INTER-AMERICAN TROPICAL TUNA COMMISSION

COMISION INTERAMERICANA DEL ATUN TROPICAL

Internal Report - Informe Interno

No. 10

ESTIMATES OF THE RATES OF MORTALITY OF SKIPJACK TUNA IN THE EASTERN PACIFIC OCEAN DERIVED FROM TAGGING EXPERIMENTS

by

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La Jolla, California

1977

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ESTIMATES OF THE RATES OF MORTALITY OF SKIPJACK TUNA IN THE EASTERN PACIFIC OCEAN DERIVED FROM TAGGING EXPERIMENTS

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ABSTRACT

Tag release and return data for five areas of the eastern Pacific Ocean, Baja California, the Revillagigedo Islands, the Gulf of Panama, the Gulf of Guayaquil, and Peru, were used to estimate the rates of attrition (fishing and natural mortality, shedding of the tags, mortality due to carrying the tags, and emigration) for skipjack. The returns of tagged fish per unit of fishing effort for two or more experiments in each area were employed to make these estimates. The coefficient of monthly attrition exclusive of fishing mortality was estimated to be less than 0.25, but the crudeness of this estimate limits its usefulness. Estimates of the coefficients of catchability for all five areas were made.

INTRODUCTION

Estimates of the mortality of skipjack, Katsuwonus pelamis, in the eastern Pacific Ocean have been made from tag return data by Schaefer, Chatwin, and Broadhead (1961), Fink (1965), and Joseph and Calkins (1969). The first of these studies was based upon relatively few data, and no adjustments were made to compensate for temporal differences in the fishing effort which would affect the numbers of tagged fish recaptured in different time periods. The following estimates of the annual instantaneous rate of attrition (fishing and natural mortality plus shedding of the tags and mortality due to carrying the tags) were obtained: area south of 10°N, 1.8 to 2.6; entire eastern Pacific Ocean, 1.5 to 2.7. Fink's study was based upon somewhat more data, and adjustments to compensate for temporal differences in the fishing effort were made. His estimates of the annual rate of attrition were much higher, 7.0 for Baja California and 5.0 for northern Peru. These rates, however, include losses by emigration, whereas those of Schaefer et al. do not. He estimated the coefficients of catchability, in Class-4 baitboat days, to be 6.00×10^{-4} and 0.67×10^{-4} for the Baja California and northern Peru areas, respectively. For the third study only data for three large-scale experiments not included in the two previous analyses were used. The following estimates were obtained: Baja California, monthly rate of attrition, including emigration, 0.8 to 1.6, monthly rate of natural mortality plus shedding of the tags, mortality due to carrying the tags, and emigration, 0.23 to 0.30, coefficient of catchability, 2.5 to 11.5×10^{-4}; Gulf of Panama, coefficient of catchability, 0.5×10^{-4}. Both coefficients of catchability are expressed in Class-4 baitboat days.

The present study includes the data used in the three previous analyses, plus all additional data which are available, as it is believed that this makes it possible to evaluate the results in the best manner.

ACKNOWLEDGMENTS

Unpublished data on the dates of release of the tagged fish for three California Department of Fish and Game cruises were furnished by Messrs. Harold B. Clemens and Robert R. Bell. The manuscript was read critically by Dr. James Joseph.

MATERIALS AND METHODS

The materials and methods used in this study were the same as those employed for yellowfin by Bayliff (1971), except that a modified version (Anonymous, 1972: pages 17-18) of Tomlinson's (1970) computer program was used to calculate solutions to the Murphy catch equation.

DATA EMPLOYED

Tag releases and returns

The areas selected for study are shown in Figure 1. Only the fish which were released in these areas and recaptured in the same areas are considered in this report. The areas were selected because tagged fish released at various locations within them were frequently recaptured in all parts of the areas where substantial fishing effort was exerted, but rarely outside the areas. The only exceptions are the fish released in the Gulf of Panama area, which includes, for this report, only the area north of 5°N and east of 80°W. Fink and Bayliff (1970: page 40) demonstrated that tagged fish released in that area leave it quickly, travelling either west and northwest toward Central America or south toward the Gulf of Guayaquil. Those released there in 1959 went mostly to the south, while those released there in 1961 went mostly to the west and northwest, so the areas of recapture were chosen accordingly.

The tag release and return data are listed in Tables 1 through 6. The return data include fish recaptured through the end of 1974. Cruises 58C1, 58C2, and 58C3 were conducted by the California Department of Fish and Game (Blunt and Messersmith, 1960), while the others were conducted by the Tuna Commission. In most cases the numbers of returns in Table 1 are slightly higher than those for the same cruises in Tables 2 through 6. This is because all the returns are included in Table 1, whereas the other tables include only the ones which were usable for estimation of the attrition rates. The returns which resulted from fish recaptured outside the areas of release or in unknown areas were not used. The returns for which the years of recapture were unknown were also not considered, but those for which the months were unknown but the years were known were prorated among the months of the year of recapture according to the portions of the known recaptures made during each month of the years in question. Since 1966 the fishery for yellowfin tuna has been regulated by an annual quota on the total catch of that species in the Commission's Yellowfin Regulatory Area (Anonymous, 1975: Figure 1). Vessels which leave port prior to the date that regulation begins may fish without restriction until that fishing trip is completed; also, vessels which are in port on that date may fish without restriction on their next trips, provided they leave port within 30 days. Vessels which do not meet either of these requirements are subject to various restrictions after the date that regulation begins. As a result, the vessels which are subject to regulation devote a considerable portion of their effort to the capture of species other than yellowfin and skipjack, and the data for many of these trips are not included in the Commission's catch and effort statistics, described in the next section. Accordingly, the tag return data for such trips are not used in this study.

Statistics of the fishery

The statistical data routinely collected by the Tuna Commission include the logged catches in short tons of skipjack by 1-degree and 5-degree areas, by months, quarters, and years, by types of gear (purse seine and baitboat), by size classes of vessels, and by regulation status, and the corresponding effort in days of fishing, both unstandardized and standardized to Class-3 purse-seine (vessels of 101-200 short tons capacity) days and Class-4 baitboat (vessels of 201-300 short tons capacity) days (Shimada and Schaefer, 1956; Joseph and Calkins, 1969). Data for trips are not included in this system if: (1) the logbook is not available for preparation of an abstract by a Tuna Commission employee; (2) the estimate of the total catch in the logbook differs by more than 25 percent from the total weight of fish landed (making allowances for fish discarded at sea or given to other vessels); or (3) the catch of species other than skipjack or yellowfin makes up more than one third of the total catch. All effort for unregulated trips included in the system is assumed to be yellowfin effort, but because there is a large area off southern Mexico where skipjack are infrequently caught in most years (Joseph and Calkins, 1969) this assumption is not reasonable for skipjack. Accordingly, in this report only effort data for areas where skipjack are frequently caught are employed. This will be explained more fully below. However, as the regulations do not apply to skipjack, effort for both unregulated and regulated trips which meet the criteria above is assumed to be skipjack effort.

When estimating the coefficient of attrition of a group of fish it is necessary that the fishing effort in the area in question be standardized to one particular type of gear. Broadhead (1962) devised a method for converting Class-3 purse-seine effort to Class-4 baitboat effort for yellowfin, and Joseph and Calkins (1969) used the same method to convert unstandardized purse-seine effort to Class-4 baitboat effort for skipjack. They used unstandardized purse-seine effort because their results indicated that the catches per unit of effort (CPUEs) of skipjack did not differ significantly among size classes of purse seiners (Joseph and Calkins, 1969: page 33). In the present study it was decided to convert the purse-seine effort to baitboat effort for the experiments for which most of the recaptures were made by baitboats and to convert the baitboat effort to purse-seine effort for the other experiments. The first group includes the experiments initiated during 1957-1959 and

1973 and the second group those initiated during 1960-1965. The 26 pairs of CPUE values of Joseph and Calkins (1969: Appendix Table 1) which meet their criterion that there be at least 20 days of effort for each gear for the major area-month strata were employed to calculate the log-log relationships of baitboat CPUE to purse-seine CPUE and purse-seine CPUE to baitboat CPUE. The equations obtained were as follows:

relationship to baitboat CPUE to purse-seine CPUE

$$\log CPUE_{BB} = 0.585931 + 0.289918 (\log CPUE_{PS}) \qquad (1a)$$

or

$$CPUE_{BB} = 3.854 (CPUE_{PS}^{0.289918}); \qquad (1b)$$

relationship of purse-seine CPUE to baitboat CPUE

$$\log CPUE_{PS} = -0.201175 + 0.957709 (\log CPUE_{BB}) \qquad (2a)$$

or

$$CPUE_{PS} = 0.629 (CPUE_{BB}^{0.957709}). \qquad (2b)$$

These relationships are plotted in the left panel of Figure 2. The fact that the lines do not approximately coincide at the CPUEs commonly encountered (about 0 to 10 tons per day) indicates that the procedure is faulty. For example, from (1) or the dashed line it is calculated that a purse-seine CPUE of 5.0 tons is equivalent to a baitboat CPUE of 6.1 tons (that is, if the abundance in an area-time stratum was such that the purse-seine CPUE was 5.0 tons baitboats fishing in the same stratum would have a CPUE of 6.1 tons). However, from (2) or the solid line it is calculated that a baitboat CPUE of 6.1 tons is equivalent to a purse-seine CPUE of only 3.6 tons. Accordingly, the data were graphed on log-log paper to search for outliers for possible discarding. This search produced three such outliers, corresponding to the central area for October 1960 and July and October 1961

(Joseph and Calkins, 1969: Appendix Table 1). With the three outliers deleted the equations are as follows:

relationship of baitboat CPUE to purse-seine CPUE

$$\log CPUE_{BB} = 0.496412 + 0.429009 (\log CPUE_{PS}) \quad (3a)$$

or

$$CPUE_{BB} = 3.136 (CPUE_{PS}^{0.429009}); \quad (3b)$$

relationship of purse-seine CPUE to baitboat CPUE

$$\log CPUE_{PS} = -0.681928 + 1.67432 (\log CPUE_{BB}) \quad (4a)$$

or

$$CPUE_{PS} = 0.208 (CPUE_{BB}^{1.67432}). \quad (4b)$$

The relationships are plotted in the right panel of Figure 2. Obviously the lines coincide much more closely in the critical range of about 0 to 10 tons per day. For example, from (3) or the dashed line it is calculated that a purse-seine CPUE of 5.0 tons is equivalent to a baitboat CPUE of 6.3 tons, whereas from (4) or the solid line it is calculated that a baitboat CPUE of 6.3 tons would be equivalent to a purse-seine CPUE of 4.5 tons. Therefore, Formulae (3) and (4) were adopted for conversion of effort data between gears.

For the Baja California and Revillagigedo Islands areas the logged catches of skipjack by purse seiners (if the effort data were to be converted from purse-seine to baitboat units) or baitboats (if they were to be converted from bait-boat to purse-seine units) in what are considered to be skipjack fishing areas north of 15°N and the corresponding effort data were tabulated by month for the years in question, and the latter were divided into the former to get 12 CPUE values for each year. The skipjack fishing areas north of 15°N are considered to be the 5-degree areas which are wholly or partially included in the Baja California and Revillagigedo Islands areas shown in Figure 1. The total monthly logged effort in Class-4 baitboat days for the Baja California experiments initiated in 1957, 1958, and 1973 was estimated by

$$f_{ijk(PS+BB)BB} = f_{ijkBBBB} + \left[\frac{(C/f)_{jkPSPS}}{(C/f)_{\cdot\cdot BB}}\right] f_{ijkPSPS} \qquad (5)$$

where

$f_{ijk(PS+BB)BB}$ = total logged effort in area i during month j of year k by purse seiners and baitboats in Class-4 baitboat days,

$f_{ijkBBBB}$ = total logged effort in area i during month j of year k by baitboats in Class-4 baitboat days,

$(C/f)_{jkPSPS}$ = CPUE in skipjack fishing areas north of 15°N during month j of year k by purse seiners in unstandardized purse-seine days,

$(C/f)_{\cdot\cdot BB}$ = CPUE corresponding to $(C/f)_{jkPSPS}$ in Class-4 baitboat days, estimated from Formula (3), and

$f_{ijkPSPS}$ = total logged effort in area i during month j of year k by purse seiners in unstandardized purse-seine days.

Similarly, the total monthly logged effort in unstandardized purse-seine days for the Baja California area experiments initiated in 1960, 1962, and 1963 and for the Revillagigedo Islands area experiments was estimated by

$$f_{ijk(PS+BB)PS} = f_{ijkPSPS} + \left[\frac{(C/f)_{jkBBBB}}{(C/f)_{\cdot\cdot PS}}\right] f_{ijkBBBB} \qquad (6)$$

where

$f_{ijk(PS+BB)PS}$ = total logged effort in area i during month j of year k by purse seiners and baitboats in unstandardized purse-seine days,

$f_{ijkPSPS}$ = total logged effort in area i during month j of year k by purse seiners in unstandardized purse-seine days,

$(C/f)_{ijkBBBB}$ = CPUE in skipjack fishing areas north of 15°N during month j of year k by baitboats in Class-4 baitboat days,

$(C/f)_{..PS}$ = CPUE corresponding to $C/f)_{jkBBBB}$ in unstandardized purse-seine days, estimated from Formula (4), and

$f_{ijkBBBB}$= total logged effort in area $\underline{i}$ during month $\underline{j}$ of year $\underline{k}$ by baitboats in Class-4 baitboat days.

The pertinent data for these two areas are shown in Table 7.

For the Gulf of Panama experiments the areas of consideration varied between experiments (Figure 1). The method used for conversion of purse-seine effort to baitboat effort (1959 experiment) and of baitboat effort to purse-seine effort (1961 experiment) was similar to that used for the Baja California and Revillagigedo Islands areas except that the CPUE values used to make the conversions for areas between 0°and 15°N and for areas south of 0° were calculated from data for the skipjack fishing areas between 0°and 15°N and south of 0°,respectively. The skipjack fishing areas between 0° and 15°N were considered to be all areas south of 10°N plus Area 0-10-085. (The method of designating the 5-degree areas is described by Shimada and Schaefer (1956: page 379). Briefly, the first digit indicates whether the area is north or south of the equator (0 = north, 2 = south), the second and third digits indicate the southern edge of the area, and the last three digits indicate the eastern edge of the area. Thus area 0-10-085 is the 5-degree area bounded on the south by 10°N and on the east by 85°W.) All areas south of 0° were considered to be skipjack fishing areas. The catches by small vessels in Area 2-05-080 created an additional problem, which will be discussed below. The pertinent effort data for the areas in Figure 1 are shown in Table 8.

Additionally, the procedure of Joseph and Calkins (1969), which involves gradual expansion of the area of consideration in accordance with the dispersion of the fish, as determined by tag returns, was used. For this procedure the method of Beverton and Holt (1957) was used to calculate the fishing effort to be used to make the estimates of the attrition of tagged skipjack released in the Gulf of Panama area. This was accomplished by

$$\tilde{f}_i = \frac{\sum_{j=1}^{n} r_{ij}}{\sum_{j=i}^{n} \left[\frac{r_{ij}}{f_{ij}} \right]} \qquad (7)$$

where

$\tilde{f}_i$ = weighted mean fishing intensity for month i for the cruise in question,

r_{ij} = number of tag returns during month i in 5-degree area j,

f_{ij} = effort exerted during month i in 5-degree area j, and

n = number of 5-degree areas for which there was at least one tag return.

For the 1959 experiment the following effort data were used: April 1959, 0-05-075; May 1959, 0-05-075 and 0-00-075; following months, 0-05-075, 0-00-075, 0-00-080, and 2-05-080. For the 1961 experiment the effort data used were as follows: May 1961, 0-05-075; June 1961, 0-05-075 and 0-05-080; following months, 0-05-075, 0-05-080, 0-05-085, 0-10-085, and 0-10-090.

For the Gulf of Guayaquil area the statistics are complicated by the fact that many small purse seiners and baitboats were fishing in the area during the years when tagging was conducted, and that there are no effort data for these vessels. Total catch statistics are available for these vessels, however, and these catches are known to have practically all been made in the Gulf of Guayaquil area. The effort data for the large vessels were calculated by a method similar to that used for the Baja California and Revillagigedo Islands areas except that the CPUE values used to make the conversions were calculated for the area south of 0°. For the experiments initiated in 1958 and 1959 the total monthly logged effort by large purse seiners and baitboats plus the total monthly effort by small purse seiners and baitboats, all in Class-4 baitboat days, was estimated by

$$f_{ijk(PS+BB+ps+bb)BB} = \frac{C_{ijkPS} + C_{ijkBB} + C_{ijkps} + C_{ijkbb}}{\dfrac{C_{ijkPS} + C_{ijkBB}}{f_{ijk(PS+BB)BB}}} \quad (8)$$

where

$f_{ijk(PS+BB+ps+bb)BB}$ = total logged effort by large purse seiners and baitboats plus total effort by small purse seiners and baitboats in Class-4 baitboat days in area *i* during month *j* of year *k*,

C_{ijkPS} and C_{ijkBB} = logged catches in area *i* during month *j* of year *k* by large purse seiners and large baitboats, respectively, and

C_{ijkps} and C_{ijkbb} = catches in area *i* during month *j* of year *k* by small purse seiners and small baitboats, respectively.

Similarly, for the experiments initiated in 1960, 1961, and 1962, the total monthly logged effort by all vessels in unstandardized purse-seine days was estimated by

$$f_{ijk(PS+BB+ps+bb)PS} = \frac{C_{ijkPS} + C_{ijkBB} + C_{ijkps} + C_{ijkbb}}{\dfrac{C_{ijkPS} + C_{ijkBB}}{f_{ijk(PS+BB)PS}}} \quad (9)$$

where

$f_{ijk(PS+BB+ps+bb)PS}$ = total logged effort by large purse seiners and baitboats plus total effort by small purse seiners and baitboats in unstandardized purse-seine days in area *i* during month *j* of year *k*.

The pertinent effort data for this area are shown in Table 9.

The total monthly logged effort in Class-4 baitboat days for the Peru experiments was estimated in the same way as was the effort for large vessels in Area 2-05-080 for the Gulf of Panama and Gulf of Guayaquil experiments. The pertinent effort data for this area are shown in Table 10.

REQUIREMENTS, ASSUMPTIONS, AND SOURCES OF ERROR

Mortalities, emigration, and shedding

It is assumed that when several or all members of a group of fish are tagged an unknown and varying portion of them die due to the effects of tagging and handling or shed their tags before there is a chance for any of them to be recaptured (Type-1 loss). The remainder are subject to five types of exponential decrease, fishing mortality, mortality due to carrying the tags, shedding of the tags, natural mortality, and emigration. The following notation is used for these in this report:

q = coefficient of catchability;

f = fishing effort;

F = qf = coefficient of fishing mortality;

G = coefficient of mortality due to carrying the tags;

L = coefficient of loss due to shedding of the tags;

Q = $G + L$;

M = coefficient of natural mortality;

E = coefficient of emigration;

X = $Q + M$;

X' = $Q + M + E$;

Z' = $F + X$;

Z''' = $F + X'$

G and L are defined as Type-2 losses. All these types of attrition except F and E are assumed to be constant among years and within years. Neither of the two components of F, q or f, is assumed to be constant either among years or within years. A hypothesis regarding E is discussed in the next section. The subcripts m and a following the coefficients are used to designate monthly and annual values of them, respectively.

Availability

The skipjack which are caught in the eastern Pacific Ocean are believed to have resulted from spawning in the central Pacific. They apparently enter the eastern Pacific Ocean as they approach catchable size, reside there for a variable period, during which time they are exploited by the eastern Pacific purse-seine and baitboat fisheries, and then return to the central Pacific Ocean as they approach maturity (Schaefer, 1963: page 50; Rothschild, 1965; Joseph and Calkins, 1969; Williams, 1972). Until the fish begin their westward migration out of the eastern Pacific it is assumed that their availability within the areas of study remains constant among years and within years, i.e. that there is no interchange of fish, either permanent or temporary, among the areas. This assumption is believed to be fairly well satisfied (Fink and Bayliff, 1970), except for the fish released in the Gulf of Panama area; the data for these fish were subjected to a different method of analysis, as described above, to compensate for this.

The fish are believed to remain in the eastern Pacific Ocean for "several months" (Rothschild, 1965: 2, 18) or "probably 12 months or less, but only rarely longer than this" (Williams, 1972: 742). According to Rothschild (1965: Figure 2) the fish migrate from the central to the eastern Pacific at lengths of "up to 35 cm" and return to the central Pacific when 40 to 65 cm in length. This represents a sojourn of about 2 months to more than 2 years (Joseph and Calkins, 1969: Figure 30).

Twelve tagged skipjack released in the eastern Pacific Ocean have been recaptured in the central Pacific (Seckel, 1972; Anonymous, 1975 and 1977). Seven of these were released off Baja California, two near the Revillagigedo Islands, two near Clipperton Island, and one in the vicinity of 4°N-119°W. The data for those released off Baja California and near the Revillagigedo Islands are as follows:

Release			Recapture		
Area	Date	Length	Area	Date	Length
Baja California	Sep. 5, 1960	?	Hawaii	Jun. 12, 1962	774 mm
Baja California	Sep. 22,1961	?	Christmas Is.	Apr. 5, 1963	ca.700 mm
Baja California	Jun. 5, 1973	49 cm	Hawaii	Jun. 21, 1974	723 mm
Baja California	Jun. 8, 1973	47 cm	Hawaii	Aug. 30, 1974	75 cm
Baja California	Jul. 6, 1975	65 cm	Hawaii	Aug. 22, 1976	80 cm
Baja California	Jul. 6, 1975	59 cm	Hawaii	Sep. 1, 1976	727 mm
Baja California	Jul. 20,1975	45 cm	Hawaii	Sep. 1, 1976	751 mm
Revillagigedo Is.	Apr. 17,1960	?	Hawaii	Aug. 22, 1962	ca.780 mm
Revillagigedo Is.	Jun. 5, 1965	45 cm	Hawaii	Jun. 27, 1967	814 mm

The four fish released during the 1960's appeared in the Central Pacific Ocean 2 years later, while the five released during the 1970's appeared there 1 year later. Many tagged fish were recaptured in the eastern Pacific after 6 or more months at liberty, and quite a few 12 or more months after release (Tables 2-6). Accordingly, it is hypothesized that no fish emigrated from the eastern Pacific Ocean until 6 or more months after they were tagged.

Tag returns

Estimation of the extent of non-return of tags borne by recaptured fish has been attempted by conducting test tagging experiments (placing tags on dead fish aboard fishing vessels to determine what portion are returned by cannery workers) (Bayliff,1971 and 1974). Additional experiments were conducted in 1970 and 1971, but the results were inconclusive. These experiments were abandoned due to the inadequacy of the method and the realization that gradual temporal changes in the portions of the tags returned are not likely to affect greatly the estimates of the mortality rates, since most of the returns are made within 1 year of release. (If the portions which are returned remain constant the effect of the loss of those which are not returned is the same as that of Type-1 loss.)

Statistics of the fishery

Usable logbook data were not secured for all fishing trips by large purse seiners and baitboats, so the effort by these vessels is underestimated. It is not possible to know the total catch and effort for a given area because the vessels from which usable logbook data were not obtained as a rule fished in several areas, so their catches and effort could not be assigned to areas, even though their total catches, at least, were known. The portion of the catches and effort for which usable logbook data were obtained is believed to be about 90 percent for the experiments initiated in the Baja California, Revillagigedo Islands, Gulf of Panama, and Peru areas, and nearly 100 percent for those initiated in the Gulf of Guayaquil area. Thus the effort data in Tables 7, 8, and 10 represent about 90 percent of the total effort, while those in Table 9 represent virtually all the effort.

All fishing effort by tuna purse seiners and baitboats in the skipjack areas is assumed to be directed toward skipjack (and also toward yellowfin for unregulated vessels), except that for the few trips for which species other than skipjack or yellowfin made up more than one third of the total weight of the catch. Actually, in some areas at some times yellowfin are much more abundant than skipjack and the fishing effort could be directed primarily or entirely toward yellowfin. Unfortunately, no method has been devised to separate the effort directed toward skipjack from the total effort (Bayliff and Orange 1967), so this could constitute a source of error in the analysis.

It is obvious from the discussion of the conversion of purse-seine effort data to baitboat effort data and vice versa that there are errors in these procedures. Also, the assumption that purse seiners of all sizes have equal fishing power is probably not satisfied for all area-time strata, and there is almost certainly error involved in the standardization of the baitboat effort to effort by Class-4 vessels.

RESULTS

Coefficients of total attrition

The adjusted numbers of tag returns were calculated by Bayliff's (1971: pages 388-389) method, using the total effort for each area (Tables 7-10) and also, for the Gulf of Panama area, only effort for selected 5-degree areas, as described on pages 9-10. The data are shown in Tables 2-6 and Figures 3-7. These were used to make the estimates of $\underline{Z_m}''$ and $\underline{Z_m}'$ by the methods of Chapman and Robson (1960), Robson and Chapman (1961), and Paulik (1962). These are shown in Table 11 and Figures 3-7. The truncated estimates were made using in each case only the data for the first month in which tagged fish were recaptured and the following five months, in conformity with the hypothesis made previously regarding the length of time the fish remain in the eastern Pacific Ocean.

This method includes a feature which causes the data for the early time periods to be eliminated if the slope of the curve is considerably less steep for those periods. The first months used for the estimation of $\underline{Z_m}''$ and $\underline{Z_m}'$ for the various cruises are indicated by small circles on the catch curves in Figures 3-7. This feature is useful for reduction of the irregularity of the curves due to inadequate dispersion of the tagged fish during the first few months after tagging, but it occasionally results in the elimination of a large portion of the data, as is the case for the Baja California experiment of 1973.

It would be expected that if the hypothesis regarding the length of time the fish remain in the eastern Pacific Ocean is correct, or approximately so, the estimates of $\underline{Z_m}'''$ would be consistently higher than those of $\underline{Z_m}'$, but such is the case for only 13 of the 26 experiments listed in Table 11. It is believed that this test is not valid, however, due to the fact that there are not enough tag returns from fish at liberty more than 6 months.

The likelihood of a single-tagged fish losing its only tag is greater than that of a double-tagged fish losing both its tags, so the estimates of $\underline{Z_m}'''$ and $\underline{Z_m}'$ should be slightly higher for the single-tagged fish than for the double-tagged fish of the same experiments. Such is the case for only one of the two experiments in which fish were single and double tagged with dart tags, however.

Joseph and Calkins (1969) stated that the rates of shedding of loop and dart tags were different, and hence estimates obtained from experiments in which different types of tags were employed would not be comparable. Bayliff and Mobrand (1972) demonstrated that for yellowfin the retention of the dart tags was significantly better than that of the loop tags. Sufficient data to estimate the rate of shedding of either type of tag from skipjack are not available, however, so for this study it is assumed that the rates of shedding of the two types of tags are about the same. It is believed that the error, if any, due to non-fulfillment of the assumption is much less than those which will be discussed next. This permits the use of all the data in a single study.

The catch curves are quite irregular, just as were those for yellowfin (Bayliff, 1971 and 1974). The reasons for this could be one or more of the following:

(1) emigration of the tagged fish from the areas in question to other areas of the eastern Pacific Ocean and possible later return of them to the original areas; (2) temporal variation in the vulnerability of the tagged fish to capture; (3) temporal variation in the portion of the fishing effort directed toward skipjack; (4) secondary effects of (2) and (3) or any other factors, such as temporal variation in $\underline{G}$, $\underline{L}$, or $\underline{M}$, which would cause the total rate of attrition to be non-constant.

Emigration to other areas of the eastern Pacific Ocean is not considered to have been a serious problem, except for the fish released in the Gulf of Panama area, as explained previously.

Temporal variation in the vulnerability of the tagged fish to capture is believed to have been an important cause of the irregularity of the catch curves. Among the possible causes of this variation are differences in the behavior of the fishermen relative to fish of different ages, differences in the behavior of the fish of different ages which affect their vulnerability of the gear, differences in the weather which affect the efficiency of the gear and/or the behavior of the fish, and failure of the tagged and untagged fish to mix completely during the periods of recapture of the former coupled with uneven distribution of the fishing effort with respect to the distribution of the fish.

Partial avoidance by the fishermen of the fish of less than legal size obviously decreases their vulnerability to the fishery. The minimum legal size for skipjack landed in California is 4 pounds (about 45 cm), and an appreciable number of the tagged fish released in the Baja California area (Cruise 1042) were less than legal size (Fink and Bayliff, 1970: Appendix 2). This might reduce the slope of the catch curve for all or part of the first few months after the experiment was initiated. To eliminate the possibility of such bias the returns from fish which were less than 45 cm long when released were eliminated from the data for that cruise, and the returns per unit of effort for the remainder of the data were calculated. The shape of the catch curve (not shown) was not much changed, which indicates that the fact that many of the tagged fish were of sublegal size when released was not an important cause of the irregularity of the catch curve. Bayliff (1971 and 1974) obtained similar results for yellowfin, for which the minimum legal size in California is 7 1/2 pounds (about 55 cm).

Nothing is known about temporal differences in the behavior of the fish of different ages within the range of ages under consideration which might affect their vulnerability to the gear.

Differences in the weather can certainly cause differences in the efficiency of the gear, and when the catches of both skipjack and yellowfin are high in the same month or *vice versa* it is likely that unusually good or bad weather is an important factor. Unfortunately, however, it is not possible to correct the fishing effort for variations in efficiency due to the weather, except that when the weather is too bad to search for fish on certain days those days are not counted as days of fishing effort. Nothing is known about the effect of the weather on the behavior of the fish.

Temporal variation in the portion of the fishing effort directed toward skipjack could be an important cause of the irregularity of the catch curves. Bayliff (1971 and 1974) investigated this for the Baja California, Revillegigedo Islands, Gulf of Panama, and Gulf of Guayaquil areas by comparing the monthly returns of tagged yellowfin and skipjack released in the same areas at the same times. In general (with one notable exception), the months which produced high returns of skipjack also produced high returns of yellowfin and *vice versa*, whereas the converse would be expected if the vessels directed most of their effort toward skipjack in some months and yellowfin in others. These data, therefore, tend to support the assumption that all the fishing effort in the skipjack areas is directed toward skipjack. The exception is provided by the data for Cruise 1027; for this cruise 80 of the 122 total usable skipjack returns were from fish caught in May 1959, but for yellowfin only 1 of the 26 usable returns was from a fish caught in that month. Obviously vessels fishing in and near the Gulf of Panama in May 1959 were fishing primarily for skipjack, probably because at that time they were more vulnerable than were the yellowfin.

Nothing is known about temporal variation in the natural mortality rates of skipjack of the ages under consideration, nor about temporal variations in the mortality due to carrying tags or in shedding of the tags.

Nothing is known of the extent to which schools of skipjack maintain their integrity beyond the fact that occasionally individuals from groups of tagged fish released in the same locations at the same times are sometimes recaptured at widely scattered locations shortly after release. This does not mean that some of the fish do not remain together for long periods, however.

Effort data for the Gulf of Panama cruises selected by the method of Beverton and Holt, described previously, were also used with the tag return data to calculate the adjusted tag returns. This was done to examine the possibility that the catch curves derived from effort data calculated by the Beverton and Holt method are superior or inferior to catch curves derived from the effort data listed in Table 8 in cases where the tagged fish are increasing their average distances from the locations of release during most or all of the period of their recapture. The superior method would probably be the one which produces more regular catch curves. The adjusted returns calculated with the effort data obtained by the Beverton and Holt method are shown as dots on Figure 5. It is evident that catch curves drawn with these points would be about as irregular as those produced by the other method, so the two methods are probably about equal. In three cases out of four the confidence limits of the estimates of $\underline{Z_m'''}$ and $\underline{Z_m'}$ are about the same (Table 11).

Coefficients of catchability

Beverton and Holt method

Beverton and Holt (1956) pointed out that when the fishing effort in different years for which estimates of Z are available varies considerably the linear relationship $Z = M + qf$ can be fitted by the method of least squares to obtain estimates of the constants M and q. For the present data the linear relationship is

$$Z_m'''' = X_m + q\overline{f}_m \tag{10}$$

where

Z_m'''' = coefficient of total mortality plus shedding and emigration adjusted to what it would be if all the fish had been single tagged,

but the method is the same.

This method was employed with the data for the Baja California, Revillagigedo Islands, Gulf of Guayaquil, and Peru areas. The $\overline{f}_m$ values were calculated from the effort data for the months in which the first tagged fish recaptures were made and the following five months. This period was chosen because most of the tag returns are from fish which had been at liberty less than 6 months. The Z_m''' values for the experiments in which some of the fish were double tagged were adjusted upward to make them comparable to those for the experiments in which all the fish were single tagged. This was accomplished by

$$Z_m'''' = Z_m''' + \left(0.025 \times \frac{r_d}{r_s + r_d}\right) \tag{11}$$

where

r_d = returns of double-tagged fish,

r_s = returns of single-tagged fish, and

0.025 = approximate value of L_m (using the estimate of Bayliff and Mobrand

(1972) for yellowfin because no such estimate exists for skipjack). The values of $\overline{f_m}$ and the estimates of Z_m''' and Z_m'''' are listed in Table 12. The relationships between Z_m'''' and $\overline{f_m}$ are shown in Figure 8. The points are obviously too widely scattered to be useful for estimating X_m and q.

Murphy-Tomlinson method

A modification (Anonymous, 1972; pages 17-18) of Tomlinson's (1970) computer program for use with the Murphy (1965) method was used to try to estimate F_m and X_m'. The input for this program is a vector of unadjusted tag returns for the months (or combinations of months if there occur two or more consecutive months with no returns) before and including the last time period for which there was at least one return, a vector of effort values for the same time periods, a trial value of F_m for the last time period for which there was at least one return, and a trial value of X_m'. Trial values of F_m of 0.05 through 0.60 at intervals of 0.05 and trial values of X_m' of 0.03 through 0.36 at intervals of 0.03 were used. The output includes estimates of q for each time period and of the population of tagged fish at the beginning of each time period.

Use of trial values of F_m which are too low or too high is likely to produce estimates of q for the other time periods which decrease or increase precipitously, while use of trial values of X_m' which are too low or too high is likely to produce estimates of the initial population (the number of tagged fish remaining alive after the Type-1 losses have taken place) which are too low or too high. It is likely that q at first increases with time when the fish are smaller and later decreases with time as they leave the eastern Pacific Ocean, but it is not believed that it should change precipitously during most of the portion of the life span of the fish included in the present study. The estimate of the initial population should be somewhat less than the number of tagged fish released because of Type-1 losses. If it is higher than the number of fish released the trial value of $\underline{X_m}'$ is believed to be too high, but since the extent of the Type-1 loss is not known, and probably varies considerably among experiments, it is not possible to determine from the estimates of the initial population when the trial values of $\underline{X_m}'$ are too low.

The occurrence of precipitously changing estimates of $\underline{q}$ was of little or no use in deciding which of the trial values of $\underline{F_m}$ were poor estimates, as it was sometimes difficult to decide which were precipitously changing and because the precipitously changing estimates tended to occur with all trial values for a few of the experiments and none for most of the experiments. Furthermore, within these experiments all the precipitously changing estimates of $\underline{q}$ were increasing or decreasing at all trial values of the final $\underline{F_m}$, whereas they would be expected to increase at high trial values and decrease at low trial values.

The occurrence of impossibly high estimates of the initial population was helpful, however. In Figure 9 are shown the occurrences of these impossibly high values for the experiments for which these were obtained. For two of the experiments it appears that $\underline{X_m}'$ is less than about 0.25, which is approximately in agreement with Joseph and Calkins' (1969) estimate of 0.23. The latter estimate was subtracted from each of the $\underline{Z_m}''''$ values to estimate $\underline{F_m}$ which, in turn, was divided by $\underline{\overline{f}_m}$ to estimate $\underline{q}$. These data are shown in Table 13. The estimates would be expected to differ among areas, of course, being the highest for the areas with the lowest populations of fish. They would also be expected to differ somewhat among years within the same area, due to year-to-year fluctuations in population. The high estimate of $\underline{q}$ for the 1973 Baja California experiment is apparently due to the fact that $\underline{Z_m}''''$ was calculated only from data for October 1973 through April 1974. If the data from June 1973 through April 1974 had been used the estimate for $\underline{Z_m}''''$ would have been 0.370 and that for $\underline{q}$ would have been 7.1×10^{-4}. Also, due to regulation of the fishery for yellowfin in 1973, there were more vessels which caught skipjack but for which the catch and effort data were not included with the Commission's catch and effort statistics than in previous years, so $\overline{f_m}$ is underestimated. The high estimates of q for the Peru area indicate a relatively small population of fish in that area. Skipjack are caught there only sporadically, however, so it is likely that the fish which were tagged there were emigrating at a high rate, either to parts of the eastern Pacific Ocean where they are not caught or to the central Pacific Ocean. It is also possible that they remained in the same area, but became progressively less vulnerable to the fishery. In either case the population would have been greater than indicated by the high estimates of q for that area.

SUMMARY AND CONCLUSIONS

Tag release and return data for five areas of the eastern Pacific Ocean, Baja California, the Revillagigedo Islands, the Gulf of Panama, the Gulf of Guayaquil, and Peru, were used to estimate the rates of attrition (fishing and natural mortality, shedding of the tags, mortality due to carrying the tags, and emigration) of skipjack. This report includes all the available tag return data which are sufficient for estimating the rates of mortality of skipjack in the eastern Pacific Ocean.

The graphs on semilogarithmic paper of the tag returns per unit of effort plotted against time are very irregular; this is apparently caused principally by temporal variation in the vulnerability of the tagged fish to capture. This, in turn, is principally the result of failure of the tagged and untagged fish to mix completely during the periods of recapture of the former, coupled with uneven distribution of the fishing effort with respect to the distribution of the fish. Such being the case, it is not possible to make good estimates of the rates of attrition. $\underline{X_m'}$ appears to be less than about 0.25, which is approximately in agreement with Joseph and Calkins' (1969) estimate of 0.23.

Subtraction of 0.23 from the estimates of $\underline{Z_m''''}$ and division of the remainders by average values of the fishing effort gave estimates of $\underline{q}$, the coefficient of catchability. These estimates are believed, for various reasons, to be biased in at least some instances.

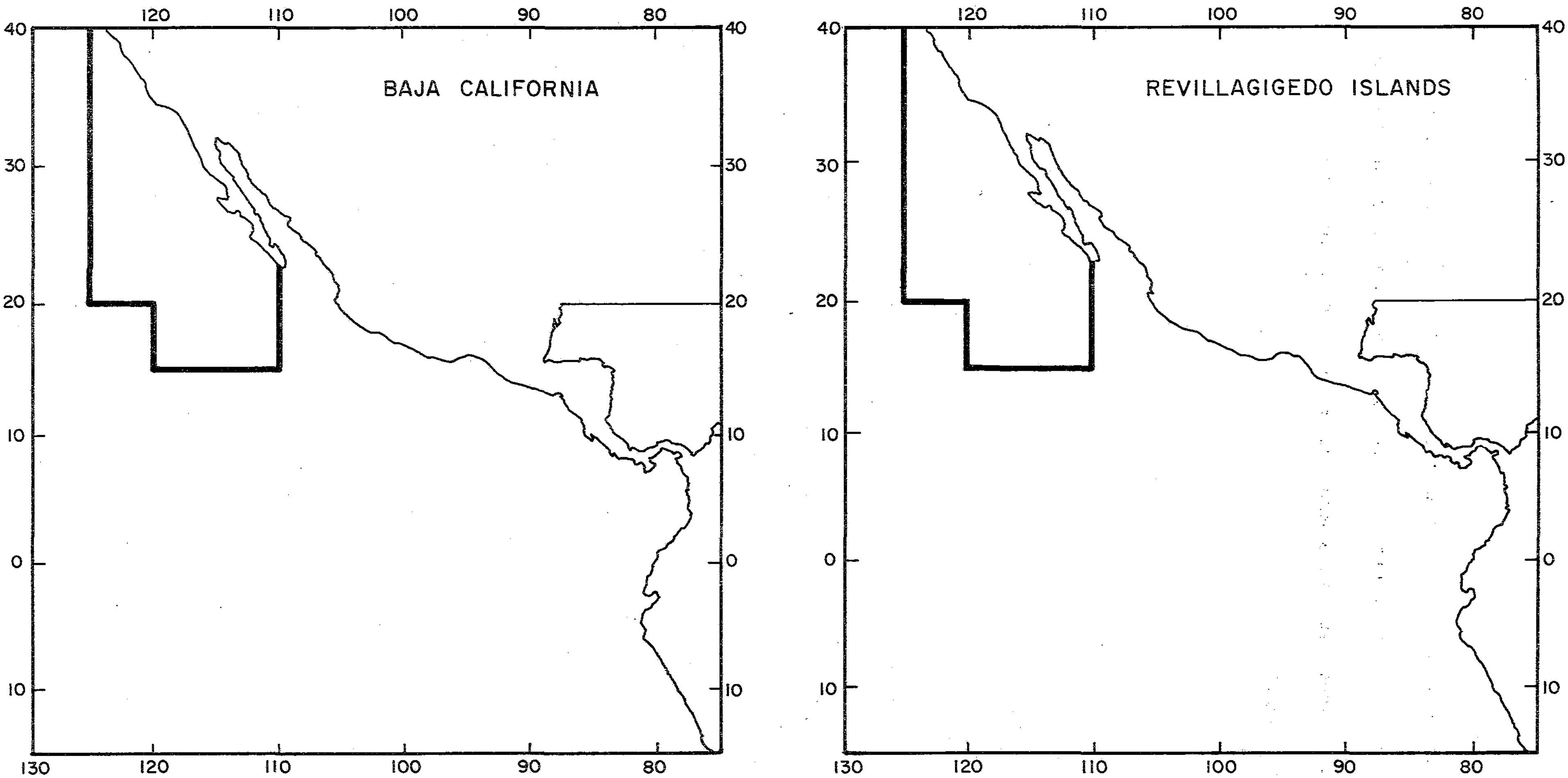


FIGURE 1. Map of the eastern Pacific Ocean, showing the Baja California, Revillagigedo Islands, Gulf of Panama, Gulf of Guayaquil, and Peru areas.

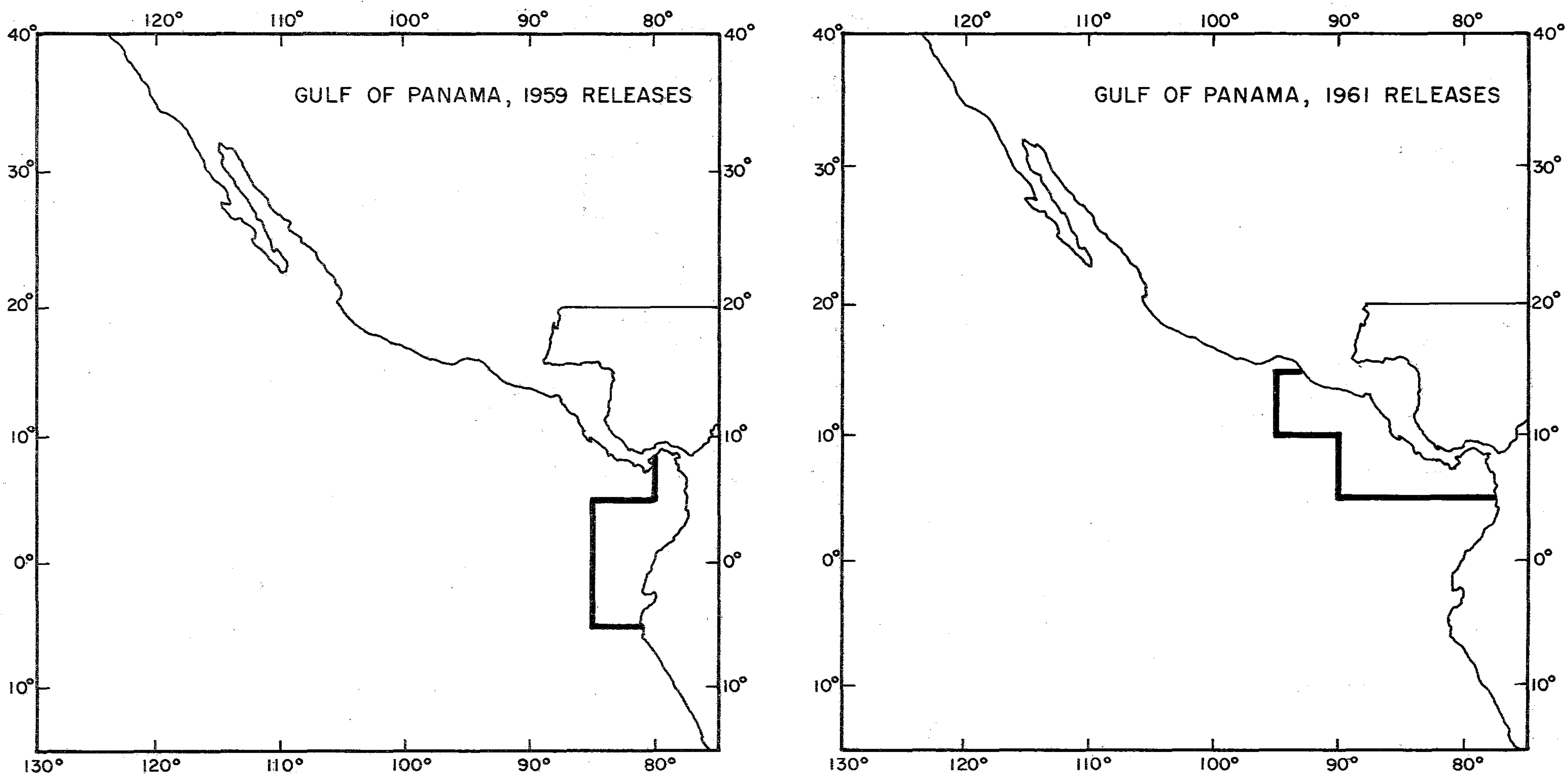
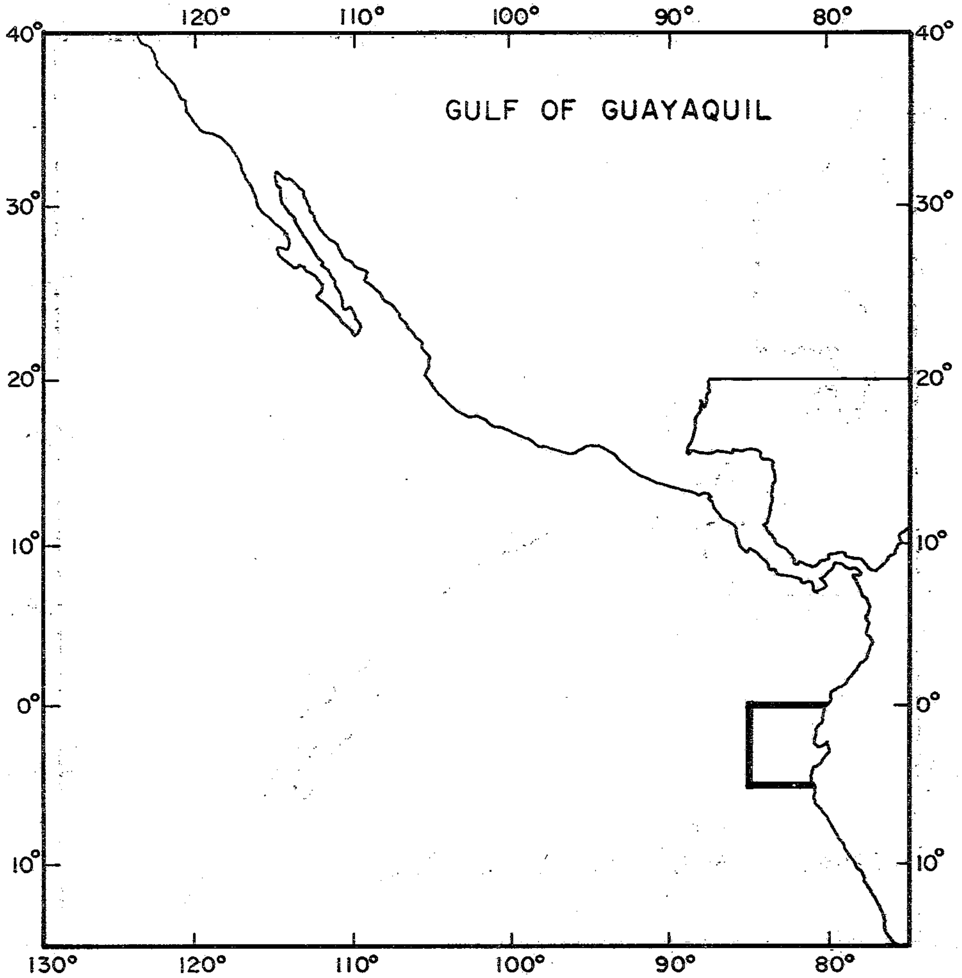


FIGURE 1 (Continued).



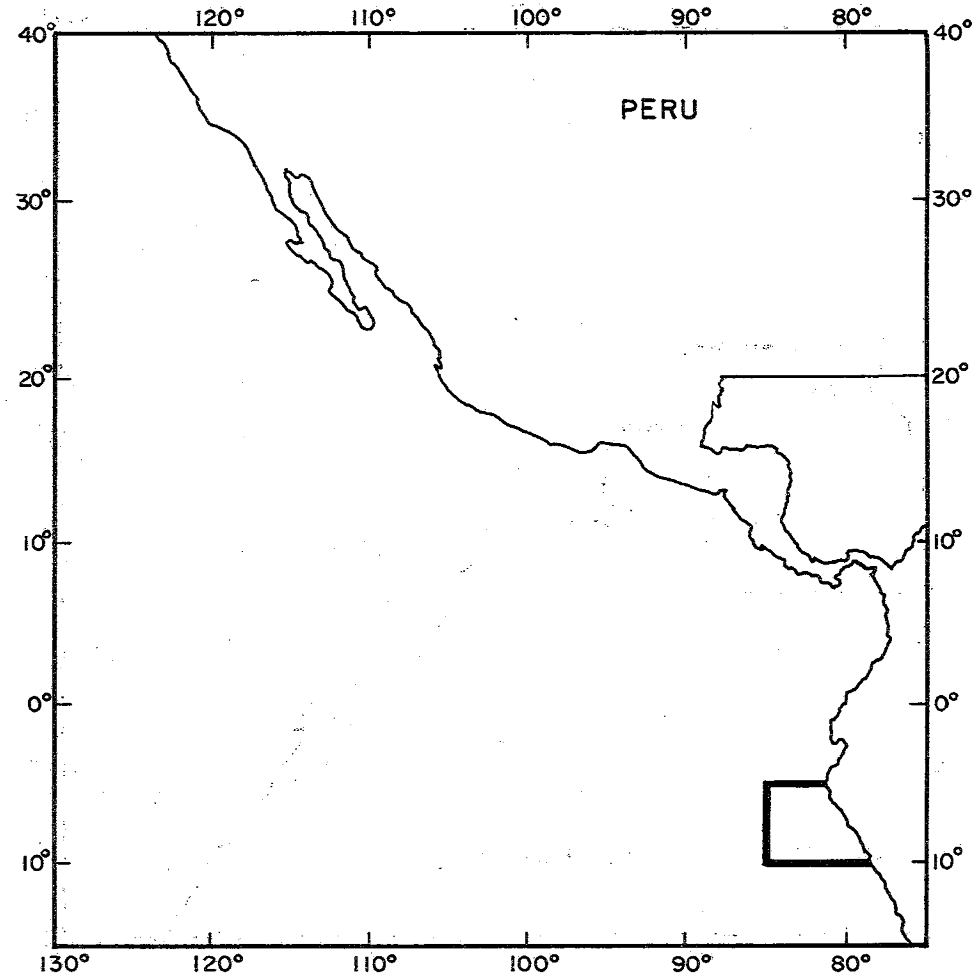


FIGURE 1 (Continued).

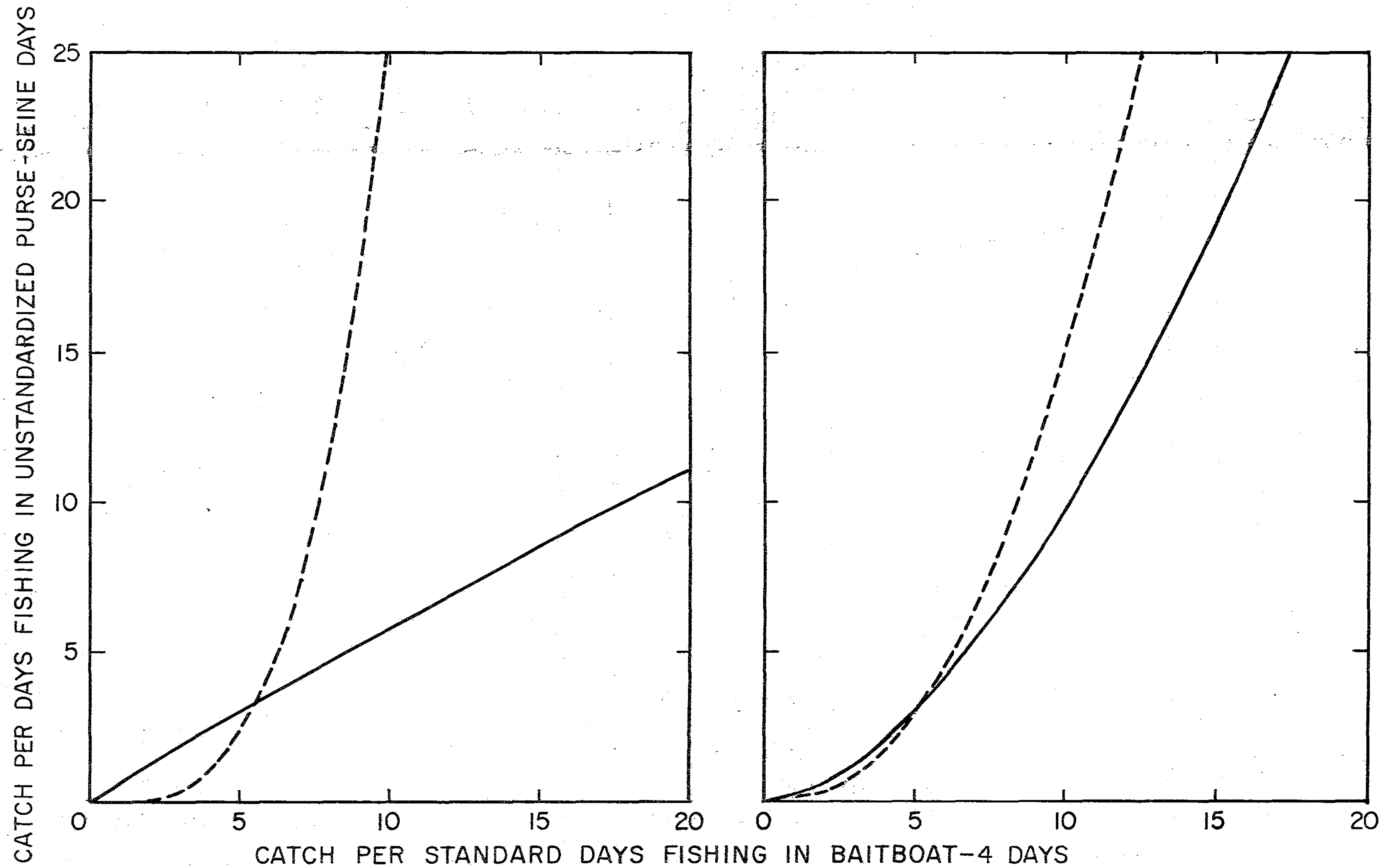


FIGURE 2. Relationship of unstandardized skipjack catch per unit of effort by purse seiners to that by baitboats in Class-4 days (solid line) and the reverse relationship (dashed line). The curves in the left panel are based on all the data, while those in the right panel are based on the data with three outliers deleted.

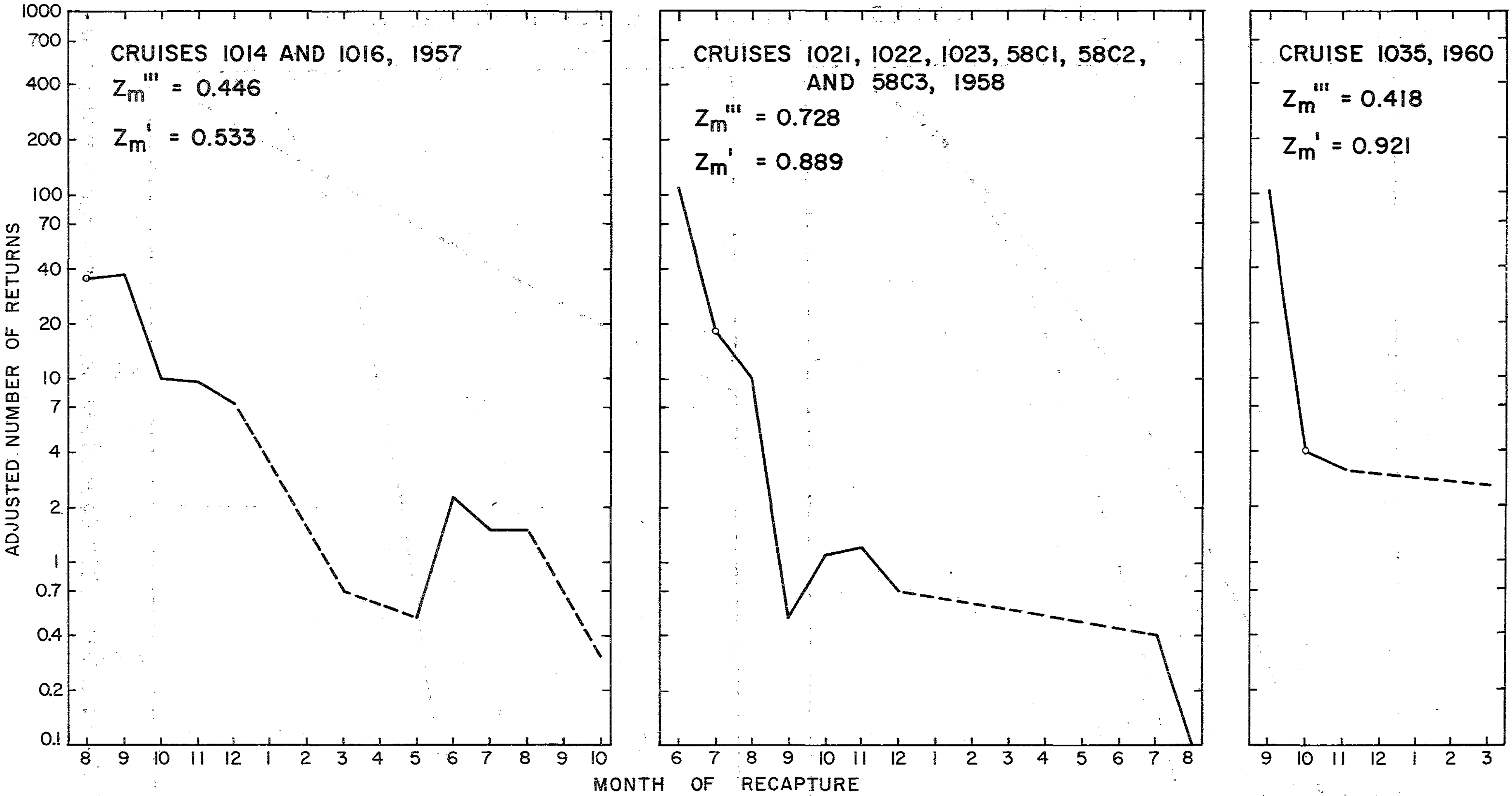


FIGURE 3. Adjusted tag returns by month of recapture for the Baja California area releases. The values for Z_m''' and Z_m' are for the untruncated and truncated data, respectively.

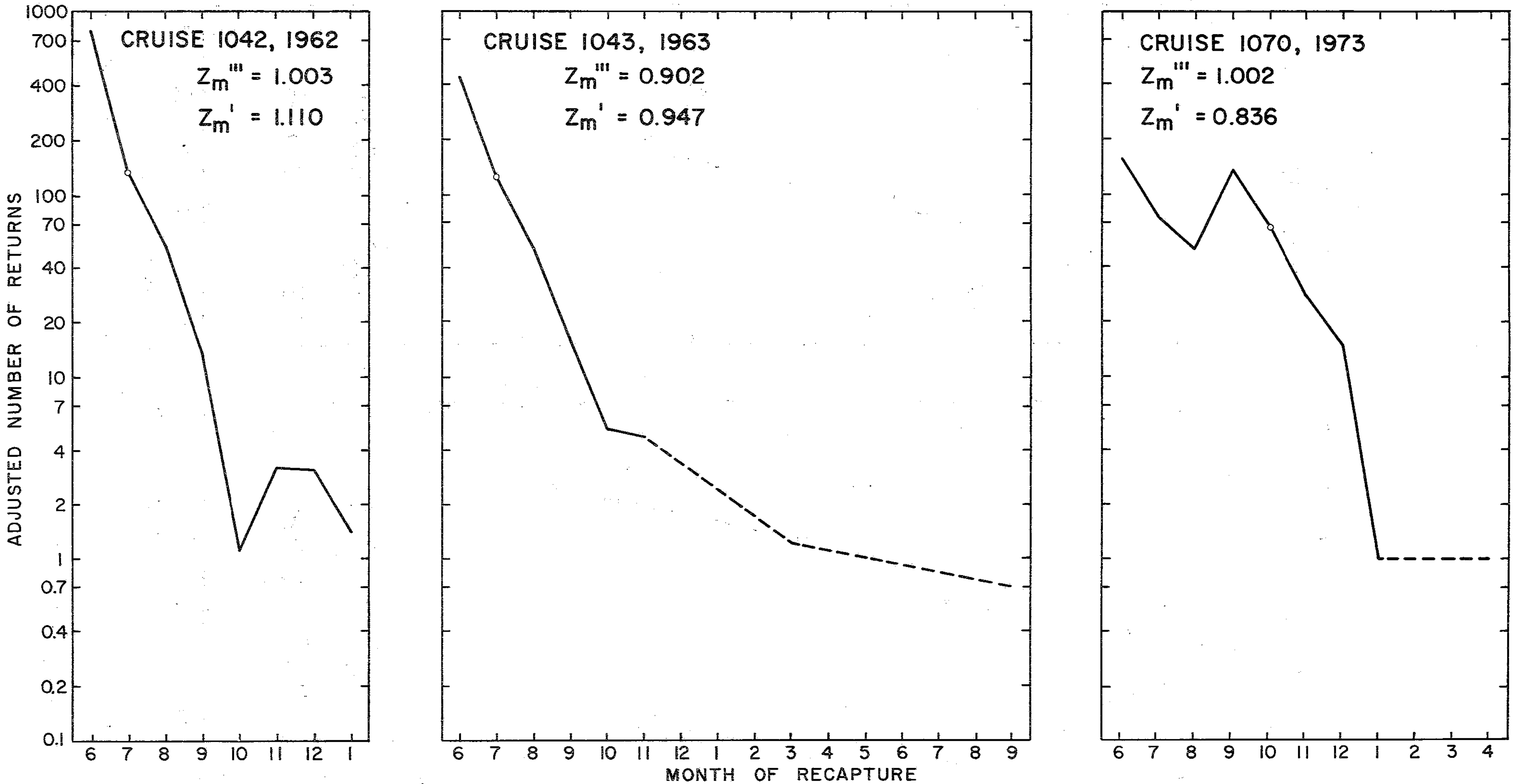


FIGURE 3 (Continued).

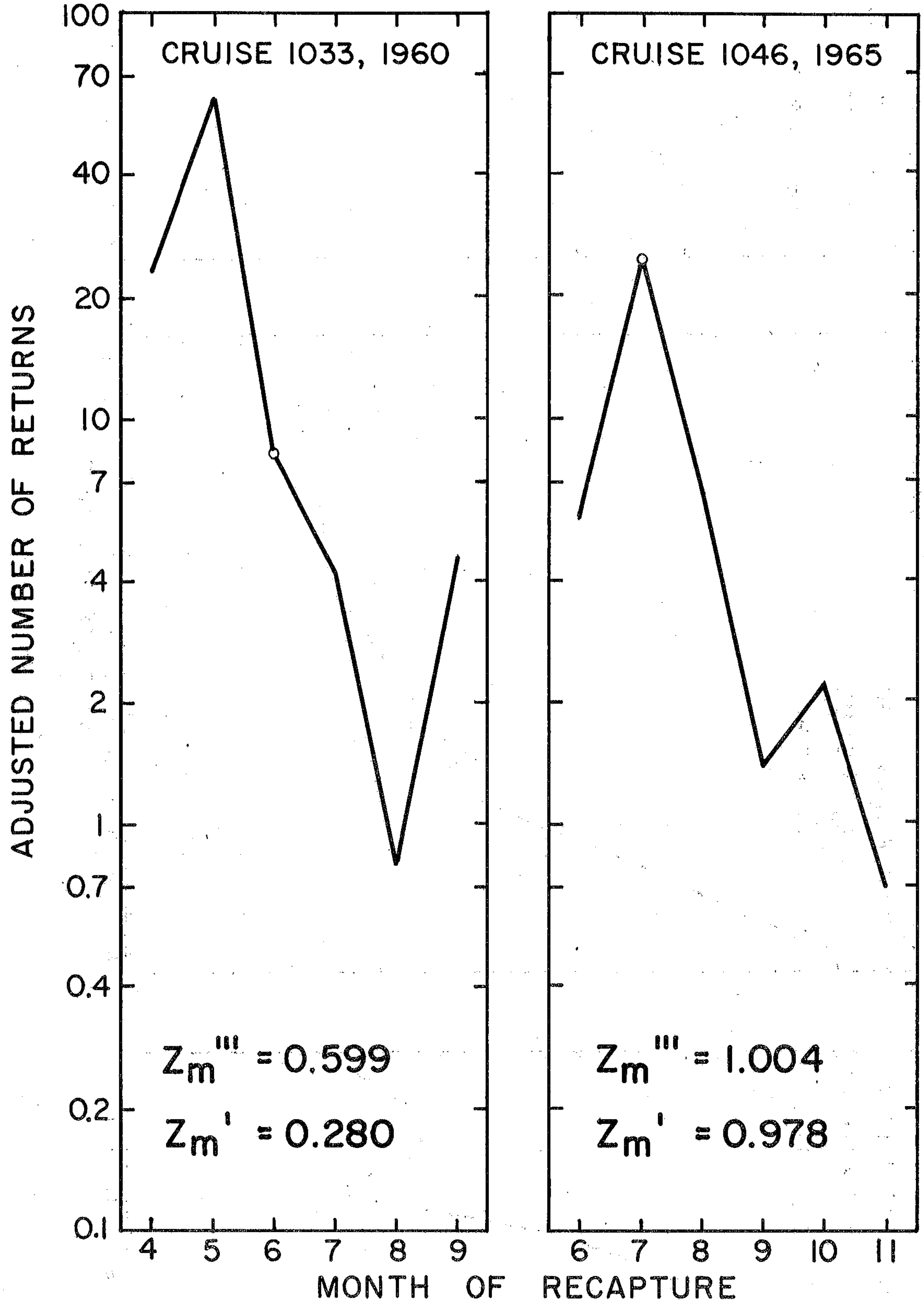


FIGURE 4. Adjusted tag returns by month of recapture for the Revillagigedo Islands area releases. The values for $\underline{Z_m}'''$ and $\underline{Z_m}'$ are for the untruncated and truncated data, respectively.

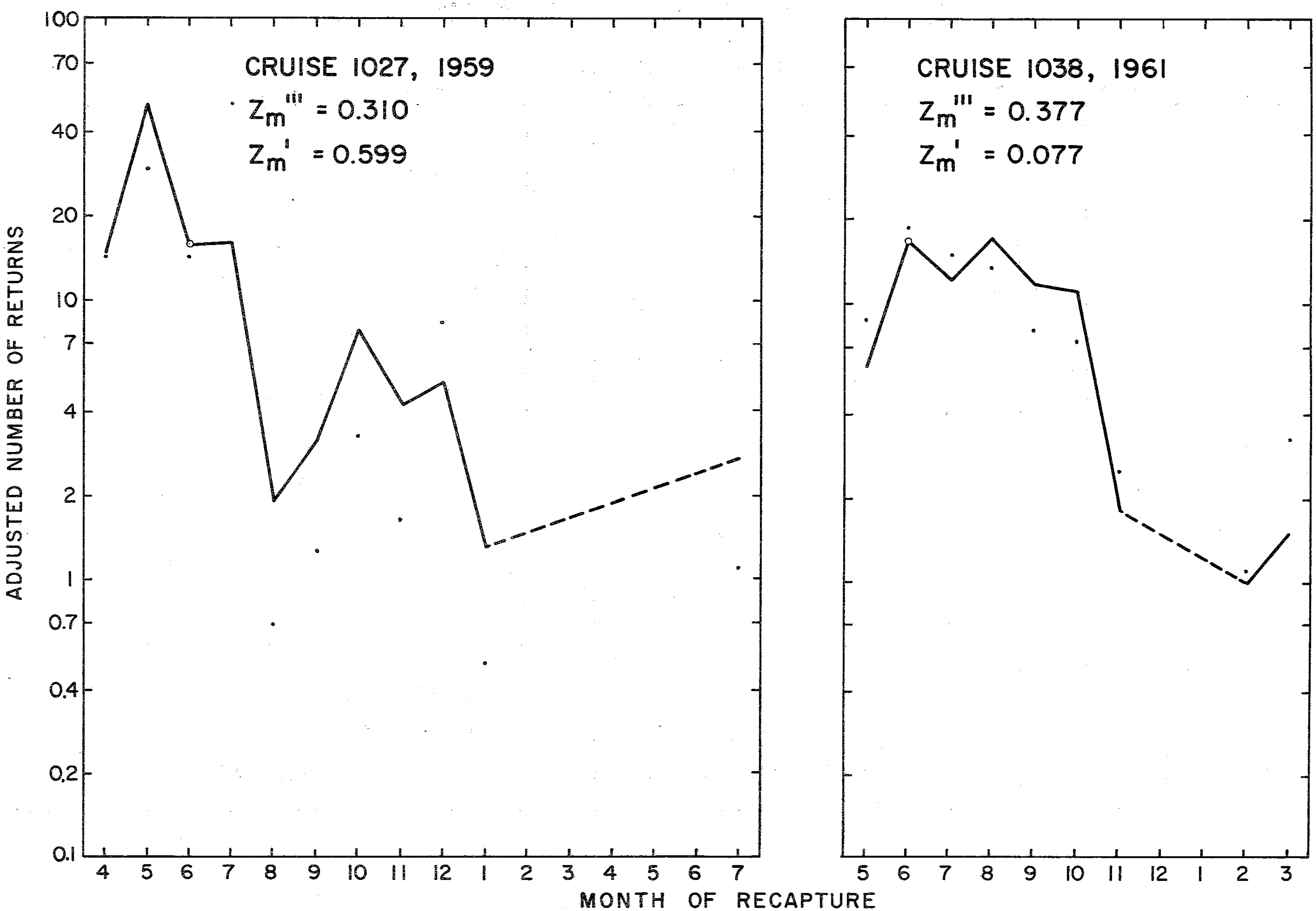


FIGURE 5. Adjusted tag returns by month of recapture for the Gulf of Panama area releases. The values for Z_m''' and Z_m' are for the untruncated and truncated data, respectively.

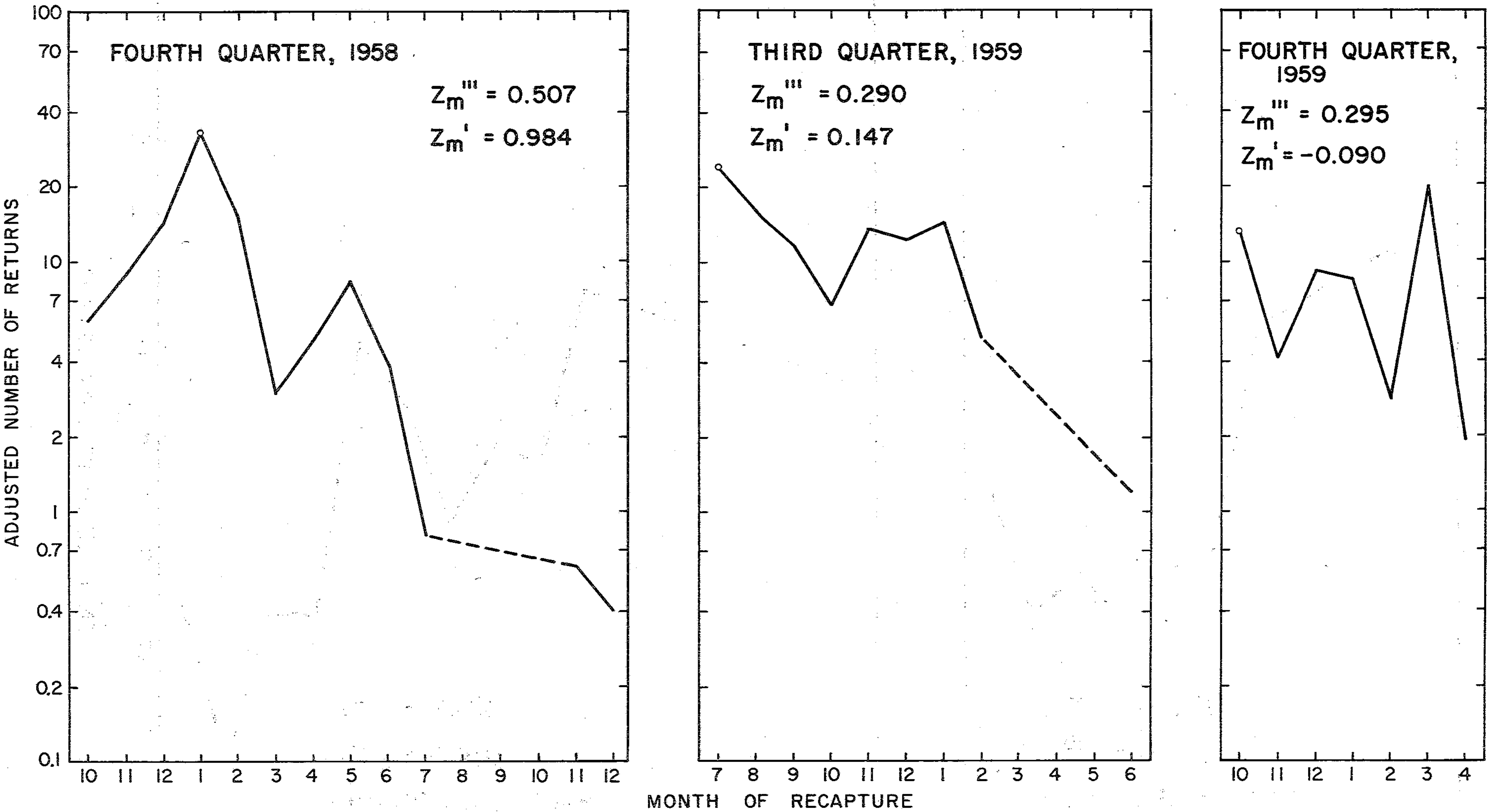


FIGURE 6. Adjusted tag returns by month of recapture for the Gulf of Guayaquil area releases. The values for Z_m''' and Z_m' are for the untruncated and truncated data respectively.

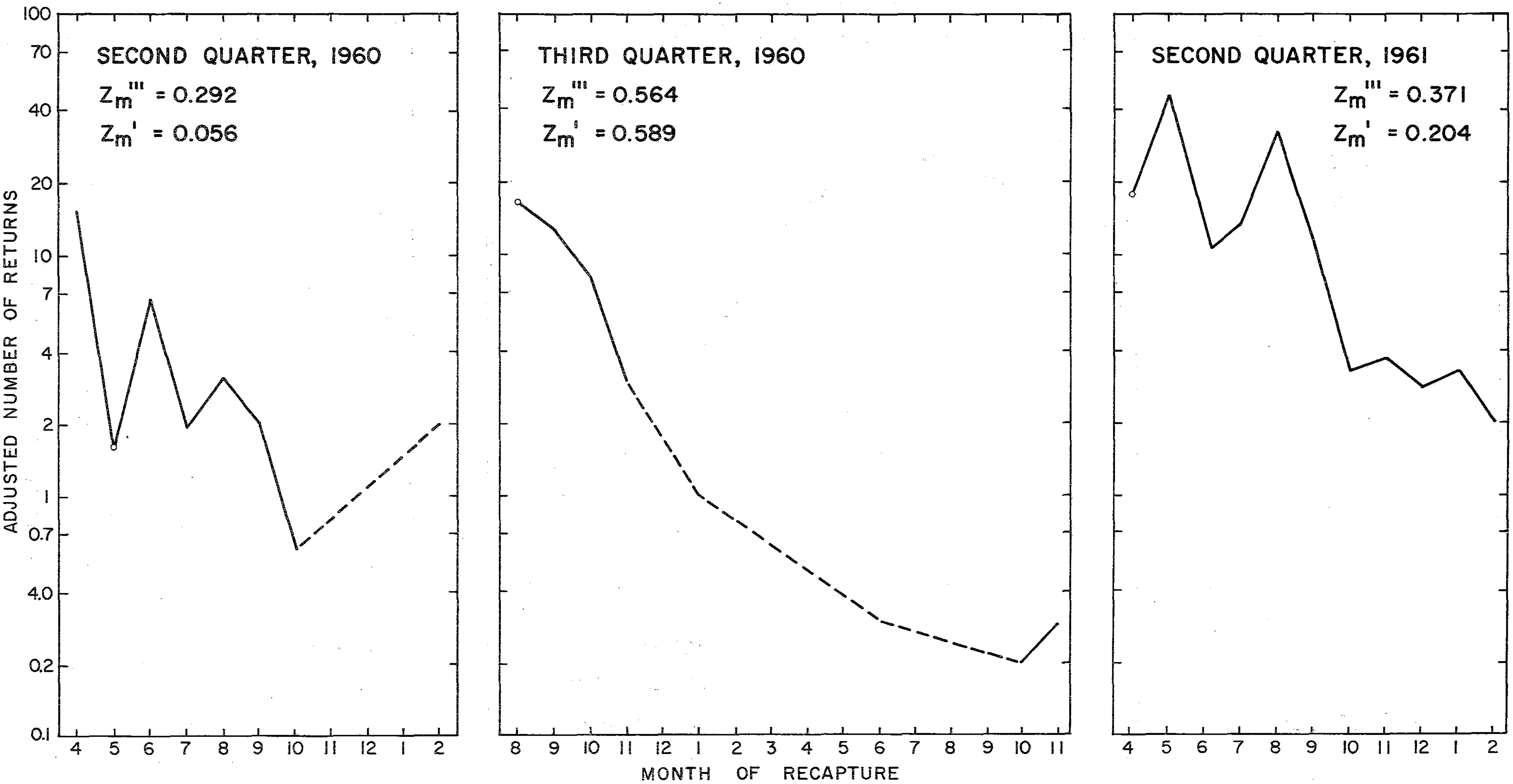


FIGURE 6 (Continued).

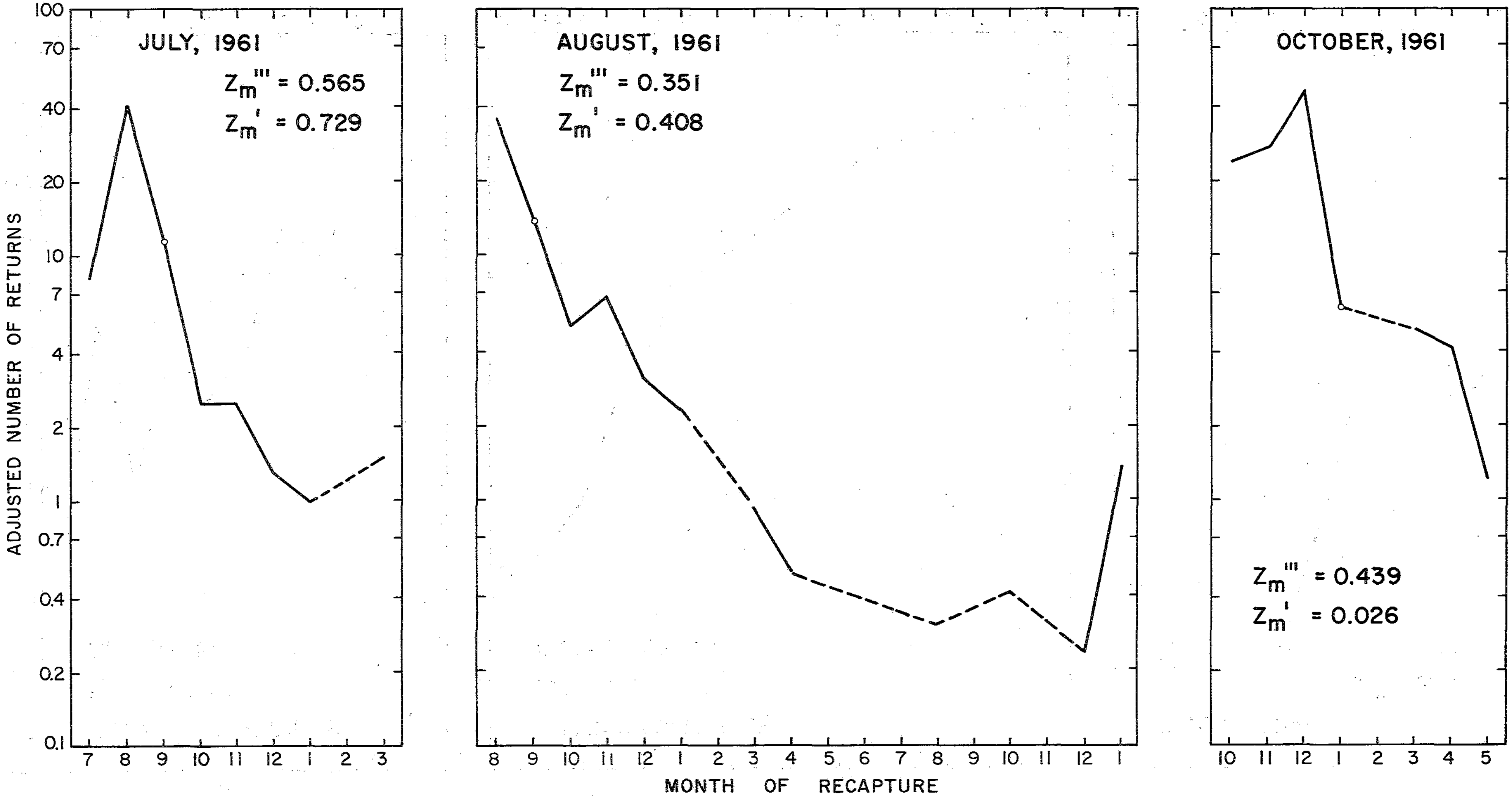


FIGURE 6 (Continued).

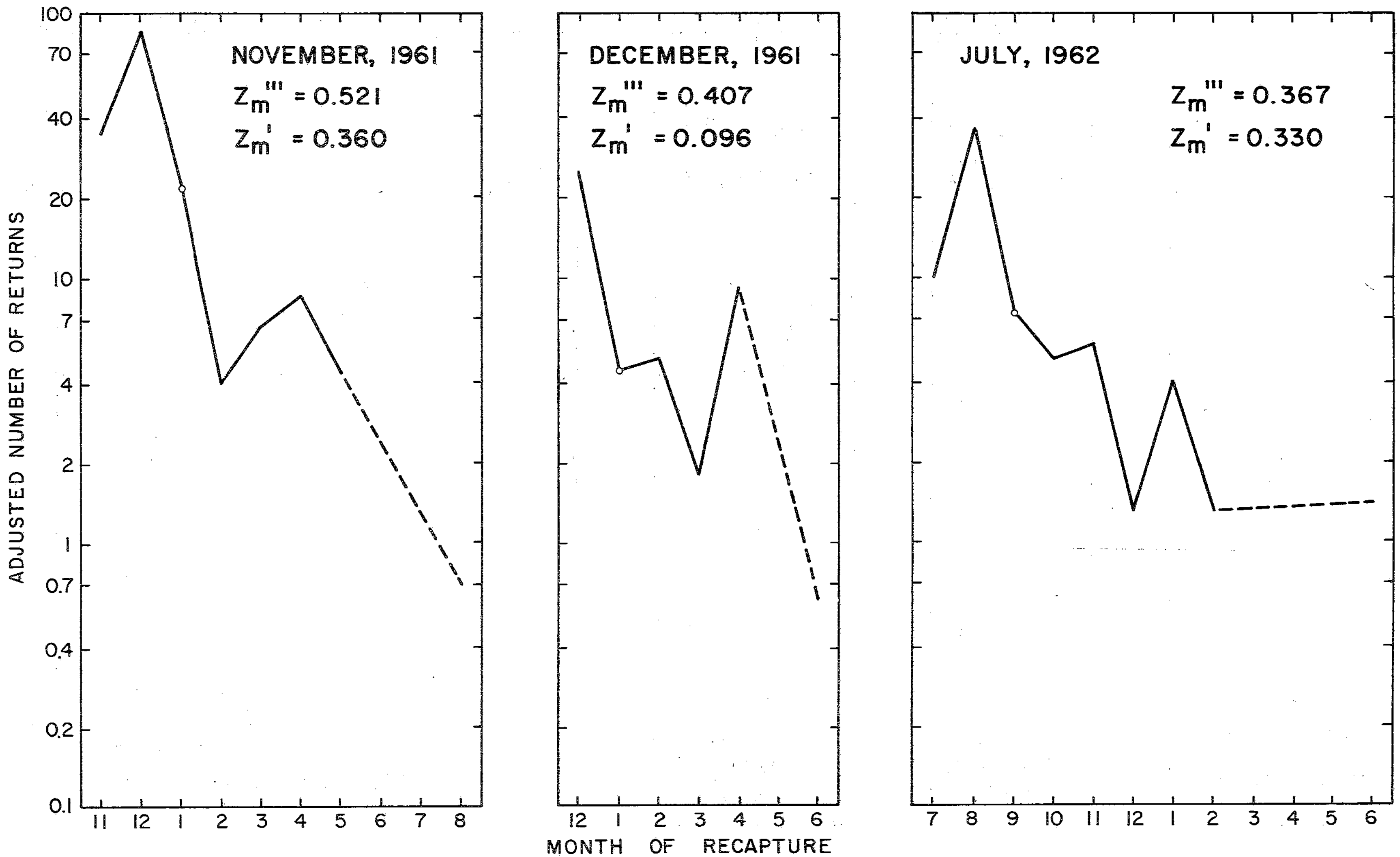


FIGURE 6 (Continued).

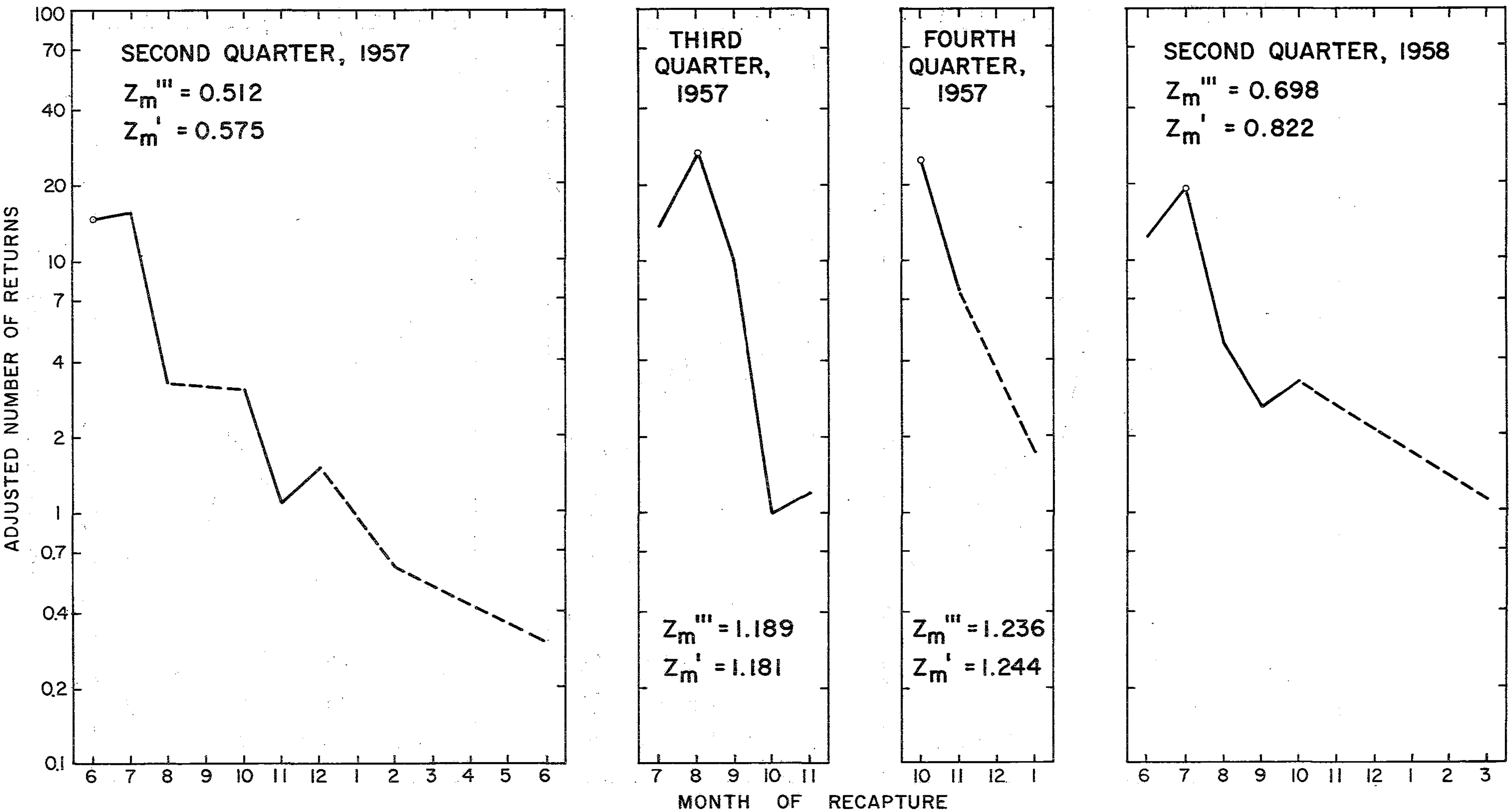


FIGURE 7. Adjusted tag returns by month of recapture for the Peru area releases. The values of Z_m''' and Z_m' are for the untruncated and truncated data, respectively.

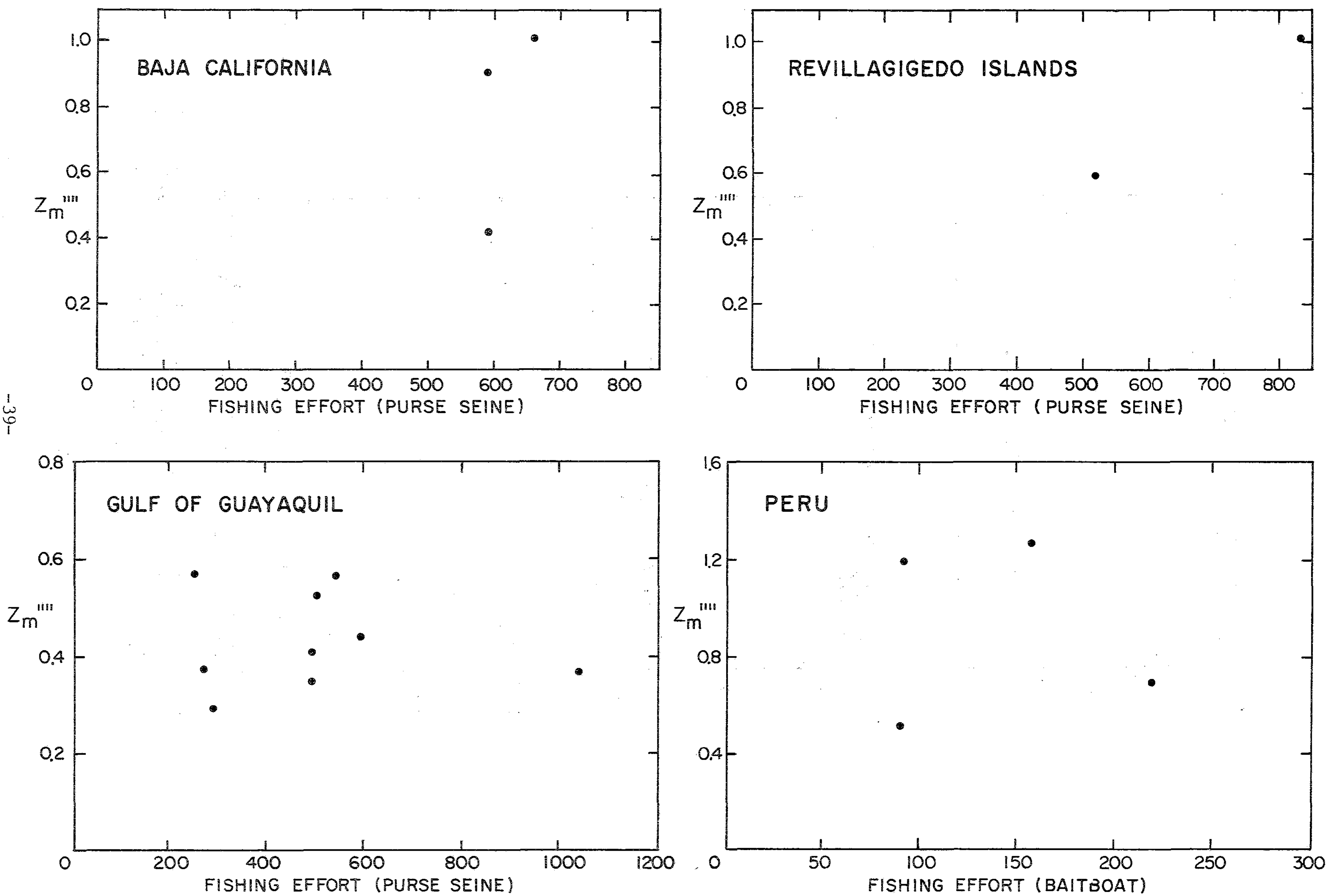


FIGURE 8. Relationships between Z_m'''' and $\overline{f_m}$ for the Baja California, Revillagigedo Islands, Gulf of Guayaquil, and Peru areas.

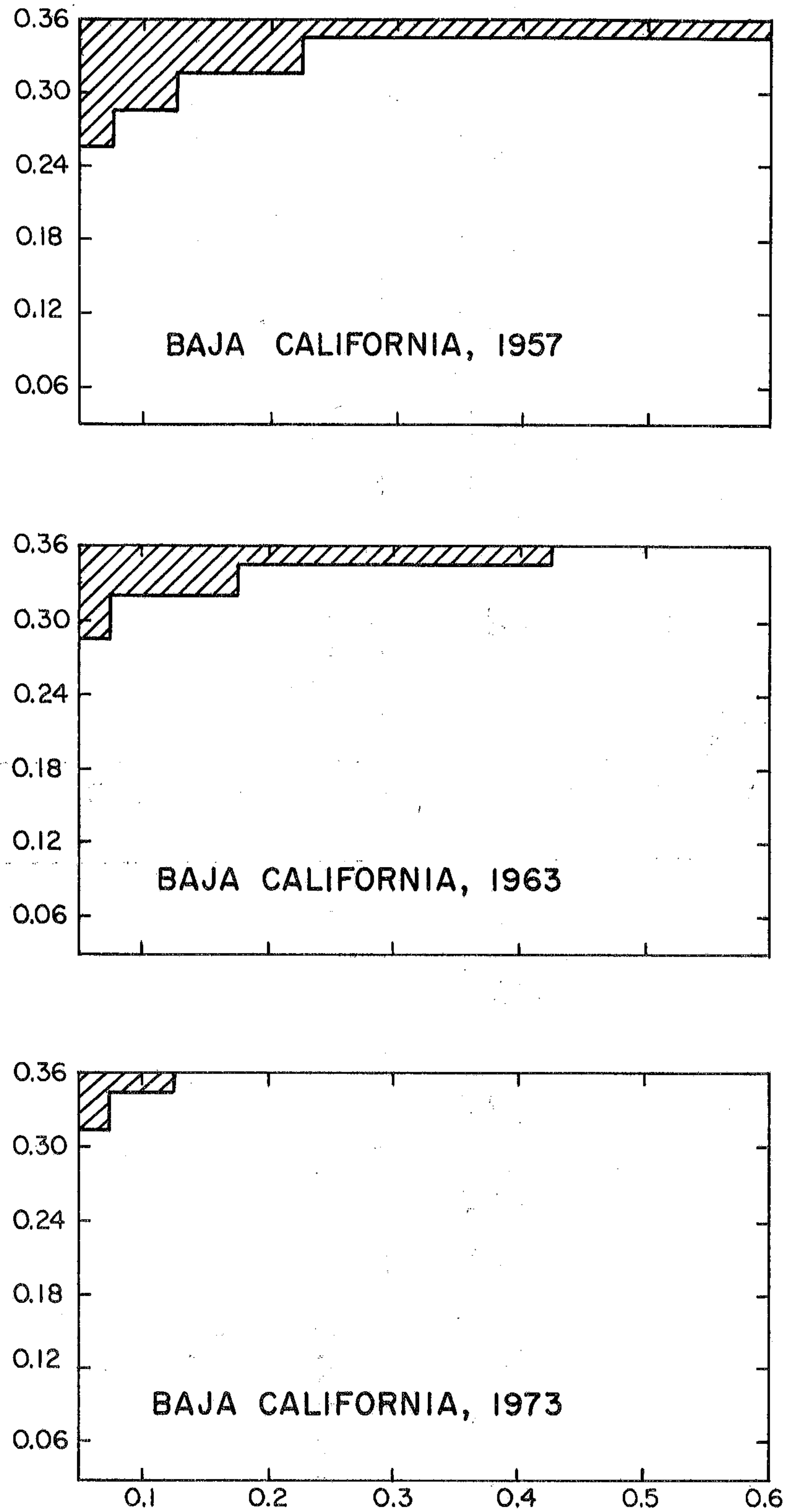


FIGURE 9. Data for estimation of X_m' with Tomlinson's (1970) computer program. The shaded areas represent combinations of F_m and X_m' which result in impossibly high estimates of the initial population.

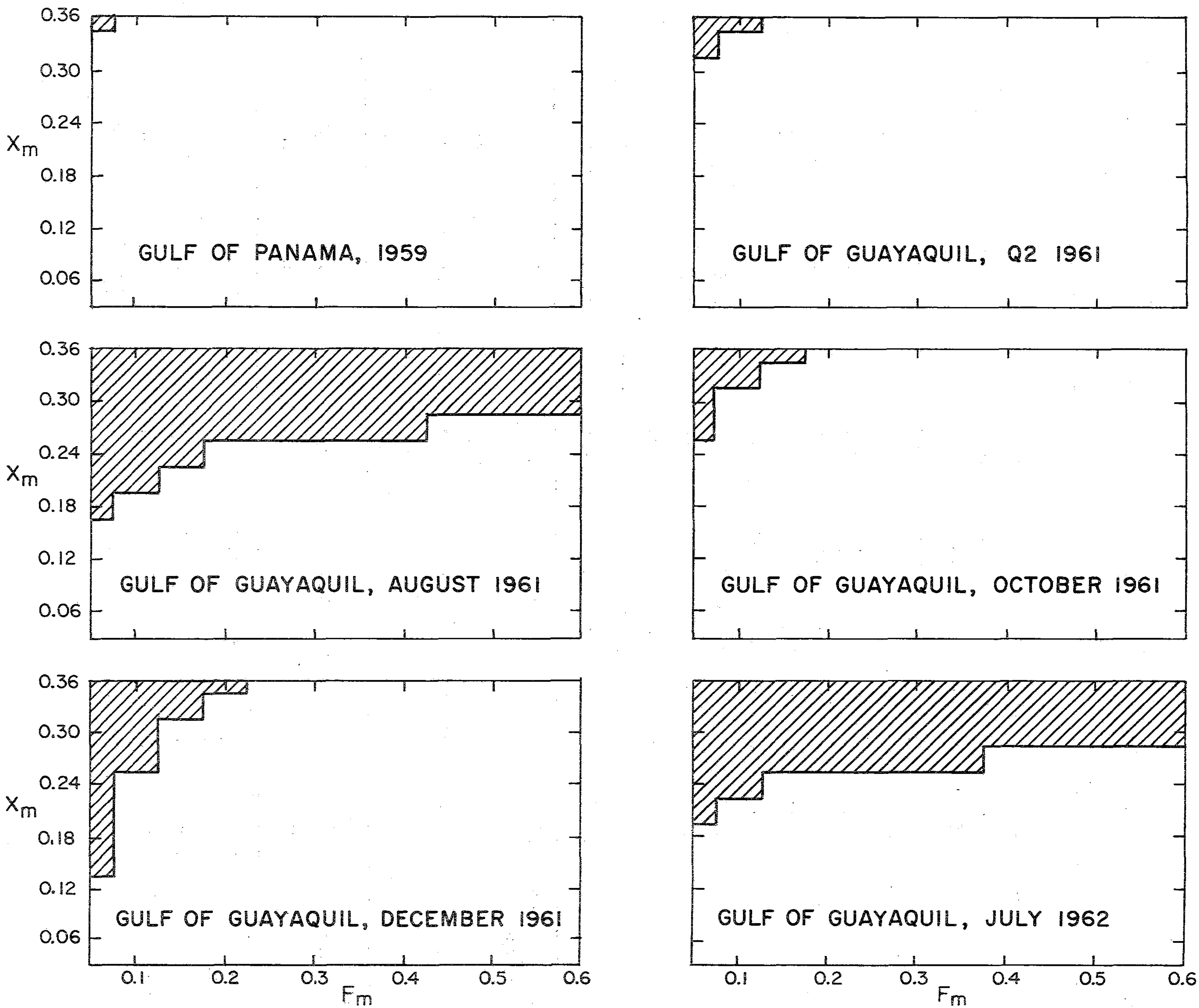


FIGURE 9 (Continued).

TABLE 1. Tagged fish release and return data used for estimation of the mortality of skipjack tuna.

Area	Cruise number	Date of release	Tag type	Number released	Number returned
Baja California	1014	Aug.1 - Sep. 21,1957	loop	903	69
	1016	Oct.19 - Dec. 1, 1957	loop	586	44
	1021	May 15 - Jul. 7,1958	loop	235	23
	1022	Jul. 5 - Aug. 3,1958	loop	1,090	20
	1023	Aug. 4 - 25, 1958	loop	7,602	47
	58C1	May 22 - Jul. 9,1958	loop	526	47
	58C2	Jul.10 - Sep. 2,1958	loop	962	13
	58C3	Aug.24, 1958	loop	12	0
	1035	Aug.10 - Sep. 14,1960	dart	471	118
	1042	Jun. 2 - 24, 1962	dart	3,856	1,011
	1043	Jun. 5 - Jul. 1,1963	dart	1,086	529
		Jun.19 - Jul. 8,1963	dart + loop	157	25
		Jun. 5 - 27, 1963	double dart	261	111
	1070	Jun. 5 - Jul. 6,1973	dart	1,863	516
Revillagigedo Islands	1033	Apr.17 - 19, 1960	loop	646	22
		Apr.17 - 19, 1960	dart	1,720	81
	1046	Jun. 4 - 21, 1965	single dart	217	30
		Jun. 4 - 21, 1965	double dart	213	14
			unknown	-	1
Gulf of Panama	1027	Apr.13 - 22, 1959	loop	4,446	132
	1038	Apr. 7 - May 2,1961	dart	3,325	101
Gulf of Guayaquil	various	Oct. 6 - Dec.27, 1958	loop	2,596	115
	various	Jul. 1 - Sep.28, 1958	loop	3,735	116
	various	Oct. 1 - Dec.28, 1959	loop	976	61
	various	Apr. 2 - Jun.29, 1960	loop	1,038	36

TABLE 1 (continued).

	various	Jul.6 - Sep.30,1960	loop	623	10
		Sep. 18 - 30, 1960	dart	650	32
	various	Apr. 12 - Jun. 25,1961	dart	1,719	149
	various	Jul. 3 - 28, 1961	dart	696	70
	various	Aug. 10 - 27, 1961	dart	1,022	74
	8032	Oct. 1 - 15, 1961	dart	339	113
	8033	Nov. 2 - 9, 1961	dart	814	173
	8034	Dec. 2 - 17, 1961	dart	197	50
	8036	Jul. 6 - 18, 1962	dart	171	77
Peru	various	Apr. 30 - Jun.29, 1957	loop	2,911	46
	various	Jul. 8 - Sep. 13, 1957	loop	1,973	58
	various	Oct. 9 - Dec. 23, 1957	loop	984	38
	various	Apr. 11 - Jun.30, 1958	loop	2,045	46

TABLE 2. Returns by month of recapture for tagged skipjack released in the Baja California area and recaptured in the same area.

Month	1957		1958		1960		1962		1963								1973	
									Dart		Loop + dart		Double dart		Total			
	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted
Year 0																		
Jun.			27	111.2			798	800.2	167	339.3	11	22.2	28	73.2	206	441.4	74.6	105.7
Jul.			21	18.7			138	134.0	210	110.3	8	1.7	36	17.7	254	125.2	131.1	74.4
Aug.	14.2	35.5	67	10.0			54	52.8	89	41.1	4	0.7	26	11.2	119	51.6	44.8	49.3
Sep.	28.3	36.9	3	0.5	98	103.2	11	13.3	25	10.3	1	0.2	15	5.8	41	15.9	53.6	103.5
Oct.	9.1	10.0	11	1.1	5	4.0	1	1.1	10	4.3			3	1.2	13	5.2	77.0	66.8
Nov.	21.2	9.5	9	1.2	9	3.2	3	3.2	8	3.8	1	0.2	2	0.9	11	4.9	49.0	27.5
Dec.	14.2	7.3	3	0.7			3	3.1									11.0	14.6
Year 1																		
Jan.							1	1.4									1	0.9
Feb.																		
Mar.	1	0.7			1	2.6			1	1.2					1	1.2		
Apr.																	1	0.5
May	1	0.5																
Jun.	6	2.3																
Jul.	5	1.5	2	0.4														
Aug.	5	1.5	1	0.1														
Sep.									1	0.7					1	0.7		
Oct.	1	0.3																
Total	106	106.0	144	143.9	113	113.0	1,009	1,009.1	511	511.0	25	25.0	110	110.0	646	646.1	443	443.2

TABLE 3. Returns by month of recapture for tagged skipjack released in the Revillagigedo Islands area and recaptured in the area shown in Figure 2.

Month	1960				1965			
	Dart		Total		Single dart		Total	
	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted
Year 0								
Apr.	5	15.8	8	23.1				
May	34	46.3	49	61.1				
Jun.	15	7.9	17	8.2	2	3.6	3	5.7
Jul.	17	4.1	19	4.2	17	13.0	30*	24.3
Aug.	2	0.9	2	0.8	4	6.4	4	6.7
Sep.	7	5.1	7	4.6	1	1.3	1	1.4
Oct.					1	1.0	2	2.2
Nov.					1	0.7	1	0.7
Total	80	80.1	102	102.0	26	26.0	41	41.0

*includes one fish bearing a single tag with the number partially oblitarated, so it could not be determined if the fish had originally been single tagged or double tagged

TABLE 4. Returns by month of recapture for tagged skipjack released in the Gulf of Panama area and recaptured in the areas shown in Figures 2 (1959) and 3 (1961).

Month	1959		1961	
	Original	Adjusted	Original	Adjusted
Year 0				
Apr.	2	14.9		
May	80	49.3	6	5.9
Jun.	2	15.8	4	16.7
Jul.	8	16.0	9	12.1
Aug.	2	1.9	22	17.0
Sep.	5	3.1	14	11.8
Oct.	6	7.8	18	11.1
Nov.	5	4.2	2	1.8
Dec.	9	5.0		
Year 1				
Jan.	2	1.3		
Feb.			1	1.0
Mar.			3	1.5
Apr.				
May				
Jun.				
Jul.	1	2.7		
Total	122	122.0	79	78.9

TABLE 5. Returns by month of recapture for tagged skipjack released in the Gulf of Guayaquil area and recaptured in the same area.

Month	Oct.-Dec. 1958		Jul.-Sep. 1959		Oct.-Dec. 1959		Apr.-Jun. 1960		Jul.-Sep. 1960				Apr.-Jun. 1961		Jul. 1961		Aug. 1961		Oct. 1961		Nov. 1961		Dec. 1961		Jul. 1962	
									Dart		Total															
	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted
Year 0																										
Apr.							1	15.3					1	17.7												
May							1	1.6					8	45.4												
Jun.							9	6.6					24	10.6												
Jul.			2	23.7			8	1.9					35	13.3	11	7.9									6	10.0
Aug.			8	16.5			7	3.1	2	18.1	8	16.4	22	32.6	24	40.9	7	35.8							38	36.2
Sep.			17	11.5			3	2.0	7	8.2	9	12.7	9	11.2	8	11.4	8	13.5							8	7.3
Oct.	5	5.8	13	6.7	10	13.1	2	0.6	18	3.8	18	8.1	17	3.3	11	2.5	19	5.1	27	23.8					8	4.9
Nov.	13	9.0	16	13.2	4	4.1			1	1.0	3	3.0	12	3.7	7	2.5	16	6.7	24	27.2	28	35.0			6	5.6
Dec.	27	14.5	24	12.1	23	9.1							12	2.8	5	1.3	10	3.1	51	42.8	111	84.5	28	25.0	2	1.3
Year 1																										
Jan.	34	32.9	18	14.2	15	8.4			1	0.5	1	1.0	4	3.3	1	1.0	2	2.3	2	6.1	8	22.1	2	4.5	2	4.0
Feb.	6	14.9	5	4.9	4	2.8	2	2.0					2	2.0							4	4.0	5	5.0	1	1.3
Mar.	3	3.0			2	19.6									2	1.5	1	0.9	2	4.9	3	6.6	1	1.8		
Apr.	2	4.8			1	1.9											1	0.5	3	4.1	7	8.6	9	9.1		
May	3	8.2																	1	1.2	4	4.4				
Jun.	3	3.9	1	1.2					1	0.1	1	0.3											1	0.6	1	1.4
Jul.	1	0.8																								
Aug.																	1	0.3			1	0.7				
Sep.																										
Oct.									1	0.1	1	0.2					2	0.4								
Nov.	1	0.6							1	0.1	1	0.3														
Dec.	1	0.4															1	0.2								
Year 2																										
Jan.																	2	1.3								
Total	99	98.8	104	104.0	59	59.0	33	33.1	32	31.9	42	42.0	146	145.9	69	69.0	70	70.1	110	110.1	166	165.9	46	46.0	72	72.0

TABLE 6. Returns by month of recapture for tagged skipjack released in the Peru area and recaptured in the same area.

Month	Apr.-Jun.1957		Jul.-Sep.1957		Oct.-Dec.1957		Apr.-Jun. 1958	
	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted
Year 0								
Jun.	4.1	14.6					6	12.2
Jul.	21.6	15.6	12	13.7			25	19.1
Aug.	2.1	3.3	23	26.3			5	4.7
Sep.			9	9.8			4	2.6
Oct.	7.2	3.1	4	1.0	9	24.8	1	3.3
Nov.	2.1	1.1	4	1.2	19	7.5		
Dec.	1.0	1.5						
Year 1								
Jan.					6	1.7		
Feb.	1	0.6						
Mar.							2	1.1
Apr.								
May								
Jun.	1	0.3						
Total	40.1	40.1	52	52.0	34	34.0	43	43.0

TABLE 7. Total logged fishing effort exerted in the Baja California and Revillagigedo Islands areas during August 1957-August 1959, April 1960-November 1965, and June 1973-April 1974.

Month	Purse seine f_{PSPS}	Purse seine f_{PSBB}	Baitboat f_{BBBB}	Total $f_{(PS+BB)BB}$
		1957		
Aug.	26.0	9.1	706.8	715.9
Sep.	0.0	0.0	386.1	386.1
Oct.	0.0	0.0	408.7	408.7
Nov.	93.0	1.9	712.1	714.0
Dec.	135.5	4.1	559.2	563.3
		1958		
Jan.	64.0	5.1	420.7	425.8
Feb.	270.0	59.4	299.5	358.9
Mar.	48.0	0.5	397.2	397.7
Apr.	14.0	0.1	382.8	382.9
May	9.0	0.1	545.9	546.0
Jun.	223.0	95.9	658.5	754.4
Jul.	86.0	22.4	950.1	972.5
Aug.	154.0	63.1	911.8	974.9
Sep.	5.0	3.9	561.8	565.7
Oct.	81.0	121.5	854.6	976.1
Nov.	56.0	19.6	728.9	748.5
Dec.	32.0	16.3	403.5	419.8
		1959		
Jan.	35.0	0.4	145.9	146.3
Feb.	22.0	0.2	124.8	125.0
Mar.	8.0	0.1	165.6	165.7
Apr.	91.5	0.9	193.8	194.7
May	137.5	1.4	214.2	215.6
Jun.	0.0	0.0	87.0	87.0
Jul.	402.0	442.2	89.4	531.6
Aug.	369.0	258.3	460.8	719.1

Month	Purse seine f_{PSPS}	Baitboat f_{BBBB}	Baitboat f_{BBPS}	Total $f_{(PS+BB)PS}$
		1960		
Apr.	97.5	34.9	118.3	215.8
May	12.0	48.7	192.4	204.4
Jun.	274.5	151.6	256.2	530.7
Jul.	726.0	292.0	432.2	1,158.2
Aug.	445.0	113.9	184.5	629.5
Sep.	140.5	158.4	243.9	384.4
Oct.	36.5	147.4	359.7	396.2
Nov.	65.5	296.7	813.0	878.5
Dec.	11.0	84.0	418.3	429.3
		1961		
Jan.	45.5	91.9	1,157.0	1,202.5
Feb.	45.5	32.3	216.7	262.2
Mar.	17.0	35.8	102.7	119.7
Apr.	223.0	113.8	570.1	793.1
May	204.0	130.2	630.2	834.2
Jun.	421.5	246.8	1,026.7	1,448.2
Jul.	487.0	142.8	991.0	1,478.0
Aug.	216.5	266.4	578.1	794.6
Sep.	360.0	169.5	318.7	678.7
Oct.	298.0	121.9	207.2	505.2
Nov.	72.5	237.5	325.4	397.9
Dec.	28.0	43.7	87.4	115.4
		1962		
Jan.	60.0	98.2	159.1	219.1
Feb.	35.5	100.2	574.1	609.6
Mar.	139.0	40.5	122.3	261.3
Apr.	238.0	88.3	896.2	1,134.2
May	310.5	58.8	187.6	498.1
Jun.	589.5	134.6	339.2	928.7
Jul.	335.5	121.2	322.4	657.9
Aug.	314.5	139.9	338.6	653.1
Sep.	404.0	73.0	124.1	528.1
Oct.	327.0	116.1	265.9	592.9
Nov.	258.0	105.1	346.8	604.8
Dec.	171.0	122.2	444.8	615.8
		1963		
Jan.	304.5	47.8	154.4	458.9
Feb.	206.0	9.2	196.0	402.0
Mar.	113.0	3.2	4.2	117.2
Apr.	103.0	19.4	30.8	133.8
May	181.0	97.8	195.6	376.6
Jun.	162.0	108.1	228.1	390.1
Jul.	372.0	105.2	175.7	547.7
Aug.	499.5	104.9	122.7	622.2
Sep.	489.5	135.7	203.6	695.8
Oct.	491.5	93.3	178.2	669.7
Nov.	432.0	125.9	175.0	607.0
Dec.	99.0	54.6	183.5	282.5

TABLE 7 (continued).

Month	Purse seine f_{PSPS}	Baitboat f_{BBBB}	f_{BBPS}	Total $f_{(PS+BB)PS}$
		1964		
Jan.	51.0	0.9	3.7	54.7
Feb.	199.0	19.2	93.5	292.5
Mar.	138.0	26.9	63.5	201.5
Apr.	38.0	101.8	192.4	230.4
May	116.5	107.2	201.5	318.0
Jun.	401.0	244.0	507.5	908.5
Jul.	664.0	84.4	166.3	830.3
Aug.	324.5	13.6	14.0	338.5
Sep.	436.5	4.0	4.8	441.3
Oct.	288.0	12.6	35.5	323.5
Nov.	189.0	64.7	102.2	291.2
Dec.	142.0	49.1	387.4	529.4
		1965		
Jan.	63.0	31.7	175.6	238.6
Feb.	82.0	42.9	1,045.9	1,127.9
Mar.	159.0	53.0	127.2	286.2
Apr.	97.0	89.1	529.3	626.3
May	189.0	134.0	1,120.2	1,309.2
Jun.	410.0	175.8	344.6	754.6
Jul.	757.0	173.3	332.7	1,089.7
Aug.	222.0	194.4	301.3	523.3
Sep.	439.0	132.1	188.9	627.9
Oct.	447.5	214.5	360.4	807.9
Nov.	473.5	139.2	718.3	1,191.8

Month	Purse seine f_{PSPS}	f_{PSBB}	Baitboat f_{BBBB}	Total $f_{(PS+BB)BB}$
		1973		
Jun.	172.0	29.2	209.9	239.1
Jul.	129.0	51.6	220.2	271.8
Aug.	143.5	40.2	98.9	139.1
Sep.	79.0	41.1	38.1	79.2
Oct.	58.0	3.5	172.8	176.3
Nov.	61.5	17.2	255.6	272.8
Dec.	25.0	7.5	108.0	115.5
		1974		
Jan.	188.0	88.4	82.3	170.7
Feb.	58.0	17.4	166.5	183.9
Mar.	131.0	100.9	127.3	228.2
Apr.	37.5	37.5	287.6	325.1

TABLE 8. Total logged fishing effort exerted for tagged fish released in the Gulf of Panama area during April 1959-July 1960 and May 1961-March 1962.

Month	Purse seine f_{PSPS}	Purse seine f_{PSBB}	Baitboat f_{BBBB}	Total $f_{(PS+BB)BB}$
		1959		
Apr.	15.0	30.0	64.7	94.7
May	5.0	11.0	480.6	491.6
Jun.	11.0	19.8	18.4	38.2
Jul.	20.0	56.0	95.5	151.5
Aug.	36.0	61.2	261.3	322.5
Sep.	50.5	80.8	410.8	491.6
Oct.	25.0	16.6	215.5	232.1
Nov.	22.0	25.3	331.3	356.6
Dec.	1.0	0.2	546.4	546.6
		1960		
Jan.	8.0	18.4	445.9	464.3
Feb.	7.0	8.4	164.0	172.4
Mar.	4.0	6.0	10.5	16.5
Apr.	21.0	45.1	200.4	245.5
May	24.0	40.8	329.7	370.5
Jun.	27.0	48.6	95.7	144.3
Jul.	13.0	29.9	83.7	113.6

Month	Purse seine f_{PSPS}	Baitboat f_{BBBB}	Baitboat f_{BBPS}	Total $f_{(PS+BB)PS}$
		1961		
May	481.5	111.0	162.1	643.6
Jun.	130.5	17.0	20.1	150.6
Jul.	409.0	35.4	56.3	465.3
Aug.	693.5	59.3	116.2	809.7
Sep.	487.0	138.3	254.5	741.5
Oct.	829.5	74.3	185.0	1,014.5
Nov.	704.5	0.0	0.0	704.5
Dec.	373.5	8.3	9.8	383.3
		1962		
Jan.	178.0	33.1	72.8	250.8
Feb.	631.5	11.3	24.7	656.2
Mar.	1,061.5	81.9	178.5	1,240.0

TABLE 9. Total logged fishing effort by large purse seiners and baitboats plus estimated total fishing effort by large and small purse seiners and baitboats in the Gulf of Guayaquil area during October 1958-June 1960 (in Class-4 baitboat units) and April 1960-June 1963 (in purse-seine units).

Date		Large								Small			Total	
		Catch			Effort				C/f	Catch			Catch	Effort
		PS	BB	Total	PS f_{PSPS}	f_{PSBB}	BB f_{BBBB}	Total $f_{(PS+BB)BB}$		PS	BB	Total		
1958	Oct.	0.00	4,414.76	4,414.76	0.0	0.0	790.1	790.1	5.59	706.22	297.76	1,003.98	5,418.74	969.8
	Nov.	0.00	1,560.80	1,560.80	0.0	0.0	369.3	369.3	4.23	881.97	276.33	1,158.30	2,719.10	643.4
	Dec.	0.00	2,410.33	2,410.33	0.0	0.0	448.0	448.0	5.38	392.83	314.89	707.72	3,118.05	579.5
1959	Jan.	0.00	2,196.62	2,196.62	0.0	0.0	210.3	210.3	10.45	614.64	345.52	960.16	3,156.78	302.2
	Feb.	0.00	263.69	263.69	0.0	0.0	51.0	51.0	5.17	130.16	212.58	342.74	606.43	117.3
	Mar.	0.00	71.70	71.70	0.0	0.0	26.0	26.0	2.76	595.00	141.87	736.87	808.57	293.2
	Apr.	387.00	16.63	403.63	15.0	30.0	22.7	52.7	7.66	340.85	186.74	527.59	931.22	121.6
	May	205.00	170.20	375.20	5.0	11.0	30.9	41.9	8.95	325.35	252.13	577.48	952.68	106.4
	Jun.	230.00	37.20	267.20	11.0	19.8	5.9	25.7	10.40	590.00	1,451.20	2,041.20	2,308.40	222.0
	Jul.	875.00	495.38	1,370.38	20.0	56.0	70.4	126.4	10.84	745.66	1,728.10	2,473.76	3,844.14	354.6
	Aug.	653.66	3,306.07	3,959.73	36.0	61.2	247.1	308.3	12.84	354.21	872.62	1,226.83	5,186.56	403.8
	Sep.	882.00	2,460.16	3,342.16	47.5	80.8	396.7	477.5	7.00	398.25	783.21	1,181.46	4,523.62	646.3
	Oct.	91.23	352.90	444.13	24.0	16.3	191.6	207.9	2.14	156.62	975.70	1,132.32	1,576.45	737.9
	Nov.	290.00	1,669.10	1,959.10	14.0	25.2	306.7	331.9	5.90	182.18	573.46	755.64	2,714.74	459.9
	Dec.	0.00	2,469.45	2,469.45	0.0	0.0	502.8	502.8	4.91	545.63	667.78	1,213.41	3,682.86	749.9
1960	Jan.	263.05	1,952.24	2,215.29	8.0	18.4	386.7	405.1	5.47	396.49	6.12	402.57	2,617.86	478.7
	Feb.	96.00	143.69	239.69	7.0	8.4	93.3	101.7	2.36	361.51	308.28	669.79	909.48	385.9
	Mar.	120.00	0.00	120.00	4.0	6.0	0.0	6.0	20.00	120.78	305.24	426.02	546.02	27.3
	Apr.	716.00	198.30	914.30	14.0	40.6	40.1	80.7	11.33	264.85	438.80	703.65	1,617.95	142.8
	May	450.15	337.50	787.65	24.0	40.8	52.0	92.8	8.49	426.07	1,251.35	1,677.42	2,465.07	290.4
	Jun.	567.16	371.30	938.46	27.0	48.6	44.9	93.5	10.04	440.73	1,721.06	2,161.79	3,100.25	308.9

Date		Catch			Effort				C/f	Catch			Catch	Effort
		PS	BB	Total	PS f_{PSPS}	BB f_{BBBB}	f_{BBPS}	Total $f_{(PS+BB)PS}$		PS	BB	Total		
1960	Apr.	716.00	198.30	914.30	14.0	40.1	77.0	91.0	10.05	264.85	438.80	703.65	1,617.95	161.0
	May	450.15	337.50	787.65	24.0	52.0	77.0	101.0	7.80	426.07	1,251.35	1,677.42	2,465.07	316.0
	Jun.	567.16	371.30	938.46	27.0	44.9	53.4	80.4	11.67	440.73	1,721.06	2,161.79	3,100.25	265.7
	Jul.	416.82	171.20	588.02	13.0	66.8	176.4	189.4	3.10	538.28	528.09	1,066.37	1,654.37	533.7
	Aug.	150.00	428.70	578.70	5.0	65.6	91.2	96.2	6.02	336.72	788.05	1,124.77	1,703.47	283.0
	Sep.	0.00	182.40	182.40	0.0	33.1	52.3	52.3	3.49	117.36	359.02	476.38	658.78	188.8
	Oct.	0.00	190.80	190.80	0.0	40.9	74.8	74.8	2.55	250.91	548.54	799.45	990.25	388.3
	Nov.	0.00	3.20	3.20	0.0	3.1	14.6	14.6	0.22	127.19	509.56	636.75	639.95	–
	Dec.	0.00	0.00	0.00	0.0	0.0	0.0	0.0	–	145.65	532.69	678.34	678.34	–

TABLE 9 (continued).

Date	Large								Small			Total	
	Catch			Effort				C/f	Catch			Catch	Effort
	PS	BB	Total	PS f_{PSPS}	BB f_{BBBB}	f_{BBPS}	Total $f_{(PS+BB)PS}$		PS	BB	Total		
1961 Jan.	0.00	330.50	330.50	0.0	31.4	41.4	41.4	7.98	483.00	513.51	996.51	1,327.01	166.3
Feb.	0.00	0.00	0.00	0.0	2.4	6.3	6.3	0.00	169.40	122.47	291.87	291.87	-
Mar.	0.00	0.00	0.00	0.0	0.0	0.0	0.0	-	104.52	2.73	107.25	107.25	-
Apr.	353.00	214.80	567.80	8.0	32.2	34.1	42.1	13.49	258.73	873.23	1,131.96	1,699.76	126.0
May	1,768.00	99.70	1,867.70	47.0	4.8	1.5	48.5	38.51	687.11	1,819.99	2,507.10	4,374.80	113.6
Jun.	6,499.88	397.10	6,896.38	325.0	70.5	69.8	394.8	17.47	1,082.27	2,446.16	3,528.43	10,424.81	596.7
Jul.	1,657.10	373.70	2,030.80	174.5	64.0	94.7	269.2	7.54	86.58	1,745.52	1,832.10	3,862.90	512.3
Aug.	209.50	261.10	470.60	14.5	27.0	28.6	43.1	10.92	284.46	679.55	964.01	1,434.61	131.4
Sep.	23.00	412.80	435.80	7.0	38.4	37.2	44.2	9.86	324.68	787.55	1,112.23	1,548.05	157.0
Oct.	0.00	305.50	305.50	0.0	70.7	127.3	127.3	2.40	840.24	1,238.44	2,078.68	2,384.18	993.4
Nov.	1,101.50	323.00	1,424.50	78.0	111.3	262.7	340.7	4.18	292.09	910.70	1,202.79	2,627.29	628.5
Dec.	4,013.46	171.00	4,184.46	422.5	57.2	133.3	555.8	7.53	508.06	1,703.18	2,211.24	6,395.70	849.4
1962 Jan.	85.00	37.00	122.00	54.5	7.8	23.7	78.2	1.56	129.57	113.54	243.11	365.11	234.0
Feb.	2.00	0.00	2.00	6.0	5.4	31.8	37.8	0.05	150.13	75.80	225.93	227.93	-
Mar.	135.07	6.30	141.37	74.0	11.0	63.7	137.7	1.03	16.93	143.95	160.88	302.25	293.4
Apr.	1,861.25	0.00	1,861.25	395.5	11.3	41.6	437.1	4.26	60.06	317.31	377.37	2,238.62	525.5
May	1,711.13	45.00	1,756.13	236.0	6.0	9.4	245.4	7.16	272.20	2,213.13	2,485.33	4,241.46	592.4
Jun.	4,781.34	51.30	4,832.64	353.5	38.0	163.4	516.9	9.35	40.37	3,086.00	3,126.37	7,959.01	851.2
Jul.	6,149.39	9.10	6,158.49	486.0	24.7	245.8	731.8	8.42	114.35	1,590.05	1,704.40	7,862.89	933.8
Aug.	5,269.05	40.30	5,309.35	503.0	43.1	227.6	730.6	7.27	435.51	643.11	1,078.62	6,387.97	878.7
Sep.	3,310.43	21.60	3,332.03	346.0	42.5	321.7	667.7	4.99	214.44	1,065.91	1,280.35	4,612.38	924.3
Oct.	1,272.02	31.10	1,303.12	281.0	50.1	332.7	613.7	2.12	493.66	1,083.34	1,577.00	2,880.12	1,354.5
Nov.	1,586.51	74.10	1,660.61	365.0	48.6	190.0	555.0	2.99	307.46	737.14	1,044.60	2,705.21	904.8
Dec.	511.65	3.00	514.65	270.0	20.8	376.5	646.5	0.80	151.26	337.33	488.59	1,003.24	1,254.1
1963 Jan.	1,629.60	0.00	1,629.60	241.0	0.0	0.0	241.0	6.76	528.48	694.53	1,223.01	2,852.61	422.0
Feb.	887.04	0.00	887.04	214.0	9.5	231.6	445.6	1.99	352.06	43.99	396.05	1,283.09	644.8
Mar.	1,581.50	0.00	1,581.50	161.0	0.0	0.0	161.0	9.82	462.87	298.47	761.34	2,342.84	238.6
Apr.	864.47	25.50	889.97	277.5	24.0	124.8	402.3	2.21	12.86	751.42	764.28	1,654.25	748.5
May	2,807.00	47.70	2,854.79	112.5	34.5	133.5	246.0	11.60	783.38	4,577.01	5,360.39	8,215.18	708.2
Jun.	8,747.80	2.00	8,749.80	354.0	6.5	68.8	422.8	20.69	1,956.93	1,824.34	3,781.27	12,531.07	605.7

TABLE 10. Total logged fishing effort exerted in the Peru area during April 1957-March 1959.

Month	Purse seine f_{PSPS}	Purse seine f_{PSBB}	Baitboat f_{BBBB}	Total $f_{(PS+BB)BB}$
		1957		
Apr.	0.0	0.0	2.6	2.6
May	0.0	0.0	30.7	30.7
Jun.	0.0	0.0	36.4	36.4
Jul.	0.0	0.0	101.9	101.9
Aug.	0.0	0.0	46.3	46.3
Sep.	0.0	0.0	39.6	39.6
Oct.	0.0	0.0	169.1	169.1
Nov.	0.0	0.0	146.5	146.5
Dec.	0.0	0.0	49.2	49.2
		1958		
Jan.	4.0	1.6	179.3	180.9
Feb.	0.0	0.0	133.0	133.0
Mar.	0.0	0.0	272.8	272.8
Apr.	0.0	0.0	151.0	151.0
May	0.0	0.0	11.1	11.1
Jun.	0.0	0.0	241.9	241.9
Jul.	0.0	0.0	297.0	297.0
Aug.	0.0	0.0	244.0	244.0
Sep.	0.0	0.0	353.6	353.6
Oct.	0.0	0.0	68.4	68.4
Nov.	0.0	0.0	117.8	117.8
Dec.	0.0	0.0	18.0	18.0
		1959		
Jan.	0.0	0.0	6.6	6.6
Feb.	0.0	0.0	3.1	3.1
Mar.	0.0	0.0	395.3	395.3

TABLE 11. Estimates of the coefficients of total mortality and emigration plus shedding, and the upper and lower 95-percent confidence limits, for tagged skipjack.

Area	Date of release	Tag type	Released	Returned	Not truncated			Truncated		
					Z_m'''	Z_{mL}'''	Z_{mU}'''	Z_m'	Z_{mL}'	Z_{mU}'
Baja California	Aug.-Dec. 1957	loop	1,489	106	0.446	0.358	0.534	0.533	0.384	0.681
	May -Sep. 1958	loop	10,427	144	0.728	0.461	0.994	0.889	0.499	1.278
	Aug.-Sep. 1960	dart	471	113	0.418	0.138	0.697	0.921	-0.047	1.888
	Jun. 1962	dart	3,856	1,009	1.003	0.858	1.149	1.110	0.933	1.286
	Jun.-Jul. 1963	dart	1,086	511	1.033	0.937	1.129	1.071	0.967	1.174
		dart + loop	157	25	1.674	0.848	2.501	1.664	0.816	2.511
		double dart	261	110	0.959	0.767	1.150	0.943	0.743	1.144
		total	1,504	646	0.902	0.771	1.034	0.947	0.790	1.103
	Jun.-Jul. 1973	dart	1,863	443	1.002	0.801	1.203	0.836	0.383	1.289
Revillagigedo Islands	Apr. 1960	dart	1,720	80	0.571	0.289	0.853	0.216	-0.218	0.650
		total	2,366	102	0.599	0.301	0.897	0.280	-0.164	0.723
	Jun. 1965	single dart	217	26	0.860	0.470	1.251	0.816	0.375	1.257
		total	430	41	1.004	0.640	1.368	0.978	0.585	1.372
Gulf of Panama	Apr. 1959	loop	4,446	122	0.310	0.227	0.392	0.599	0.255	0.943
	(method of Joseph and Calkins, 1969)				0.391	0.314	0.467	0.379	0.218	0.540
	Apr.-May 1961	dart	3,325	79	0.377	0.288	0.466	0.077	-0.095	0.248
	(method of Joseph and Calkins, 1969)				0.381	0.289	0.473	0.227	0.043	0.411
Gulf of Guayaquil	Oct.-Dec. 1958	loop	2,596	99	0.507	0.383	0.631	0.984	0.548	1.421
	Jul.-Sep. 1959	loop	3,735	104	0.290	0.232	0.347	0.147	0.016	0.277
	Oct.-Dec. 1959	loop	976	59	0.295	0.217	0.372	-0.090	-0.246	0.066
	Apr.-Jun. 1960	loop	1,038	33	0.292	0.151	0.433	0.056	-0.309	0.420
	Jul.-Sep. 1960	dart	650	32	0.781	0.490	1.072	0.853	0.500	1.205
		total	1,273	42	0.564	0.385	0.742	0.589	0.346	0.832
	Apr.-Jun. 1961	dart	1,719	146	0.371	0.305	0.437	0.204	0.068	0.341
	Jul. 1961	dart	696	69	0.565	0.303	0.827	0.729	0.188	1.271
	Aug. 1961	dart	1,022	70	0.351	0.229	0.473	0.408	0.122	0.693
	Oct. 1961	dart	339	110	0.439	0.214	0.664	0.026	-0.717	0.770
	Nov. 1961	dart	814	166	0.521	0.364	0.677	0.360	0.065	0.656
	Dec. 1961	dart	197	46	0.407	0.225	0.520	0.096	-0.220	0.412
	Jul. 1962	dart	171	72	0.367	0.219	0.514	0.330	-0.104	0.764
Peru	Apr.-Jun. 1957	loop	2,911	40	0.512	0.347	0.678	0.575	0.324	0.826
	Jul.-Sep. 1957	loop	1,973	52	1.189	0.766	1.612	1.181	0.737	1.625
	Oct.-Dec. 1957	loop	984	34	1.236	0.764	1.708	1.244	0.758	1.730
	Apr.-Jun. 1958	loop	2,045	43	0.698	0.435	0.961	0.822	0.440	1.203

TABLE 12. Data used for comparison of Z_m'''' and $\overline{f}_m$ values.

Area	Date of release		$\overline{f}_m$	Z_m'''	Z_m''''
Baja California	Aug.-Sep.	1960	592.2	0.418	0.418
	Jun.	1962	660.9	1.003	1.003
	Jun.-Jul.	1963	588.8	0.902	0.906
Revillagigedo Islands	Apr.	1960	520.5	0.599	0.599
	Jun.	1965	832.5	1.004	1.013
Gulf of Guayaquil	Apr.-Jun.	1960	291.4	0.292	0.292
	Jul.-Sep.	1960	256.6	0.564	0.564
	Apr.-Jun.	1961	272.8	0.371	0.371
	Jul.	1961	545.3	0.565	0.565
	Aug.	1961	499.0	0.351	0.351
	Oct.	1961	599.7	0.439	0.439
	Nov.	1961	506.2	0.521	0.521
	Dec.	1961	498.9	0.407	0.407
	Jul.	1962	1,041.7	0.367	0.367
Peru	Apr.-Jun.	1957	90.0	0.512	0.512
	Jul.-Sep.	1957	92.1	1.189	1.189
	Oct.-Dec.	1957	158.6	1.236	1.236
	Apr.-Jun.	1958	220.4	0.698	0.698

TABLE 13. Data used for estimation of q.

Area	Date of release		Z_m''''	F_m	$\overline{f}_m$	$q \times 10^4$ PS-3 units	$q \times 10^4$ BB-4 units
Baja California	Aug.-Dec.	1957	0.446	0.216	535.6		4.0
	May -Sep.	1958	0.728	0.498	832.0		6.0
	Aug.-Sep.	1960	0.418	0.188	592.2	3.2	
	Jun.	1962	1.003	0.773	660.9	11.7	
	Jun.-Jul.	1963	0.906	0.676	588.9	11.5	
	Jun.-Jul.	1973	1.002	0.772	196.4		39.3
Revillagigedo Islands	Apr.	1960	0.599	0.369	520.5	7.1	
	Jun.	1965	1.013	0.783	832.5	9.4	
Gulf of Panama	Apr.	1959	0.310	0.080	265.0		3.0
(method of Joseph and Calkins, 1969)			0.391	0.161	195.7		8.2
	Apr.-May	1961	0.377	0.147	637.5	2.3	
(method of Joseph and Calkins, 1969)			0.381	0.151	272.1	5.5	
Gulf of Guayaquil	Oct.-Dec.	1958	0.507	0.277	484.2		5.7
	Jul.-Sep.	1959	0.290	0.060	558.7		1.1
	Oct.-Dec.	1959	0.295	0.065	473.3		1.4
	Apr.-Jun.	1960	0.292	0.062	291.4	2.1	
	Jul.-Sep.	1960	0.564	0.334	256.6	13.0	
	Apr.-Jun.	1961	0.371	0.141	272.8	5.2	
	Jul.	1961	0.565	0.335	545.3	6.1	
	Aug.	1961	0.351	0.121	499.0	2.4	
	Oct.	1961	0.439	0.209	599.7	3.5	
	Nov.	1961	0.521	0.291	506.2	5.7	
	Dec.	1961	0.407	0.177	498.9	3.5	
	Jul.	1962	0.367	0.137	1,041.7	1.3	
Peru	Apr.-Jun.	1957	0.512	0.282	90.0		31.3
	Jul.-Sep.	1957	1.189	0.959	92.1		104.1
	Oct.-Dec.	1957	1.236	1.006	158.6		63.4
	Apr.-Jun.	1958	0.698	0.468	220.4		21.2

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