175	17.1	1232	77	16.0	0	0	-	4818	289	16.7
	4	219	21	10.4	32	12	2.7	1477	153	9.7	57	3	19.0	1785	189	9.4
	Total	954	74	12.9	3665	309	11.9	3614	299	12.1	57	3	19.0	8290	685	12.1
1963	1	352	31	11.4	1425	206	6.9	2337	195	12.0	0	0	-	4114	432	9.5
	2	1742	114	15.3	2299	223	10.3	665	35	19.0	0	0	-	4706	372	12.7
	4	118	10	11.8	789	131	6.0	175	23	7.6	0	0	-	1082	164	6.6
	Total	2212	155	14.3	4513	560	8.1	3177	253	12.6	0	0	-	9902	968	10.2
1964	1	312	28	11.1	6618	701	9.4	1006	102	9.9	28	2	14.0	7964	833	9.6
	2	3424	195	17.6	4417	435	10.2	225	22	10.2	10	1	10.0	8076	653	12.4
	4	198	8	24.8	2202	333	6.6	489	55	8.9	0	0	-	2889	396	7.3
	Total	3934	231	17.0	13237	1469	9.0	1720	179	9.6	38	3	12.7	18929	1882	10.1
1965	1	5	5	1.0	2587	447	5.8	244	40	6.1	27	4	6.8	2863	496	5.8
	2	262	16	16.4	1917	306	6.3	843	63	13.4	0	0	-	3022	385	7.8
	4	183	9	20.3	630	114	5.5	264	25	10.6	0	0	-	1077	148	7.3
	Total	450	30	15.0	5134	867	5.9	1351	128	10.6	27	4	6.8	6962	1029	6.8
1966	1	109	12	9.1	514	157	3.3	598	101	5.9	6	3	2.0	1227	273	4.5
	2	328	32	10.3	692	109	6.3	9	1	9.0	0	0	-	1029	142	7.2
	4	81	3	27.0	673	145	4.6	26	2	13.0	0	0	-	780	150	5.2
	Total	518	47	11.0	1879	411	4.6	633	104	6.1	6	3	2.0	3036	565	5.4
1962-1966	1	914	92	9.9	11790	1633	7.2	5090	507	10.0	61	9	6.8	17855	2241	8.0
	2	6355	394	16.1	12312	1248	9.9	2974	198	15.0	10	1	10.0	21651	1841	11.8
	4	799	51	15.7	4326	735	5.9	2431	258	9.4	57	3	19.0	7613	1047	7.3
	Total	8068	537	15.0	28428	3616	7.9	10495	963	10.9	128	13	9.8	47119	5129	9.2

TABLE 35. Ratios of successful to total sets by school type in Area 2. The three columns under each size class refer to successful sets, total sets, and ratio of successful to total sets, respectively.

TYPE OF SCHOOL

	"School fish"			Porpoise			Night			Floating object		
1962	93	223	0.417	311	692	0.449	327	412	0.794	3	3	1.000
1963	226	498	0.454	596	1112	0.536	299	420	0.712	2	5	0.400
1964	385	804	0.479	1620	2755	0.588	274	411	0.667	4	8	0.500
1965	51	175	0.291	901	1389	0.649	148	212	0.698	8	11	0.727
1966	64	156	0.410	557	824	0.676	133	203	0.655	6	7	0.857
Total	819	1856	0.441	3985	6772	0.588	1181	1658	0.712	23	34	0.676

TABLE 36. Analyses of variance for the catch per successful set for the sets by vessels assisted by aircraft and by those not receiving such assistance

Year	Quarter	Size class	Aircraft assistance	Geometric mean of catch per successful set plus 1	Sample size	F	Degrees of freedom	Probability
1961	1	3	no	9.2	231			
			yes	11.6	101	5.18	1,330	< 0.05
			total	9.8	332			
1961	1	4	no	10.9	181			
			yes	15.9	79	9.15	1,258	< 0.01
			total	12.2	260			
1961	1	5	no	10.9	94			
			yes	15.7	44	4.35	1,136	< 0.05
			total	12.3	138			
1961	2	3	no	9.5	145			
			yes	15.5	13	3.33	1,156	> 0.05
			total	9.9	158			
1961	2	4	no	10.3	135			
			yes	8.7	17	0.56	1,150	> 0.05
			total	10.1	152			
1961	4	3	no	5.5	154			
			yes	10.3	12	4.89	1,164	< 0.05
			total	5.8	166			
1961	4	4	no	5.7	127			
			yes	11.9	11	6.95	1,136	< 0.01
			total	6.1	138			
1964	2	4	no	8.5	329			
			yes	18.2	17	10.52	1,344	< 0.01
			total	8.8	346			

TABLE 37. Ratios of successful to total sets in Area 2, according to whether the vessels were assisted by aircraft. The three columns under each category refer to successful sets, total sets, and ratio of successful to total sets, respectively.

Year	Quarter	Not assisted by aircraft			Assisted by aircraft			Total		
1962	1	252	517	0.487	6	9	0.667	258	526	0.490
	2	347	725	0.479	6	13	0.462	353	738	0.478
	4	246	402	0.612	1	1	1.000	247	403	0.613
	Total	845	1644	0.514	13	23	0.565	858	1667	0.515
1963	1	519	922	0.563	0	0	-	519	922	0.563
	2	498	924	0.539	8	12	0.667	506	936	0.541
	4	285	683	0.417	0	0	-	285	683	0.417
	Total	1302	2529	0.515	8	12	0.667	1310	2541	0.516
1964	1	1116	2074	0.538	23	48	0.479	1139	2122	0.537
	2	980	1626	0.603	38	50	0.760	1018	1676	0.607
	4	606	1083	0.560	0	0	-	606	1083	0.560
	Total	2702	4783	0.565	61	98	0.622	2763	4881	0.566
1965	1	609	1023	0.595	0	0	-	609	1023	0.595
	2	473	748	0.632	5	5	1.000	478	753	0.635
	4	231	396	0.583	0	0	-	231	396	0.583
	Total	1313	2167	0.606	5	5	1.000	1318	2172	0.607
1966	1	510	807	0.632	0	0	-	510	807	0.632
	2	188	314	0.599	8	10	0.800	196	324	0.605
	4	165	261	0.632	0	0	-	165	261	0.632
	Total	863	1382	0.624	8	10	0.800	871	1392	0.626
1962-1966	1	3006	5343	0.563	29	57	0.509	3035	5400	0.562
	2	2486	4337	0.573	65	90	0.722	2551	4427	0.576
	4	1533	2825	0.543	1	1	1.000	1534	2826	0.543
	Total	7025	12505	0.562	95	148	0.642	7120	12653	0.563

TABLE 38. Analysis of variance for the ratio of successful to total sets in Area 2 by quarters and whether the vessels were assisted by aircraft

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F	Degrees of freedom	Prob-abibity
Quarters	1	0.01335	0.01335	1.20	1,1	>0.05
Aircraft	1	0.00263	0.00263	0.24	1,1	>0.05
Residual	1	0.01112	0.01112			
Total	3	0.02711				

TABLE 39. Constants of the regressions of the times of the sets on the quantities of fish caught in them

Year	Quarter	Sample size	a	b	Year	Quarter	Sample size	a	b
1961	1	252	95.3	4.260	1964	1	193	123.3	2.546
	2	212	60.2	5.203		2	183	90.5	3.573
	3	132	96.6	4.615		3	147	76.5	4.158
	4	153	93.2	3.970		4	141	109.2	3.451
	Total	749	85.9	4.516		Total	664	103.9	3.281
1962	1	143	77.0	5.434	1965	1	150	80.6	4.968
	2	207	80.9	4.205		2	163	111.2	3.129
	3	109	85.5	3.000		3	133	110.8	3.952
	4	96	72.3	4.527		4	130	143.4	3.399
	Total	555	78.4	4.433		Total	576	113.3	3.704
1963	1	173	77.0	3.710	1966	1	143	99.0	4.021
	2	174	82.2	4.142		2	189	89.6	3.896
	3	129	69.5	4.103		3	165	106.3	3.901
	4	42	54.9	4.507		4	46	176.4	2.541
	Total	518	74.6	4.051		Total	543	102.9	3.818

TABLE 40. Comparisons by analysis of covariance of the regressions of the times of the sets on the quantities of fish caught in them. The significance of the F values is indicated as follows: **, <1 percent; *, 1-5 percent.

Comparison	Year	Slope		Elevation	
		F	Degrees of freedom	F	Degrees of freedom
Quarters within years	1961	3.94**	3,741	-	-
	1962	5.76**	3,547	-	-
	1963	0.88	3,510	1.95	3,513
	1964	7.16**	3,656	-	-
	1965	6.33**	3,568	-	-
	1966	1.98	3,535	3.18*	3,538
Years		11.69**	5,3593	-	-

TABLE 41. Coefficients of correlation for catch per successful set with vessel capacity, vessel speed, net length, and net depth. The significance of the coefficients of correlation is indicated as follows: **, <1 percent; *, 1-5 percent.

Year	Quarter	Sample size	Vessel capacity	Vessel speed	Net length	Net depth	Multiple
1961	1	505	0.112*	0.086	0.075	0.024	0.115
	2	350	0.106*	0.096	0.011	0.010	0.138
	4	328	0.115*	0.118*	0.099	0.043	0.140
1962	1	244	0.147*	0.069	0.173**	0.065	0.190
	2	330	0.210**	0.159**	0.150**	0.073	0.229**
	4	210	0.021	0.038	0.056	0.138*	0.150
1963	1	481	0.103*	0.030	0.080	0.090	0.133
	2	444	0.090	0.048	0.048	0.052	0.091
	4	194	0.202**	0.146*	0.184**	0.057	0.241*
1964	1	937	0.097**	0.117**	0.092**	0.057	0.138
	2	788	0.073**	0.003	0.027	0.021	0.126
	4	492	0.053	0.022	0.001	0.015	0.126
1965	1	570	0.140**	0.068	0.056	0.016	0.169
	2	439	0.140**	0.051	0.079	0.048	0.152
	4	184	0.132	0.059	0.138	0.089	0.163
1966	1	232	0.073	0.024	0.013	0.127	0.146
	2	122	0.205*	0.210*	0.154	0.111	0.232
	4	130	0.090	0.114	0.027	0.053	0.160
Total		6980	0.109**	0.072**	0.072**	0.058**	

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