INTER-AMERICAN TROPICAL TUNA COMMISSION
COMISION INTERAMERICANA DEL ATUN TROPICAL

INTERNAL REPORT--INFORME INTERNO

No. 18

MIGRATIONS OF YELLOWFIN AND SKIPJACK TUNA RELEASED IN THE CENTRAL PORTION OF THE EASTERN PACIFIC OCEAN, AS DETERMINED BY TAGGING EXPERIMENTS

by

William H. Bayliff

La Jolla, California
1984

PREFACE

The Internal Report series is produced primarily for the convenience of staff members of the Inter-American Tropical Tuna Commission. It contains reports of various types. Some will eventually be modified and published in the Commission's Bulletin series or outside journals. Others are methodological reports of limited interest or reports of research which yielded negative or inconclusive results.

These reports are not to be considered as publications. Because they are in some cases preliminary, and because they are subjected to less intensive editorial scrutiny than contributions to the Commission's Bulletin series, it is requested that they not be cited without permission from the Inter-American Tropical Tuna Commission.

PREFACIO

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ABSTRACT

Three methods, the map method, the portion-in-area method, and the Jones method, were used to analyze data on the migrations of yellowfin, Thunnus albacares, and skipjack, Katsuwonus pelamis, tuna obtained from recovery of tagged fish released in the central portion of the eastern Pacific Ocean. Yellowfin migrate further to the northwest than do skipjack, which is not surprising in view of the fact that yellowfin are abundant in the area of very warm water off southern Mexico, whereas skipjack rarely occur there. Skipjack, however, were recaptured in the central Pacific Ocean, whereas yellowfin were not. The areas of recapture varied among years, which was due partly to differences in the behavior of the fish in different years and partly to differences in the distribution of the fishing effort. In one instance significantly different migrations were found for yellowfin of different sizes released in the same area on the same dates. The yellowfin data do not refute the conclusion from previous studies that there are three semi-independent stocks of this species inhabiting the eastern, central, and western Pacific Ocean, respectively. It appears that the skipjack of the northeastern and southeastern Pacific are parts of a single group inhabiting an arc-shaped area with its tips at those two areas, and that the fish at the ends of the distribution mix to at least some extent on the spawning grounds of the central and/or western Pacific.

INTRODUCTION

The migrations of yellowfin, Thunnus albacares, and skipjack, Katsuwonus pelamis, tuna in the eastern Pacific Ocean have been studied by Blunt and Messersmith (1960), Schaefer, Chatwin, and Broadhead (1961), and Fink and Bayliff (1970). The migrations of yellowfin in the central area (off southern Mexico and northern Central America and offshore) have been studied by Bayliff and Rothschild (1974) and Bayliff (1979). The first three studies are inadequate for present needs for two reasons. First, they employ only data collected during the 1950's and early 1960's, when the fishery for tunas was conducted only within a few hundred miles of the mainland and in the vicinity of a few offshore islands and banks (Alverson, 1960 and 1963; Calkins and Chatwin, 1967). Since then the purse-seine fleet has expanded its operations

much further offshore (Calkins and Chatwin, 1971; Calkins, 1975; Orange and Calkins, 1981), which has had a profound effect on the management of the resources (Anonymous, 1982). Second, the distributions of the tag returns by area and time were examined without attempting to adjust for the effects of uneven distribution of fishing effort. These inadequacies were at least partially overcome in the last two studies, but these include only yellowfin in the central area of the fishery. The present study involves both yellowfin and skipjack tagged and released mostly in areas other than those employed in the studies of Bayliff and Rothschild (1974) and Bayliff (1979).

ACKNOWLEDGEMENTS

Acknowledgement is extended to the many members of the Tuna Commision's staff who participated in the tagging of the fish. Appreciation is likewise expressed to the captains and crews of the vessels of the fishing fleet which were used in the tagging experiments. The indispensable cooperation of the fishermen, unloaders, and cannery workers in returning the tags when the fish were recovered, together with the pertinent information, is also acknowledged with gratitude. The manuscript was reviewed by Dr. Pierre M. Kleiber and Mr. Michael D. Scott, each of whom contributed several valuable suggestions for its improvement.

MATERIALS AND METHODS

The methods of tagging the fish and handling the tag return data are described by Fink (1965), Fink and Bayliff (1970), Bayliff (1973 and 1979), and Anonymous (1982). The methods of collecting and handling the catch and effort statistics are discussed by Shimada and Schaefer (1956) and Joseph and Calkins (1969). Computer program CIAT F04A (Psaropulos, 1966) was used to perform most of the calculations.

DATA EMPLOYED

Tag releases and returns

The tag release and return data are shown in Figures 1 and 2 and

summarized in Table 1. These do not necessarily include all the releases and returns for the tagging cruises listed in that table, as data for the releases in areas other than those under consideration are not shown, and the tag returns for which information as to the areas of recapture of the fish was unavailable do not appear in the figures. Also, the figures and table do not include all the releases and returns for the areas in question, as the data for cruises which produced few returns from the releases in those areas are not considered in this report.

During the 1966-early 1980 period the fishery for yellowfin in the eastern Pacific Ocean was regulated (Cole, 1980) by an annual quota on the total catch of that species in the Commission's Yellowfin Regulatory Area (CYRA) (Anonymous, 1982: Figure 1). Vessels which left port prior to the date that regulation began could fish without restriction until that fishing trip was completed; also, vessels which were in port on that date could fish without restriction on their next trips, provided they left port within 30 days. With certain exceptions, vessels which did not meet either of these requirements were subject to various restrictions after the date the regulation began (until the next year or until they returned to port to unload, whichever occurred later). However, the restrictions applied to only a portion of the eastern Pacific Ocean, so if a vessel fished in both regulated and unregulated areas on the same trip it was subject to regulation only when it fished in the regulated area. There were no regulations for vessels leaving port during 1980 or subsequent years, but vessels which were at sea and subject to regulation at the end of 1979 were subject to regulation during 1980 until they returned to port to unload. Accordingly, the vessels which were subject to regulation devoted a considerable portion of their effort to the capture of species other than yellowfin or skipjack, and for that reason the tag return data for regulated portions of trips are not used in this study, except in Figures 1 and 2 and Table 1. Also, the tag return data for baitboat-caught fish of Cruises 1084, 1089, 1095, and 1096 were not used, for a reason to be explained on page 7.

Statistics of the fishery

The statistical data routinely collected by the Tuna Commission include

the logged catches in short tons of yellowfin, skipjack, and other species of tunas 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, transferred to other vessels, or received from other vessels); or (3) the catch of species other than yellowfin or skipjack makes up more than one third of the total catch. The effort data in the system represent about 90 percent of the total effort for the periods in question, and are assumed to have the same distribution by area and time as the total effort.

It is necessary that the fishing effort for the area-time strata in which fish of a particular species and release were recaptured be standardized to one type of gear (baitboat or purse seine). The methods employed for this are discussed below.

Yellowfin

For yellowfin, Broadhead (1962) devised a method for converting Class-3 purse-seine effort to Class-4 baitboat effort and derived equations for doing this. Bayliff (1971) used Broadhead's method and data to derive equations for converting Class-4 baitboat effort to Class-3 purse-seine effort. For the present study the purse-seine effort data (standardized to Class-3 units) corresponding to the recaptures of yellowfin tagged during Cruises 1027 and 1031 were converted to Class-4 baitboat units, using separate purse-seine catch-per-unit-of-effort (CPUE) data for north of 15°N, 0°-15°N, and south of 0°. The baitboat effort data (standardized to Class-4 units) corresponding to recaptures of yellowfin tagged during Cruises 1036 through 1054, as listed in Table 1, were converted to Class-3 purse-seine units, using separate baitboat CPUE data for the same three major areas. The effort corresponding to the

recaptures of fish from Cruises 1027 and 1031 was standardized to baitboat units because baitboats were the predominant type of gear when these two experiments were carried out, and the effort corresponding to the recaptures of fish from Cruises 1038-1054 was standardized to purse-seine units because purse-seine vessels predominated during the period when those experiments were performed. During 1979-1982 baitboats accounted for an extremely small portion of the catch in the central portion of the eastern Pacific Ocean, which made it impractical to perform the calculations which follow for those years. Accordingly, the baitboat tag returns and effort for 1979-1982 were not considered in this report.

All unregulated effort for the trips which meet the criteria given at the beginning of the section entitled Statistics of the fishery is considered to be yellowfin effort.

For the major area between the equator and 15°N and the major area north of 15°N the logged catches of yellowfin in the major area by purse seiners (if the effort data were to be converted from purse-seine to baitboat units) or baitboats (if the effort data were to be converted from baitboat to purse-seine units) 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 total logged effort, converted to Class-4 baitboat days, for a given 5-degree area-month stratum for Cruises 1027 and 1031 was estimated by

$$f_{ijk(PS+BB)BB} = f_{ijkBBBB} + \frac{(C/f)_{jkPSPS}}{(C/f)_{..BB}} f_{ijkPSPS} \qquad (1)$$

where

$f_{ijk(PS+BB)BB}$ = total logged effort in 5-degree area i during month j of year k by purse seiners and baitboats in Class-4 baitboat days,

$f_{ijkBBBB}$ = total logged effort in 5-degree area i during month j of year k by baitboats in Class-4 baitboat days,

$(C/f)_{jkPSPS}$ = CPUE in the corresponding major area during month j of year k by purse seiners in Class-3 purse-seine days,

$(C/f)_{..BB}$ = CPUE corresponding to $(C/f)_{jkPSPS}$ in Class-4 baitboat days, estimated from Broadhead's (1962) formula $\log CPUE_{BB} = 0.031830 +$

$0.516606(\log CPUE_{PS})$, and

$f_{ijkPSPS}$ = total logged effort in 5-degree area i during month j of year k by purse seiners in Class-3 purse-seine days.

Similarly, the total logged effort in Class-3 purse-seine days for Cruises 1036-1054 was estimated by

$$f_{ijk(PS+BB)PS} = f_{ijkPSPS} + \frac{(C/f)_{jkBBBB}}{(C/f)..._{PS}} f_{ijkBBBB} \qquad (2)$$

where

$f_{ijk(PS+BB)PS}$ = total logged effort in area i during month j of year k by purse seiners and baitboats in Class-3 purse-seine days,

$f_{ijkPSPS}$ = total logged effort in area i during month j of year k by purse seiners in Class-3 purse-seine days,

$(C/f)_{jkBBBB}$ = CPUE in the corresponding major area during month j of year k by baitboats in Class-4 baitboat days,

$(C/f)..._{PS}$ = CPUE corresponding to C/f_{jkBBBB} in Class-3 purse-seine days, estimated from Bayliff's (1971) Formula (1), and

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

For the area south of the equator the situation is complicated by the fact that many small baitboats and purse seiners were fishing in that area during the years when tagging was conducted, and 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 area 2-05-080. (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 2-05-080 is the 5-degree area bounded on the south by 5°S and on the east by 80°W.) The effort data for the large vessels were calculated by a method similar to that used for the 5-degree areas north of the equator except that the CPUE values used to make the conversions were calculated for the major area south of 0°. For Cruises 1027 and 1031 the total logged effort by large purse seiners and baitboats plus the total effort by small purse seiners and baitboats, all in

Class-4 baitboat days, was estimated by dividing the total catch by the CPUE in Class-4 baitboat days, i.e.,

$$f_{ijk(PS+BB+ps+bb)BB} = \frac{C_{ijkPS} + C_{ijkBB} + C_{ijkps} + C_{ijkbb}}{(C_{ijkPS} + C_{ijkBB})/f_{ijk(PS+BB)BB}} \quad (3)$$

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 Cruises 1036-1054, the total logged effort by all vessels in Class-3 purse-seine days was estimated by dividing the total catch by the CPUE in Class-3 purse-seine days, i.e.,

$$f_{ijk(PS+BB+ps+bb)PS} = \frac{C_{ijkPS} + C_{ijkBB} + C_{ijkps} + C_{ijkbb}}{(C_{ijkPS} + C_{ijkBB})/f_{ijk(PS+BB)PS}} \quad (4)$$

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 Class-3 purse-seine days in area i during month j of year k.

Skipjack

Joseph and Calkins (1969) used Broadhead's (1962) method and skipjack catch and effort data to derive equations for converting unstandardized purse-seine effort to Class-4 baitboat effort for skipjack. For the present study the purse-seine effort data (unstandardized) corresponding to the recaptures of skipjack of Cruise 1027 were converted to baitboat units and the baitboat effort data (standardized to Class-4 units) corresponding to recaptures of skipjack of Cruises 1038-1054 were converted to purse-seine units, for the reason given in the previous section. 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 of Class-4 baitboat CPUE to unstandardized purse-seine CPUE

$$\log CPUE_{BB} = 0.585931 + 0.289918(\log CPUE_{PS}) \quad (5a)$$

or

$$CPUE_{BB} = 3.854(CPUE_{PS}^{0.289918}); \quad (5b)$$

relationship of unstandardized purse-seine CPUE to Class-4 baitboat CPUE

$$\log CPUE_{PS} = -0.201175 + 0.957709(\log CPUE_{BB}) \quad (6a)$$

or

$$CPUE_{PS} = 0.629(CPUE_{BB}^{0.957709}). \quad (6b)$$

These relationships are plotted in the left panel of Figure 4. 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 (5) 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 (6) 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 Class-4 baitboat CPUE to unstandardized purse-seine CPUE

$$\log CPUE_{BB} = 0.496412 + 0.429009(\log CPUE_{PS}) \quad (7a)$$

or

$$CPUE_{BB} = 3.136(CPUE_{PS}^{0.429009}); \quad (7b)$$

relationship of unstandardized purse-seine CPUE to Class-4 baitboat CPUE

$$\log CPUE_{PS} = -0.681928 + 1.67432(\log CPUE_{BB}) \quad (8a)$$

or

$$CPUE_{PS} = 0.208(CPUE_{BB}^{1.67432}). \quad (8b)$$

These relationships are plotted in the right panel of Figure 4. Obviously the lines coincide much more closely in the critical range of about 0 to 10 tons per day. For example, from (7) 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 (8) 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 (7) and (8) were adopted for conversion of effort data between gears.

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, only catch and effort data for areas where skipjack are frequently caught were employed for calculating the monthly CPUE values for the three major areas. The following 5-degree areas are considered to be those in which skipjack are frequently caught: areas east of 125°W, north of 20°N, and west of 110°W; 0-15-110; 0-15-115; 0-10-085; areas south of 10°N and east of 110°W. All unregulated effort for the trips which meet the criteria given at the beginning of the section entitled Statistics of the fishery is considered to be skipjack effort.

For what are considered to be skipjack fishing areas within the two major areas north of the equator 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 baitboat to purse-seine units) 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 total logged effort, converted to Class-4 baitboat days, for a given 5-degree area-month stratum for Cruise 1027 was estimated by Equation (1), where $(C/f)_{jkPSPS}$ is expressed in unstandardized purse-seine days instead of Class-3 purse-seine days. Similarly, the total logged effort in unstandardized purse-seine days for Cruises 1038-1054 was estimated by Equation (2), where $f_{ijk(PS+BB)PS}$, $f_{ijkPSPS}$, and $(C/f)_{..PS}$ are expressed in unstandardized purse-seine days instead of Class-3 purse-seine days.

For the area south of the equator the complication brought about by the existence of small boats, which was described in the yellowfin section, also exists for skipjack. For Cruise 1027 the total logged effort by large purse seiners and baitboats plus the total logged effort by small purse seiners and

baitboats, all in Class-4 baitboat days, was estimated by Equation (3). Similarly, for Cruises 1038-1054 the total logged effort by all vessels in unstandardized purse-seine days was estimated by Equation (4), where $f_{ijk)PS+BB+ps+bb)PS}$ is expressed in unstandardized purse-seine days instead of Class-3 purse-seine days.

RESULTS

Percentages of return

The percentages of return of the tagged fish of the various cruises are shown in Table 1. These percentages are known to be affected by the species, the gear used to capture the fish for tagging, the type of tag used, the skill of the tagger, the year of release, and the area and month of release.

In general, the percentages of return tend to be higher for yellowfin than for skipjack, though some exceptions can be noted in Table 1.

Also, the percentages of return tend to be higher for fish released from baitboats than for those released from purse seiners.

Loop tags were used for the fish released during Cruises 1027 and 1031 and dart tags were used for those released during the other cruises. Schaefer (1961) observed that the return percentages tended to be higher for fish with dart tags than for those with loop tags, and Bayliff and Mobrand (1972) showed that at least part of the difference was due to the fact that the shedding rate is greater for loop than for dart tags. Therefore, if all other things were equal, the return percentages should be lower for Cruises 1027 and 1031 than for the other cruises, which is apparently the case. Previous to 1969 virtually all the fish were single tagged, but beginning in that year most yellowfin were double tagged. Double tagging results in higher percentages of return for yellowfin (Bayliff, 1973), so the return percentages for yellowfin for the 1969-1981 cruises should be higher than those for the 1959-1968 cruises. It is not possible to measure the effect of the change from single to double tagging, however, due to confounding with the effect of year of release, which will be discussed below.

Fish released by some taggers shed their tags at greater rates than do those released by other taggers (Bayliff, 1973), so higher percentages of return are realized for the fish released by the more skilled taggers. (It would have been possible to evaluate the skill of each tagger on each trip by comparing the proportions of double-tagged fish recaptured with both or only one tag retained, but this was not done routinely because there was a high turnover in personnel used for tagging cruises and because many factors other than skill in applying tags had to be considered in selecting personnel for these cruises.)

The intensity of fishing has increased considerably since the late 1950's (Anonymous, 1982), which is undoubtedly an important cause of the increase in return percentages for the more recent years.

Fishing effort is not evenly distributed in the various areas of the eastern Pacific nor in the various months of the year. Such being the case, different return percentages result from releases made in different areas or at different times in the same year. Also, the vulnerability to capture of some groups of fish seems to vary considerably from month to month. This is particularly evident for the yellowfin of Cruises 1027 and 1038, which were captured in small numbers in the first months after tagging and in larger numbers in later months (Bayliff, 1974: Figure 10 and Table 5). The return percentages from a group of fish will obviously be higher if it is highly vulnerable to the fishery during the first months after release than if its vulnerability is low during that period.

In addition, for no apparent reason, the percentages of return are sometimes much greater or less than expected. The percentage of return for yellowfin of Cruise 1055 was high relative to those of yellowfin of other purse-seine cruises (Bayliff, 1973: Table 1), but the percentages of return were much lower for some sets of that cruise than for others (Bayliff, 1973: Table 4).

Migrations

When there is no fishery is existence a certain portion of the fish which

occur in Area A at Time 1 will occur later in Area B at Time 2. If a fishery then commences this portion can be estimated by releasing tagged fish in Area A and sampling the fish caught in Area B and in other areas for tags, and then dividing the number of tagged fish caught in Area B by the number of tagged fish caught in all areas combined. There are various biases which should be considered, however.

Some of the fish which are destined to migrate to Area B will be recaptured in Area A before they have a chance to do so, and others will be recaptured in the areas, if any, between Area A and Area B through which the fish must pass. If the fishery in all areas is light a greater portion of those destined to migrate to Area B will be recaptured there than if the fishery in all areas is heavy. If Areas B and C are equidistant from Area A the relative portions which migrate to each can be estimated without bias regardless of the intensity of the fishery, provided it is the same in all areas. If one is closer to Area A than the other, however, the bias will be increasingly in favor of the closer area with increasing intensity of fishing.

This situation is further complicated by the fact that neither the fishing effort nor the vulnerability of the fish to capture is the same in all area-time strata. If the numbers of tagged fish occurring in two area-time strata are the same and one has greater fishing effort or greater vulnerability of the fish to capture than the other, more tagged fish are likely to be recaptured in the first area than in the second. Estimates of the fishing effort are available for each area-time strata, and these have been used with the portion-in-area and Jones methods to adjust the data for recaptures of tagged fish to compensate for the fact that the effort is not equal in the various strata. Essentially, comparisons are made of the number of tagged fish returned per unit of effort in the various area-time strata, rather than the numbers of tagged fish returned in those strata. In some cases a small number of tag returns is divided by a low number of units of effort to produce a relatively high adjusted number of tag returns. The variability of such estimates is high, of course. No estimates of the vulnerability of the fish in the various area-time strata are available, however, so no adjustments to compensate for such differences can be made, and it is implicitly assumed that the vulnerability was constant, although it is

virtually certain that such was not the case.

The foregoing deficiencies should be borne in mind when reading the remainder of this section.

Map method

The geographic features discussed in this section are shown in Figure 3. The locations of release and recapture of the fish of each group of releases are shown in Figures 1 and 2. All the returns listed in Table 1 are included in these maps except those for which the locations of recapture are unknown. These maps give a useful impression of the distances and directions traveled, but do not express these parameters in quantitative terms. Furthermore, there is no provision for indicating the dates of recapture or times at liberty, and this could be done only by substituting several maps for each of the present maps. Monthly maps were drawn for the major releases, and these were consulted during the preparation of the discussion which follows, but they are not included in this report because that would make it unwieldy.

As mentioned above, the map method does not incorporate adjustments for differences in fishing effort among area-time strata, and this should be borne in mind when reading this section.

Yellowfin

Gulf of Panama

Fish were released in the Gulf of Panama during April-May of four years, 1959 (Figure 1a), 1961 (Figure 1b), 1962 (Figure 1c), and 1981 (Figure 1d), and also during September-October 1961 (Figure 1e). Most of the returns from the 1959 releases were from fish recaptured off Central America south of 10°N during October 1959-April 1960, off southern Mexico during December 1959-April 1960, and off Ecuador during October 1959-February 1960. The return from west of the Galapagos Islands was from a fish caught by a longline vessel in April 1962. The migrations exhibited by the fish released during April-May 1961 are among the most extensive recorded for any yellowfin experiment carried out by

the IATTC. There were five returns from fish recaptured off Costa Rica during April 1961, six returns from fish caught in the Gulf of Panama during May 1961, and one return from a fish caught off Ecuador during May 1961. Most of the returns from off Ecuador were from fish recaptured during June 1961-April 1962, however. Most of the returns from the Panama Bight, including the Gulf of Panama, were from fish caught during January-April 1962. All of the returns from off Central America for April-June 1961 were from fish recaptured east of 85°W, but in July and August 1961 fish had reached 92°W, just east of the Gulf of Tehuantepec, and in September 1961 and many of the succeeding months recaptures were made both east and west of the Gulf of Tehuantepec. The return from north of 20°N was from a fish caught during June 1962. Also, there were two returns from fish recaptured near Clipperton Island during January and March 1962 and one from a fish recaptured off northern Chile during February 1962. Most of the returns from the 1962 releases were from fish recaptured off Ecuador during June 1962-May 1963 and off Central America during the same period. The fish recaptured just west of the Gulf of Tehuantepec was caught during August 1962, and the two recaptured west of 100°W were caught during May 1963. The fish released during 1981 tended to remain in or return to the Gulf of Panama more than had those released there during 1959, 1961, and 1962. Sixty-two of them were recaptured in the Gulf of Panama during June, August, and September 1981, and seven more were recaptured there during April-June 1982. The returns from south of 4°N were all from fish recaptured during September-December 1981. All but three of the returns from west of 85°W were from fish recaptured during December 1981-May 1982. The one recaptured west of 105°W was caught during September 1981. Most of the returns from the September-October 1961 releases were from fish recaptured in the Panama Bight during December 1961-April 1962, off Central America during December 1961-March 1962, and off Ecuador during March-May 1962.

Most of the fish released in the Gulf of Panama during April-May 1961 were recaptured to the west and most of those released there during April-May 1962 were recaptured to the south. Those released in the Gulf of Panama during April 1959 and September-October 1961 were recaptured in about equal numbers in each direction. Disregarding those which remained in or returned to the Gulf of Panama, the portion of fish recaptured far offshore was far greater for the 1981 releases than for those of the earlier years. This is

not surprising, in view of the fact that much more fishing was conducted far offshore during the early 1980's than during the earlier period.

Southern Central America

Fish were released off southern Central America (between 4°N and 10°N) during February-April of four years, 1964 (Figures 1f and 1g), 1979 (Figure 1h), 1980 (Figure 1i), and 1981 (Figure 1j). The 1964 releases were made in two distinct areas, north-northeast of the Galapagos Islands (Figure 1f) and in the Punta Guionos-Cabo Blanco area (Figure 1g). Most of the returns from the releases in the first area were from fish recaptured in the same area during February-March 1964. During the early and middle 1960's tuna vessels did not usually fish far offshore, except in the vicinity of a few offshore islands and banks. The February-March returns all came from two baitboats, and all the fish were reported to have been caught at or near Brito Bank (5°29'N-88°32'W), Cocos Bank (4°58'N-87°26'W), or West Cocos Bank (5°40'N-88°53'W). The other four returns were from fish recaptured in various areas during August 1964-January 1966. The fish recaptured west of 100°W was caught during August 1965. Most of the returns from the releases in the second area were from fish recaptured in the same area during April-May 1964. All but one of the other returns were from fish caught to the west of the area of release during April 1964-March 1965. The migrations exhibited by the fish released during April 1979, like those of the fish released in the Gulf of Panama during April-May 1961, are among the most extensive recorded for any yellowfin experiment carried out by the IATTC. Most of the returns were from fish recaptured in the Panama Bight during May-November 1979. Most of the Ecuador recaptures were made during October-December 1979. The returns from west of the area of release were made during June 1979-February 1981. Three of the returns from north of 20°N were from fish caught in March 1980 and the other was from one caught in November 1980. The four returns from west of 110°W were from fish caught in July, August, and November 1979 and May 1980. The three returns from the Galapagos Islands were from fish caught during September and October 1979 and the three from south and southwest of the Galapagos Islands were from fish caught during October 1979 and February 1981. Most of the returns from the fish released during 1980 were from recaptures near the area of release during May 1980 and west of the area of release

during September 1980-September 1981. The four Panama Bight returns were from fish caught during July-September 1980 and May 1981 and the two Galapagos Islands returns were from fish caught during May and September 1980. The return from north of 20°N was from a fish caught during November 1980 and the return from west of 125°W was from a fish caught during August 1981. Fish from the 1981 releases were caught principally in the area of release and in the western Panama Bight. The 131 fish recaptured in the 1-degree area bordered on the south by 4°N and on the east by 86°W were all caught on April 28 and 29 by a single purse seiner. All of the 105 fish recaptured in the two 1-degree areas bordered on the south by 4°N and 5°N and on the east by 80°W were caught during May 9-16 by five purse seiners. Most of the rest of the fish were recaptured in the Panama Bight during May-June 1981, west of 88°W during June 1981-March 1982, and west of the Gulf of Guayaquil during October-November 1981.

Movement toward the Panama Bight seems to have been stronger in 1979 and 1981 than in 1980.

Northern Central America

Fish were released off northern Central America (north of 10°N) during three years, 1960 (September, Figure 1k), 1968 (June, Figure 1l), and 1979 (April-May, Figure 1m). All but one of the returns from the 1960 releases were from fish recaptured off Central America during October 1960-April 1961. The remaining return was from a fish recaptured west of the Gulf of Tehuantepec during January 1961. All but two of the returns from the 1968 releases were from fish recaptured off Central America during June-July 1968. The other two were from a fish recaptured off Central America during January 1969 and from a fish recaptured west of the Gulf of Tehuantepec during March 1970. The 1979 releases produced returns from recaptures made in the Panama Bight (mostly during May-June 1979), south of Costa Rica (mostly during April-May 1979), south of the area of release (mostly during April-September 1979), and west of 95°W (mostly during July 1979-June 1980). The two recaptures from north of 20°N were from fish caught during January 1980, and the two recaptures from west of 125°W were from fish caught during June 1979 and June 1980.

None of returns received from fish of the 1960 or 1968 releases were from fish recaptured south of 10°N, but about half of the returns from the 1979 releases were from fish recaptured in that area, including a substantial number recaptured east of 85°W.

Colombia

Fish were released off Colombia during April 1981 (Figure 1n). Most of the recaptures were made in the Panama Bight during April and May 1981. The fish recaptured west of the Gulf of Guayaquil were caught during September-November 1981, and the one recaptured in the Galapagos Islands was caught during November 1982.

Galapagos Islands

Fish were released in the vicinity of the Galapagos Islands and north and north-northeast of there during October-December 1959 (Figure 1o). All of the recaptures were made near the areas of release during November 1959-February 1960. The maximum net distance traveled by any of the fish was only 125 miles. This is not surprising, in view of the fact that, as stated earlier, prior to the late 1960's tuna vessels did not usually fish far offshore, except in the vicinity of a few offshore islands and banks.

Clipperton Island

Fish were released off Clipperton Island in May 1981 (Figure 1p) and October-November 1981 (Figure 1q). In both cases the fish tended to remain in the vicinity of that island for long periods. Because tunas seem to have an affinity for islands and banks (Howard, 1963), and there are no banks or other islands near Clipperton Island, it is not surprising that so many fish were recaptured at the location of release. Of the 50 returns from fish of the May releases recaptured in the area of release, 38 were from fish caught during August 11-15, 1982, by three purse seiners. The fish recaptured east and north of Clipperton Island were caught during September 1981-April 1982, those recaptured north of 20°N were caught during June 1981-August 1983, the one recaptured in the Gulf of Panama was caught during May 1982, and the two

recaptured west of 125°W were caught during May and July 1982. All of the 225 returns of fish of the October-November releases recaptured in the area of release were caught during August 8-15, 1982, by three purse seiners. All but one of the fish recaptured between 94°W and 117°W were caught during January-April 1982. The three recaptured west of 120°W were caught during April-July 1982, and the one recaptured south of the equator was caught during May 1982.

There seems to have been a tendency for the fish which had previously resided north of the equator to migrate to the area to the west of the Gulf of Guayaquil during or shortly before the last four months of 1981, as 14 fish released north of the equator earlier that year were recaptured there during September-December 1981 (Figures 1d, 1j, and 1n). The logged catch of yellowfin by purse seiners in areas 2-05-080, 2-05-085, 2-10-080, and 2-10-085 during the fourth quarter of 1981 was 15,372.4 short tons, the highest on record. Evidently migration of fish from north of the equator was at least partially responsible for that large catch.

Skipjack

Gulf of Panama

Fish were released in the Gulf of Panama during April-May of three years, 1959 (Figure 2a), 1961 (Figure 2b), and 1981 (Figure 2c). Most of the returns from the 1959 releases were from fish recaptured in the Gulf of Panama during May 1959 and off Ecuador during July-December 1959. The three returns from off Costa Rica were from fish caught during October 1959. There were a few returns from the 1961 releases from fish recaptured during May (five in the Gulf of Panama and one off Ecuador), but most of the returns were from fish caught off Central America north of 9°N during June-October 1961 and off Ecuador during June-November 1961. Most of the returns from the 1981 releases were from fish recaptured in the Gulf of Panama during June, August, and October 1981 and between the Panama Bight and the Galapagos Islands during August-December 1981.

The apparent migrations of the fish differed during those three years. In 1959 most of the recaptures were made in the Gulf of Panama and off Ecuador, in 1961 most of them were made off Central America, and in 1981 most of them were made between the Panama Bight and the Galapagos Islands. The different pattern for 1981 is not surprising, in view of the fact that much more fishing was conducted far offshore during the early 1980's than during the earlier period. (As mentioned previously, adjustments for differences in fishing effort among area-time strata are not incorporated into the map method.)

Southern Central America

Fish were released off southern Central America (between 4°N and 10°N) during February-April of four years, 1964 (Figure 2d), 1979 (Figure 2e), 1980 (Figure 2f), and 1981 (Figure 2g). Most of the returns from the 1964 releases were from fish recaptured near the area of release during February-March 1964. During the early and middle 1960's tuna vessels did not usually fish far offshore, except in the vicinity of a few offshore islands and banks. The February-March returns all came from five baitboats, and all the fish were reported to have been caught at or near Brito Bank (5°29'N-88°32'W) or West Cocos Bank (5°40'N-88°53'W). The four returns in other areas were from fish caught during July 1964-March 1965. Most of the returns from the 1979 releases were from fish recaptured in the Panama Bight during May-September 1979. The two returns from north of 10°N were from fish caught during May and July 1979, the four from the vicinity of the Galapagos Islands were from fish caught during September and October 1979, and the two from south of the Galapagos Islands were from fish caught during May and October 1979. In addition, one fish was recaptured about two thirds of the way to Hawaii in August 1979. It is not certain, of course, that its destination was Hawaii. Most of the returns from the 1980 releases were from fish recaptured in the southern Panama Bight and off Ecuador during May-September 1980. The return from west of 95°W was from a fish caught during January 1981, the three from north of the Galapagos Islands were from fish caught during September and October 1980, and the four from the vicinity of the Galapagos Islands were from fish caught during May and October 1980. Most of the returns from the 1981 releases were made in the vicinity of the area of release during April

1981 and west of the Panama Bight and off Ecuador during May-June 1981. Of the 93 recaptures made in the 1-degree area bordered on the south by 4°N and on the east by 86°W, 13 were from fish caught by the tagging vessel on April 12, 1981, and 79 were from fish caught by a single purse seiner on April 28 and May 5, 1981. In addition, one fish was recaptured about one third of the way to Hawaii during September 1981, one was caught off Hawaii during August 1982, and one was recaptured about half way to the Gambier Islands during April 1982. It is not certain, of course, that the destinations of the first and third fish were Hawaii and the Gambier Islands. These three fish were released at the same "stop" on April 2, 1981, and probably were members of the same school prior to having been tagged. The third fish was caught by a longline vessel.

In general, the migrations of the tagged fish released off southern Central America during 1979, 1980, and 1981 were quite similar, the fish in all three cases having traveled mostly to the Panama Bight and Ecuador.

Northern Central America

Fish were released off northern Central America (between 12°N and 14°N) during April 1979 (Figure 2h). Most of the recaptures were made east of 86°W and north of the equator during April-August 1979. The returns from west of 90°N were from fish caught during April-July 1979.

Colombia

Fish were released off Colombia during April 1981 (Figure 2i). Most of the returns were from fish recaptured in the Panama Bight and off Ecuador during April-June 1981.

Clipperton Island

Fish were released off Clipperton Island during November 1969 (Figure 2j). All but four of the recaptures were made near the area of release in January 1970 by two baitboats and a purse seiner. Two returns were from fish caught north of Clipperton Island during January and February 1970 and two

were from fish caught off Hawaii during July and August 1970.

Portion-in-area method

This method was devised by Bayliff (1979), who called it the parallel-area method. In this report, however, the areas designated are not parallel, so it is called the portion-in-area method. The eastern Pacific has been divided into areas, as shown in Figures 5 and 6. For each release, other than those at Clipperton Island, for which 90 or more returns with usable data were obtained the returns were assigned to areas. A few of the recaptures were made outside of those areas; these were ignored for the current analyses. The data are tabulated in Tables 2 and 3 for the months in which there were four or more usable returns. It can be seen, for example, how many fish released in Area F1 were recaptured in the same area and in each of the other areas in each month. It is highly desirable, however, to adjust the number of returns in each area-month stratum according to the amount of effort in that stratum. This was accomplished by

$$p_{ijk} = \frac{r_{ijk}/f_{ijk}}{\sum_j (r_{ijk}/f_{jk})} \qquad (9)$$

where

p_{ijk} = portion of fish released in area i occurring in area j during month k,

r_{ijk} = number of returns of fish released in area i and recaptured in area j during month k, and

f_{jk} = effort in area j during month k.

Yellowfin

The portion-in-area method was used for six releases of tagged yellowfin, two in the Gulf of Panama (Cruises 1038 and 1095), three off southern Central America (Cruises 1084, 1089, and 1095), and one off northern Central America (Cruise 1084). Because the distribution of fishing effort was different during the 1961-1962 (Alverson, 1963) and 1979-1982 (Anonymous, 1982) periods, different areas were designated for the two periods. The portions of the

returns made in each area during each month are shown in Table 2 and Figure 7.

The returns from fish released in the Gulf of Panama (Area F1) during 1961 which were at liberty more than 6 months were unusually high, which makes the results of this cruise especially valuable. The fish were concentrated in the area of release during April-June 1961 and again during January-May 1962. They appeared to the west of the Gulf of Panama (Areas F2 and F3) mostly during the period when their abundance in the Gulf of Panama was least. They were caught off Ecuador and Peru (Area F10) mostly during September-November 1961 and March-May 1962. These results suggest the possibility that the fish which migrated to the west tended to return to the area of release during the early months of the following year, whereas those which migrated to the south did not return. The data for the fish released in the Gulf of Panama (Area G7) during 1981 also showed a tendency for the fish to return to that area the following year.

The fish released off southern Central America (Area G1) during 1979 and 1981 were recaptured mostly in the Panama Bight (Areas G7, G8, and G9) during May-September 1979 and May-July 1981. In October they appeared off Ecuador and Peru (Area G10). No trends are evident for the 1980 releases in this area.

No trends are evident for the fish released off northern Central America (Area G4) in 1979.

Skipjack

The portion-in-area method was used for five releases of tagged skipjack, two in the Gulf of Panama (Cruises 1027 and 1038) and three off southern Central America (Cruises 1084, 1089, and 1095). Because the areas of release and recapture differed for the Gulf of Panama (Figures 2a and 2b) and southern Central America releases (Figures 2e, 2f, and 2g) and because the distribution of fishing effort was different during the 1959-1961 and 1979-1981 periods, different areas were designated for the two periods. The portions of the returns made in each area during each month are shown in Table 3 and Figure 8.

The fish released in the Gulf of Panama (Area H1) during 1959 and 1961 were concentrated in the areas of release during May and June, and after that they tended to appear more in the other areas.

The fish released off southern Central America (Area I1) during 1979, 1980, and 1981 tended to disperse to the Panama Bight (Areas I3, I4, and I5) and the area off Ecuador and Peru (Area I6) during May-November.

Jones method

This method was originally devised by Jones (1959 and 1961). Fink and Bayliff (1970) modified the method by calculating the parameters for fish which had moved in eight different directions, as well as those for all the fish combined, and Bayliff and Rothschild (1974) further modified it by the introduction of weighting by effort in the various area-time strata.

The dispersion of the fish is analyzed from data on the months of recapture, days at liberty, distances of movement, and directions of movement. Eight directions of movement, 0°-44° true = 1, 45°-89° true = 2,..., 315°-359° true = 8, are used for presentation of the data in Figures 9-14, but the calculations were made with the actual directions, to the nearest degree.

All calculations in this section were made with weighting to compensate for differences in the amounts of fishing effort exerted in different area and time strata. This was accomplished by division of the numbers of fish, times at liberty, and distances of movement by the amounts of fishing effort expended in the corresponding 5-degree area-month strata, as shown below. The adjusted number of returns in each month-direction of movement stratum is calculated by

$$N_{jk} = \left(\sum_i \frac{n_{ijk}}{f_{ij}} \right) \left(\frac{\sum_{ijk} n_{ijk}}{\sum_{ijk} (n_{ijk}/f_{ij})} \right) \qquad (10)$$

where

N_{jk} = adjusted number of returns in month j for fish which had moved in direction k (eight directions),

n_{ijk} = actual number of returns in area i during month j for fish which had moved in direction k, and

f_{ij} = effort in area i during month j.

The following calculations were made by month of recapture, by all months of recapture combined, by direction of movement, and by all directions of movement combined:

$$\overline{T_{jk}} = \sum_i (t_{ijk}/f_{jk}) / \sum_i (1/f_{jk}) \qquad (11)$$

where

$\overline{T_{jk}}$ = adjusted average time at liberty for fish recaptured in month j which had moved in direction k and

t_{ijk} = time at liberty for fish recaptured in area i during month j which had moved in direction k,

$$\overline{R_{jk}} = \sum_i (r_{ijk}/f_{jk}) / \sum_i (1/f_{jk}) \qquad (12)$$

where

$\overline{R_{jk}}$ = adjusted average distance of movement for fish recaptured in month j which had moved in direction k and

r_{ijk} = distance of movement for fish recaptured in area i during month j which had moved in direction k,

$$V_{jk} = \frac{\sqrt{\left(\sum_i (r_{ijk}/f_{ij})\sin\theta_k\right)^2 + \left(\sum_i (r_{ijk}/f_{ij})\cos\theta_k\right)^2}}{\sum_i (t_{ijk}/f_{ij})} \qquad (13)$$

where

V_{jk} = adjusted mean velocity of dislocation for fish recaptured in month j which had moved in direction k and

θ_k = angle corresponding to direction of movement k, and

$$A_{jk}^2 = \frac{1}{\sum_i (1/f_{ij})} \left(\sum_i \frac{r_{ijk}^2}{t_{ijk} f_{ij}} - \frac{\left(\sum_i (r_{ijk}/f_{ij})\sin\theta_k\right)^2 + \left(\sum_i (r_{ijk}/f_{ij})\cos\theta_k\right)^2}{\sum_i (t_{ijk}/f_{ij})} \right) \qquad (14)$$

where

A_{jk}^2 = adjusted mean square dispersion coefficient for fish

recaptured in month j which had moved in direction k.

The significance of the mean velocity of dislocation and the mean square dispersion coefficient has been discussed by Jones (1959 and 1976). Briefly, the former pertains to directional movement and the latter to random movement. The latter is a measure of the average amount of deviation from the mean direction of movement. A high value of $V_{j.}$ and a low value of $A_{j.}^2$ would indicate directional movement with little dispersion, while a low value of $V_{j.}$ and a high value of $A_{j.}^2$ would indicate the reverse. Even if the movement is entirely random, the values of $V_{j.}$ would not be expected to equal 0 for the groups of fish which were released close to shore, as the fish were restricted in their movements toward the shore.

The directions and average distances of movement are shown in Figures 9 and 10. The 3 and 20, at the centers of the diagrams for southern Central America, 1964, indicate 18 yellowfin and 19 skipjack (adjusted to 3 and 20 respectively, by the weighting procedure of computer program CIAT F04A) which were recorded as having been recaptured at the location of release, Brito Bank (5°29'N-88°32'W). Likewise, the numbers at the centers of the diagrams for Clipperton Island indicate fish which were recorded as having been recaptured at that location. (As explained by Schaefer, Chatwin, and Broadhead (1961), because of lack of precision in recording positions at sea, fish which moved 10 or 20 miles are often recorded as having been recaptured at the locations of release.) The numbers near the heads of the arrows indicate the adjusted numbers of fish which moved in each direction and the average distances of movement, respectively. The lengths of the lines are proportional to the average distances of movement.

The directions and average distances of movement by month of recapture are shown in Figures 11 and 12. The data for fish moving in different directions are shown in different panels of the graphs. The points for consecutive months are joined by solid lines and those for non-consecutive months by dashed lines. The numbers near the points indicate the actual numbers of fish in each month. In a few cases the numbers in the bottom panels exceed the totals of those in the panels above them. The differences equal the numbers of fish which were recaptured in the locations of release

and had net movements of 0 miles. The values of $V._k$ appear in all the panels, and the values of $V..$ and $A..^2$ in the bottom panels. The diagrams are useful for detecting seasonal migrations. For instance, if the fish were at the southern end of their range in January and at the northern end of it in July, and they were tagged in January, $\overline{R_j.}$ would increase for about 6 months and then decrease. Also, there would be many fish in the panels for Directions 1 and 8 and few in the panels for Directions 4 and 5 during February-June, whereas the reverse would be true during August-December.

The adjusted mean square dispersion coefficients by month of recapture are shown in Figures 13 and 14. The points are plotted only for the months which include at least five returns. The numbers near the points indicate the actual numbers of fish recaptured during each month.

Yellowfin

Considering first Figure 9, the fish released in the Gulf of Panama went mostly in Directions 4 and 5 (off northern South America) and 6 and 7 (off Central America). Obviously, because of the presence of the coastline, the fish could not have moved far in Directions 1-3 or 8. The fish of the 1959 and April-May 1961 releases tended to go more toward Central America, while those for the 1962 releases tended to go more toward northern South America. For the other two cruises the returns were about equally divided between Central America and northern South America. The fish released off southern Central America north-northeast of the Galapagos Islands during 1964 were recaptured mainly at the location of release which, as explained in the section entitled Map method, is due to the fact that at that time there was little fishing conducted far offshore, except in the vicinity of a few offshore islands and banks. For the other four cruises the movement was in all directions, but especially in Directions 3 and 4 (Panama Bight and off northern South America). The fish released off northern Central America during 1960, 1968, and 1979 went principally in Directions 4, 5, 6, and 7. The fish released off Colombia during 1981 went chiefly in Directions 2 and 3 (Panama Bight and northern South America). Those released at the Galapagos Islands during 1959 were recaptured mostly at the locations of release or went westerly in Directions 5, 6, and 7. The fish released at Clipperton Island

were recaptured mainly at the location of release. The fish moved in nearly all directions, but more of those released in May 1981 tended to be recaptured north of the location of release, whereas more of those released in October-November 1981 tended to be recaptured south of the location of release.

For a few of the cruises (Figures 11k and 11l, for example) $\overline{R_{jk}}$ appears to have increased with time, while for most of the others this does not appear to have been the case, except during the first month or two after release. The values of $V_{..}$ and $A_{..}^2$ vary considerably among cruises, including the ones conducted in the same areas in different years.

The values of $A_{j.}^2$ are shown in Figure 13. No temporal trends are evident. The high value for May 1979 for the experiment initiated in southern Central America during 1979 is due mainly to one fish which traveled a net distance of 1,236 miles in Direction 7 (opposite to the others, which traveled in Directions 2, 3, and 4)(Figure 11g). The high value for June 1979 for the experiment initiated during 1979 is due mainly to one fish which traveled 2,017 miles in Direction 6 (Figure 11k).

Skipjack

Considering first Figure 10, the fish released in the Gulf of Panama went mostly in Directions 4 and 5 (northern South America) and 6 and 7 (off Central America). Obviously, because of the presence of the coastline, the fish could not have moved far in Directions 1-3 or 8. During 1959 and 1981 the movement was primarily in Direction 5, but during 1961 it was primarily in Direction 7. The fish released off southern Central America during 1964 were recaptured mainly at the location of release which, as explained in the section entitled Map method, is due to the fact that at that time there was little fishing conducted far offshore, except in the vicinity of a few offshore islands and banks. For the 1979, 1980, and 1981 cruises the movement was primarily in Directions 3 and 4 (Panama Bight and northern South America). There was relatively little movement in Directions 1 or 2 because of the presence of the coastline, but it seems surprising, in view of the results for Cruise 1038 (Figures 2b and 10a), that there was so little movement in Directions 7 and 8.

The fish released off northern Central America during 1979 also went principally in Directions 3 and 4. It is not surprising, however, that none went in Direction 7, as skipjack are not often found off the southern coast of Mexico (Joseph and Calkins, 1969). The fish released off Colombia during 1981 moved mostly short distances in Directions 1 and 2, into the Panama Bight. The fish released off Clipperton Island during 1969 were recaptured mainly at the location of release. There is no arrow for Direction 7 corresponding to the two fish recaptured off Hawaii because the effort data for that area (almost entirely small baitboats) have not been standardized to the effort data for the eastern Pacific.

For some of the cruises (Figures 12a, 12e, and 12g, for example) $\overline{R_{jk}}$ appears to have increased with time, while for others (Figures 12b, and 12f, for example) this does not appear to have been the case, except during the first month or two after release. The values of $V_{..}$ and $A_{..}^2$ vary considerably among cruises, including the ones conducted in the same areas in different years.

The values of $A_{j.}^2$ are shown in Figure 14. No temporal trends are evident.

Lengths of the fish at release

The lengths at release of the fish should be considered in analyzing the data, as the movements of the fish of different lengths may differ.

Yellowfin

The length frequencies at release of the yellowfin for which the tags were returned are shown in Figure 15. No data are shown for Cruises 1027, 1036, or 1039, as few or no fish were measured on those cruises. Length-frequency data for yellowfin caught in the eastern Pacific are shown by Hennemuth (1961), Davidoff (1963, 1965, and 1969), Díaz (1963), and Cole (1980). The data most suitable for study of the movements of fish of different lengths appear to be those for the fish released in the Gulf of Panama in 1961 (Cruise 1038), off southern Central America in 1979 (Cruise

1084), and off Clipperton Island in 1981 (Cruise 1096).

For Cruise 1038, unfortunately, the lengths of release are confounded with the dates of release. The distributions of the lengths at release of the fish which were recaptured were as follows:

Date of release	Length at release (cm)						
	47.5	50	55	60	65	70	80
April 25		108					
April 30		2		151		1	
May 1			107	1			
May 2		87					
others	7	45	30	11	23	19	2

Chi-square tests were performed to compare the directions of movement of smaller (47.5-50 cm) and larger (55-80 cm) fish and early-tagged (April 7-29) and late-tagged (April 30-May 2) fish, and in both cases significant values of Chi-square were obtained. No conclusions can be drawn from this, however, due to confounding of length and date of release.

For Cruise 1084, to ensure that adequate numbers of fish were in each stratum, only the data for fish released on April 14-15 and April 26-27 which had moved in Directions 1, 2, 3, and 4 were used. The results are summarized in Table 4. A G test (Sokal and Rohlf, 1969) produced the following results:

Effect	G value	Degrees of freedom	Probability
length on direction	13.392	1	<0.01
date on direction	3.444	1	>0.05

About 90 percent of the smaller fish and about 66 percent of the larger ones listed in the table had moved in Directions 3 and 4.

For Cruise 1096, again to ensure that adequate numbers of fish were in each stratum, only data for fish released during October 17-21 were used. The results are summarized in Table 5. A Chi-square test showed no difference in the portions of smaller (54-63 cm) and larger (64-84 cm) fish which had left the vicinity of Clipperton Island (χ^2 = 0.341, d. f. = 1, P>0.05).

Skipjack

The length frequencies at release of the skipjack for which the tags were returned are shown in Figure 16. No data are shown for Cruise 1027, as the skipjack were not measured on that cruise. Length-frequency data for skipjack caught in the eastern Pacific Ocean are shown by Broadhead and Barrett (1964), Rothschild (1965), Díaz (1966), and Forsbergh (1980). In most years the dominant mode in the catch occurs at about 50 cm, and the same is true for the fish which were tagged and released. The exceptions are the fish released off northern Central America in 1979, which were small, and those released off Clipperton Island in 1969, which were large. No conclusions can be drawn from this information, however, as in neither area were fish tagged and released in other years.

Population structure

Yellowfin

Suzuki, Tomlinson, and Honma (1978), who studied early life history, distribution, size composition, and tagging data for yellowfin, said that their data seemed "to support the concept of 'semi-independent' stocks with some mixing." Specifically, they proposed three stocks, inhabiting the eastern, central, and western Pacific, respectively. Since then the following returns of tagged yellowfin released in the central and western Pacific and recaptured in the eastern Pacific have been recorded:

	Release			Recapture				
Agency	Date	Area	Length (cm)	Date	Area	Length (cm)	Days free	Net distance (nm)
IATTC	Mar. 1, 1978	7°58'S-139°58'W	52	Jul. 12, 1979	11°47'N-130°25'W	?	499	1,315
IATTC-SPC*	Feb. 4, 1980	24°54'S-130°03'W	75	Dec. 16, 1980	14°37'S-90°50'W	120	317	2,290
IATTC-SPC	Feb. 4, 1980	25°00'S-130°07'W	76	Mar. 5, 1981	7°45'S-121°50'W	?	457	1,139
IATTC-SPC	Feb. 12, 1980	16°21'S-146°57'W	?	Jul. 13, 1981	8°14'N-139°25'W	?	518	1,541
IATTC-SPC	Feb. 16, 1980	17°46'S-150°32'W	85	Aug. 31, 1982	2°13'N-120°06'W	?	928	2,162
SPC	Apr. 21, 1980	16°01'S-179°48'E	53	Aug. 31, 1982	2°54'N-118°55'W	?	862	3,806
FRDA**	Jul. 22, 1978	4°05'N-159°15'W	79	Aug. 29, 1981	17°38'N-117°48'W	?	1,135	2,567

* South Pacific Commission

** Fisheries Research and Development Agency, Republic of Korea

The first six fish were recaptured outside the CYRA and the last was recaptured in Experimental Area 2, inside the CYRA (Anonymous, 1982: Figure 1). These data do not refute the hypothesis of Suzuki, Tomlinson, and Honma (1978), especially since all of the fish were recaptured far offshore. It could be argued, in fact, that the Pitcairn Islands, where the second and third fish were released, are in the eastern Pacific, rather than the central

Pacific.

Skipjack

At the time the IATTC's scientific studies were begun in the early 1950's virtually nothing was known regarding the population structure of skipjack in the Pacific Ocean. Since then information collected by the IATTC and other organizations has contributed considerably to the understanding of this important aspect of the biology of skipjack. Much of this information was reviewed by Anonymous (1981) and Richardson (1983). While these reports are extremely useful, they do not treat the eastern Pacific Ocean in much detail. Also, some recent returns of tagged skipjack have shed further light on the population structure of this species in the eastern Pacific Ocean, so it is appropriate to discuss the subject in this report.

There is little skipjack spawning in the eastern Pacific Ocean (Matsumoto, 1966), and large skipjack make up a much smaller portion of the catch of this species in eastern Pacific than in the central Pacific (Rothschild, 1965). Hence it was long suspected that the skipjack of the eastern Pacific are the result of spawning in the central and/or western Pacific, coming to the eastern Pacific as juveniles, staying there about a year, and then migrating back to the central and/or western Pacific prior to spawning. This hypothesis received considerable support during the 1960's and 1970's, when 26 fish released in the eastern Pacific were recaptured in the central and western Pacific (Rothschild, 1965; Anonymous, 1979).

During the 1950's and 1960's it appeared that in most years there were two groups of skipjack in the eastern Pacific, the northeastern group, which occurred off Baja California and near the Revillagigedo Islands and Clipperton Island, and the southeastern group, which occurred off Central America and northern South America. Tagging data had shown that there was little mixing of fish between these two areas. The Clipperton Island fish had been included in the northeastern group because Clipperton Island, though located between 10° and 11°N, is nearer to the Revillagigedo Islands than to Central America, because tagged skipjack released at Clipperton Island had been recaptured in the northeastern area, but not the southeastern area, and because prior to

1982 19 fish from Baja California, 4 fish from the Revillagigedo Islands, and 2 fish from Clipperton Island had been recaptured in the central and western Pacific Ocean, but none from Central America or northern South America had been recaptured anywhere but in the eastern Pacific. In Anonymous (1979) it was stated that "the question arises as to whether the fish of the northeastern Pacific, southeastern Pacific, and other areas come from (1) a single group of spawners or (2) ... separate groups of spawners." Several bits of evidence have accumulated which favor the first hypothesis. First, a tagged skipjack released off Clipperton Island on October 18, 1981, was recaptured at 2°27'S-106°52'W on January 2, 1982 (778 miles in 77 days). This might indicate that the distribution of skipjack in the eastern Pacific can best be described, not as two groups, but as a single group inhabiting an arc-shaped area with its tips at the Baja California-Revillagigedo Islands and Central America-northern South America areas and its center west, southwest, and south of the area of warm water off southern Mexico. This distribution is also suggested by charts of the geographical distributions of catches of skipjack during recent years (Orange and Calkins, 1981). Second, the following tag returns are evidence that skipjack from the southeastern group spawn in the same area as those from the northeastern group:

	Release			Recapture				
Agency	Date	Area	Length (cm)	Date	Area	Length (cm)	Days free	Net distance (nm)
USFWS*	Oct. 26, 1969	4°11'N-119°02'W	?	Jul. 14, 1971	Hawaii	69.5	627	?
IATTC	Apr. 14, 1979	6°26'N-86°55'W	50.6	Aug. 4, 1979	9°43'N-133°54'W	?	113	2,796
IATTC	Apr. 14, 1981	4°56'N-86°38'W	?	Aug. 24, 1982	21°32'N-158°44'W	74.5	500	4,293

* U. S. Fish and Wildlife Service

The first fish completed what may have been the second half of the trip from the southeastern area to Hawaii, the second one completed the first two thirds of that trip (although there is no assurance that its destination was Hawaii), and the third one completed the entire trip. It is not assumed from this, however, that skipjack of the eastern Pacific spawn only in the northern hemisphere, for catches of skipjack larvae in the south central Pacific (Matsumoto, 1966) indicate that skipjack spawn also in that area. Many large individuals are included in the skipjack catches of both Hawaii (Rothschild, 1965) and French Polynesia (Bayliff and Hunt, 1981), which might indicate that the French Polynesia catches include fish from the eastern Pacific, as do the Hawaii catches. One fish tagged at 4°56'N-86°38'W on April 13, 1981, was recaptured by a longline vessel at 9°19'S-105°15'W on April 29, 1982 (1,404 miles in 303 days). This fish may have been en route to the spawning grounds south of the equator. It was released at the same "stop" as the third fish in the table above, and the two fish were probably members of the same school at the time they were tagged.

SUMMARY AND CONCLUSIONS

The percentages of tags returned are affected by the species of fish, the gear used to capture the fish for tagging, the type of tag used, the year of release, and the area and month of release. The return rates are generally higher for yellowfin than for skipjack, higher for fish released from baitboats than for fish released from purse seiners, and higher for fish tagged with dart tags than for fish tagged with loop tags. The return rates in recent years have tended to be higher than those for earlier years due to the increasing fishing effort. Variations in fishing effort and vulnerability to capture among area-time strata also cause differences in the return rates for different experiments.

Three methods, the map method, the portion-in-area method, and the Jones method, were used to analyze data on the migrations of yellowfin and skipjack. The portion-in-area method and Jones method (as modified for this study) include adjustments for differences in effort in different area-month strata, but the map method does not. Yellowfin migrate further to the northwest than do skipjack, which is not surprising in view of the fact that yellowfin are

abundant in the area of very warm water off southern Mexico, whereas skipjack rarely occur there. Two skipjack released near Clipperton Island and one skipjack released off southern Central America were recaptured off Hawaii, however, whereas no yellowfin were recaptured anywhere but in the eastern Pacific. The migrations varied among years. For example, most of the returns from yellowfin released in the Gulf of Panama during April-May 1961 were from fish recaptured off Central America and southern Mexico, whereas most of those from yellowfin released in the same area during April-May 1962 were from fish recaptured off northern South America. Also, of course, more fish have been recaptured further offshore in more recent years, due to the offshore expansion of the fishery which took place during the late 1960's and early 1970's. Yellowfin released at Clipperton Island tend to remain there for long periods.

The migrations of yellowfin of different sizes were found to differ for one experiment. Of the fish which went in an easterly direction, 90 percent of the smaller ones and 66 percent of the larger ones migrated to the southeast.

It appears that the skipjack of northeastern and southeastern Pacific are parts of a single group inhabiting an arc-shaped area with its tips at those two areas, and that the fish at the ends of the distribution mix to at least some extent on the spawning grounds of the central and/or western Pacific.

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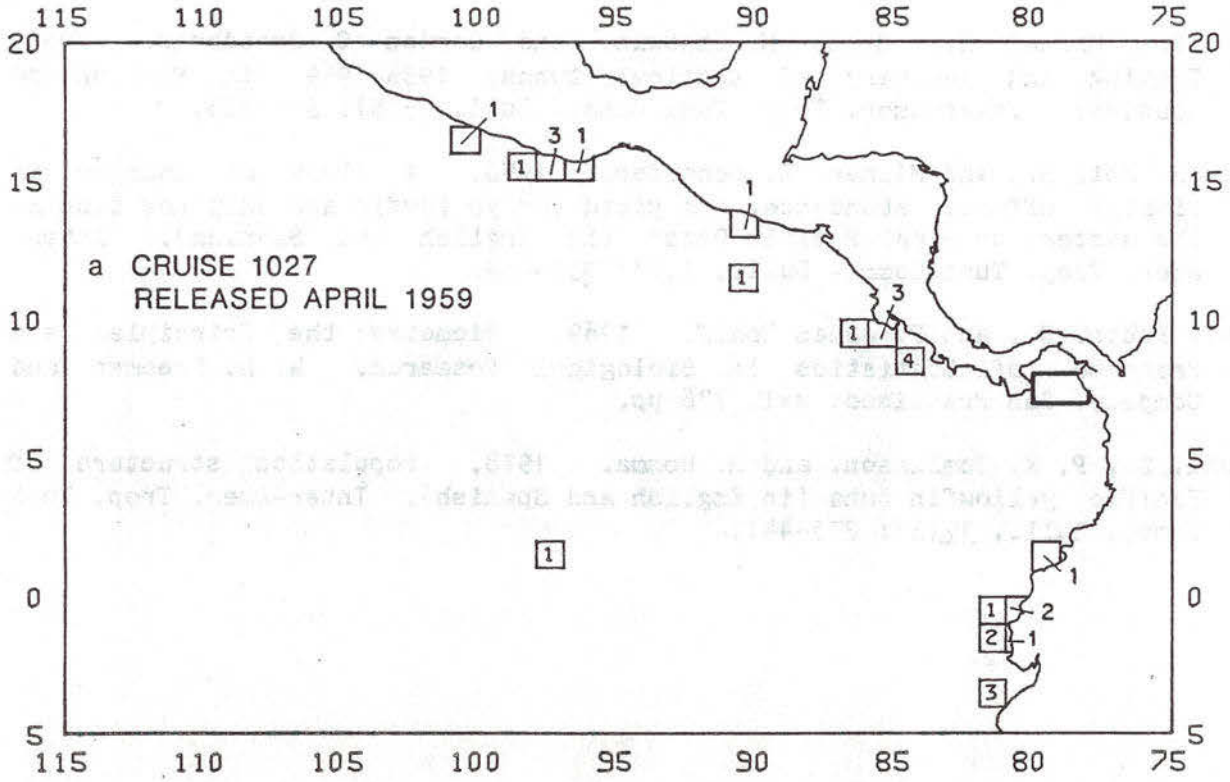
FIGURE 1. Areas of release (areas delineated by heavy lines) and areas of recapture (areas with numerals) for tagged yellowfin released in the eastern Pacific Ocean during 1959-1981.



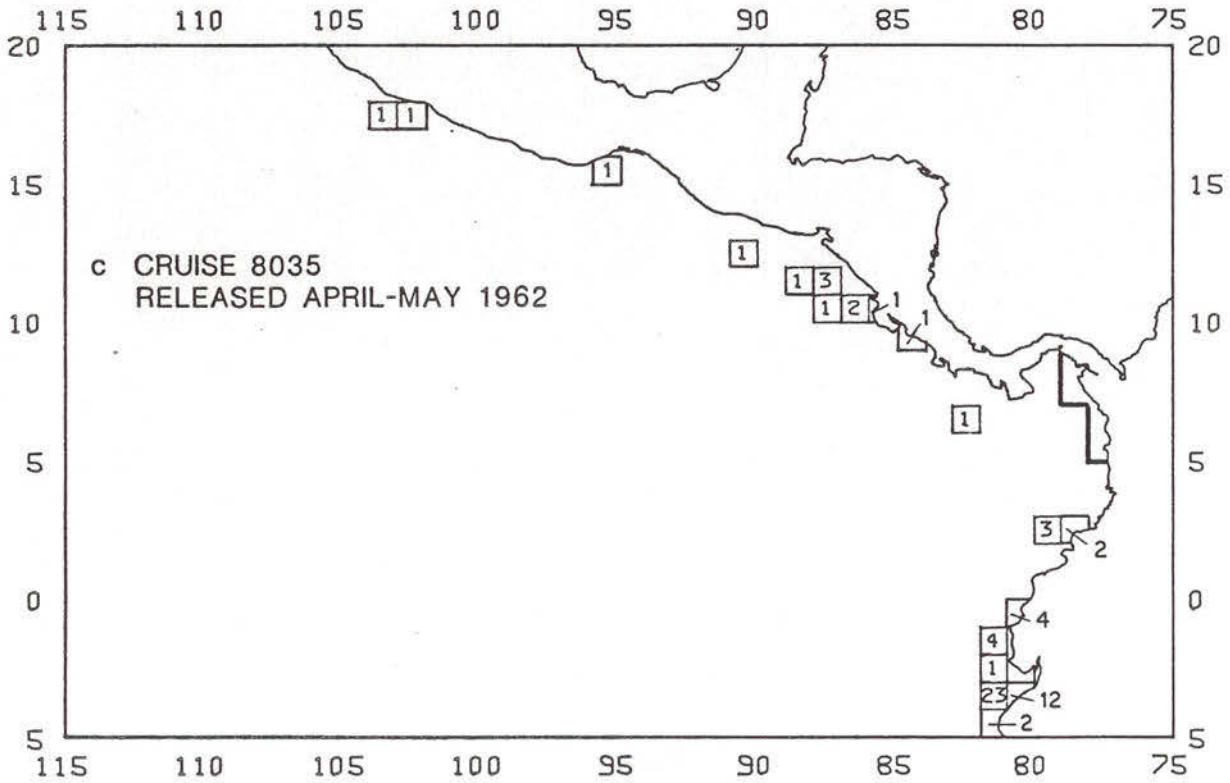
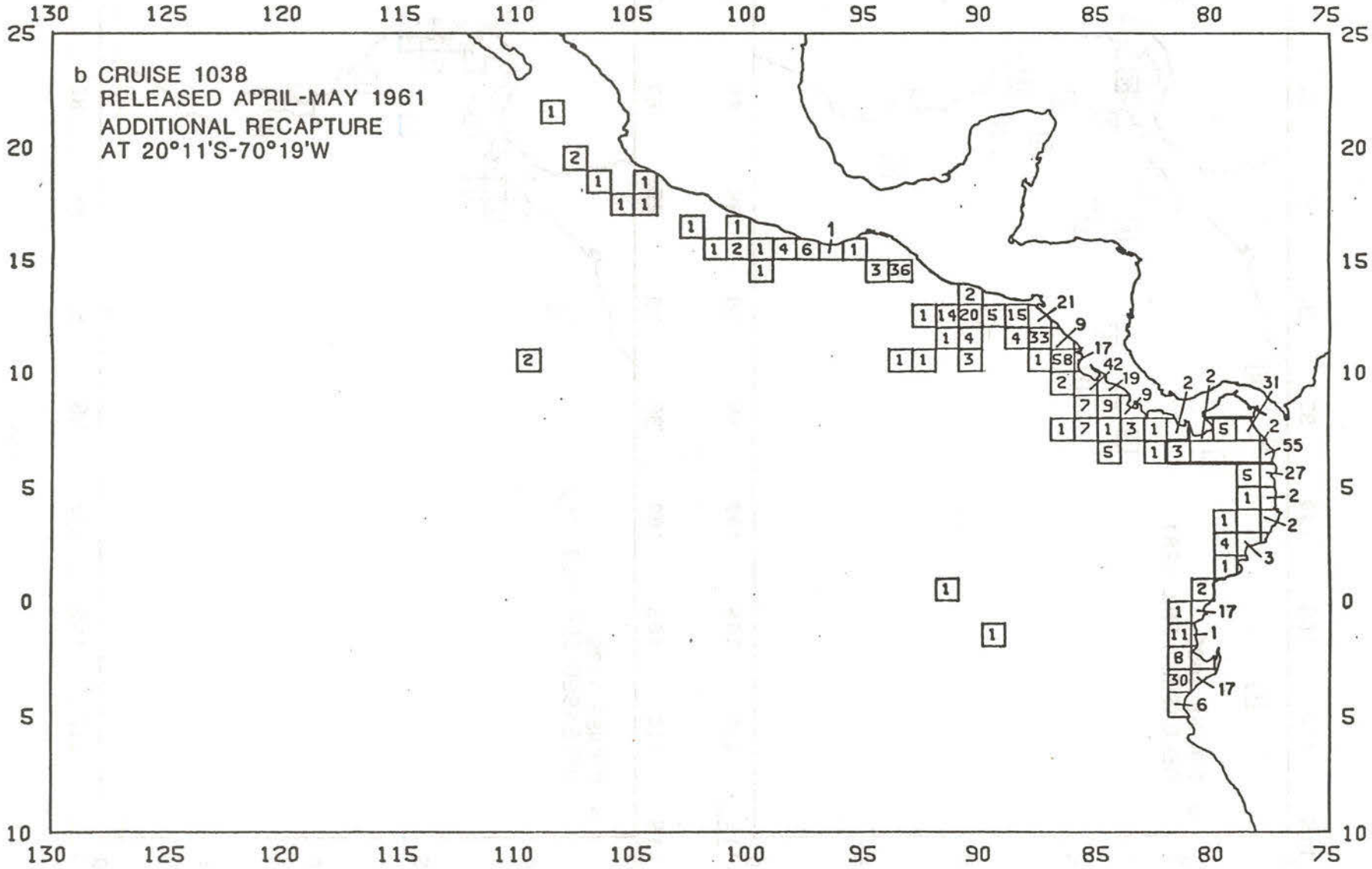


FIGURE 1. (continued)



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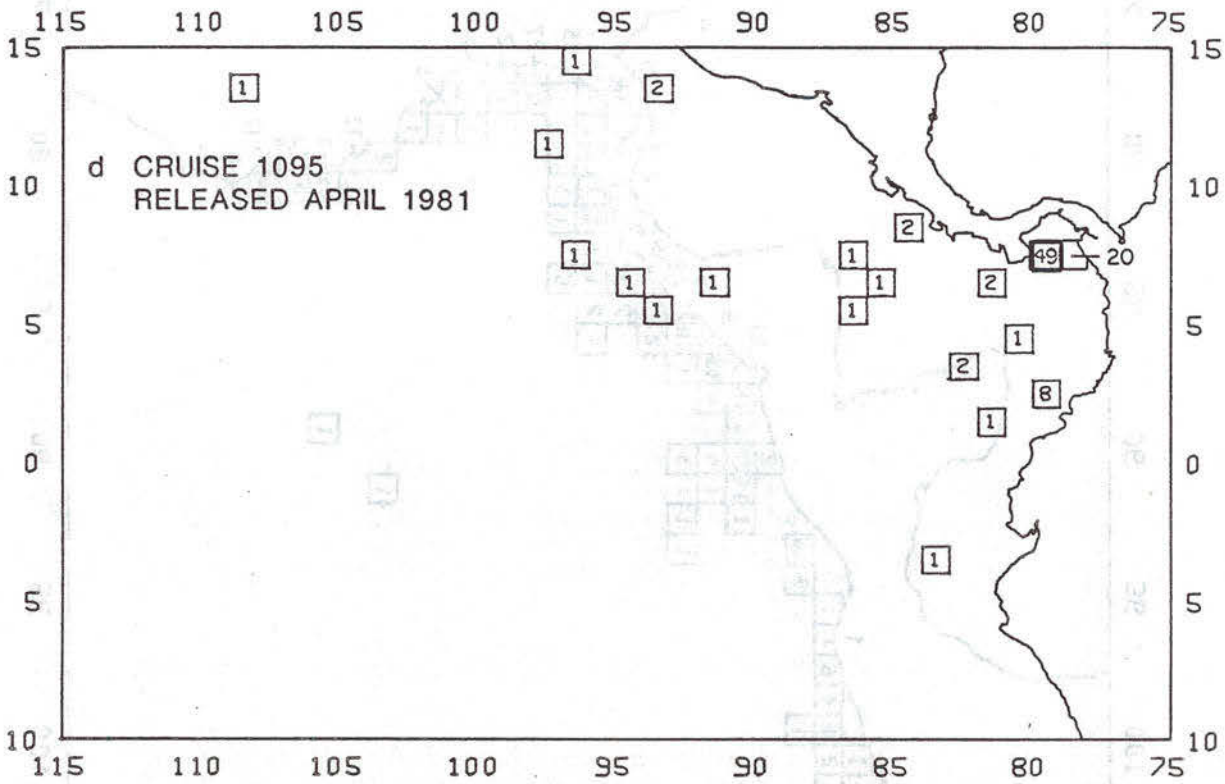

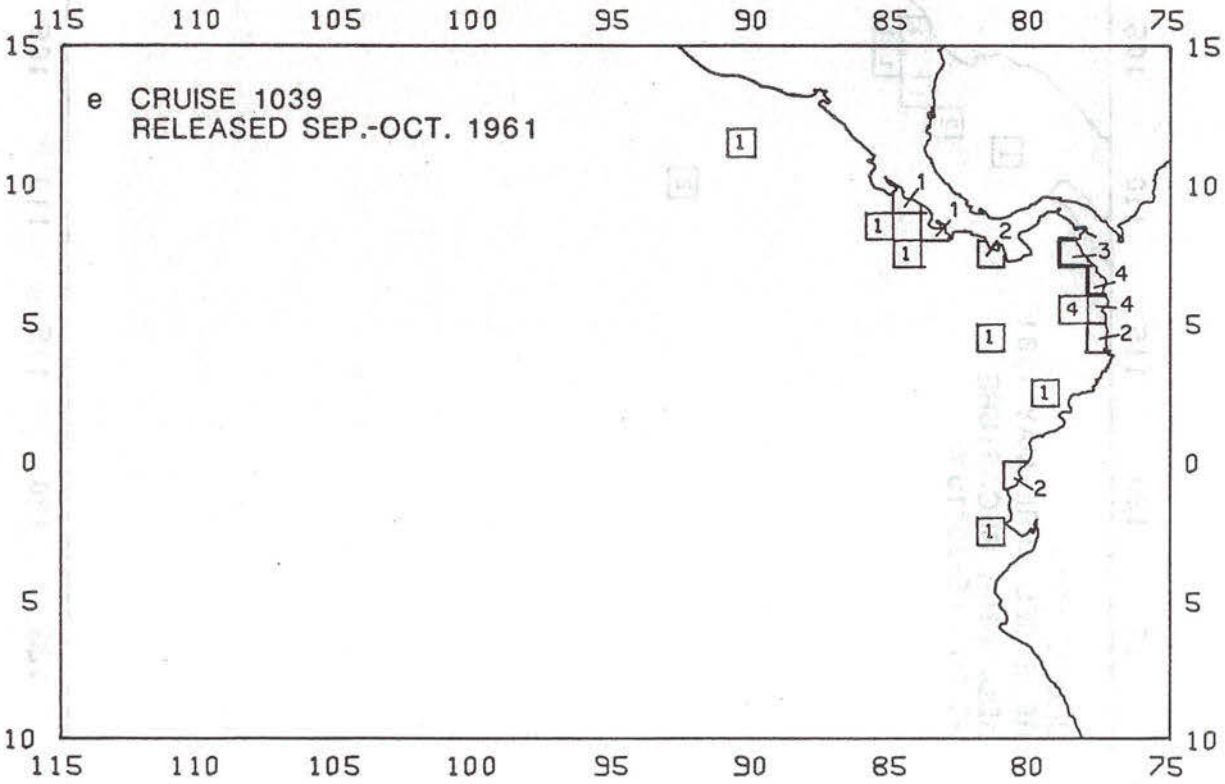

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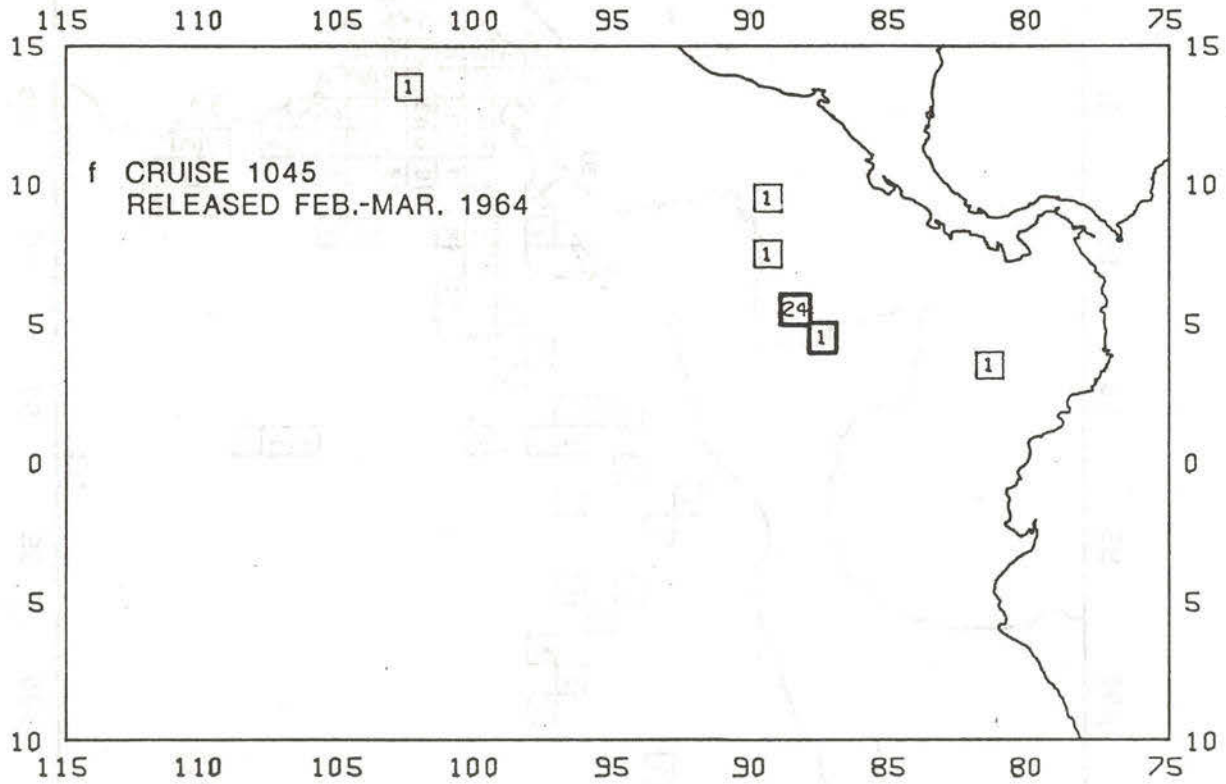

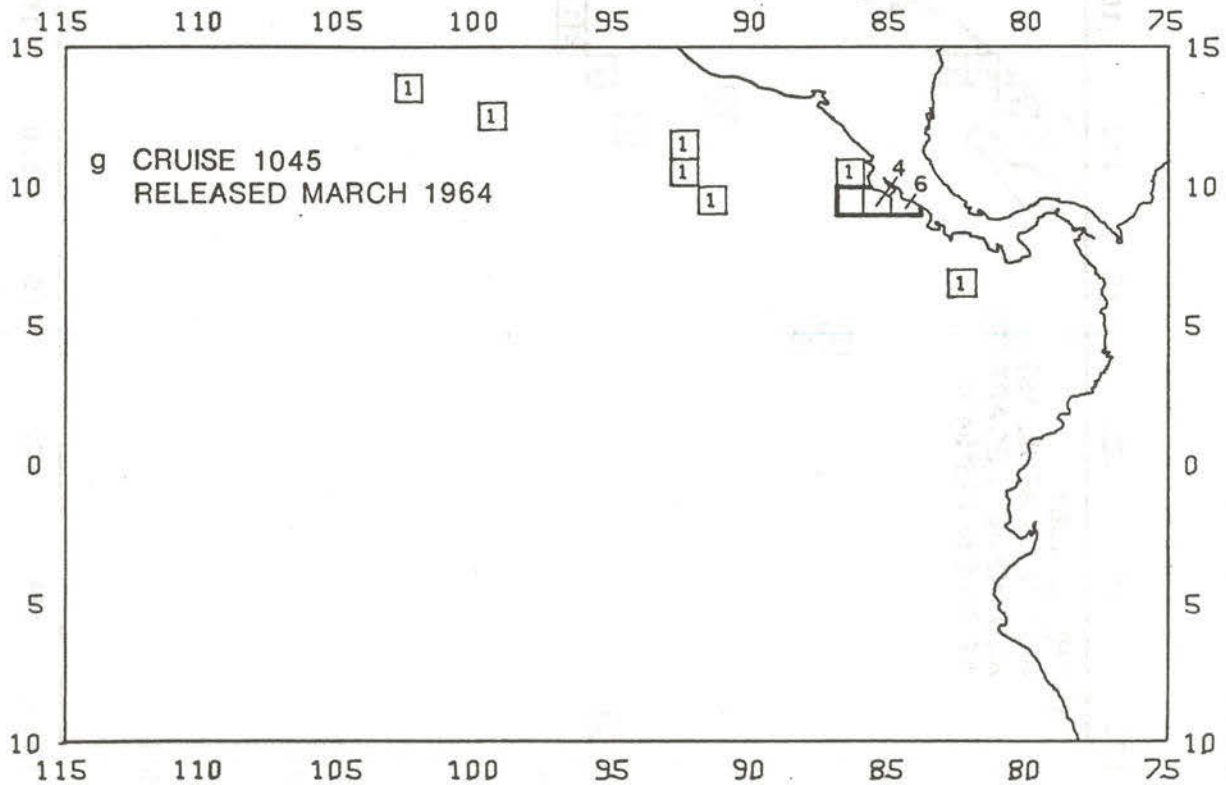

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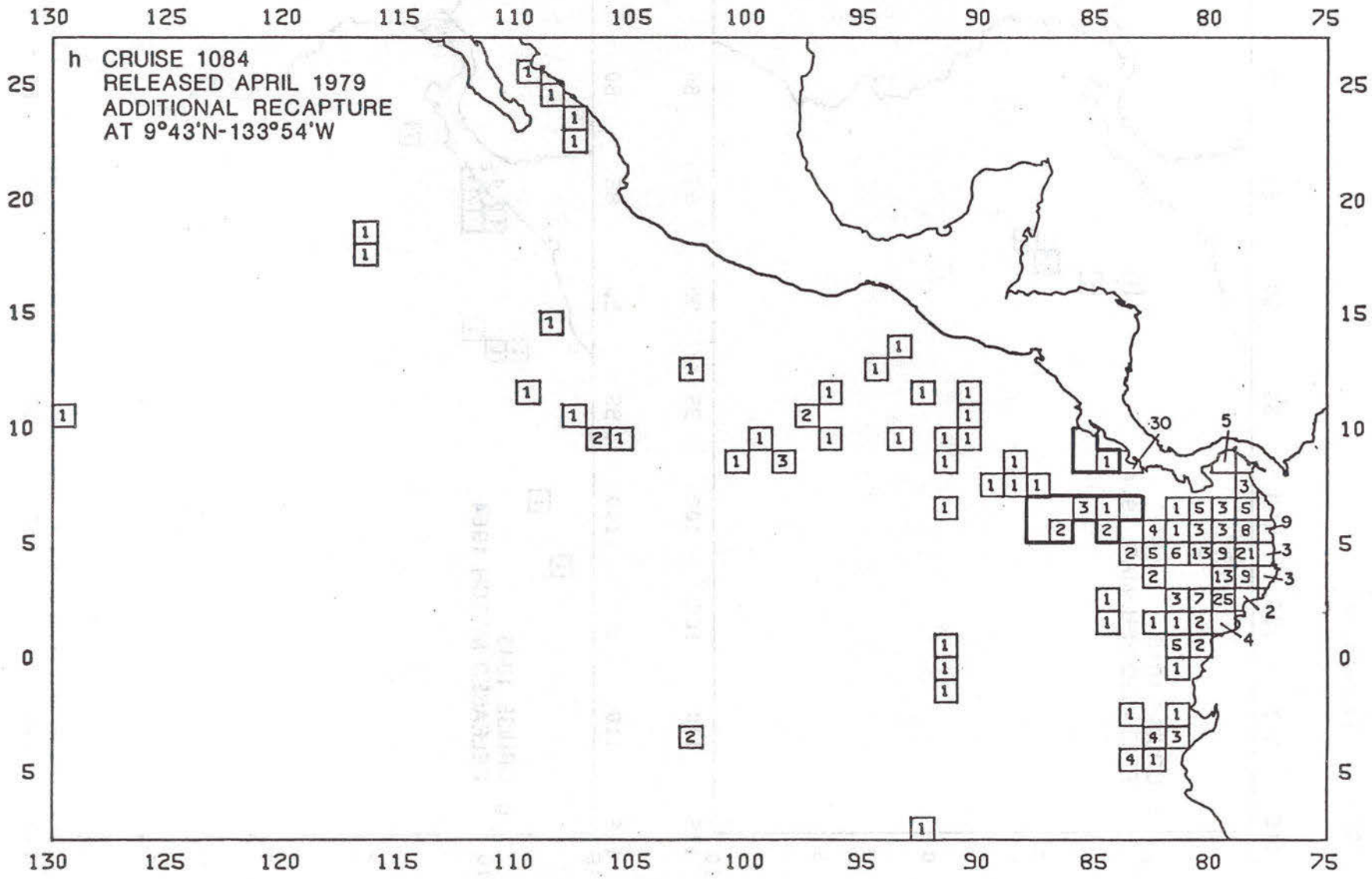

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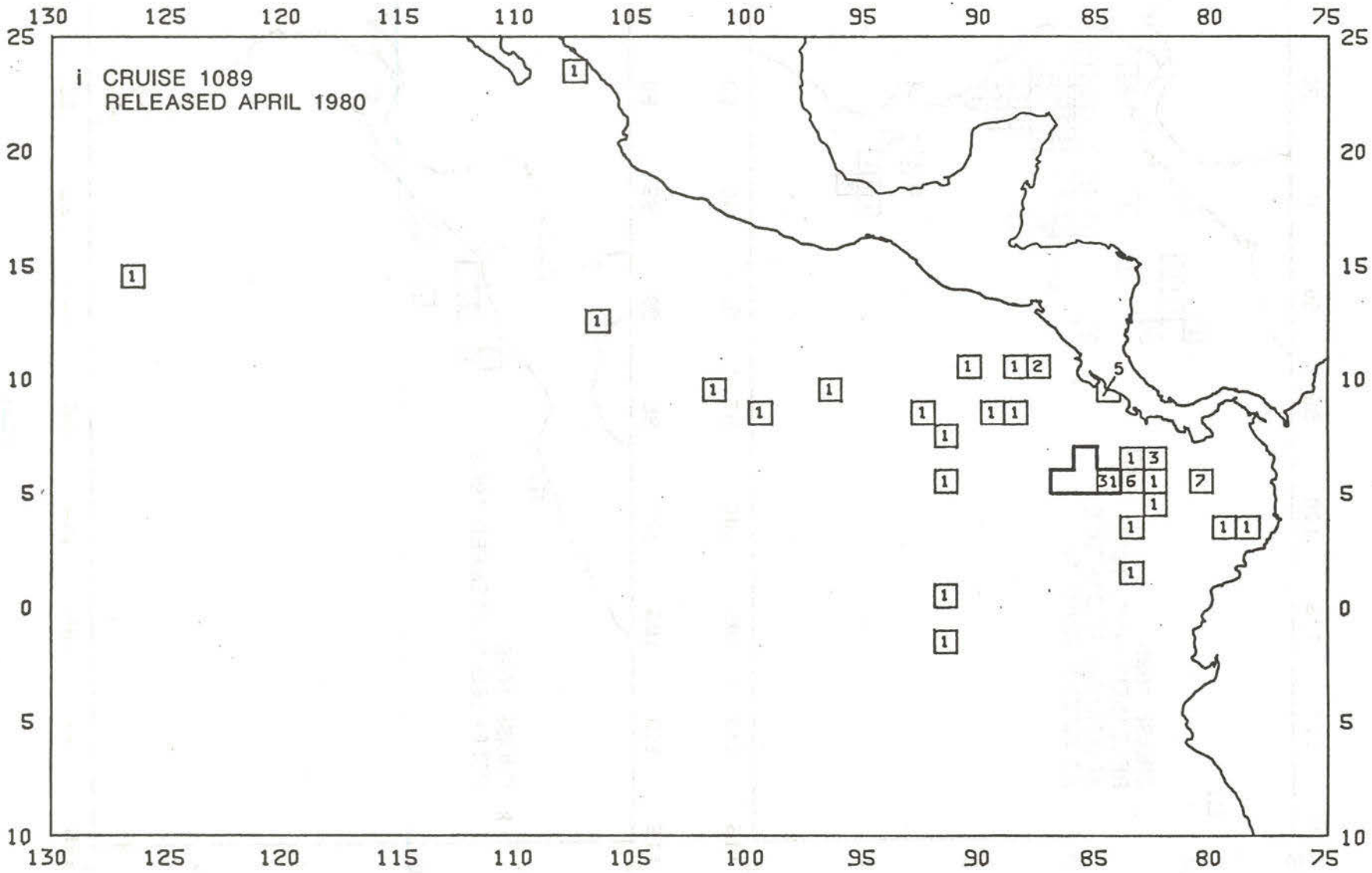

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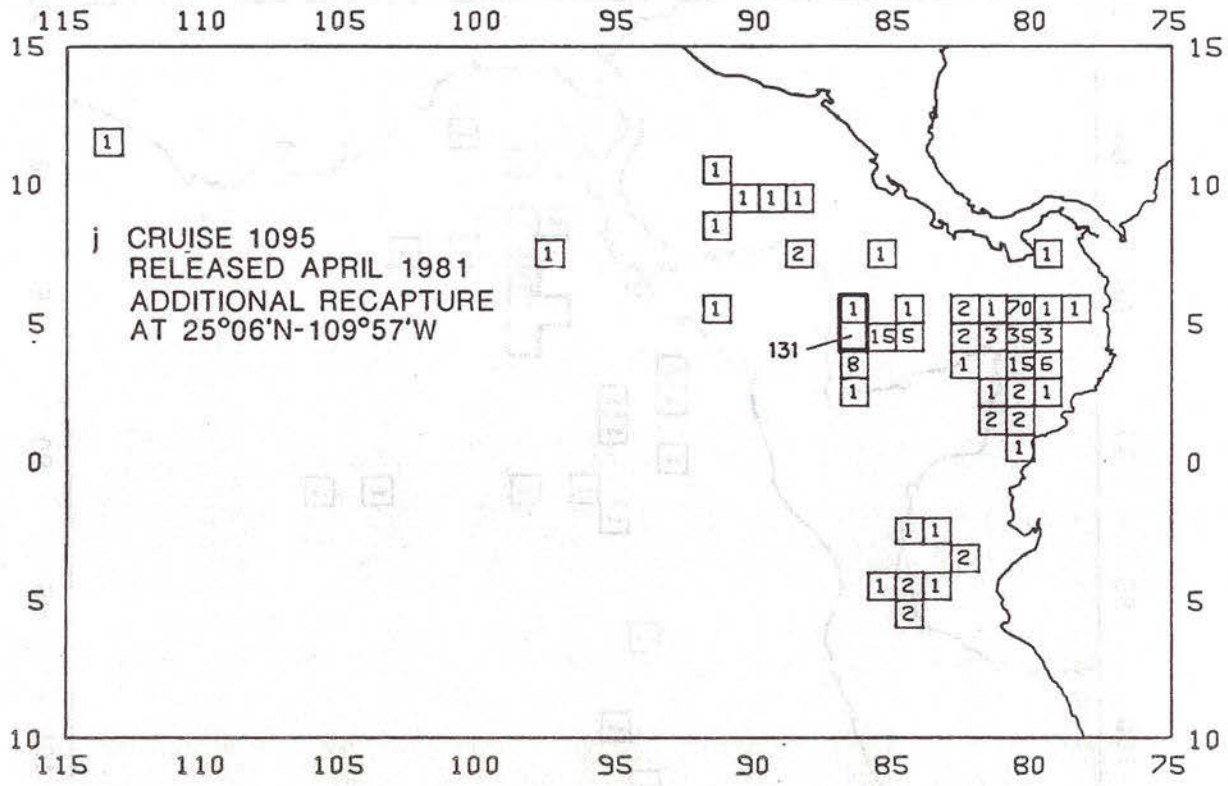

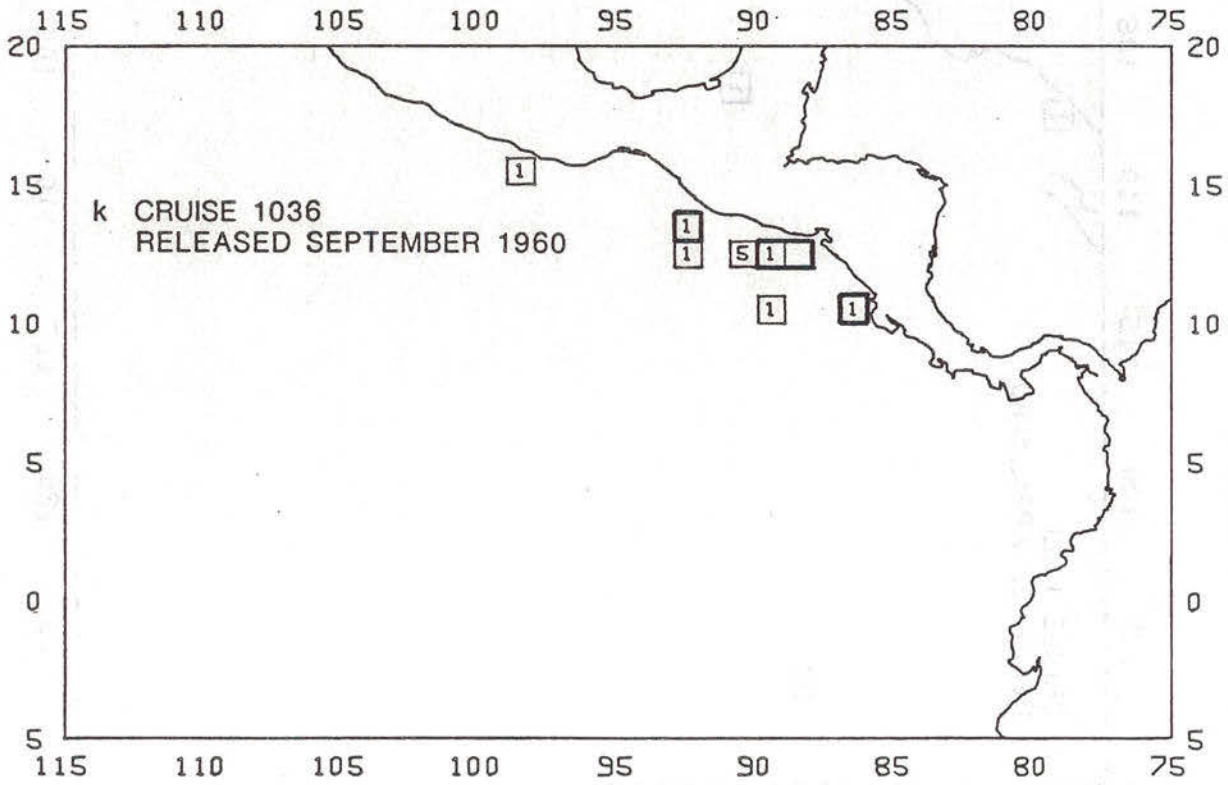

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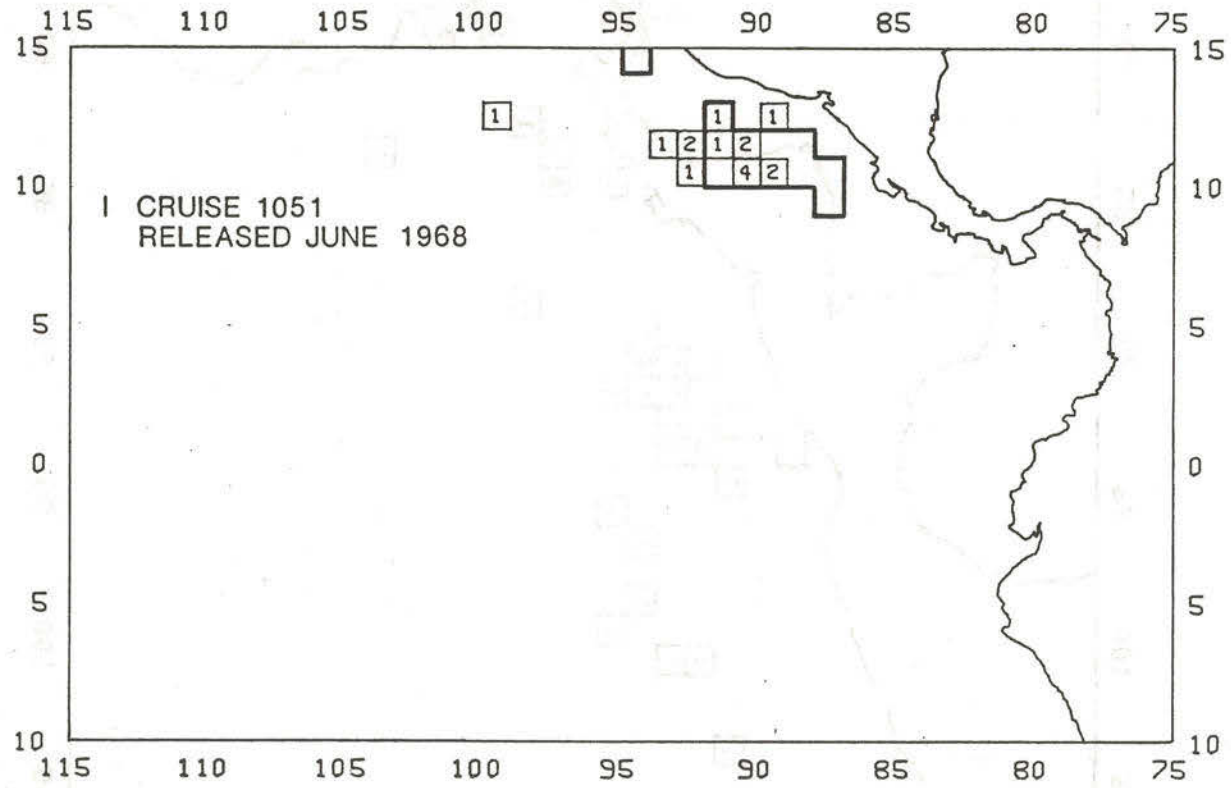

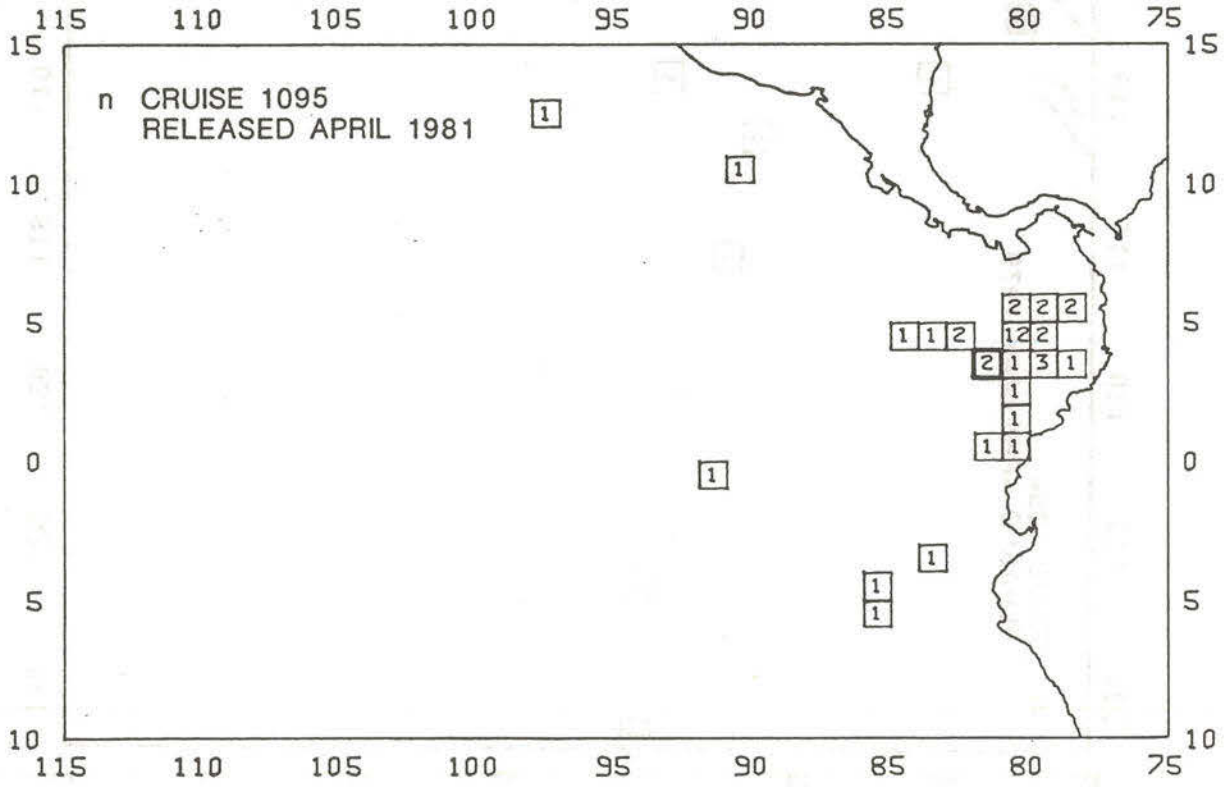

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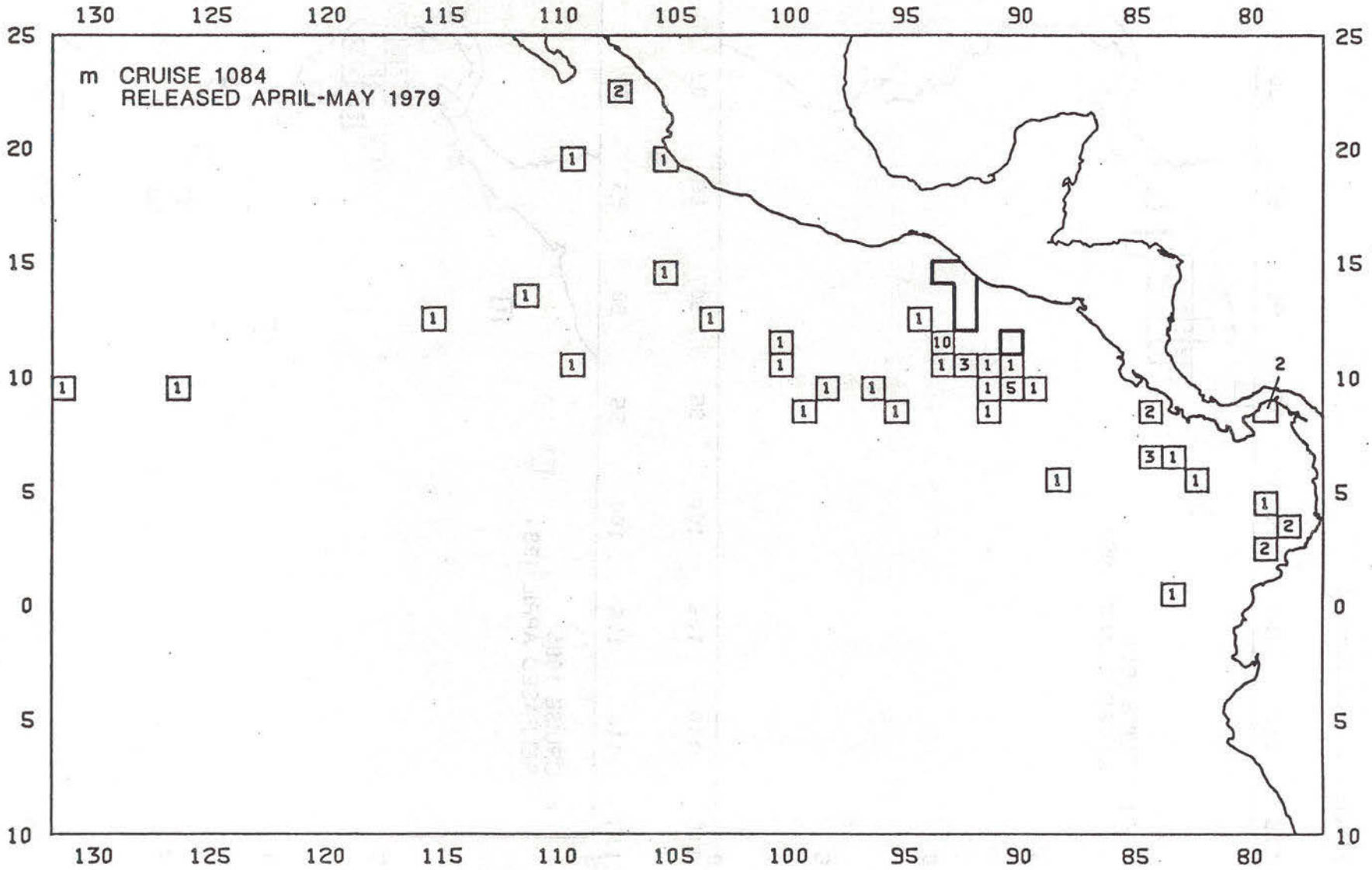

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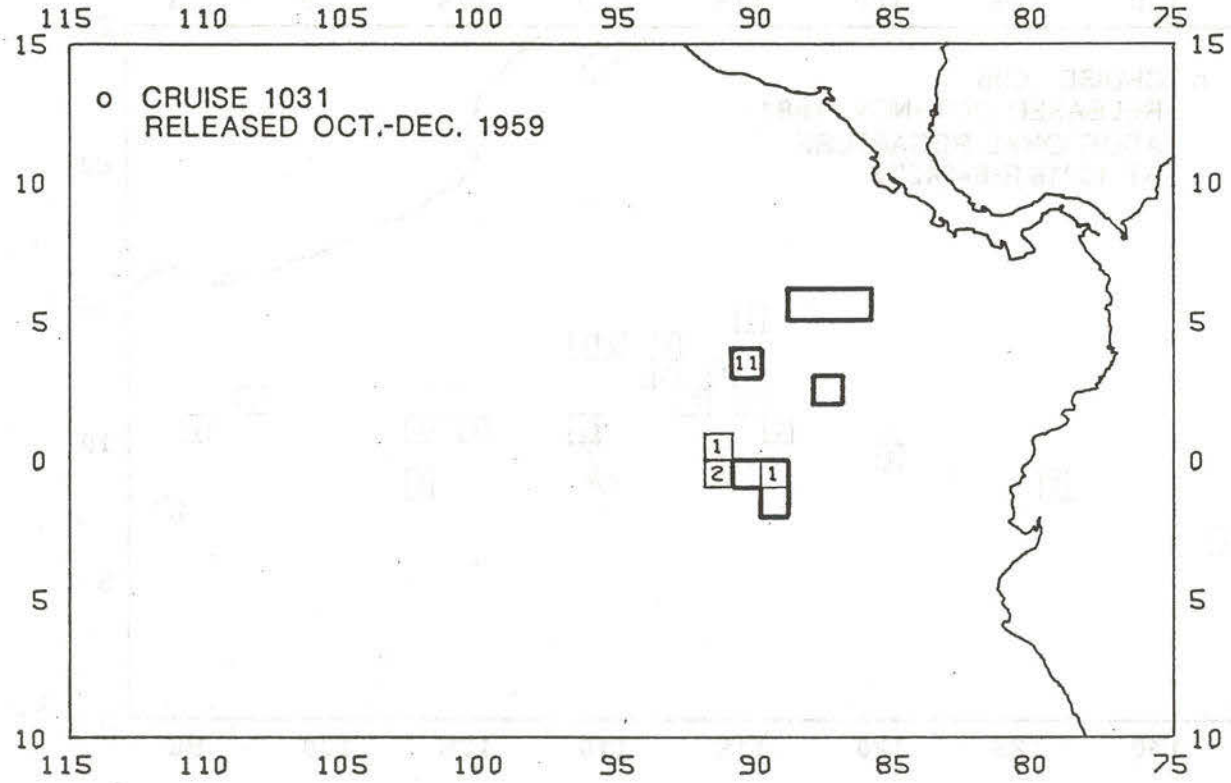

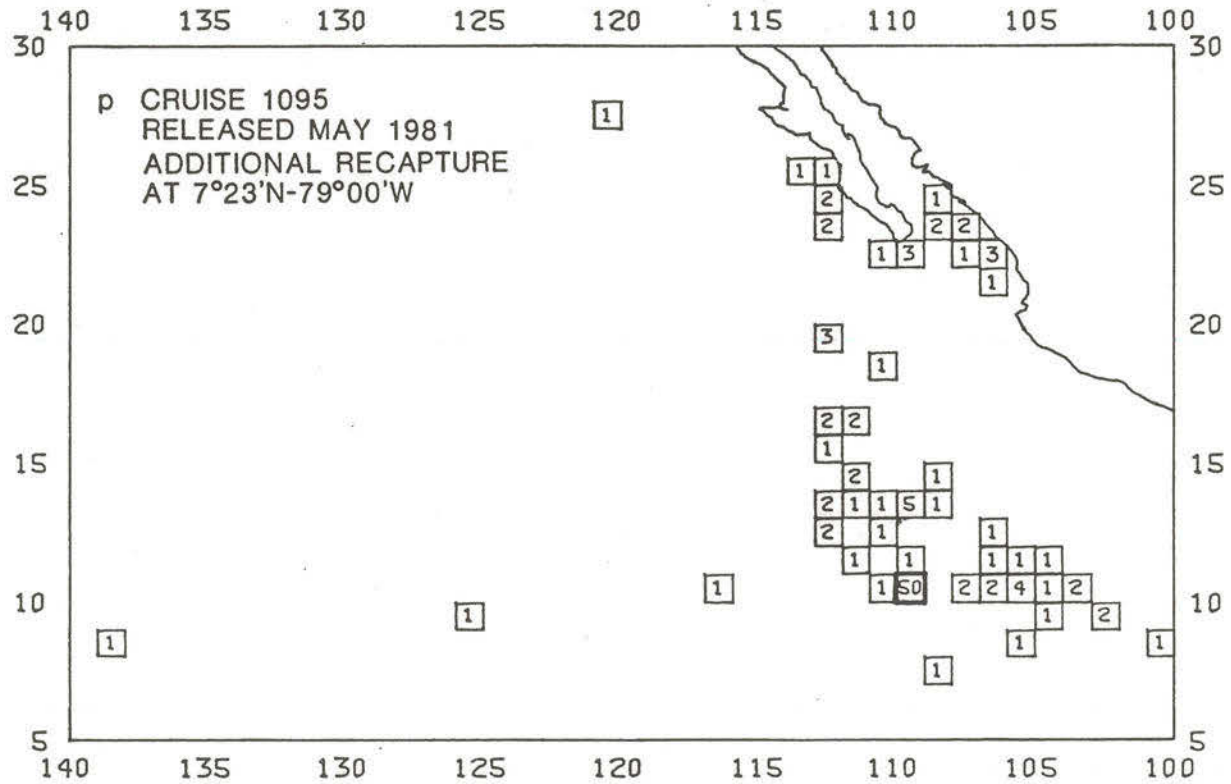

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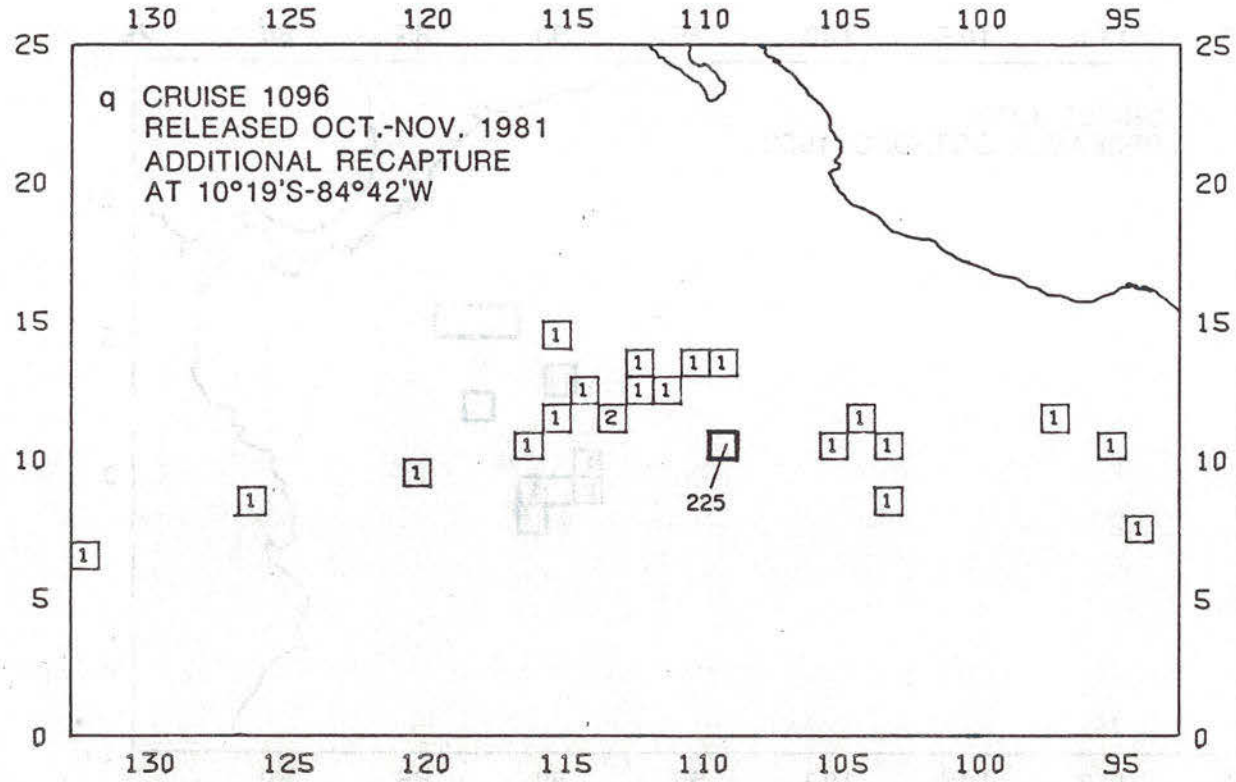
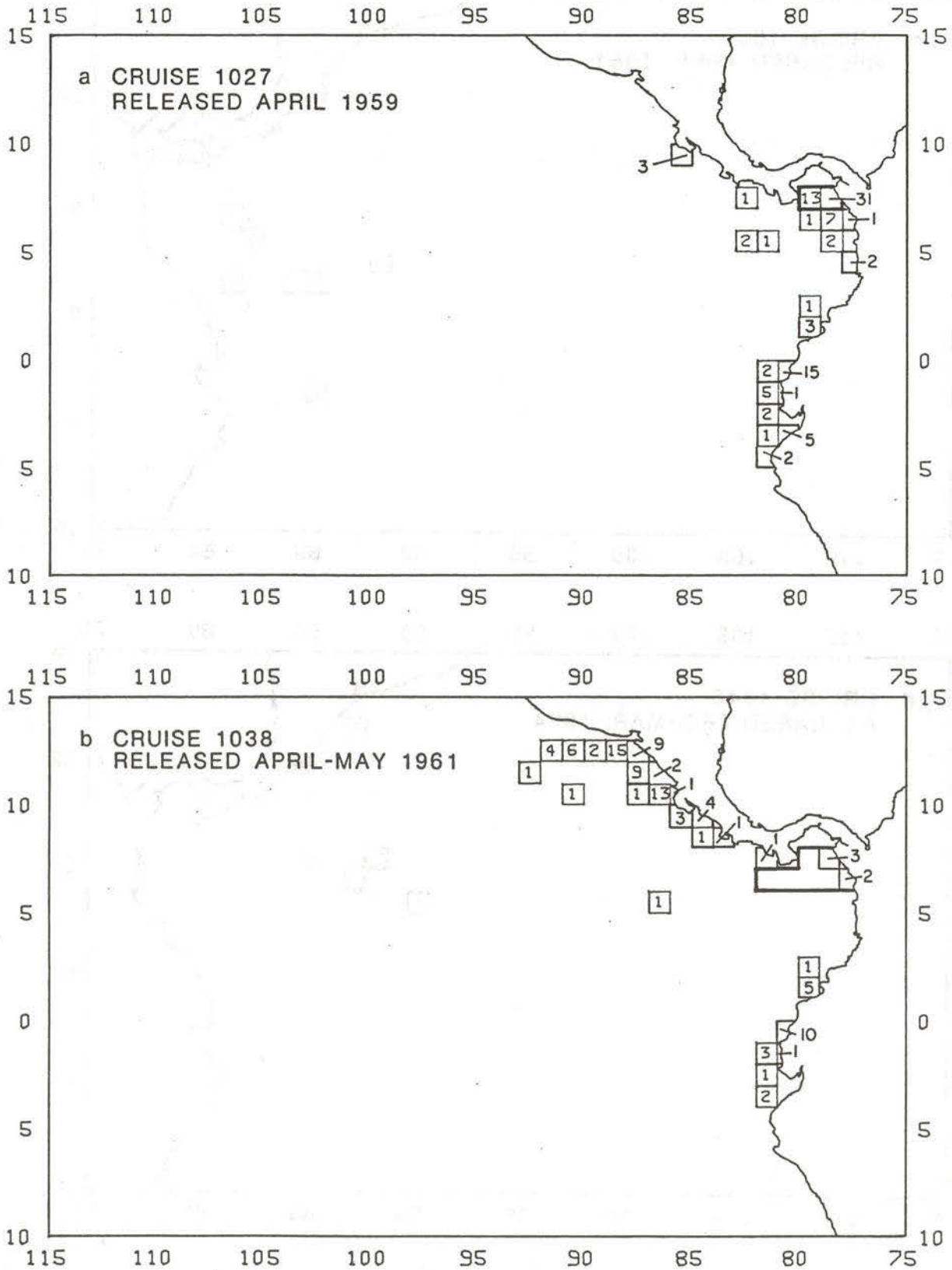


FIGURE 2. Areas of release (areas delineated by heavy lines) and areas of recapture (areas with numerals) for tagged skipjack released in the eastern Pacific Ocean during 1959-1981.



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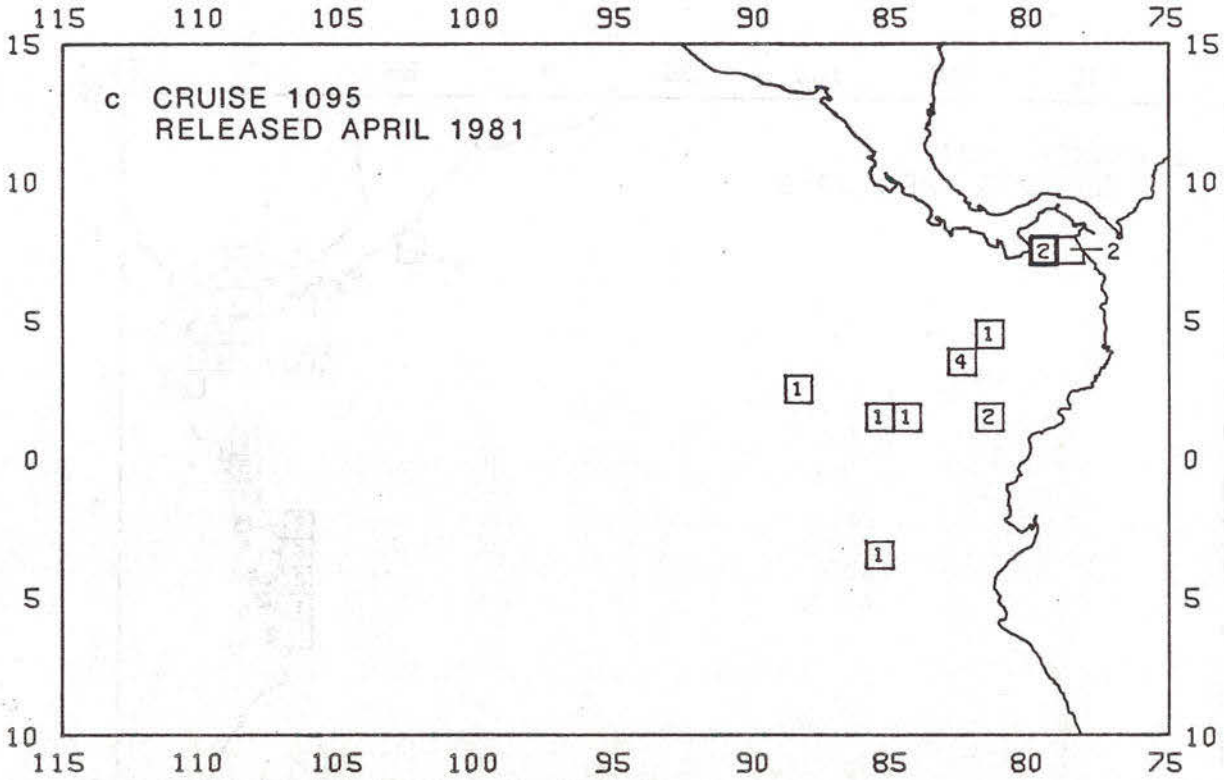

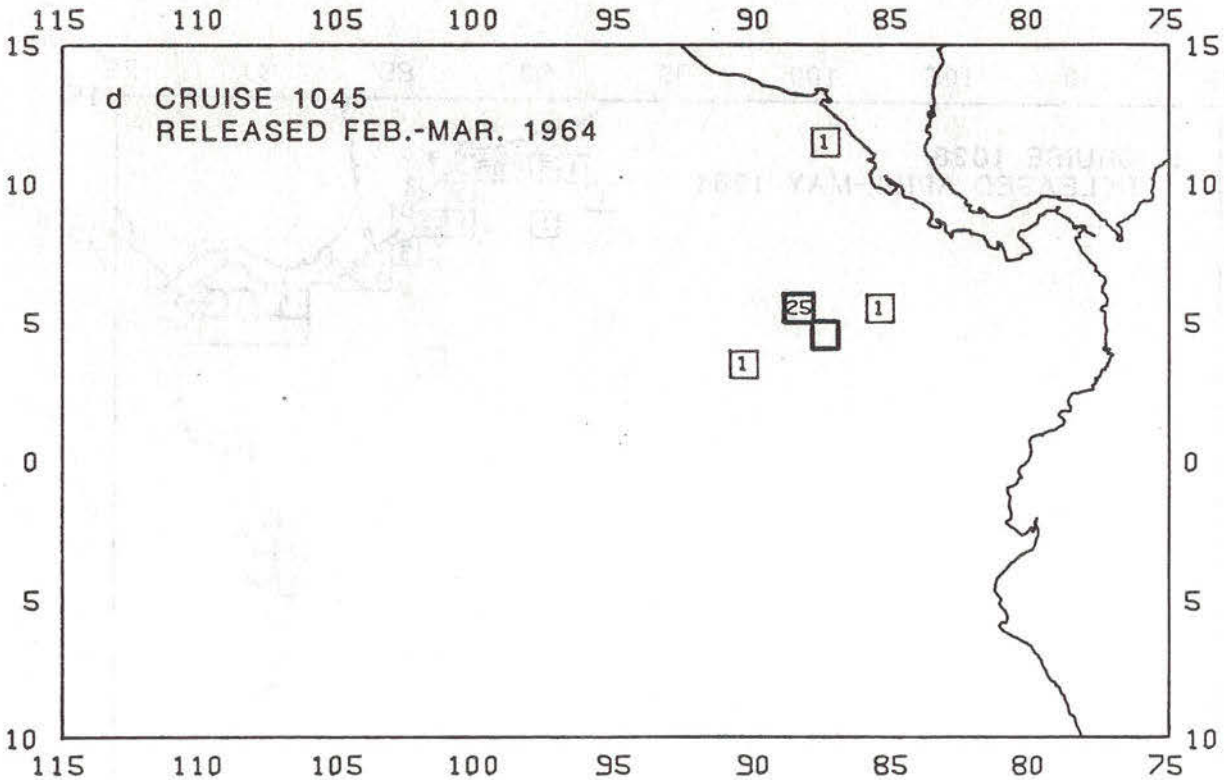

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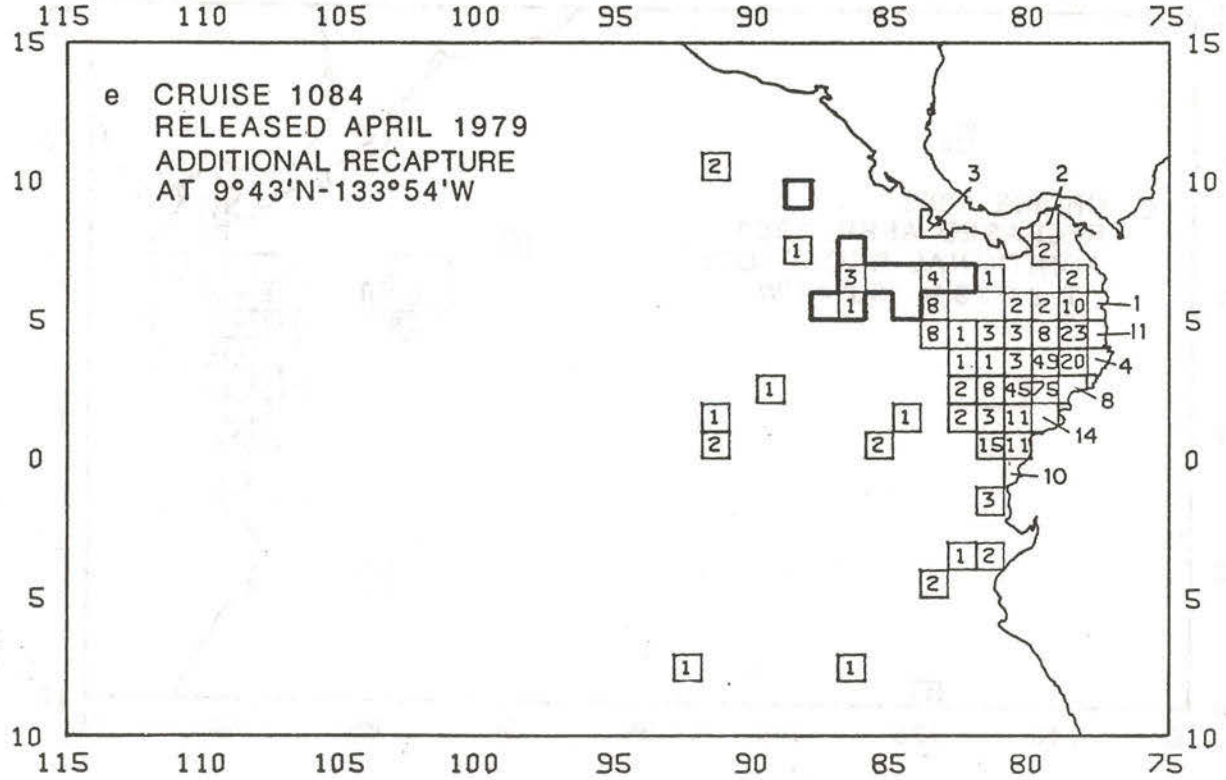

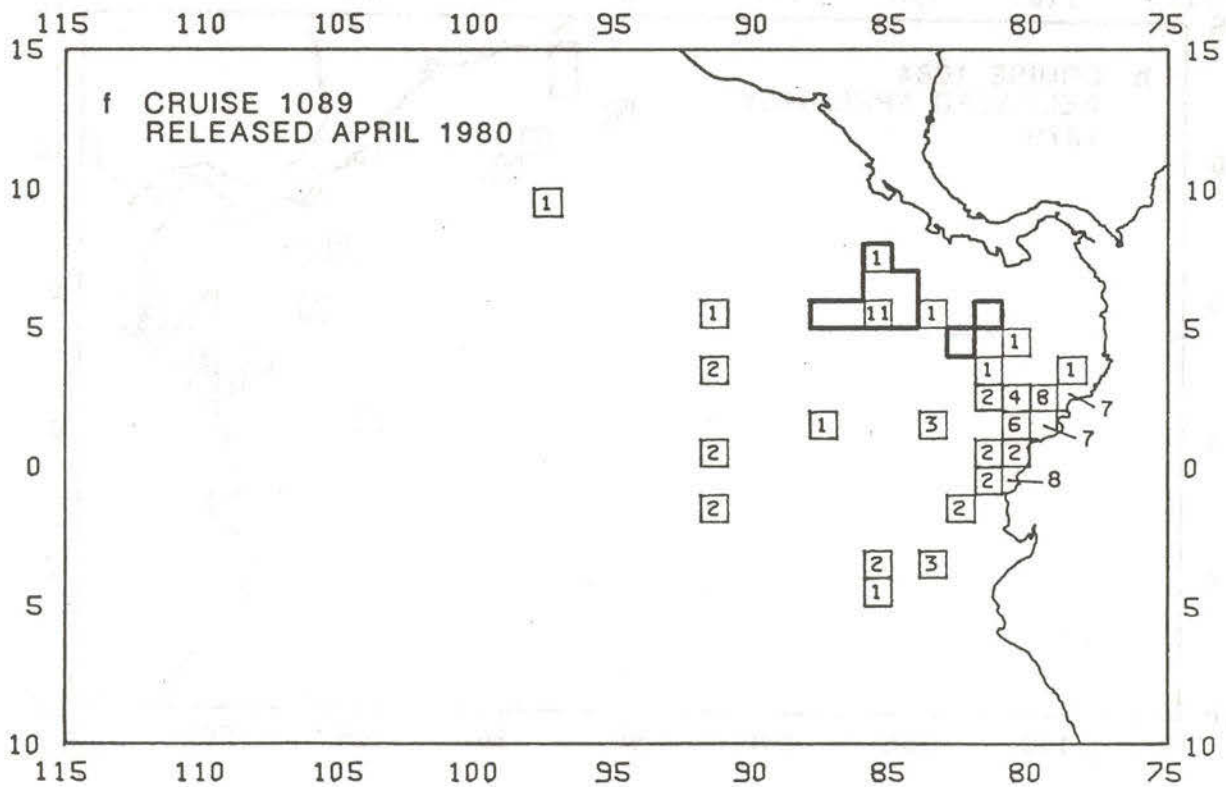

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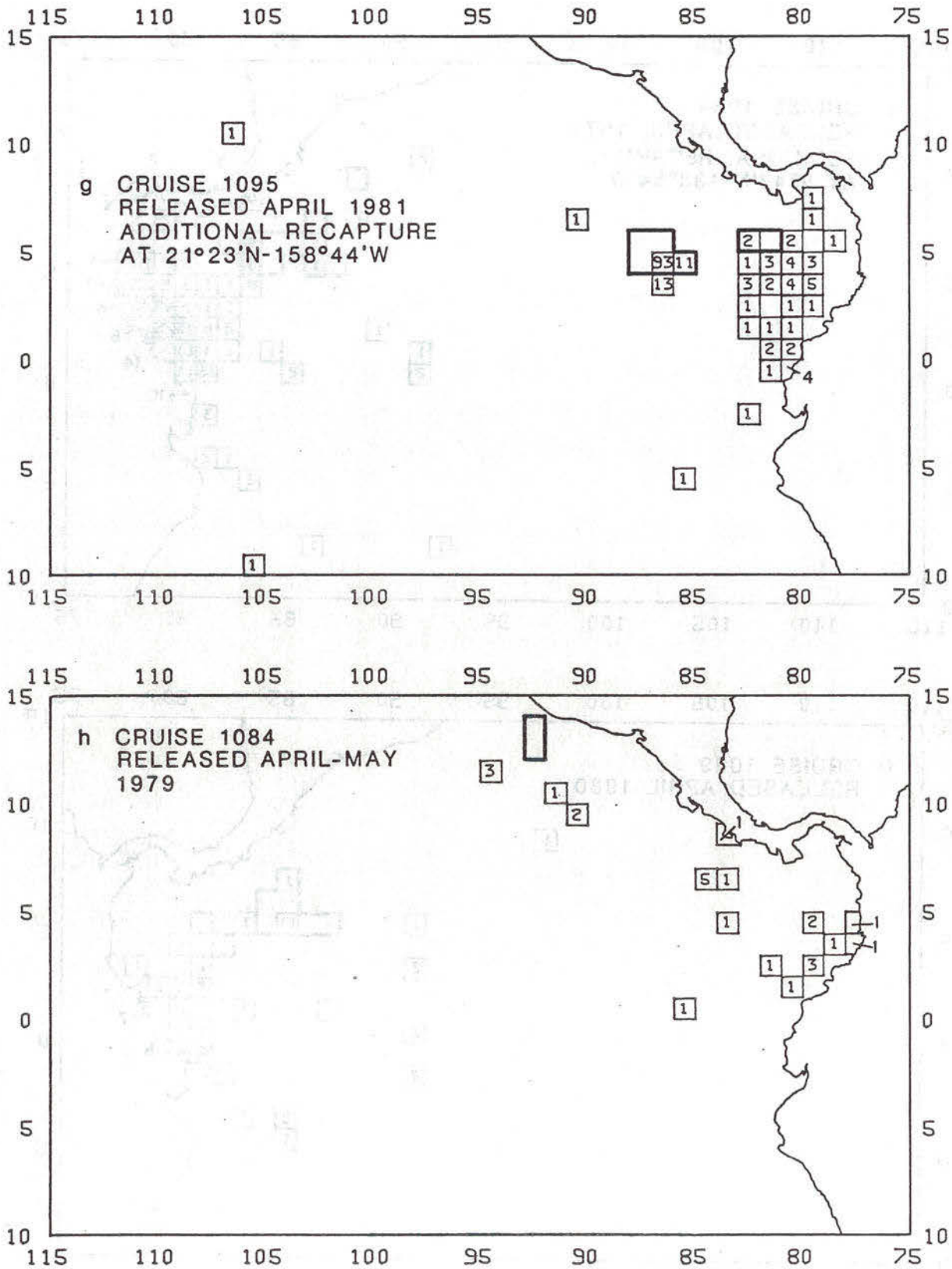

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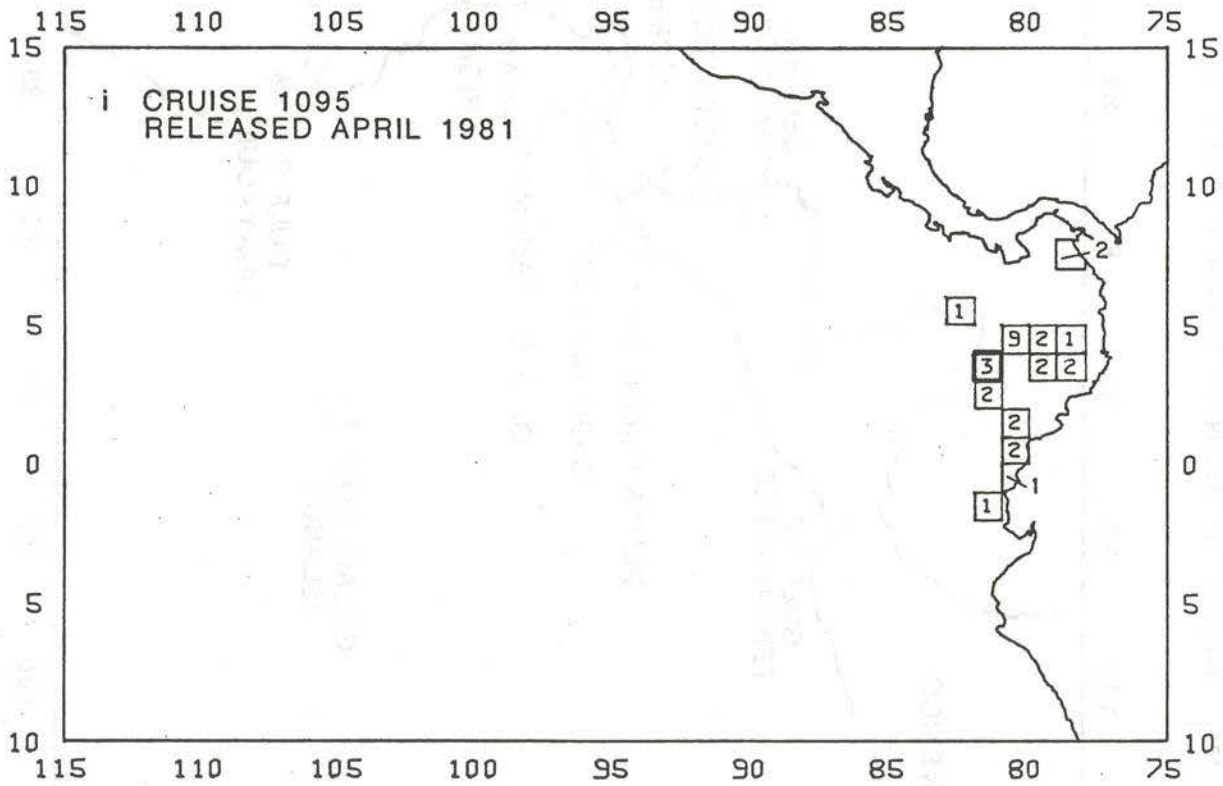

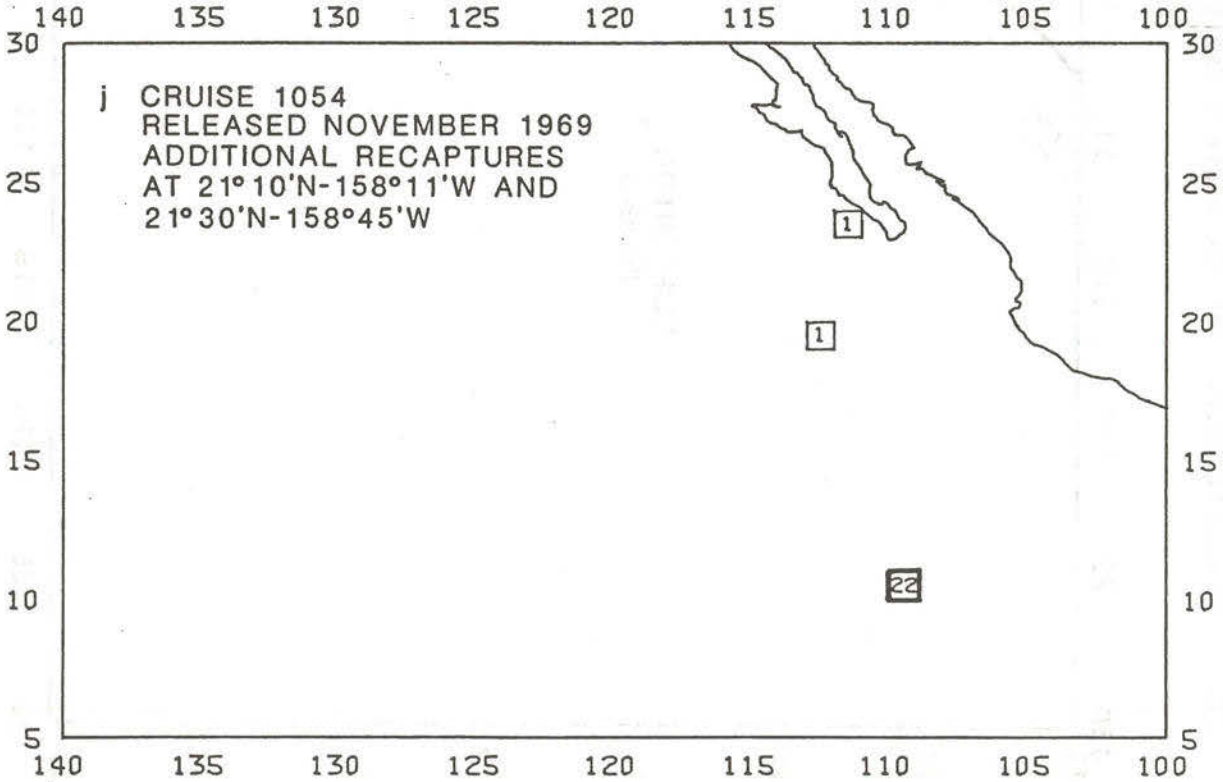

FIGURE 3. Central portion of the eastern Pacific Ocean, showing the areas mentioned in the text.

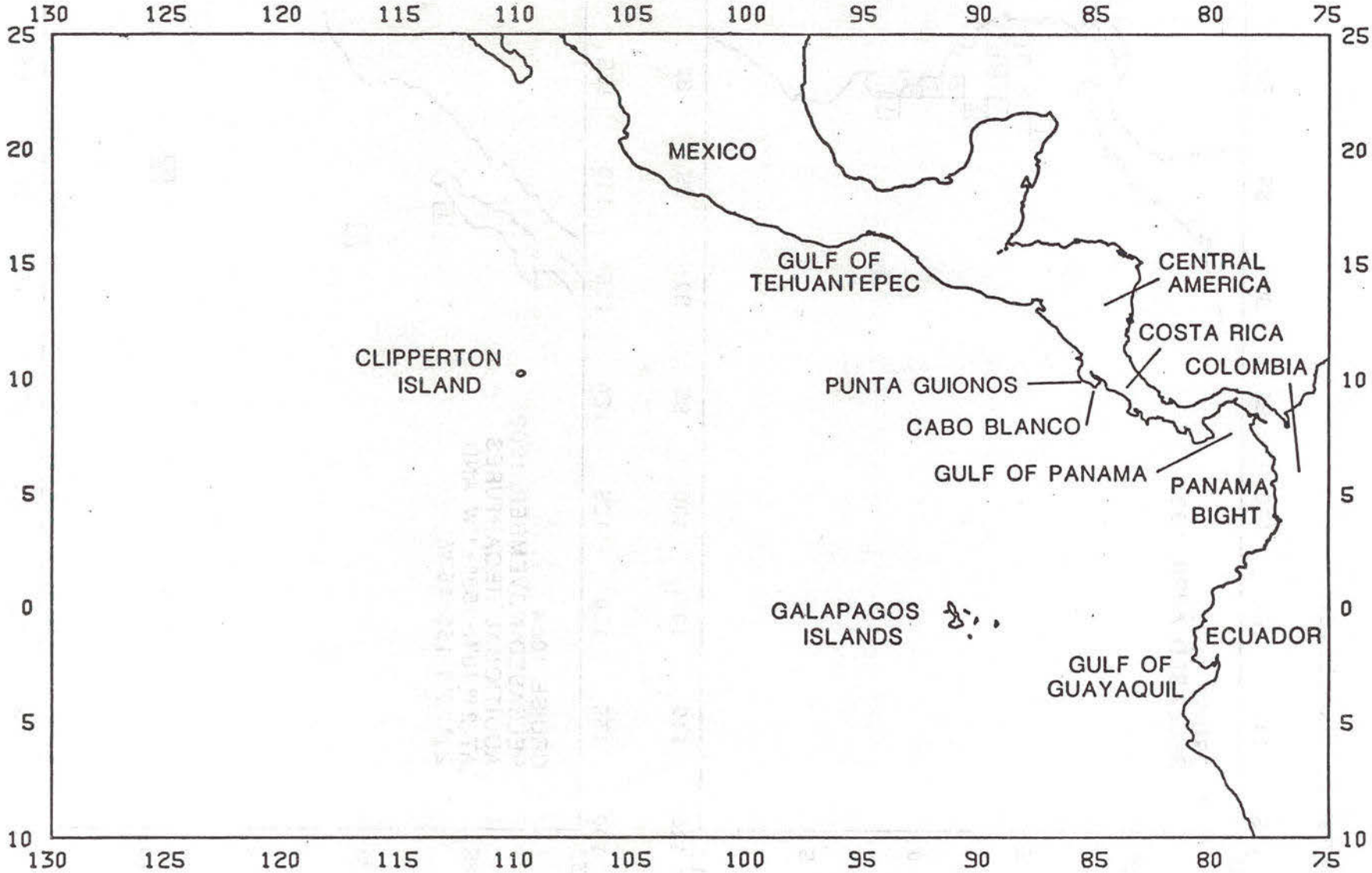

FIGURE 4. Relationship of unstandardized skipjack catch per unit of effort by purse seiners to that by baitboats in Class-4 days (solid line) and the reverse relationship (dashed line). The curves in the left panel are based on all the data, while those in the right panel are based on the data with three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

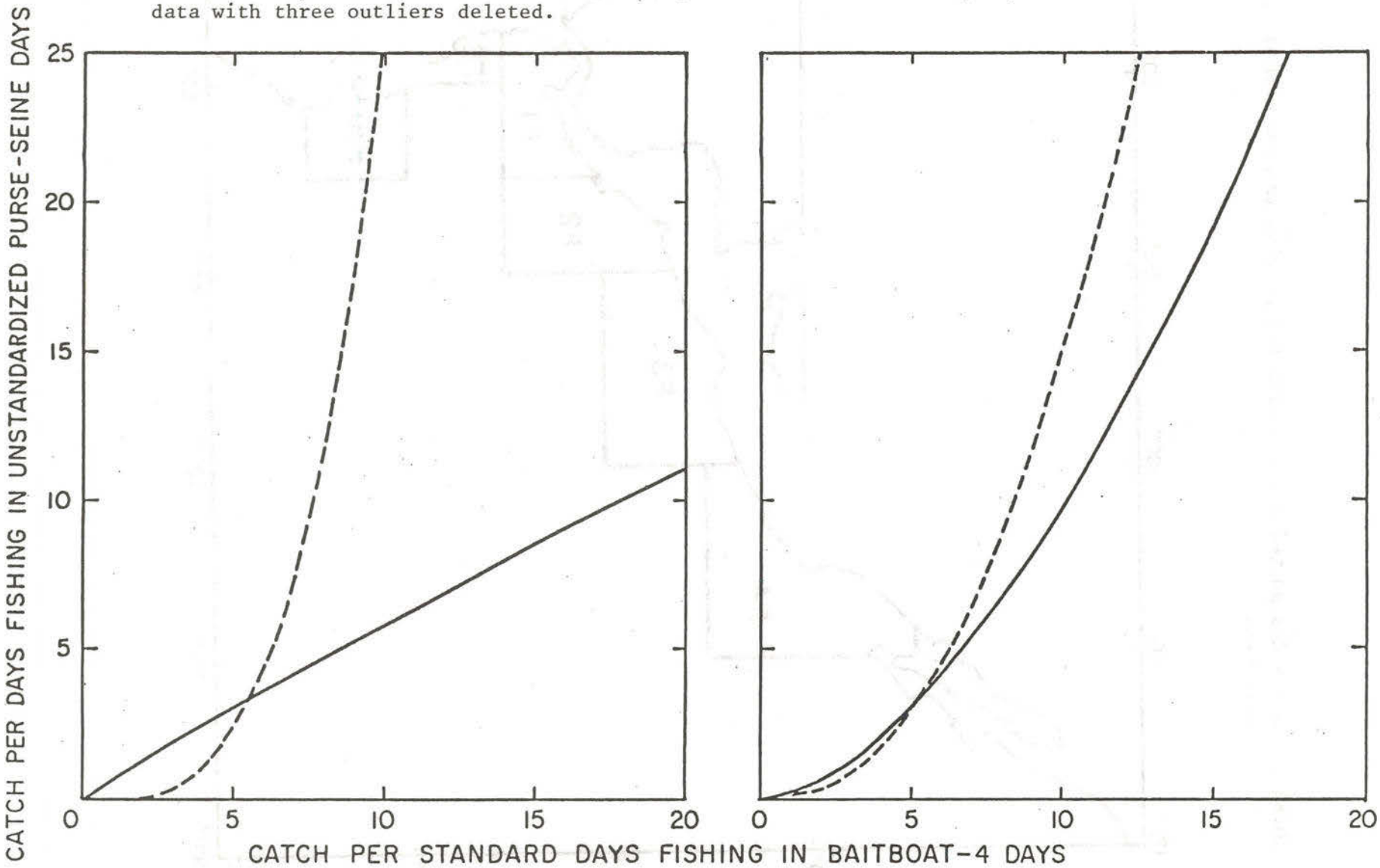

FIGURE 5. Areas designated for use with the portion-in-area method for yellowfin.

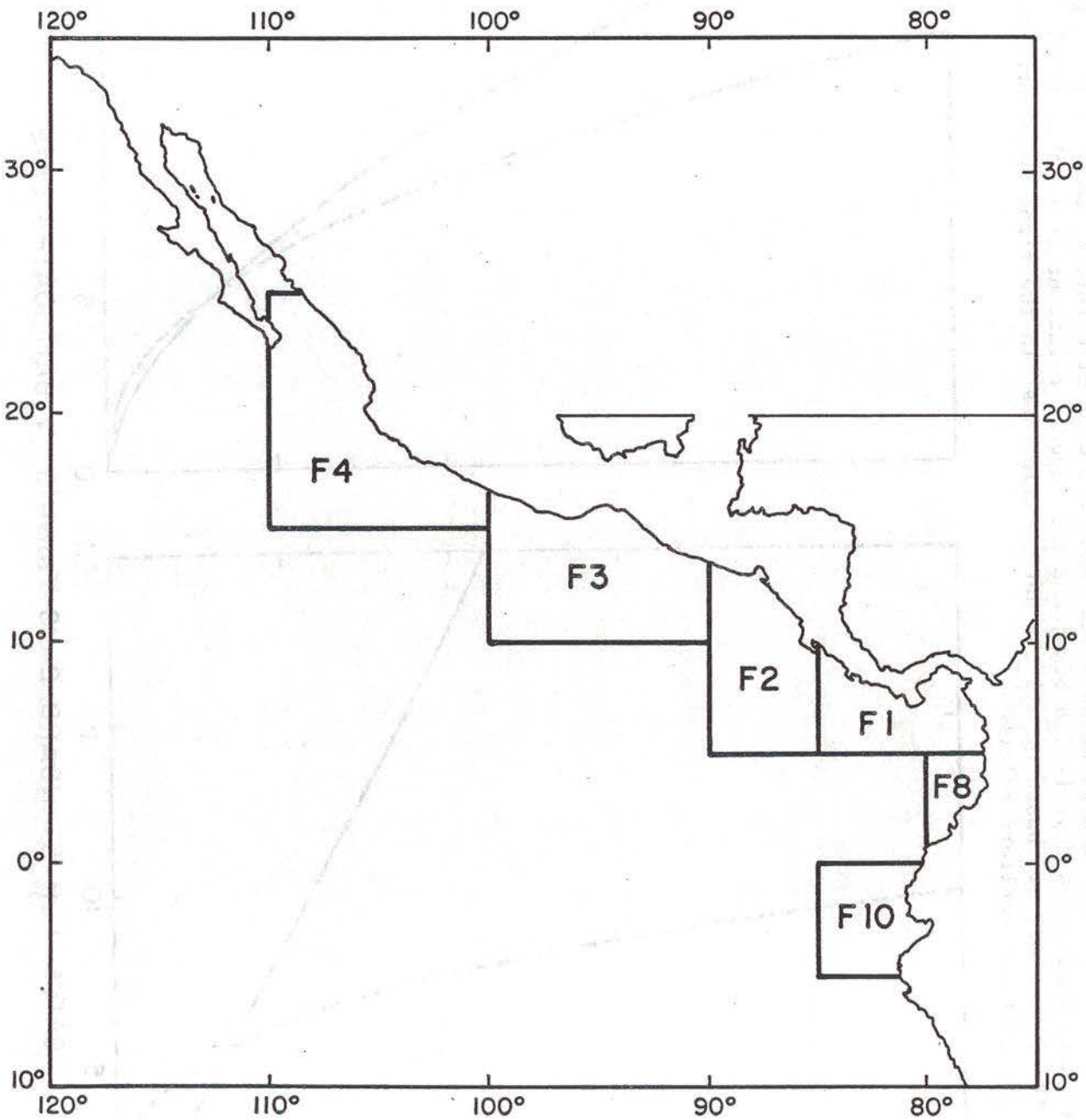

FIGURE 5. (continued)

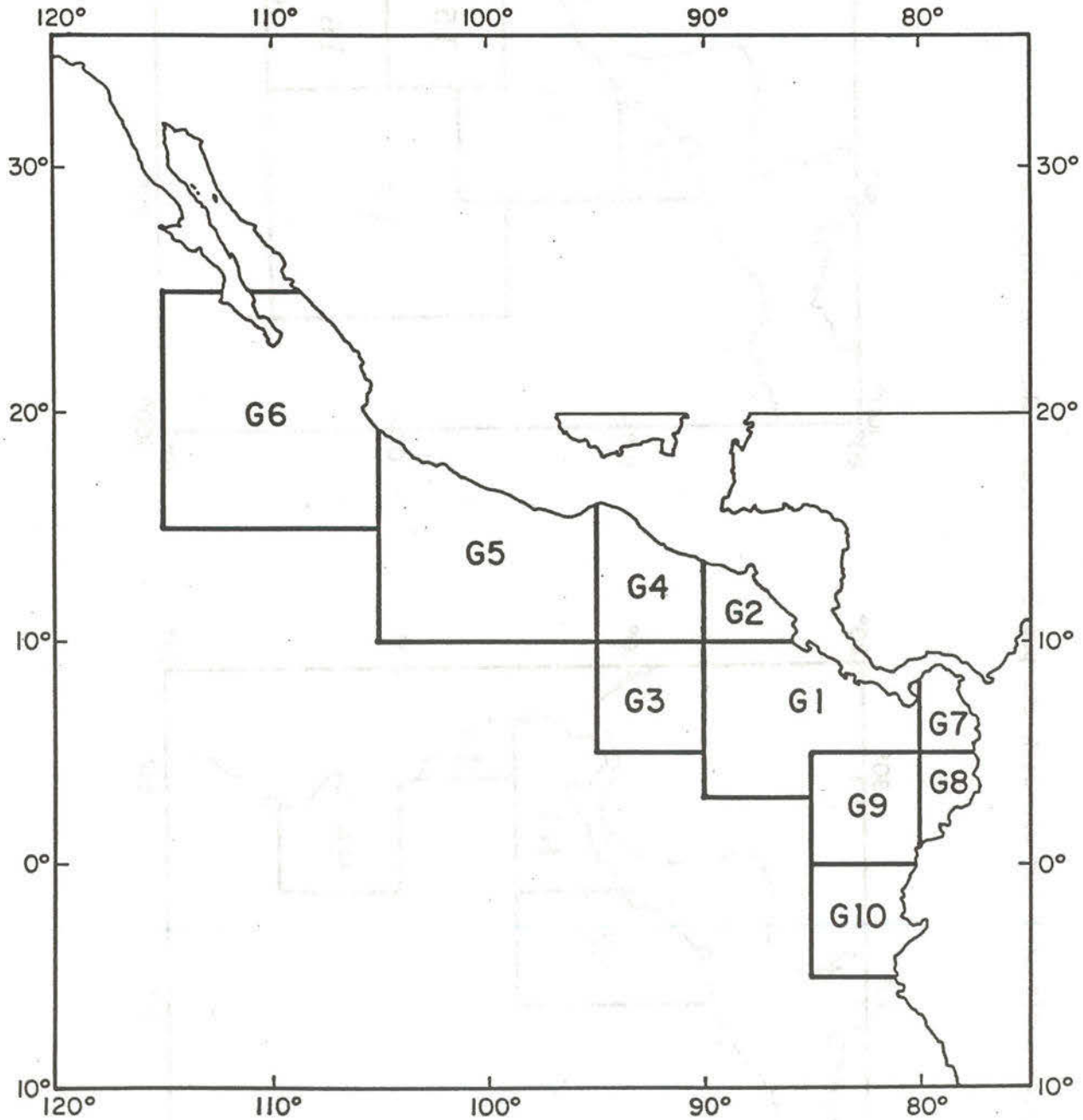

FIGURE 6. Areas designated for use with the portion-in-area method for skipjack.

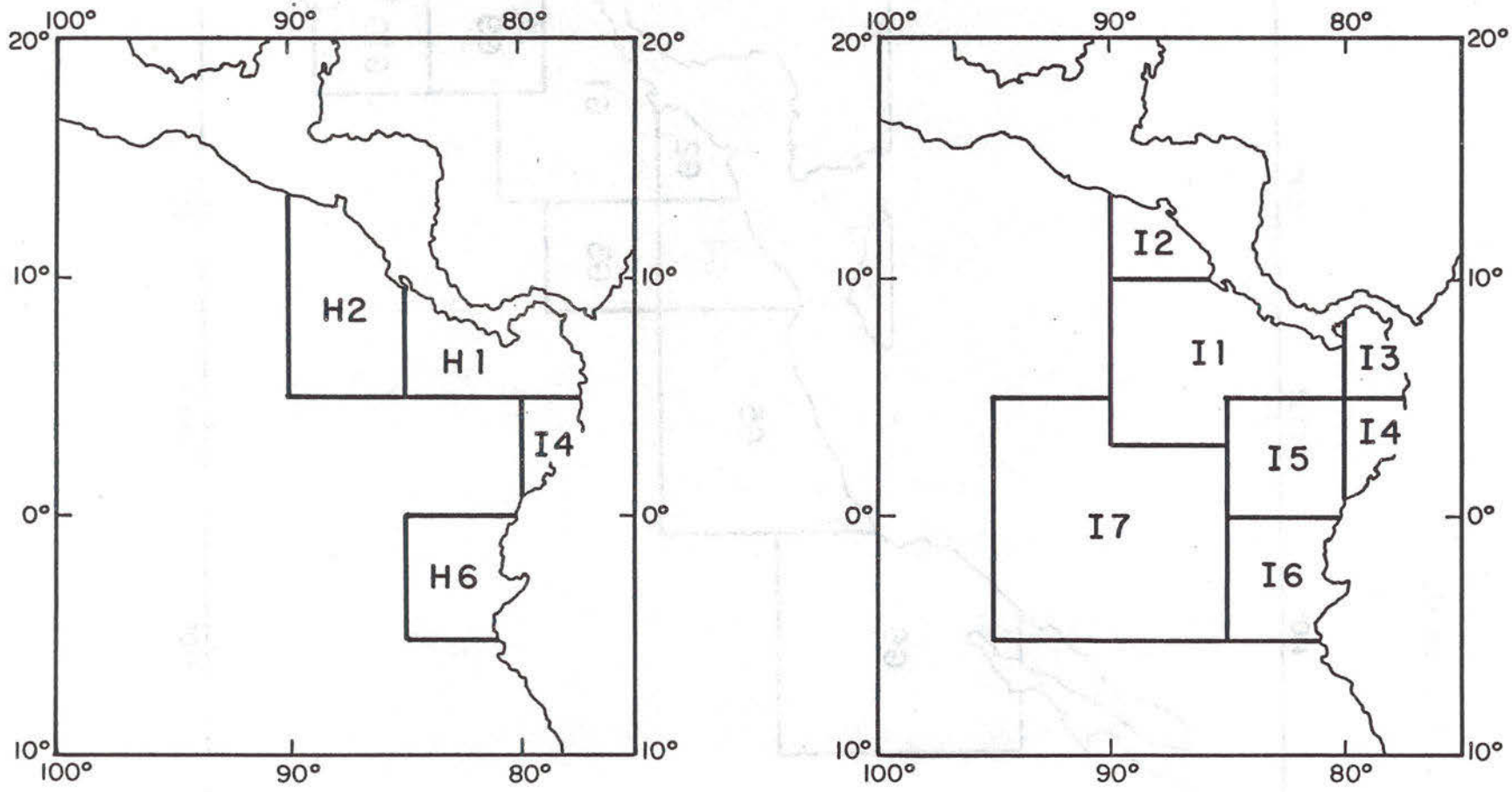

FIGURE 7. Portions of returns weighted by fishing effort in each area for yellowfin.

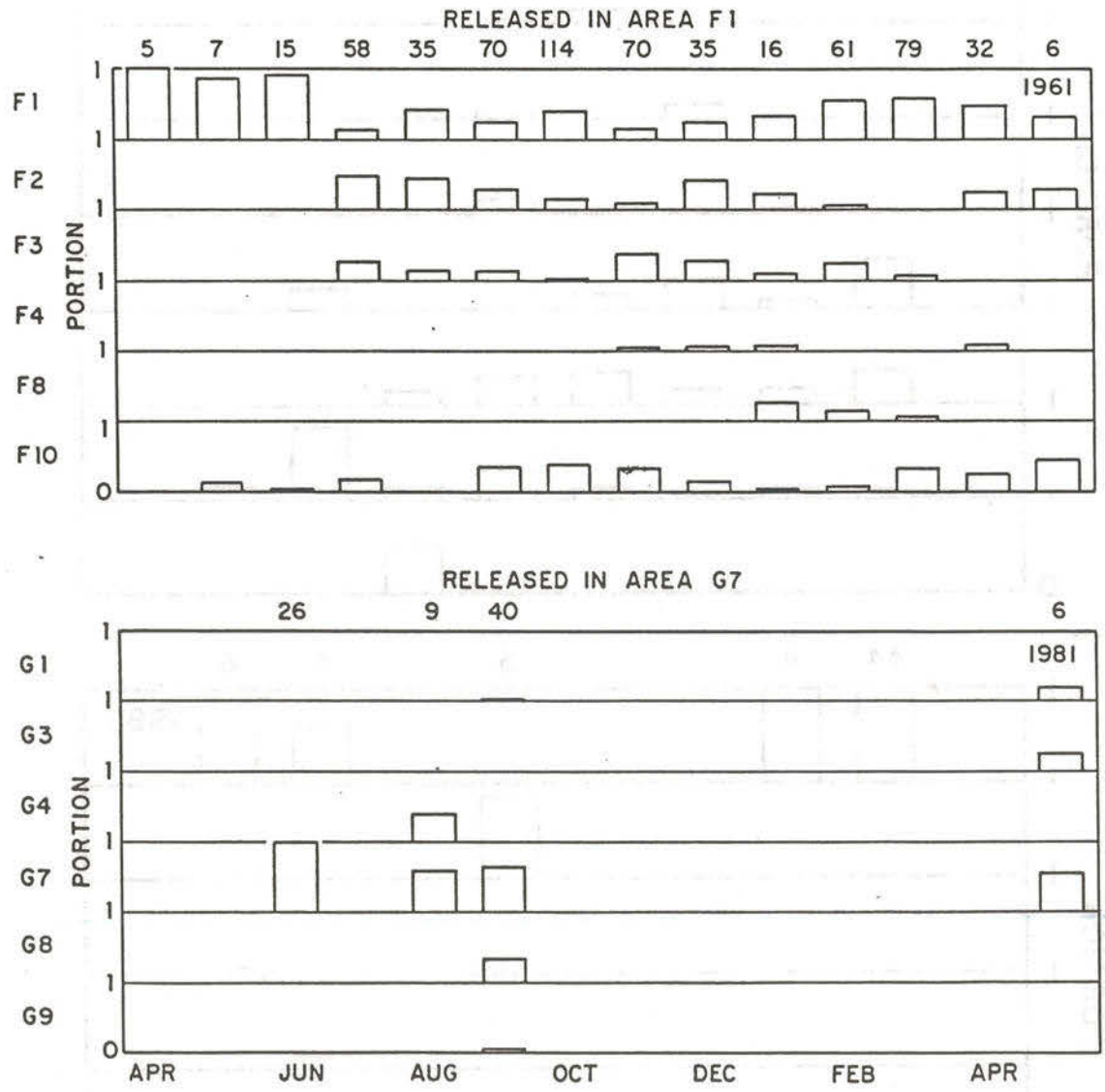

FIGURE 7. (continued)

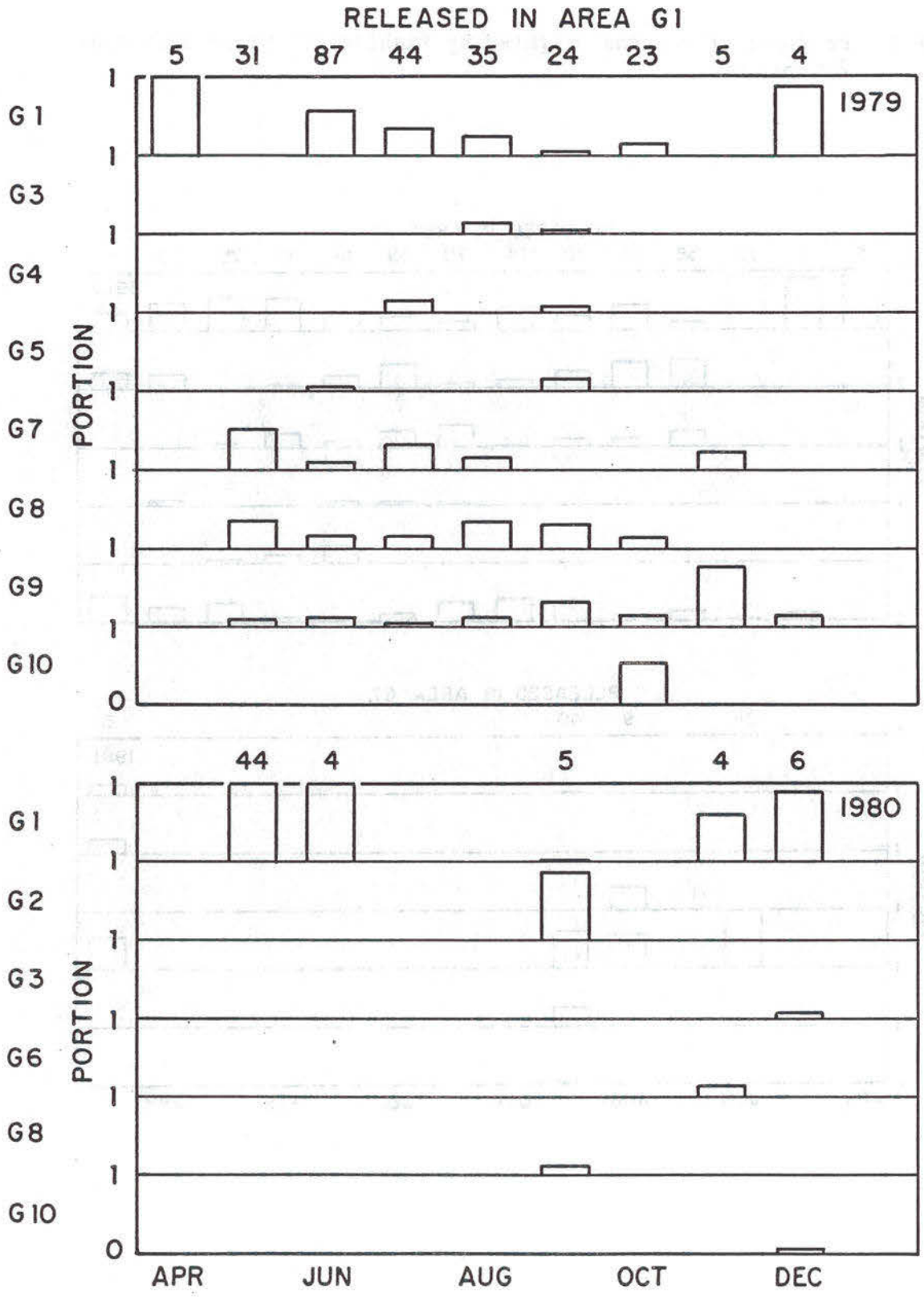

FIGURE 7. (continued)

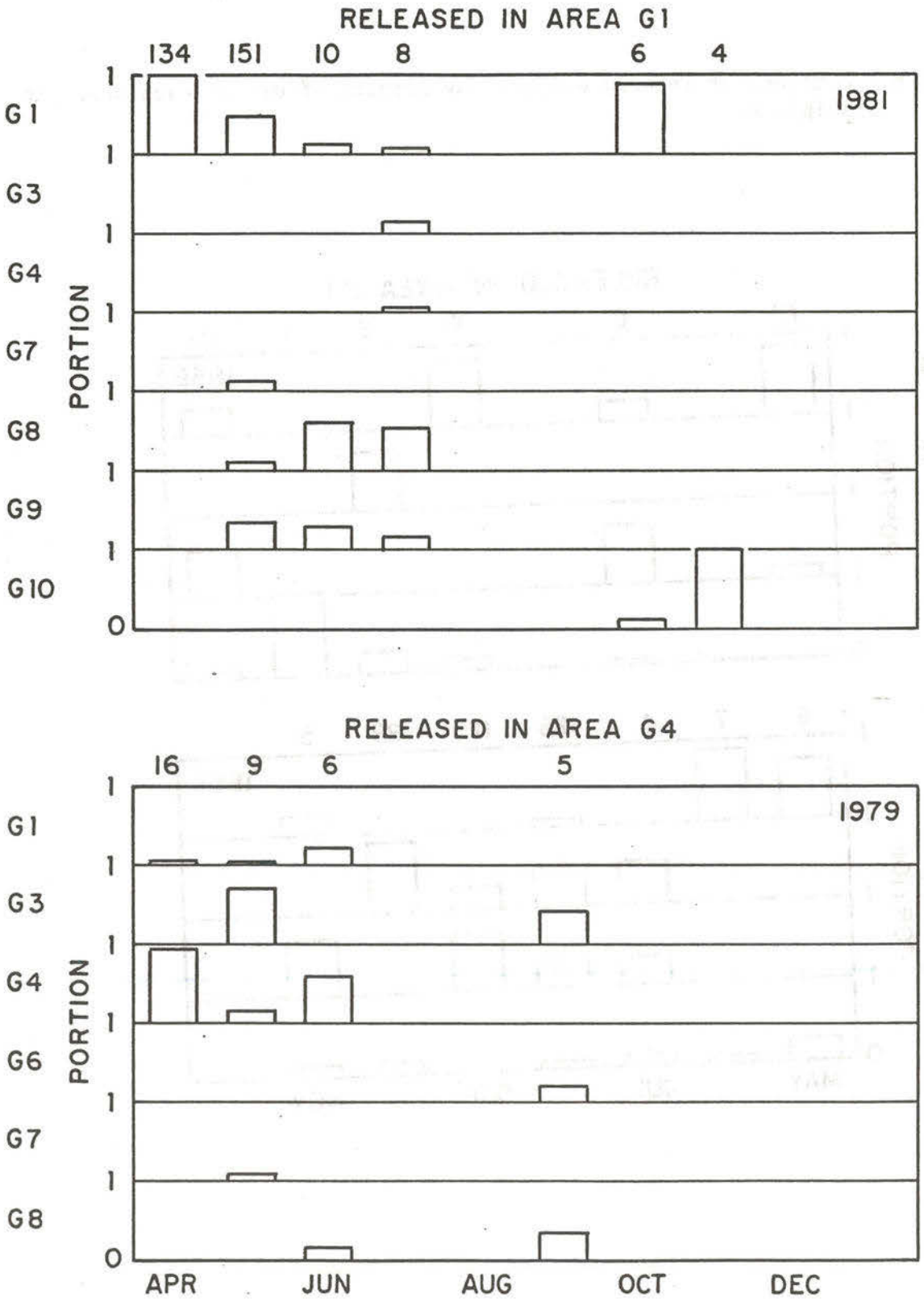

FIGURE 8. Portions of returns weighted by fishing effort in each area for skipjack.

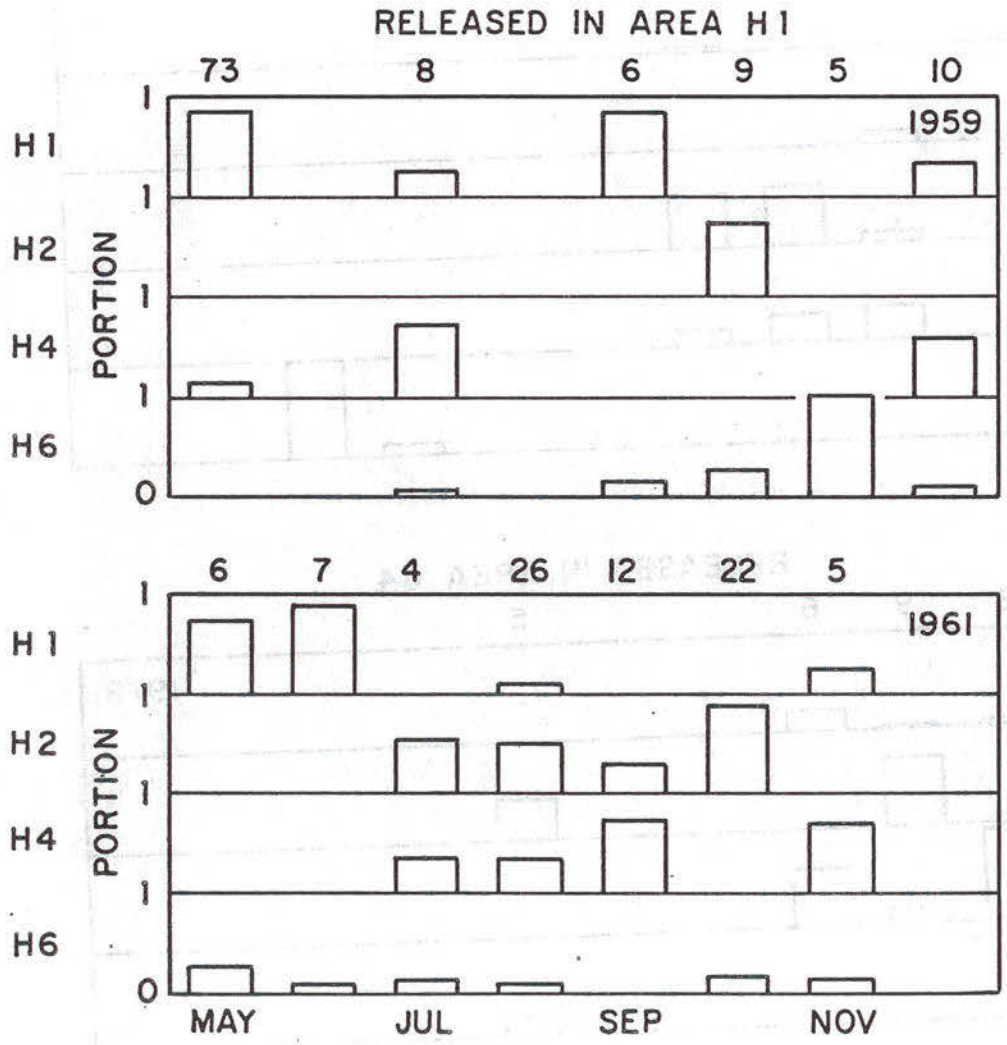

FIGURE 8. (continued)

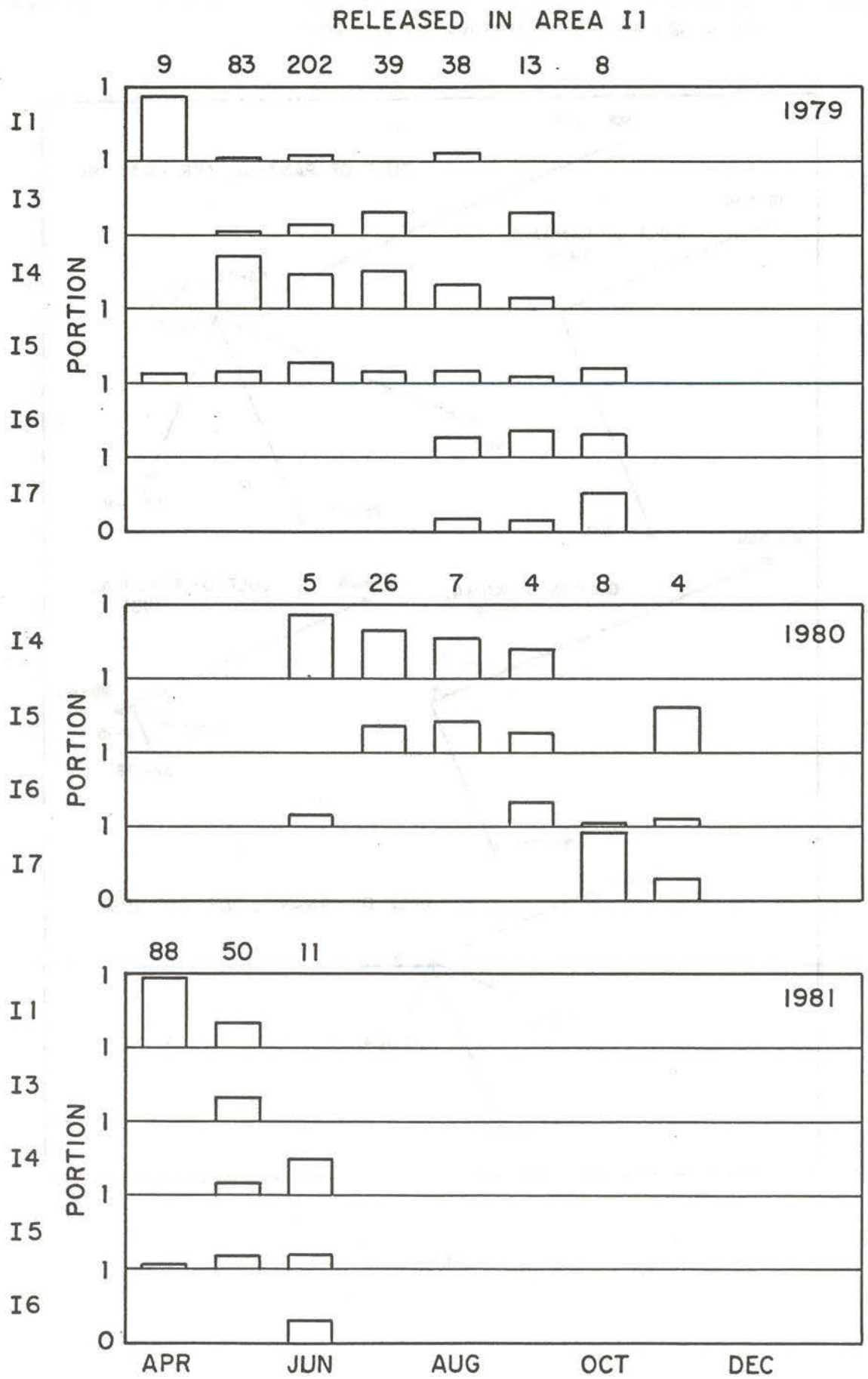

FIGURE 9. Adjusted directions and mean distances of movement for yellowfin. The diagrams are explained in the text.

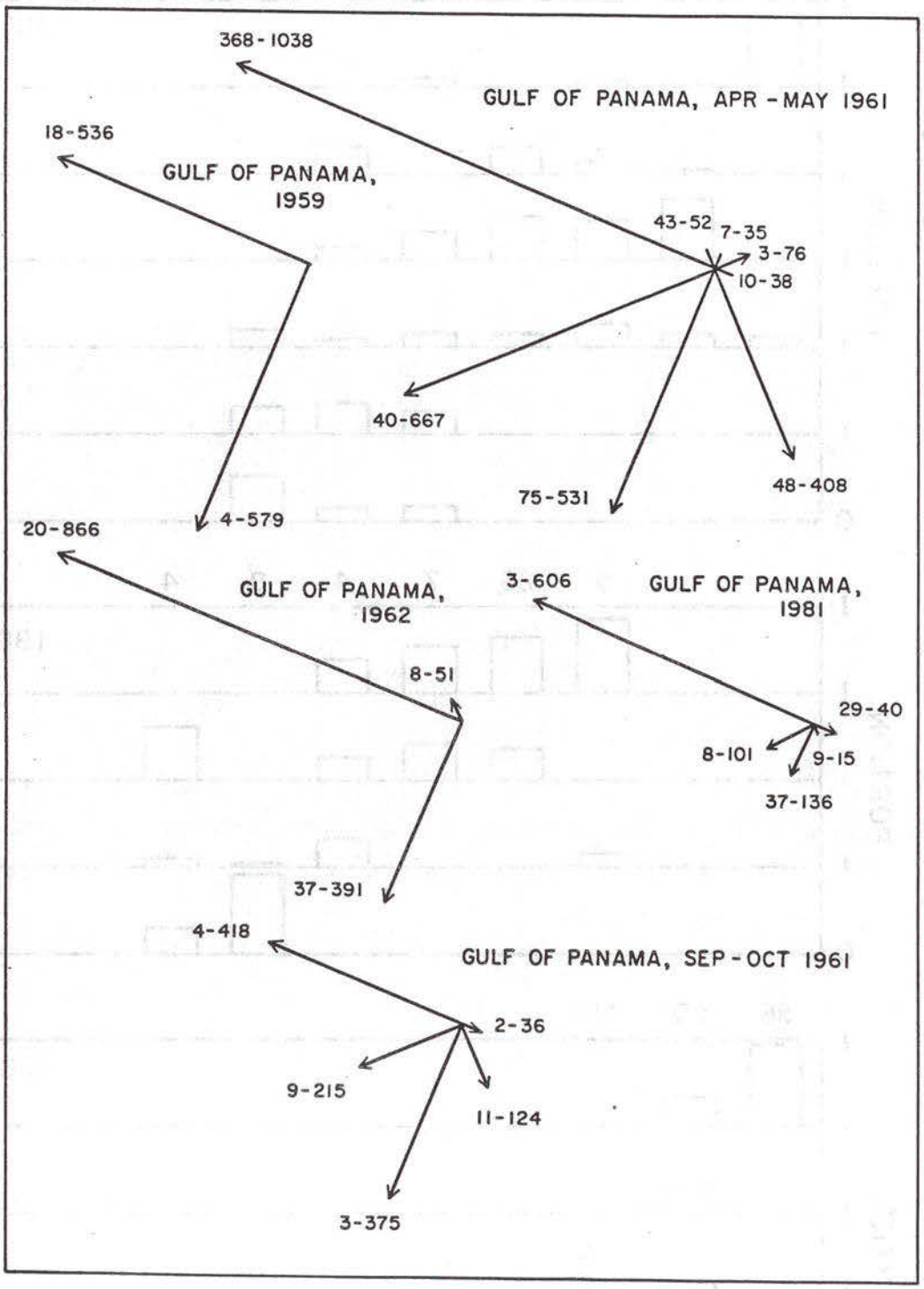

FIGURE 9. (continued)

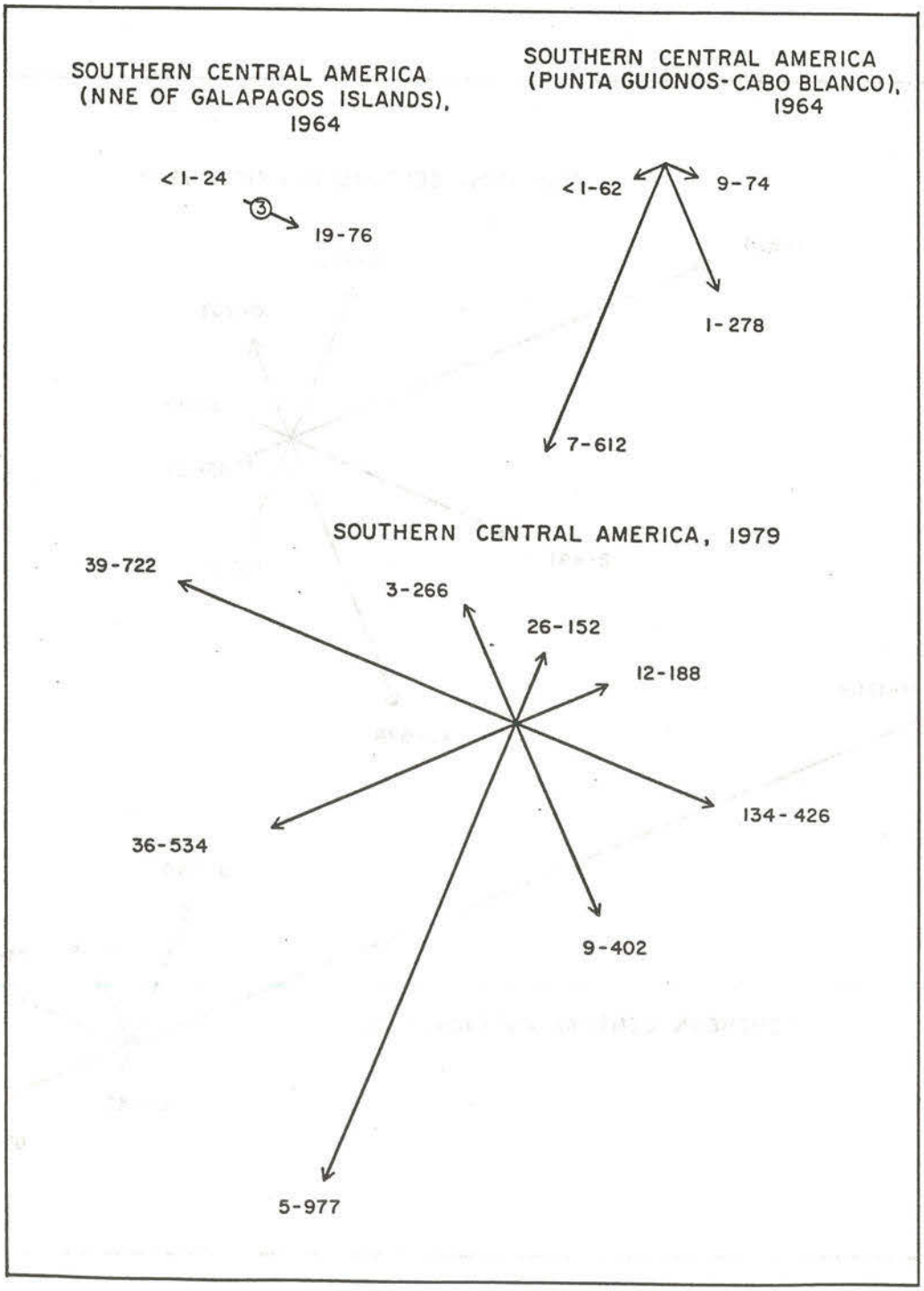

FIGURE 9. (continued)

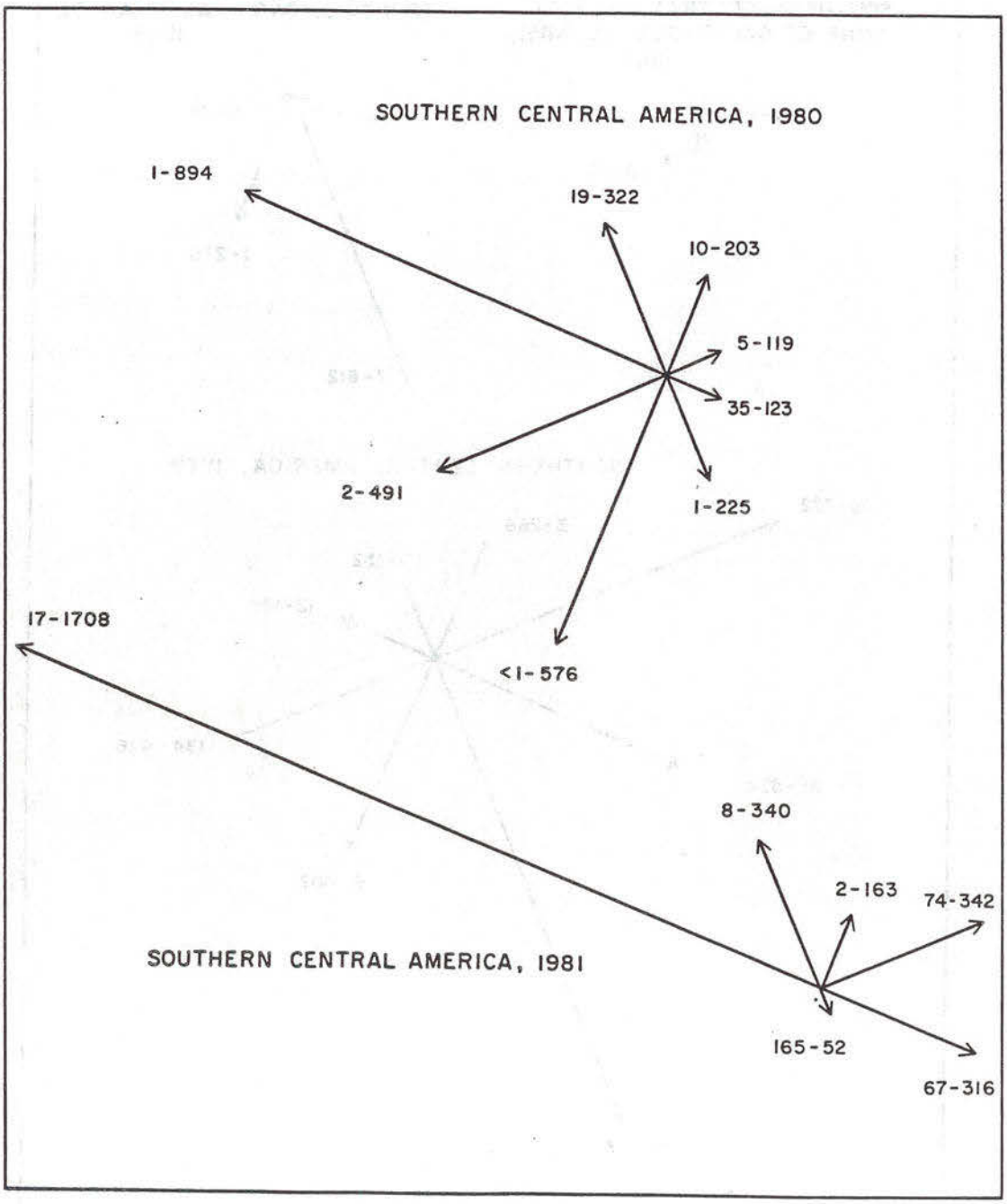

FIGURE 9. (continued)

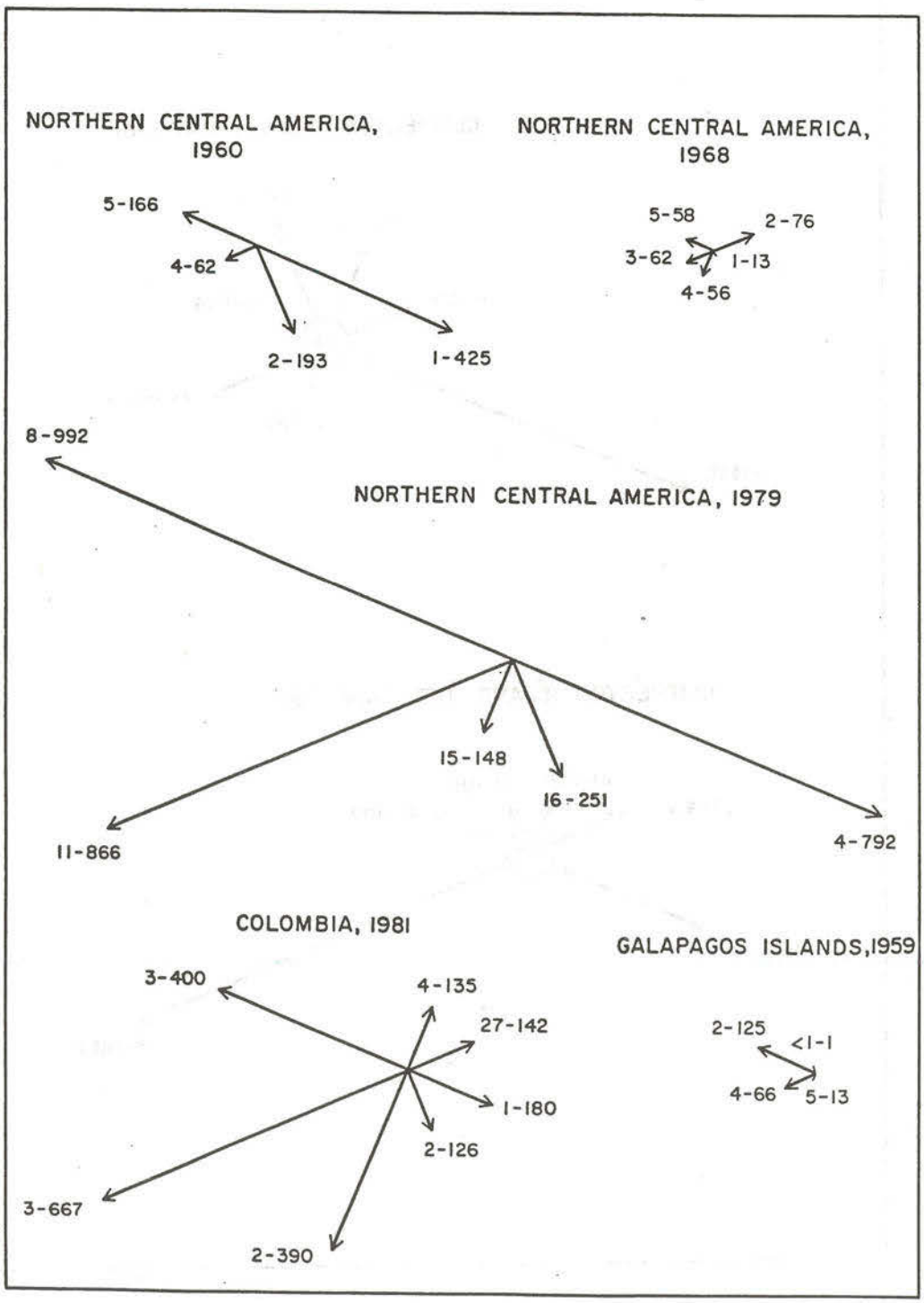

FIGURE 9. (continued)

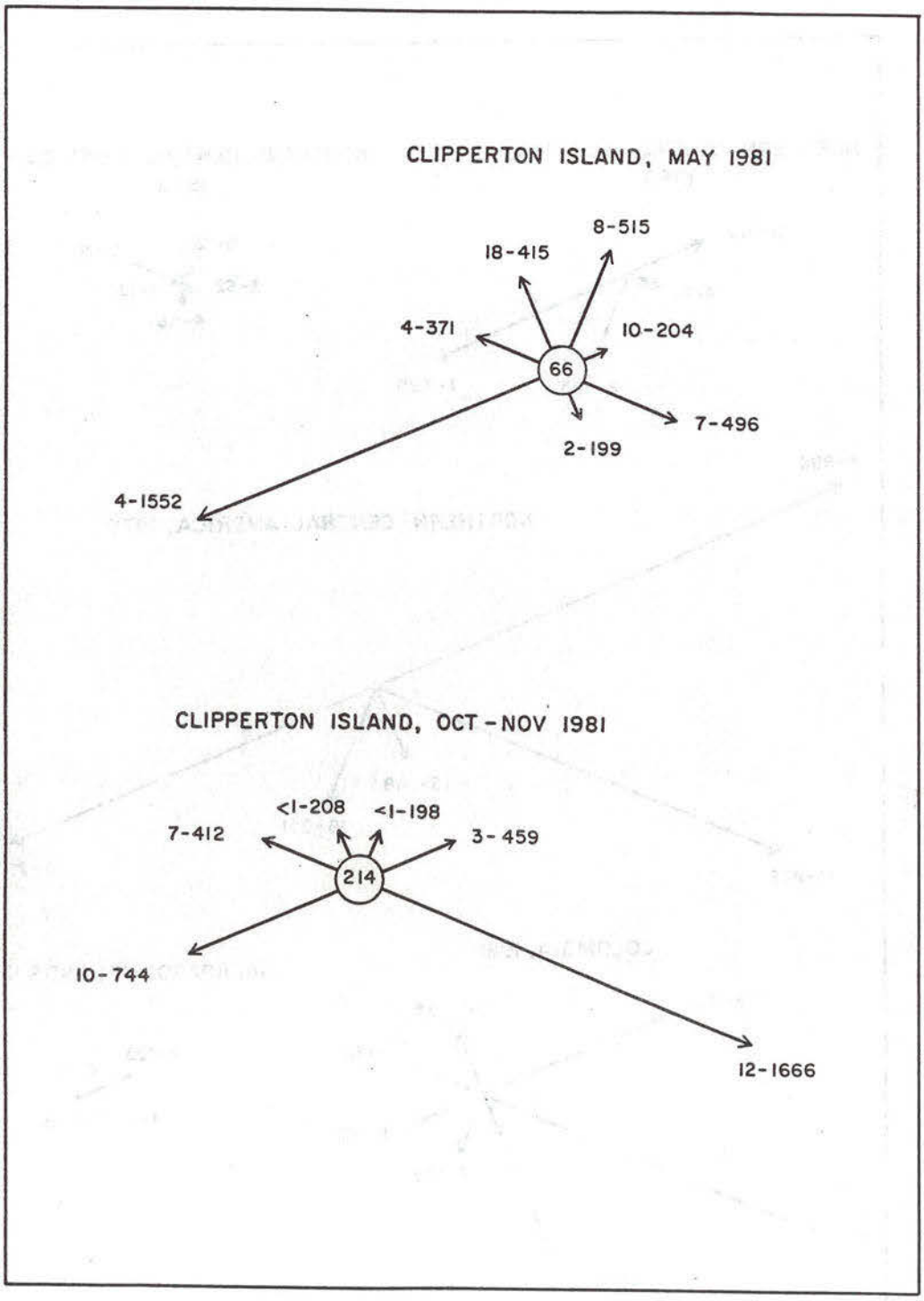

FIGURE 10. Adjusted directions and mean distances of movement for skipjack. The diagrams are explained in the text.

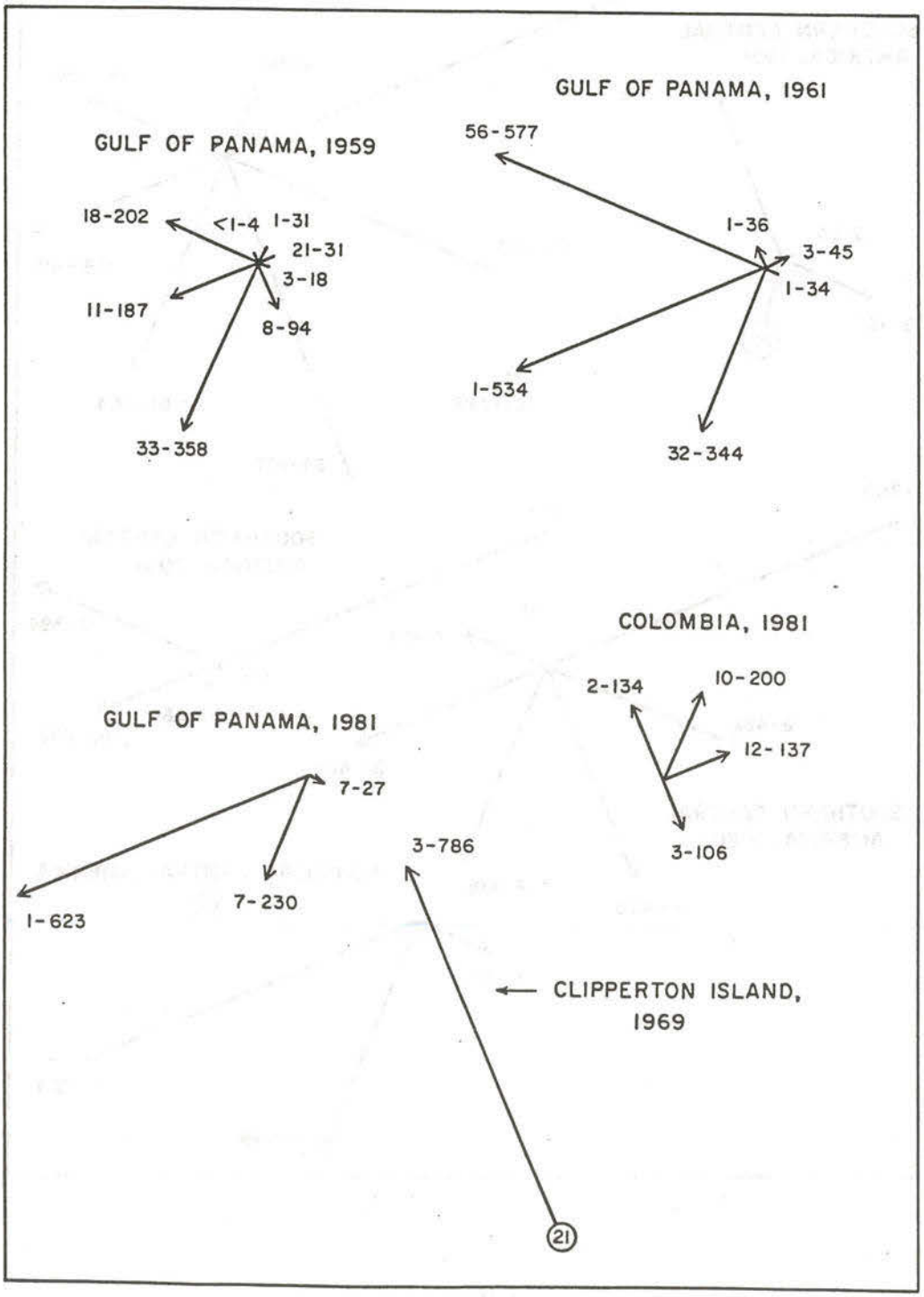

FIGURE 10. (continued)

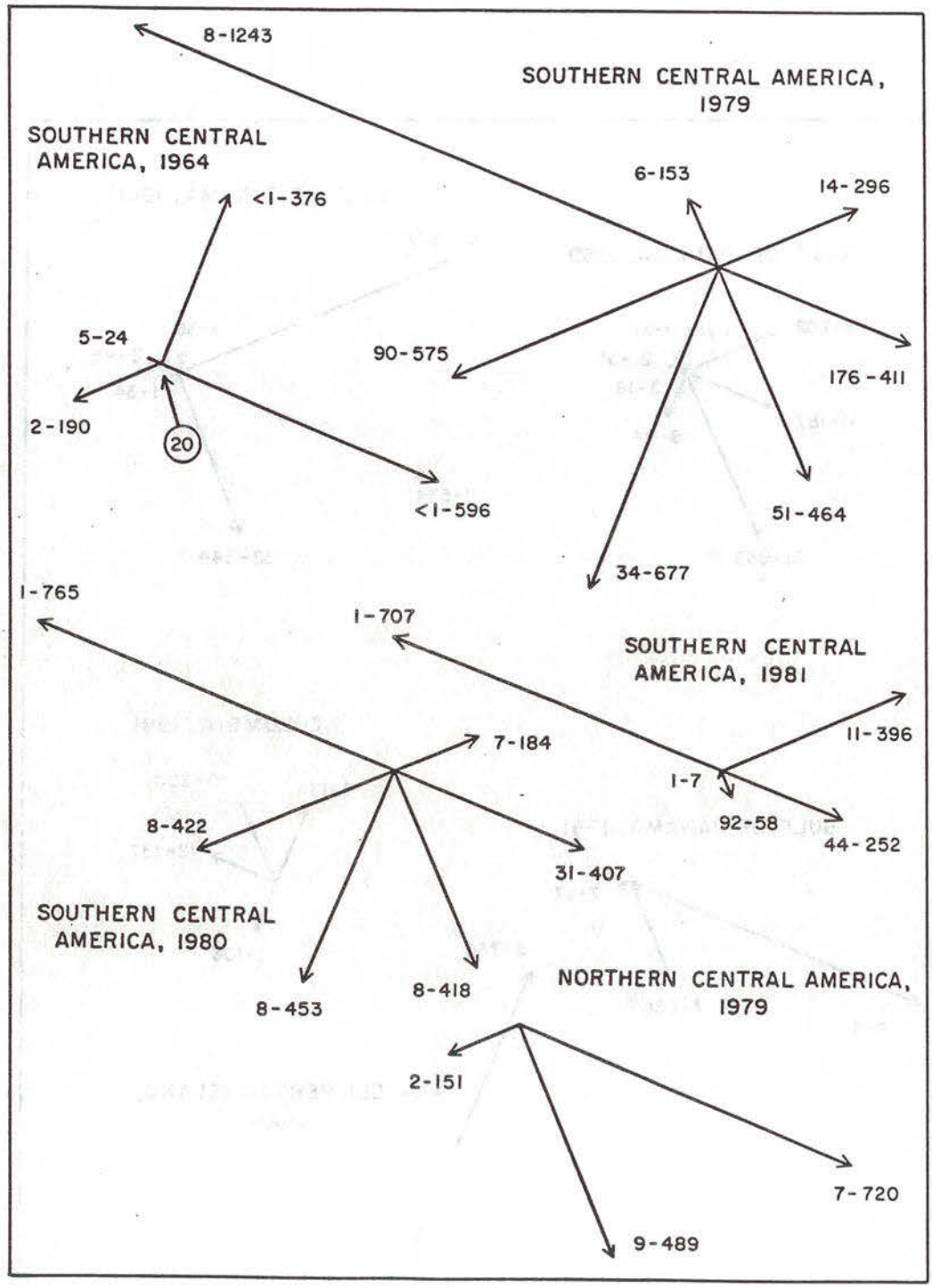

FIGURE 11. Adjusted dispersion, by directions and months of recapture, for yellowfin. The numbers in the upper left corners of the panels indicate the directions of movement.

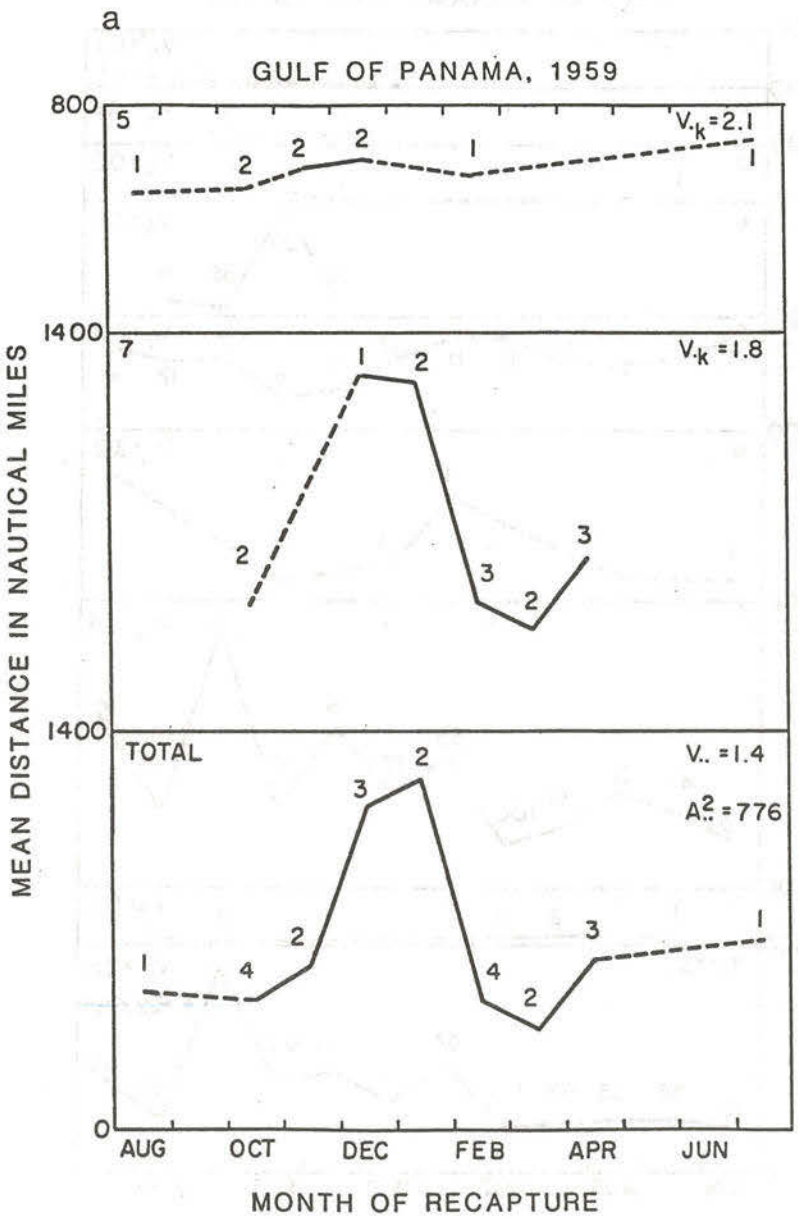

FIGURE 11. (continued)

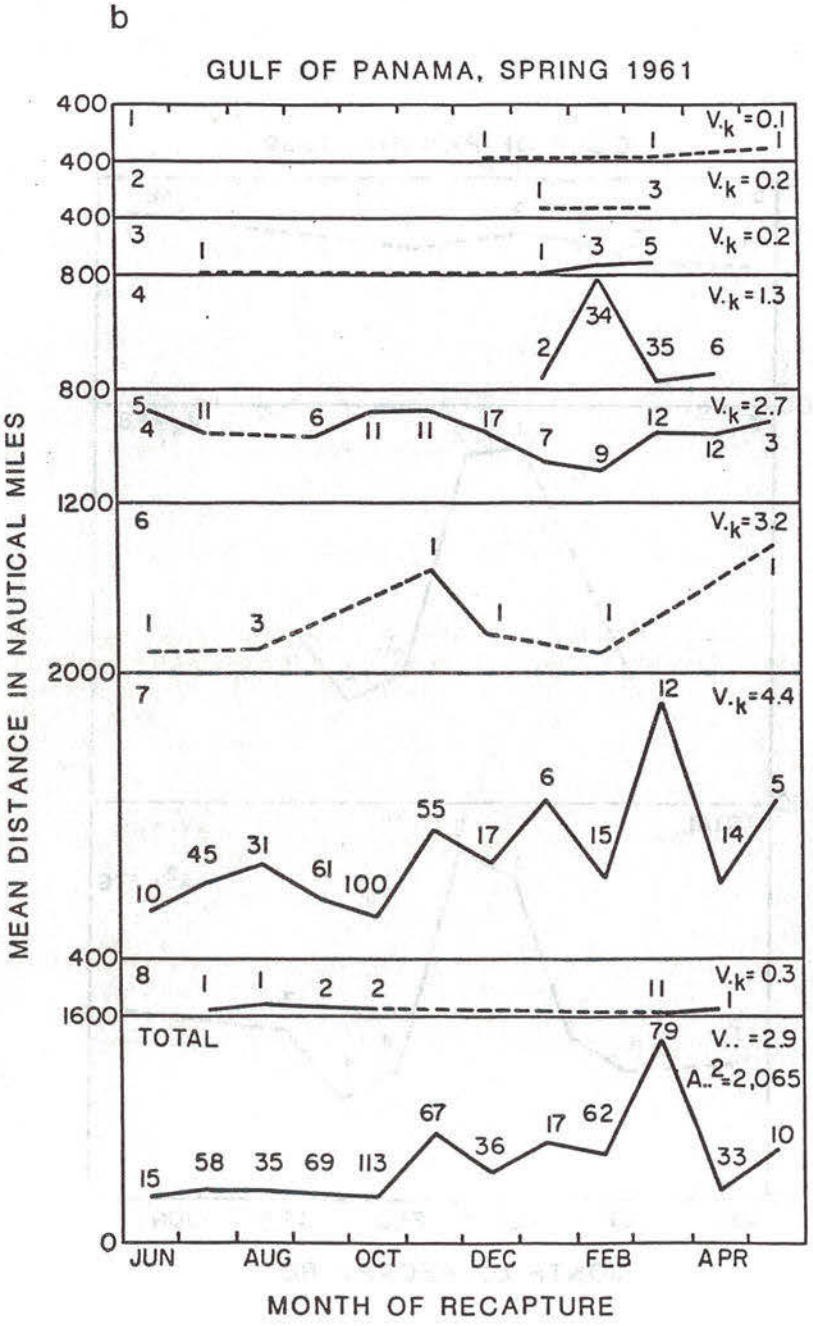

FIGURE 11. (continued)

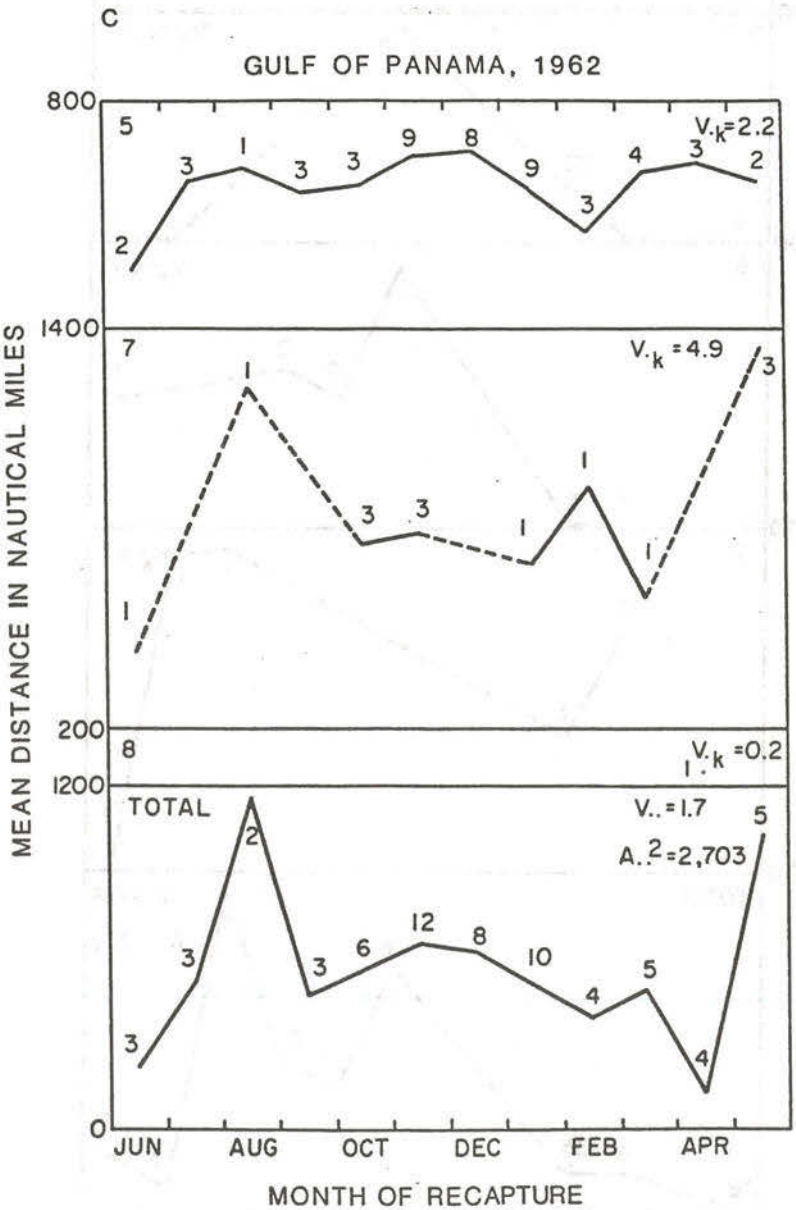

FIGURE 11. (continued)

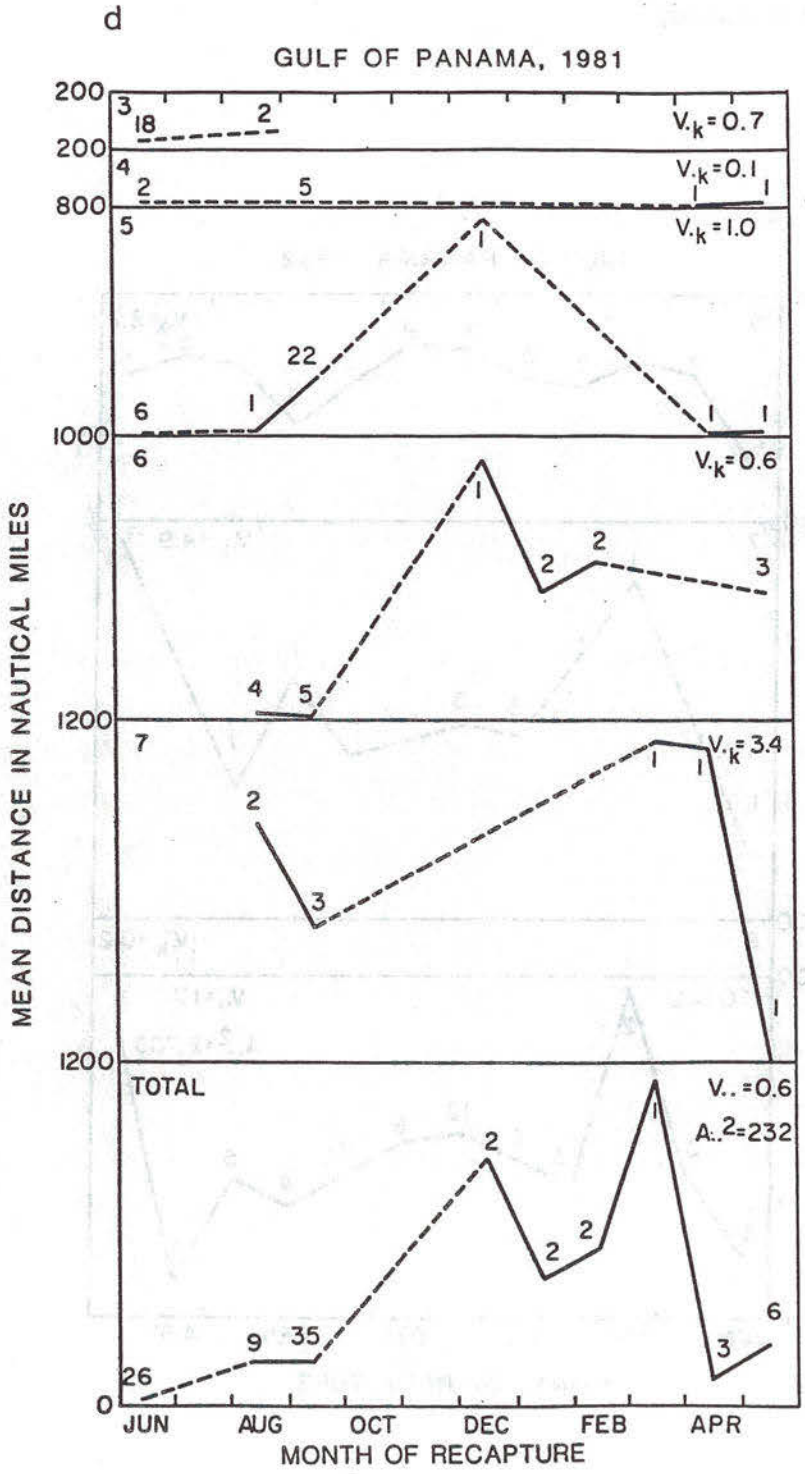

FIGURE 11. (continued)

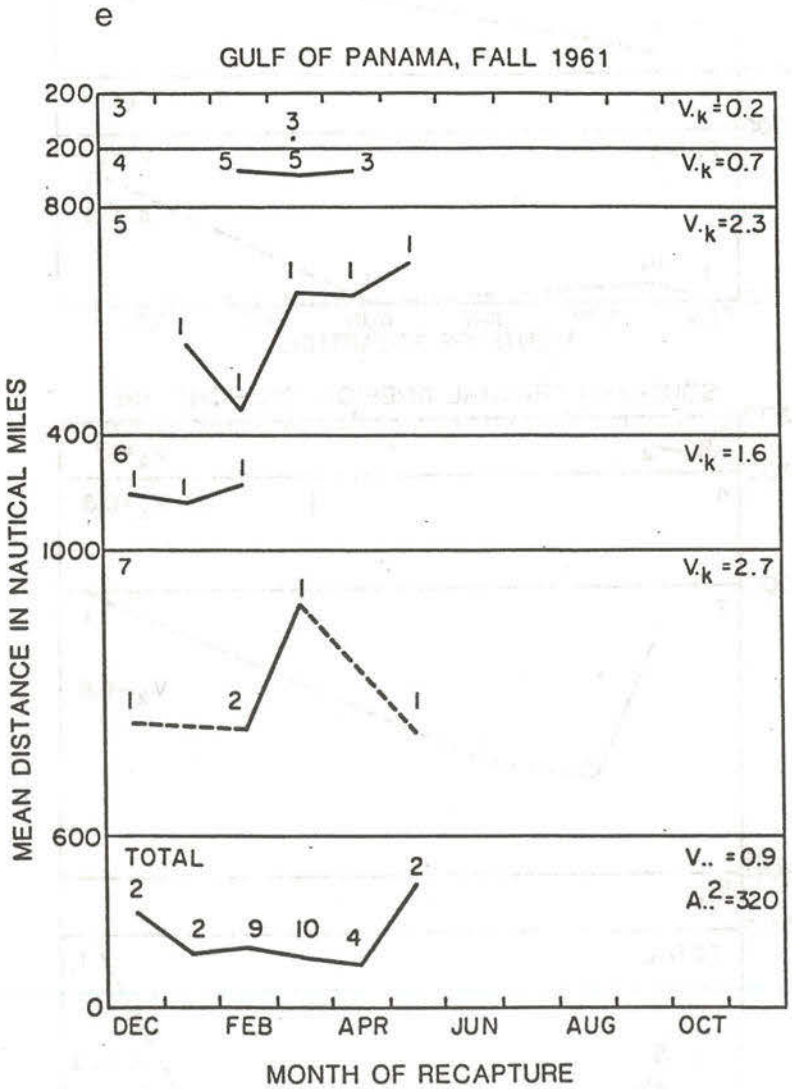

FIGURE 11. (continued)

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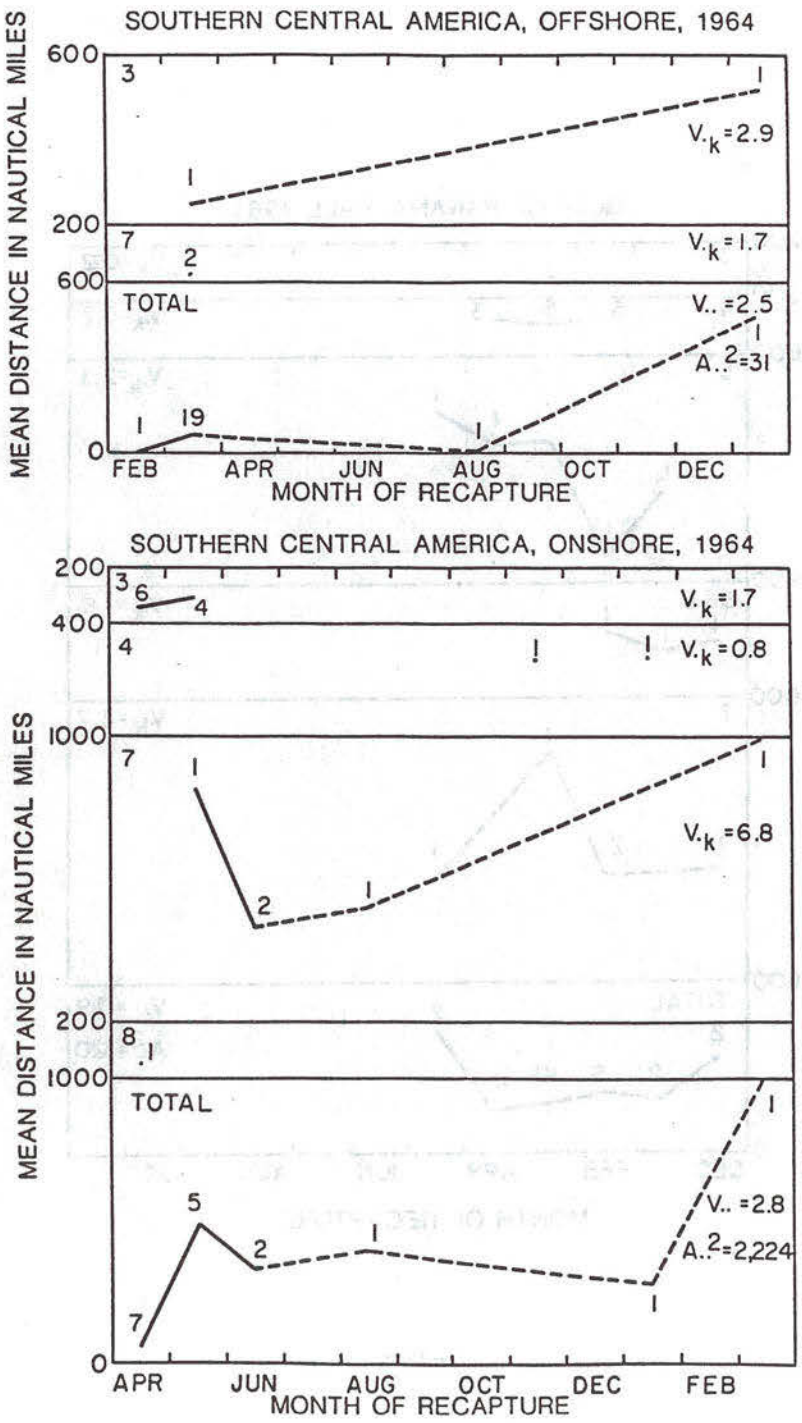

FIGURE 11. (continued)

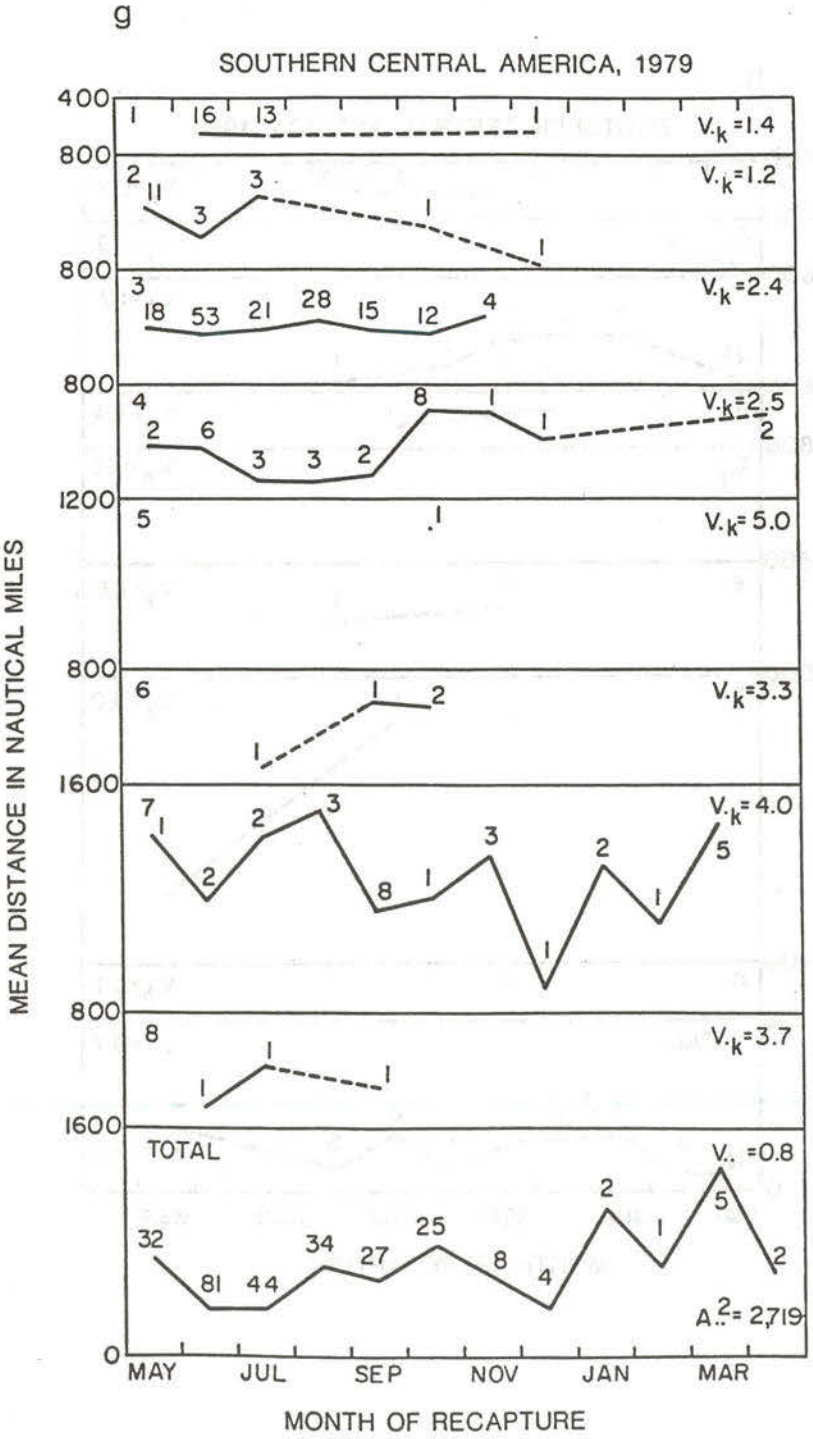

FIGURE 11. (continued)

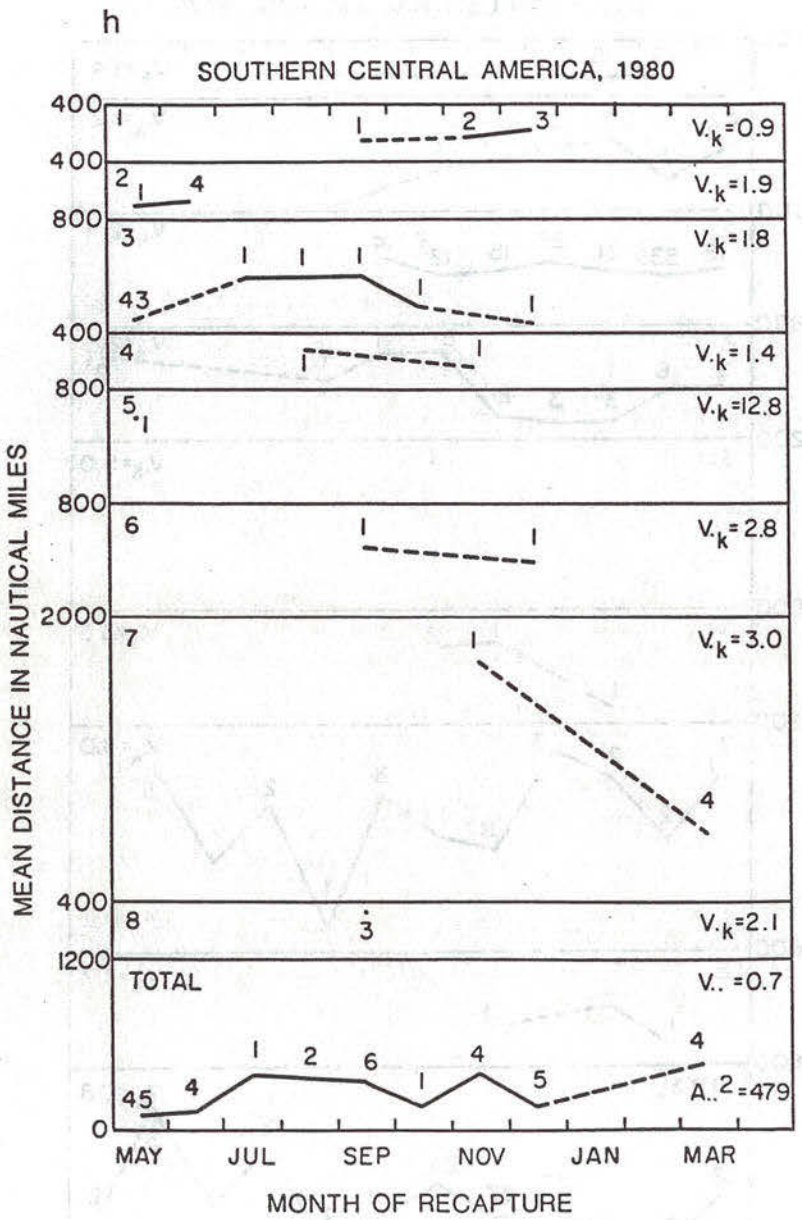

FIGURE 11. (continued)

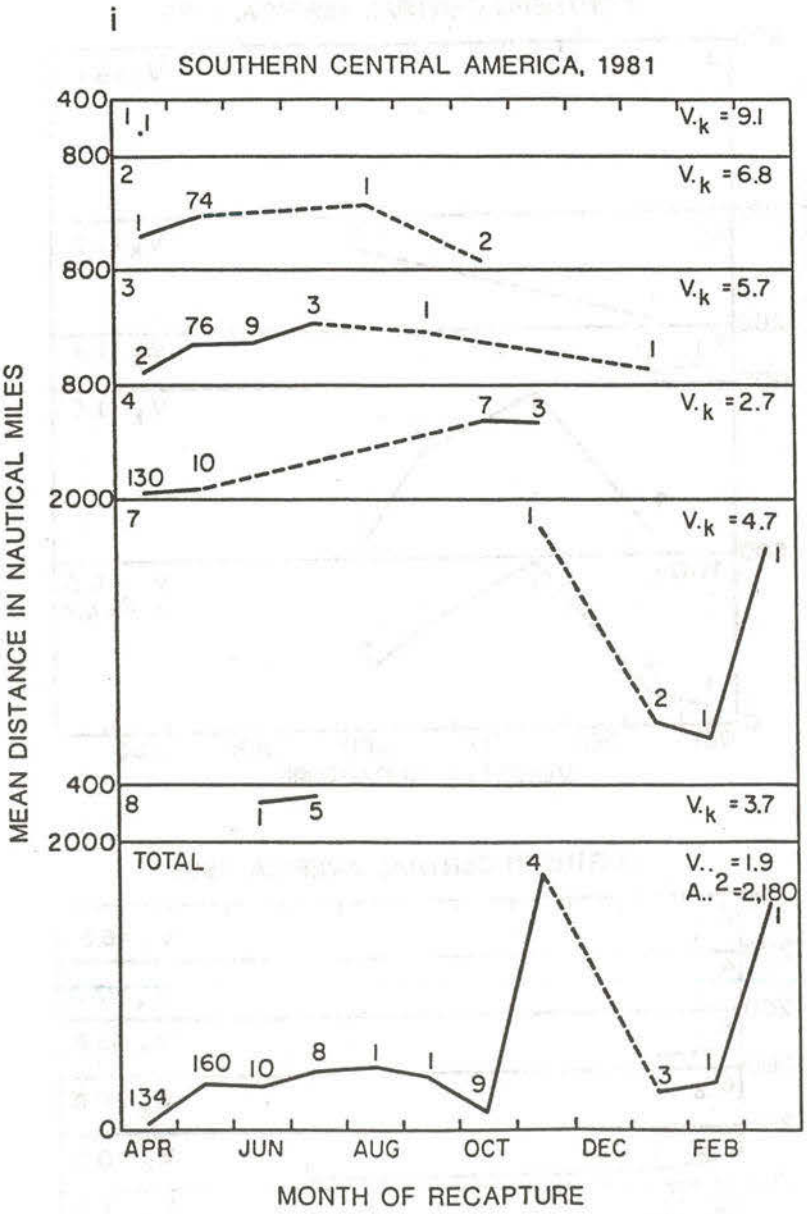

FIGURE 11. (continued)

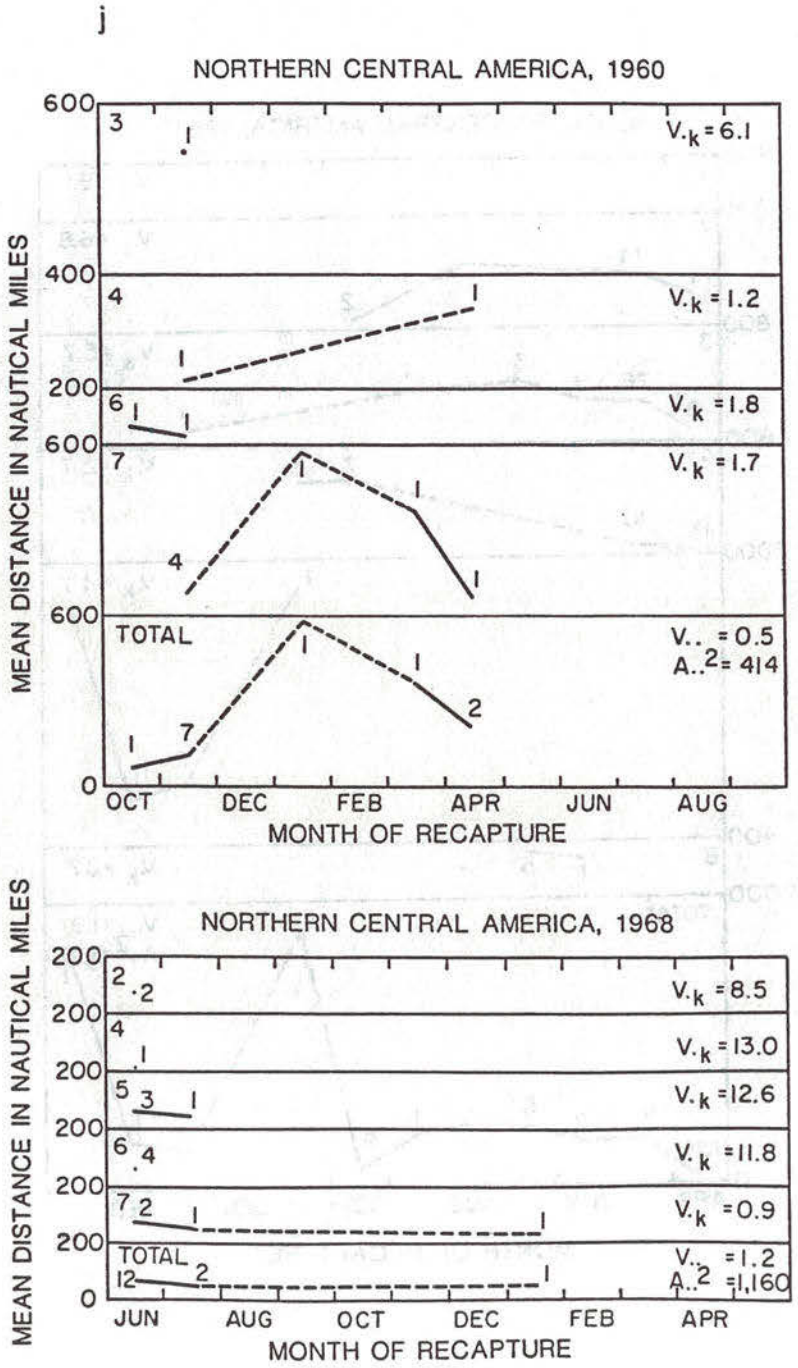

FIGURE 11. (continued)

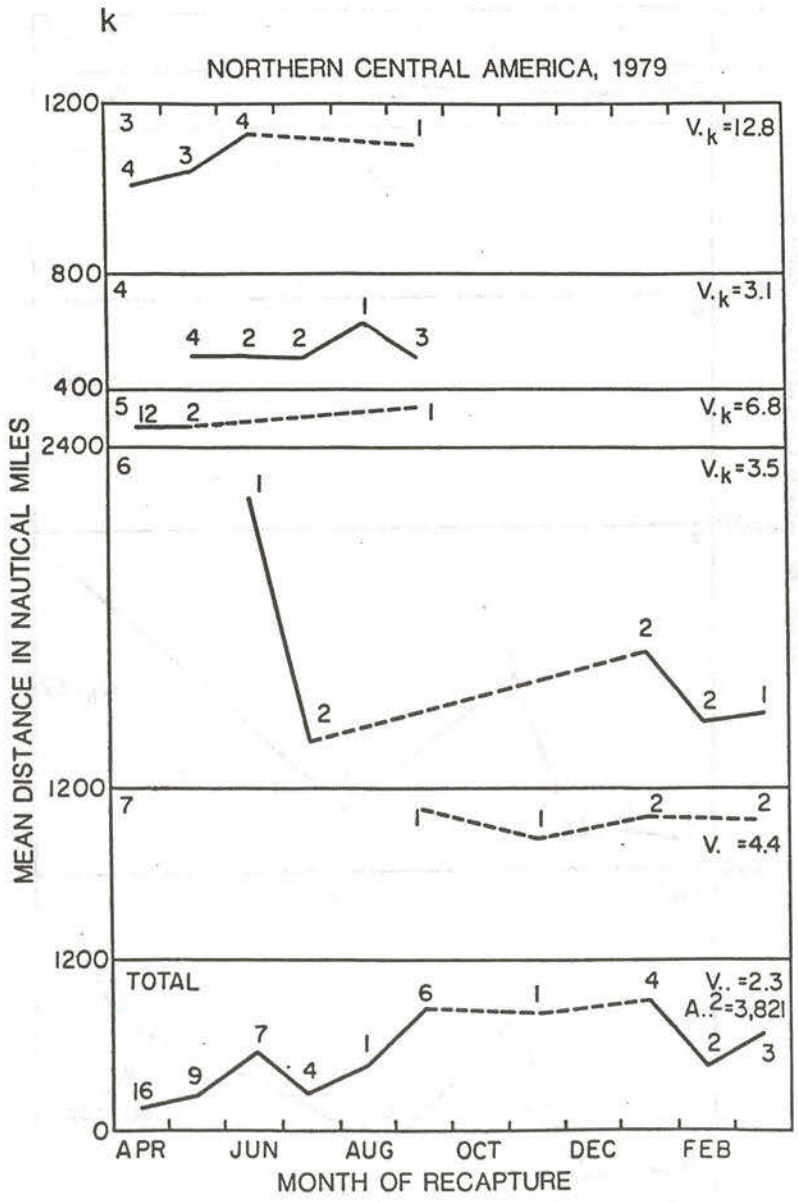

FIGURE 11. (continued)

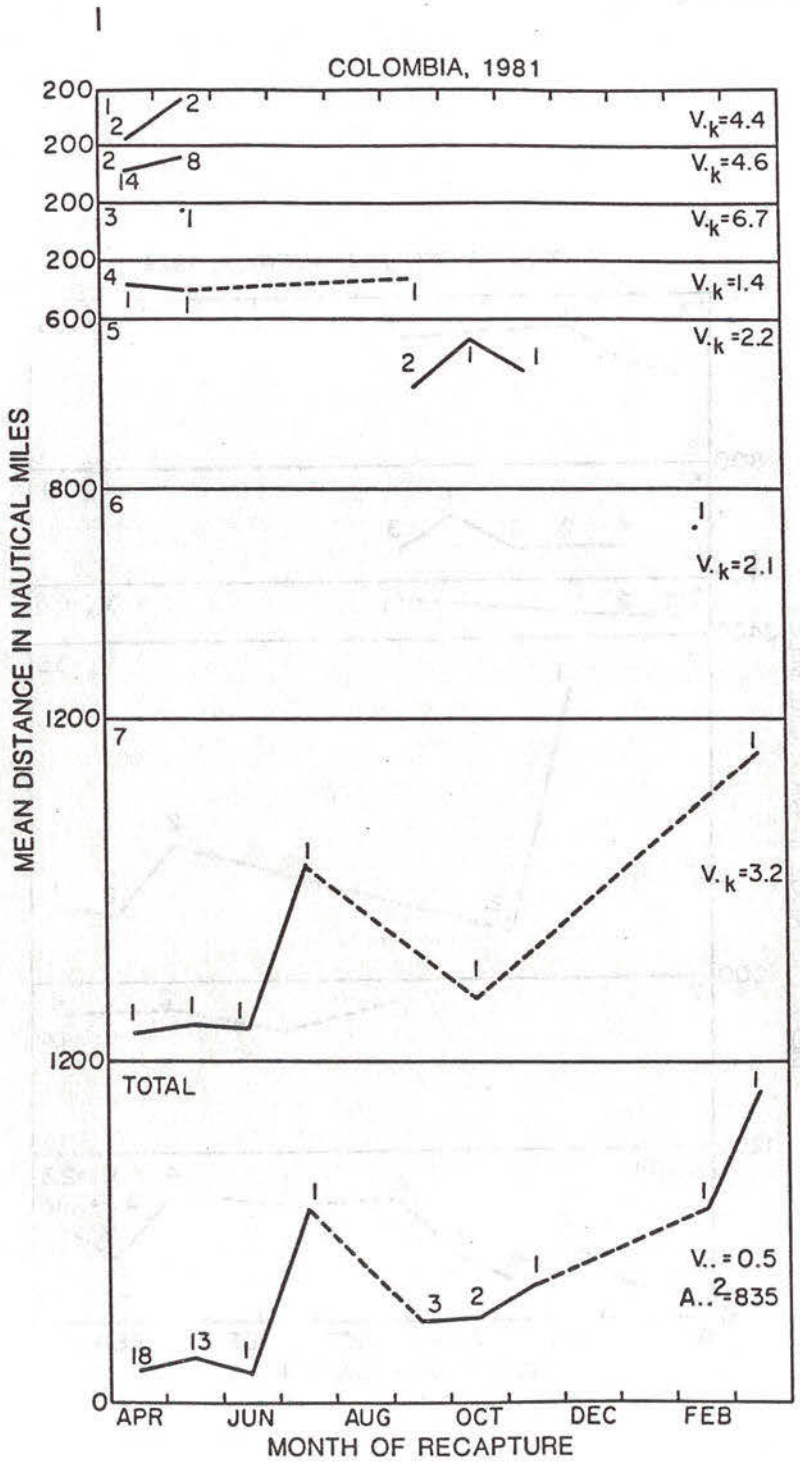

FIGURE 11. (continued)

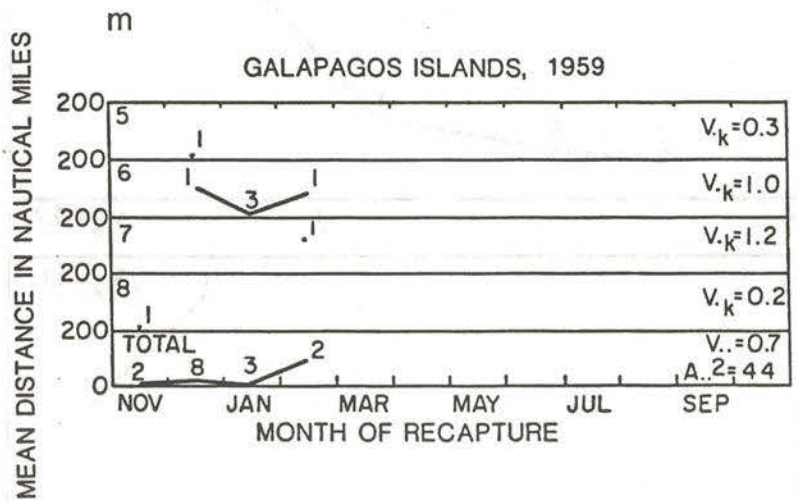

FIGURE 11. (continued)

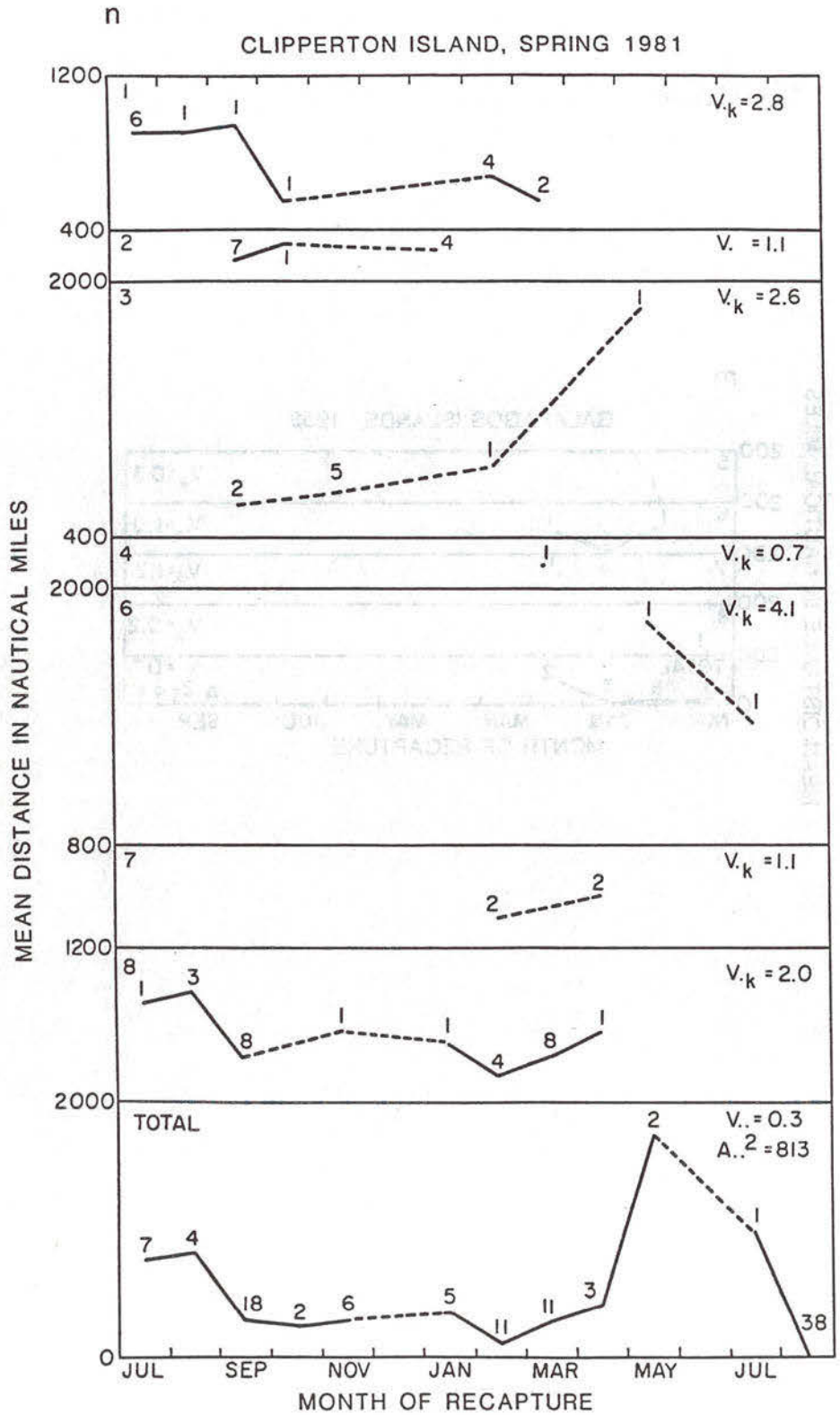

FIGURE 11. (continued)

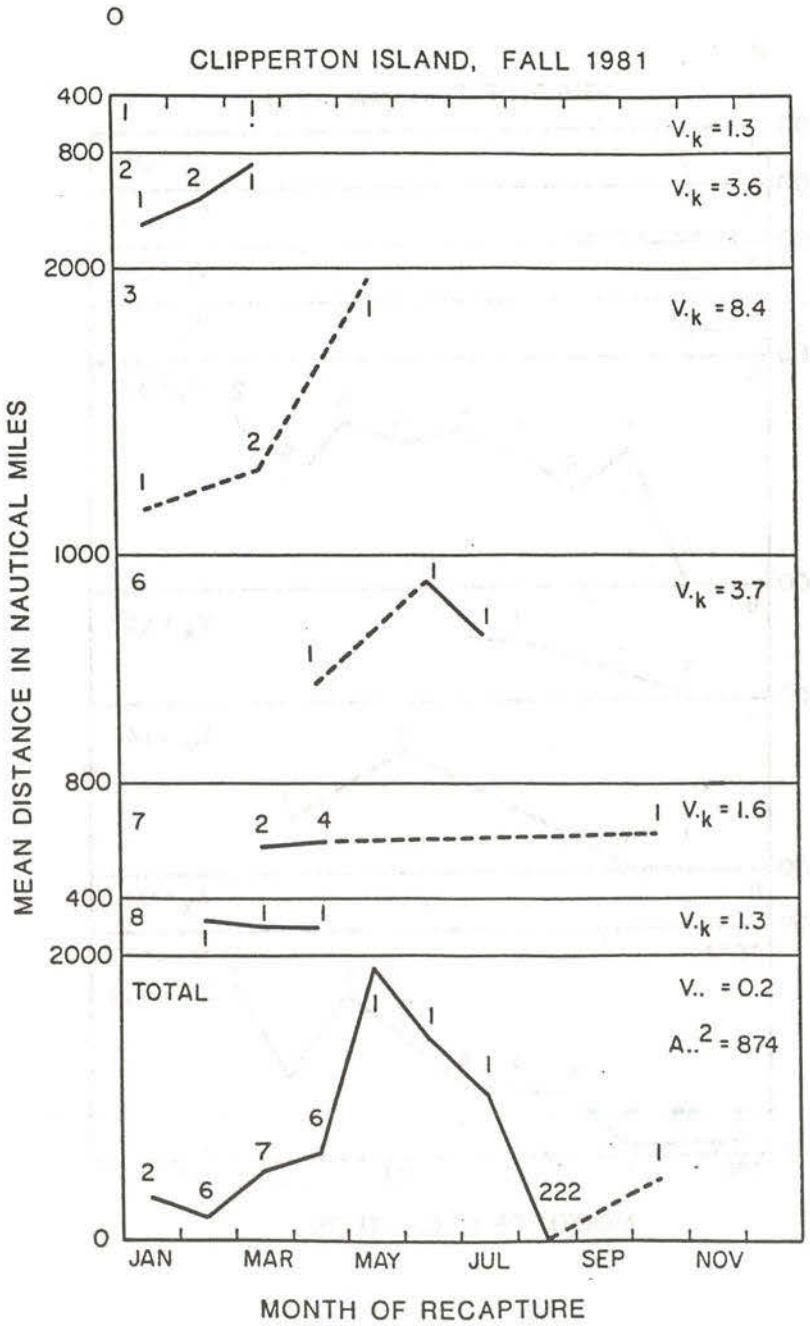

FIGURE 12. Adjusted dispersion, by directions and months of recapture, for skipjack. The numbers in the upper left corners of the panels indicate the directions of movement.

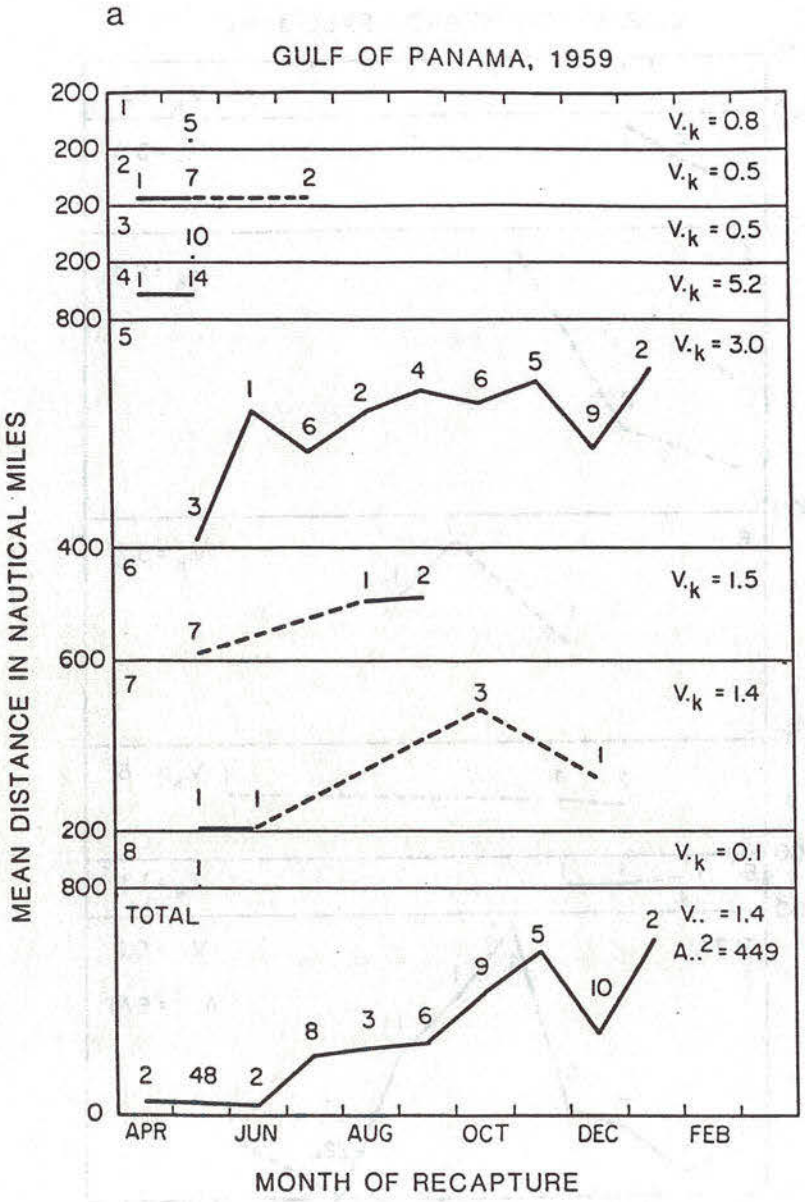

FIGURE 12. (continued)

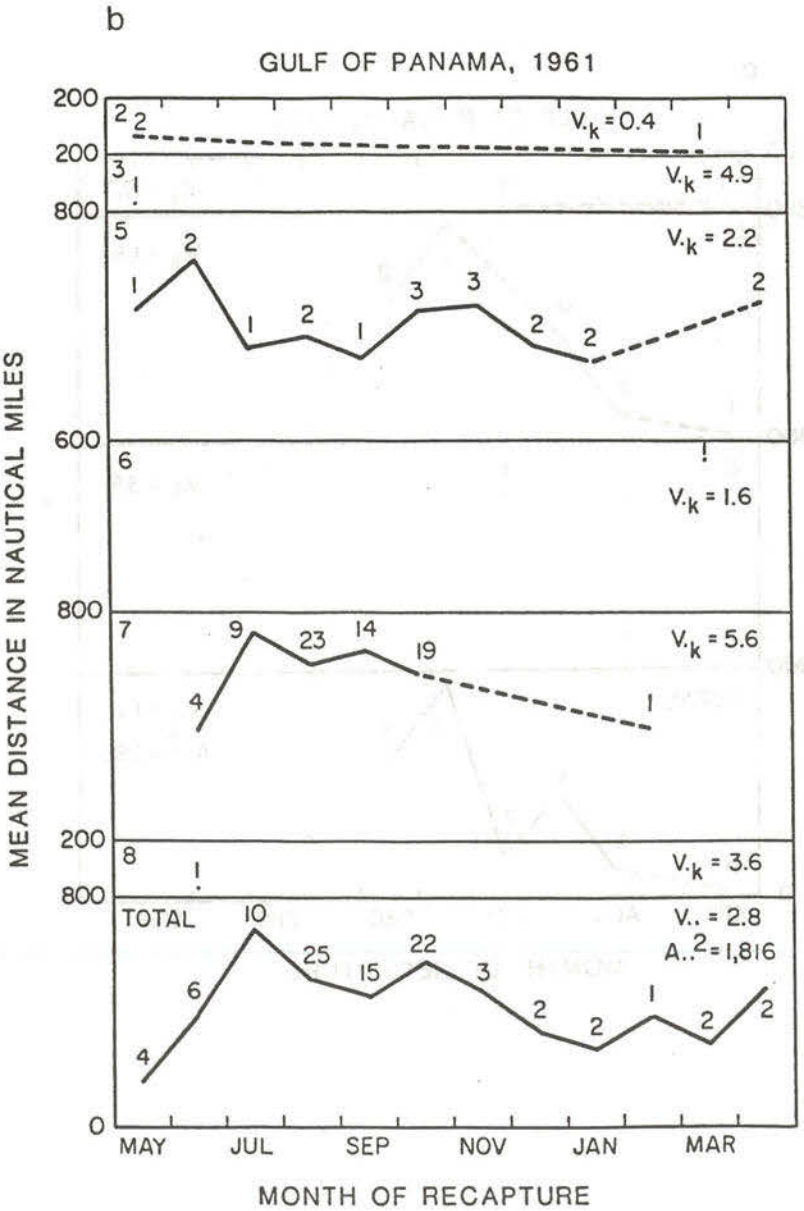

FIGURE 12. (continued)

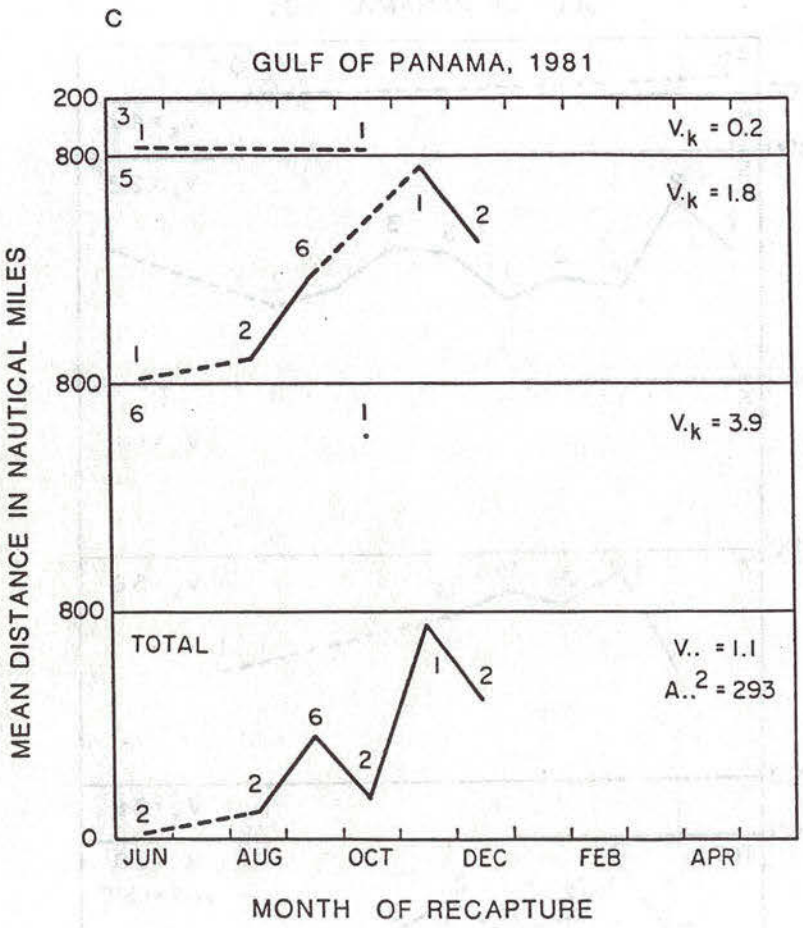

FIGURE 12. (continued)

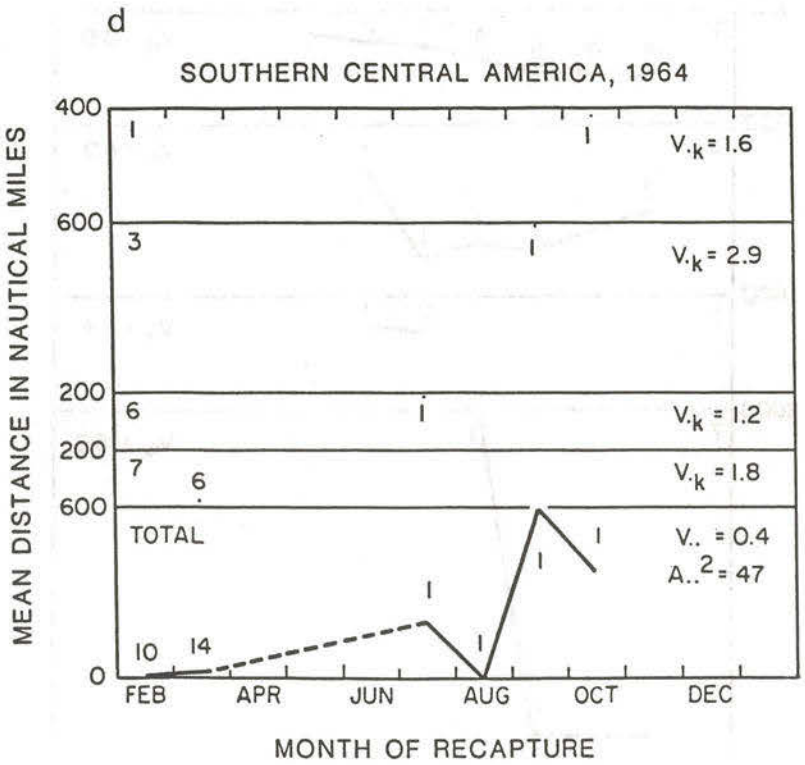

FIGURE 12. (continued)

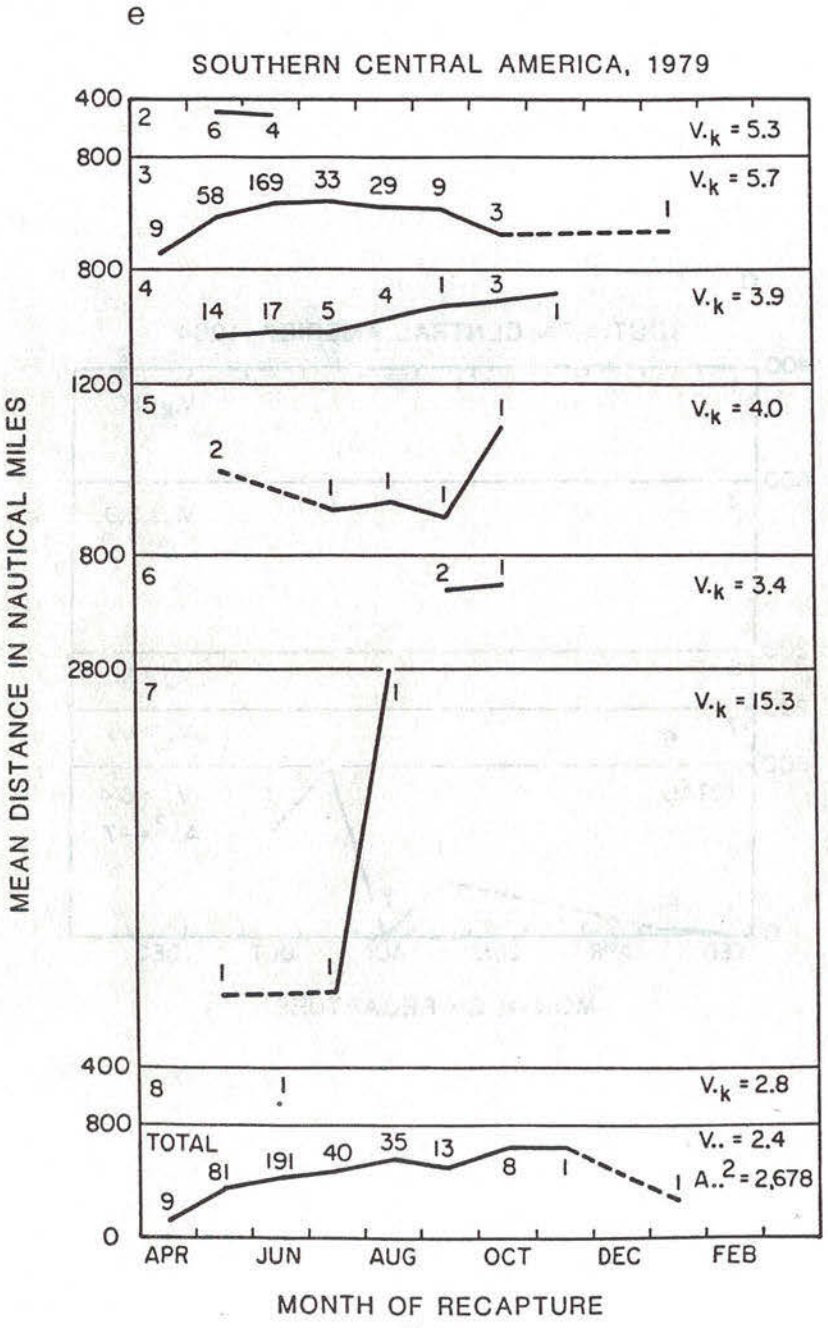

FIGURE 12. (continued)

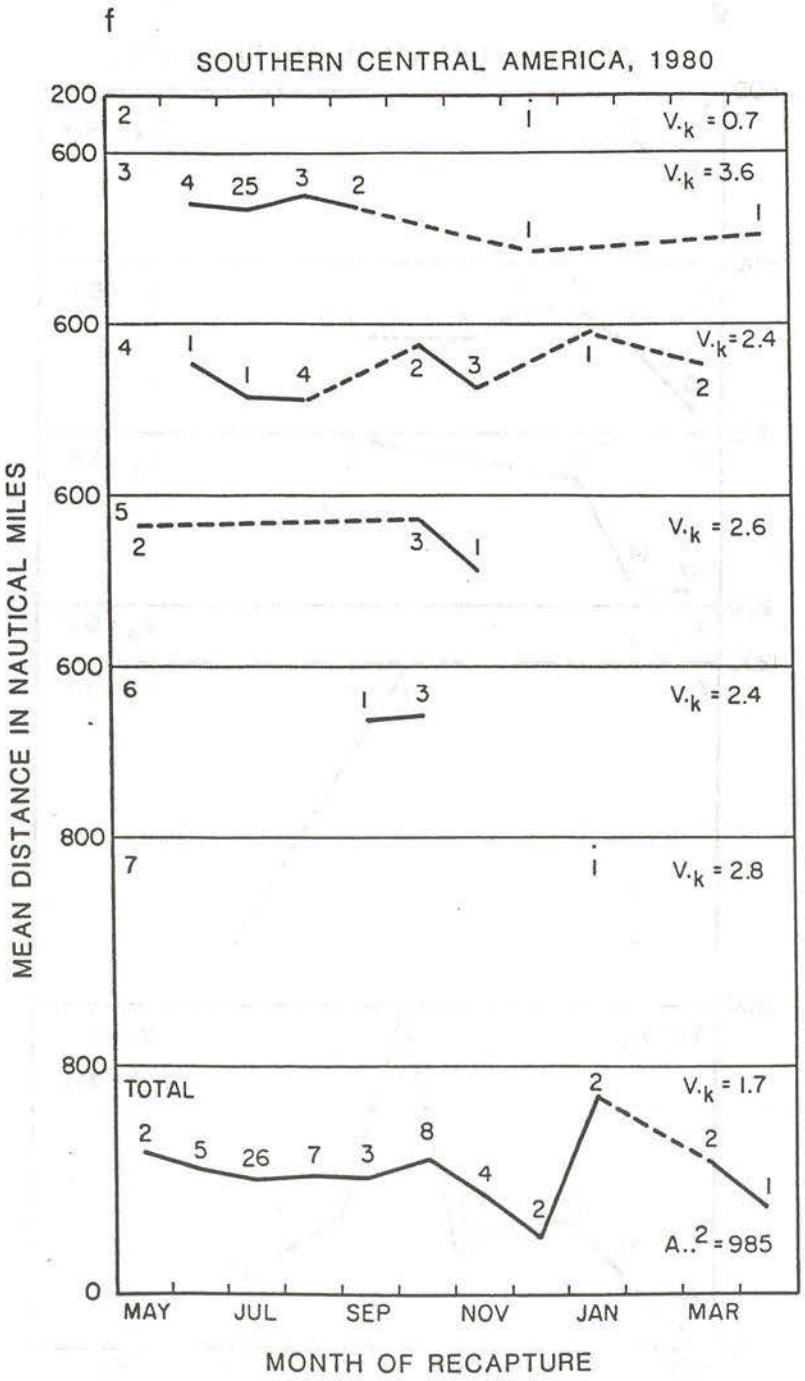

FIGURE 12. (continued)

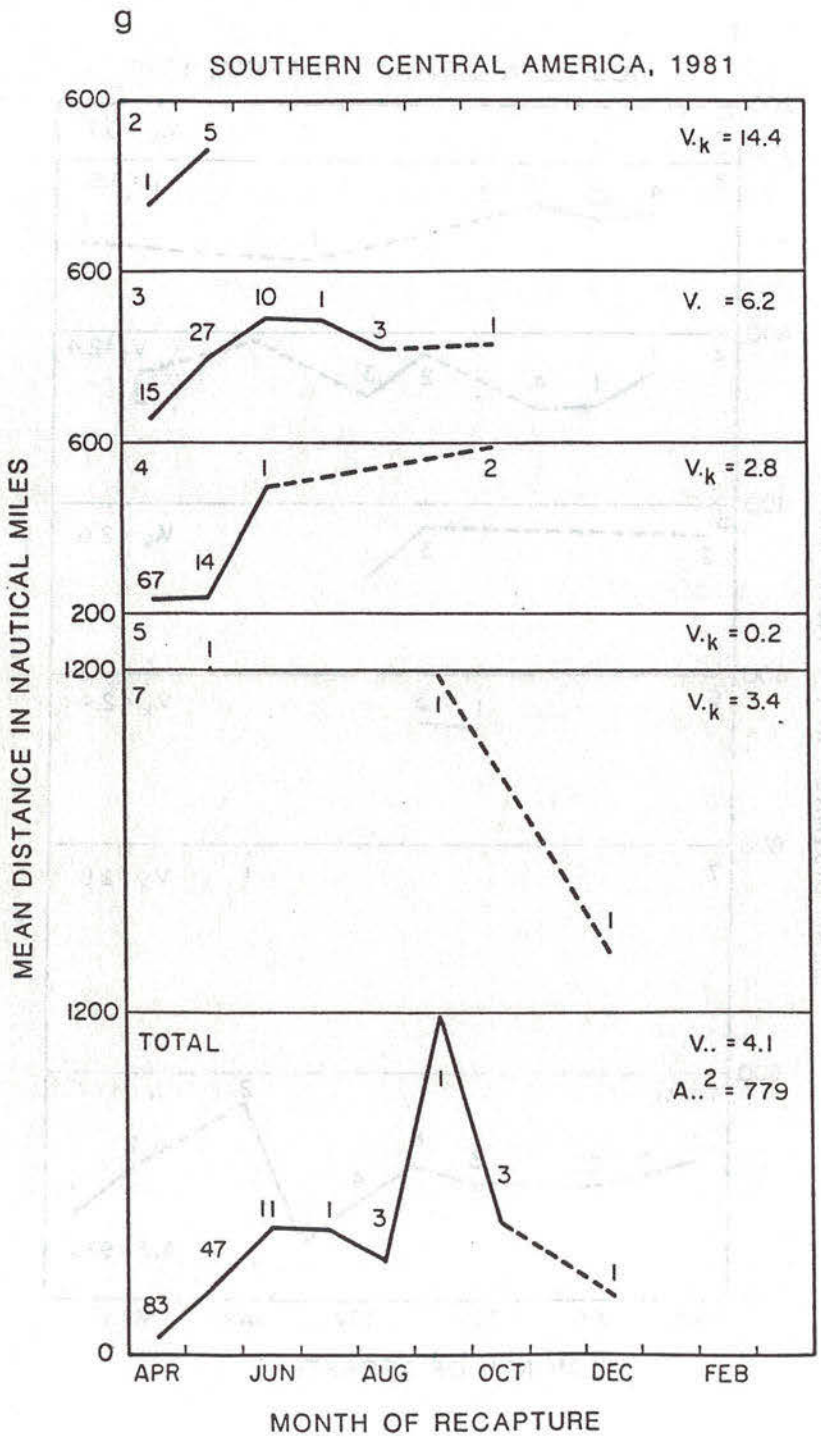

FIGURE 12. (continued)

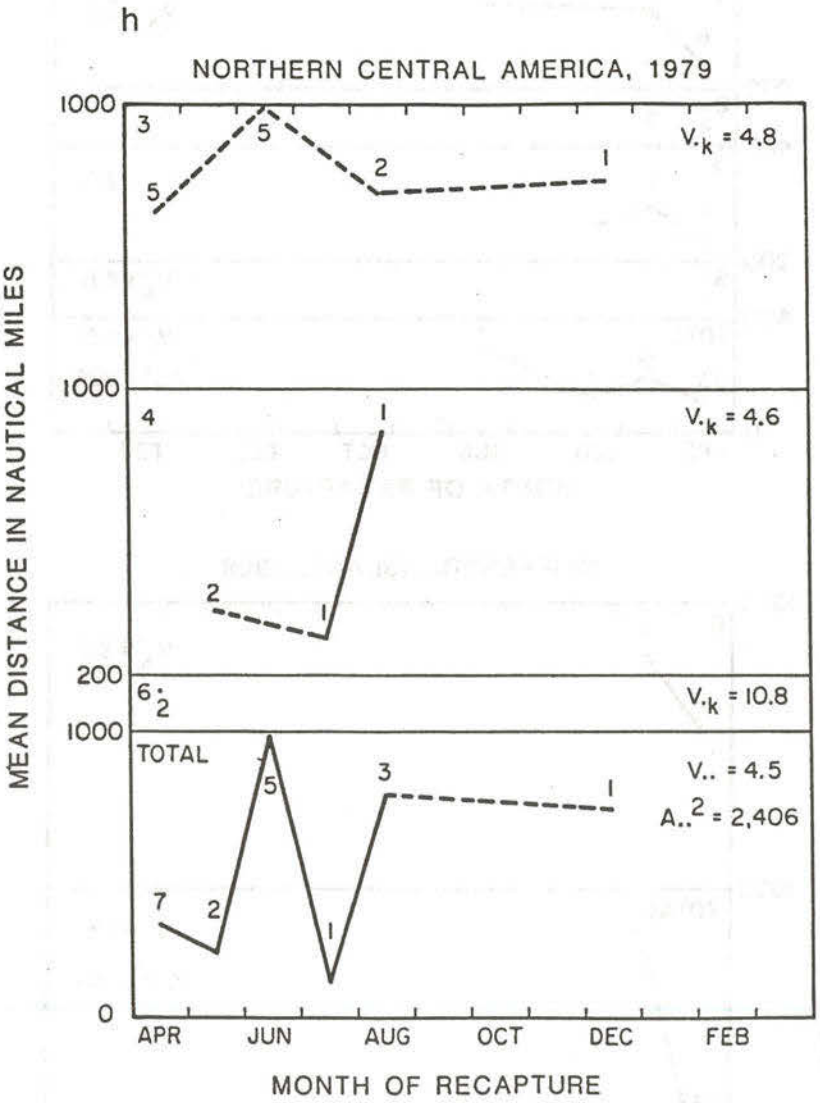

FIGURE 12. (continued)

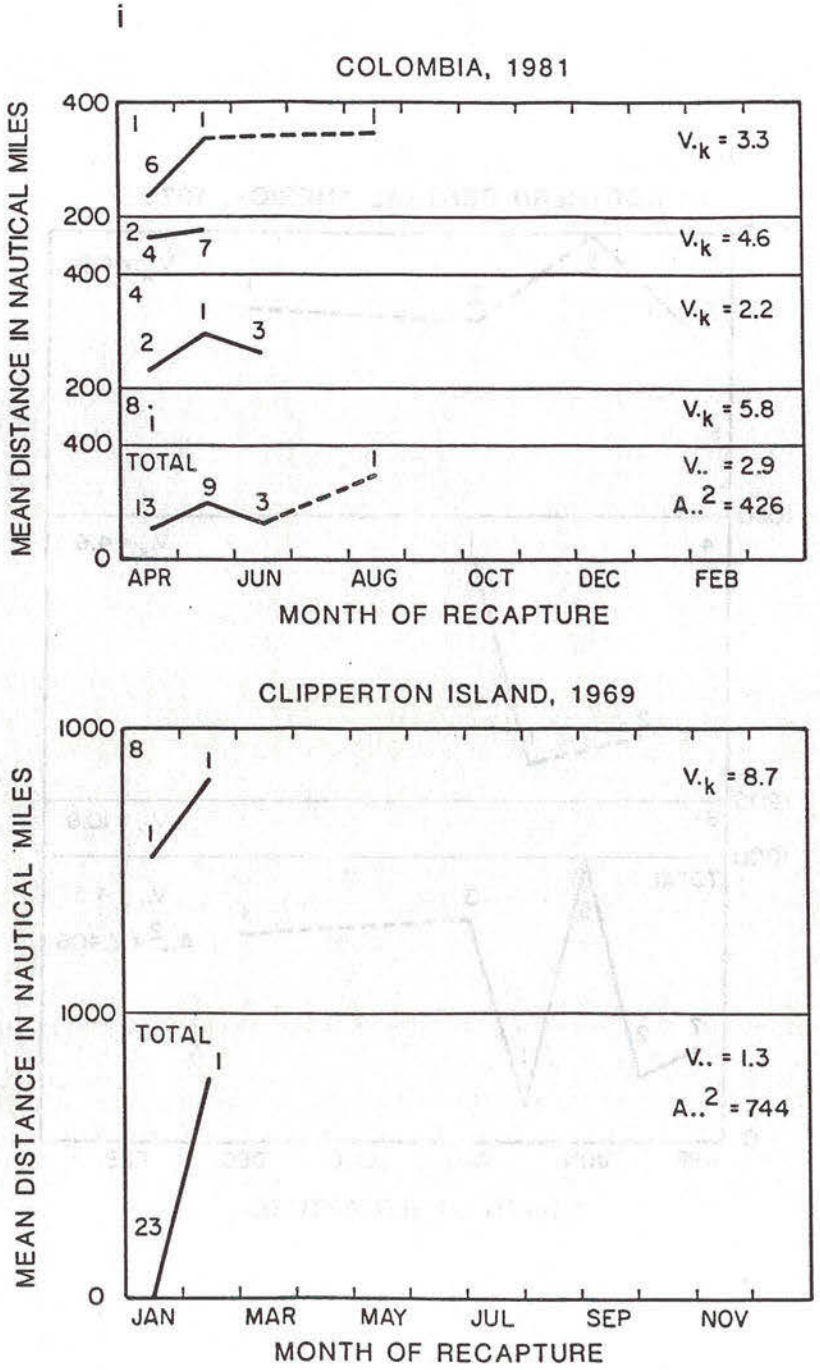

FIGURE 13. Adjusted mean square dispersion coefficients, by months of recapture, for yellowfin.

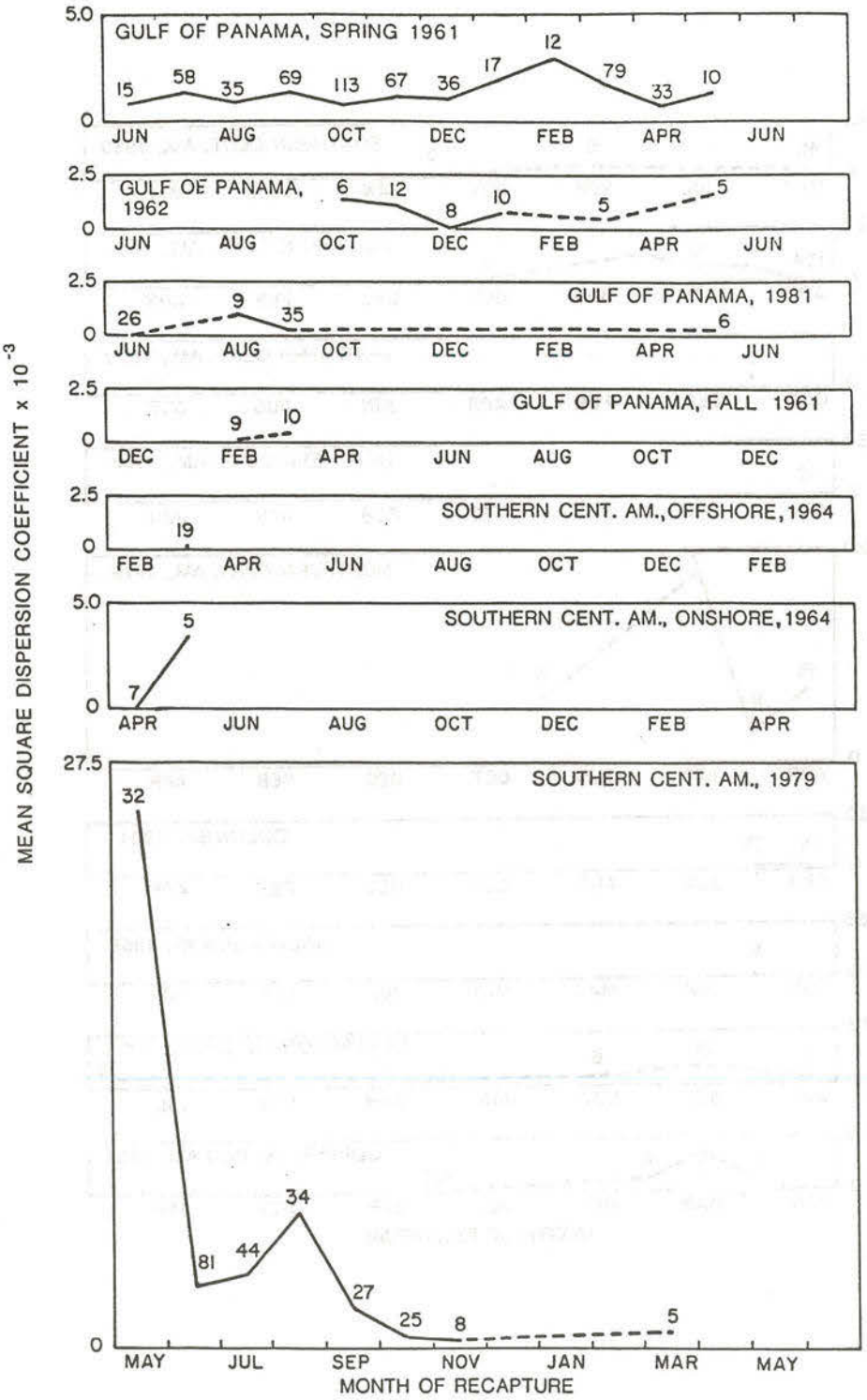

FIGURE 13. (continued)

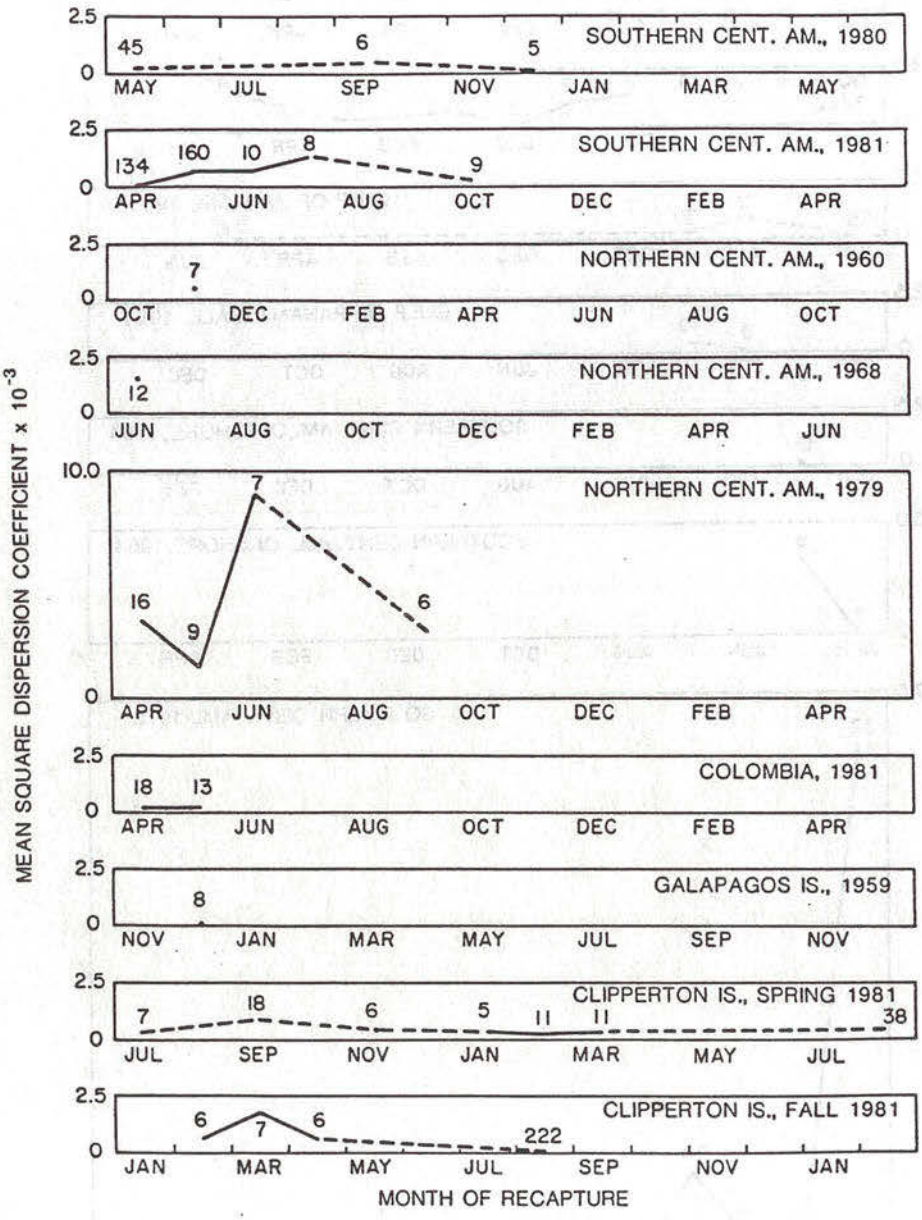

FIGURE 14. Adjusted mean square dispersion coefficients, by months of recapture, for skipjack.

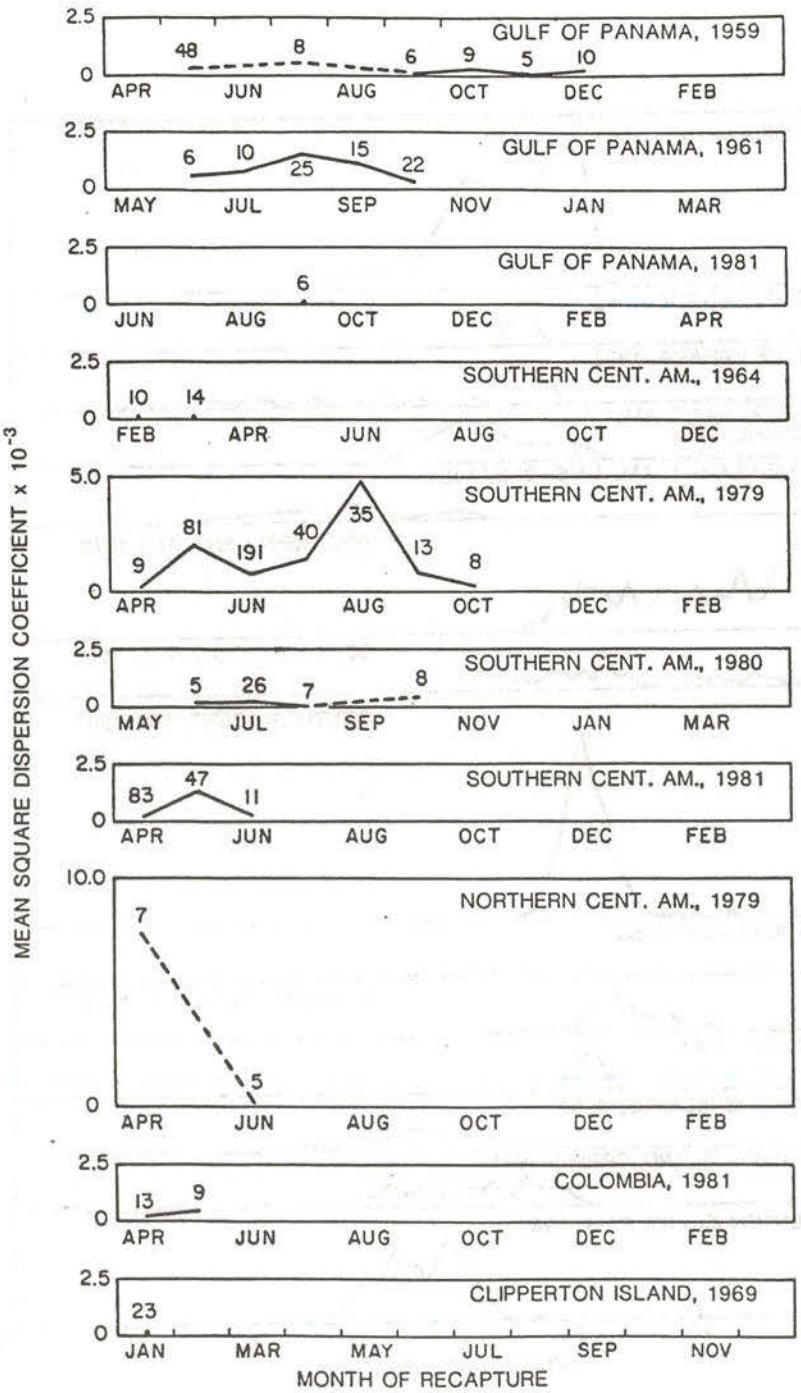

FIGURE 15. Length frequencies of tagged yellowfin which were recaptured.

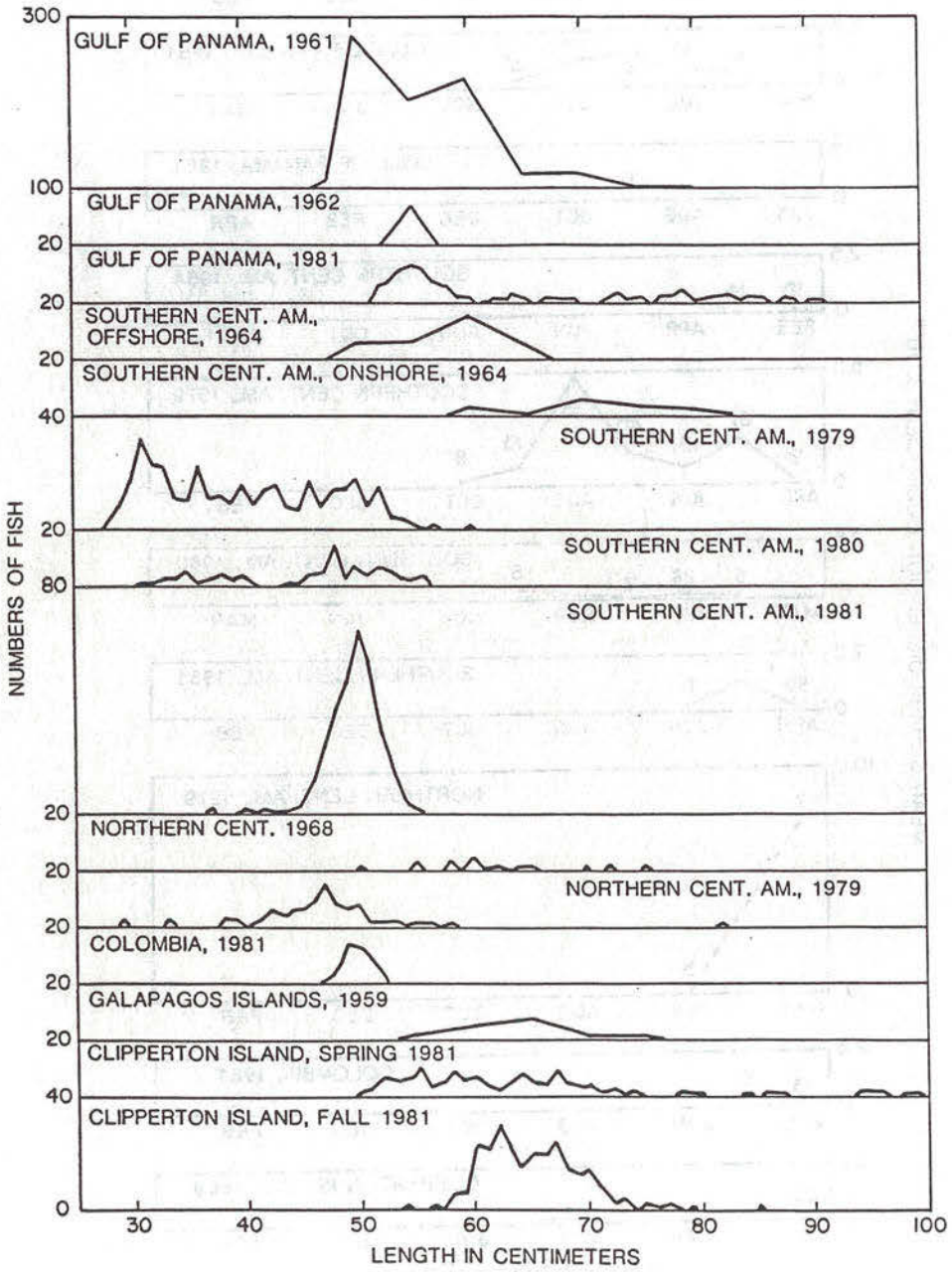

FIGURE 16. Length frequencies of tagged skipjack which were recaptured.

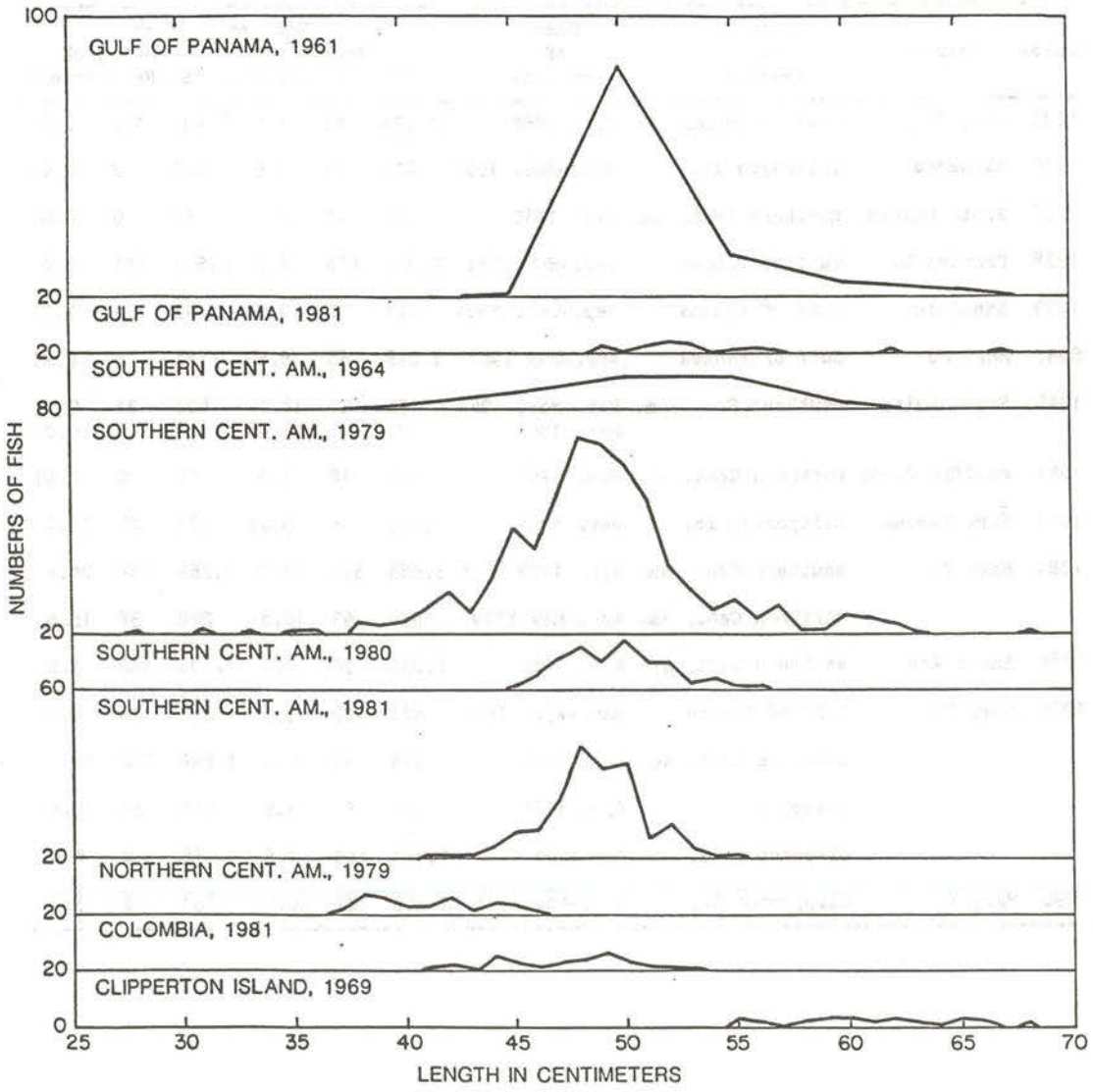

TABLE 1. Tagged fish release and return data used for studies of migrations of yellowfin and skipjack in this report (excluding the data in parentheses). All of the vessels were baitboats except the Santa Helena and the Pacific Queen, which were purse seiners. Rel., Ret., and Percent. stand for Releases, Returns, and Percentage, respectively.

Cruise	Vessel	Area of release	Date of release	Numbers of fish					
				Yellowfin			Skipjack		
				Rel.	Ret.	Percent.	Rel.	Ret.	Percent.
1027	Mary Jo	Gulf of Panama	Apr. 1959	3,329	32	1.0	4,446	132	3.0
1031	Alphecca	Galapagos Is.	Oct.-Dec. 1959	415	15	3.6	(326	2	0.6)
1036	Santa Helena	northern Cent. Am.	Sep. 1960	484	15	3.1	(2	0	0.0)
1038	Barbara K.	Gulf of Panama	Apr.-May 1961	7,345	655	8.9	3,521	106	3.0
1039	San Juan	Gulf of Panama	Sep.-Oct. 1961	274	30	10.9	(43	3	7.0)
8035	Mary Jo	Gulf of Panama	Apr.-May 1962	1,048	68	6.5	(131	9	6.9)
1045	Santa Anita	southern Cent. Am.	Feb.-Mar. 1964	171	31	18.1	401	31	7.7
			Mar. 1964	72	17	23.6	(0	0	0.0)
1051	Pacific Queen	northern Cent. Am.	Jun. 1968	540	18	3.3	(9	0	0.0)
1054	Mary Carmen	Clipperton Is.	Nov. 1969	(100	5	5.0)	231	27	11.7
1084	Mary K.	southern Cent. Am.	Apr. 1979	3,885	396	10.2	2,262	564	24.9
		northern Cent. Am.	Apr.-May 1979	858	93	10.8	240	38	15.8
1089	Sarah Ann	southern Cent. Am.	Apr. 1980	1,235	98	7.9	1,798	102	5.7
1095	Mary K.	Gulf of Panama	Mar.-Apr. 1981	687	107	15.6	221	18	8.1
		southern Cent. Am.	Apr. 1981	694	360	51.9	1,298	220	16.9
		Colombia	Apr. 1981	160	51	31.9	240	35	14.6
		Clipperton Is.	May 1981	1,977	150	7.6	(8	0	0.0)
1096	Mary K.	Clipperton Is.	Oct.-Nov 1981	1,276	262	20.5	(51	2	3.9)

TABLE 2. Returns and portions of returns weighted by fishing effort, in each area and month, from yellowfin released in Areas F1, G1, and G4. Ret. and Por. stand for Returns and Portion, respectively.

	April		May		June		July		August		September		October		November		December		January		February		March		April		May	
	Ret.	Por.	Ret.	Por.	Ret.	Por.	Ret.	Por.	Ret.	Por.	Ret.	Por.	Ret.	Por.	Ret.	Por.	Ret.	Por.	Ret.	Por.	Ret.	Por.	Ret.	Por.	Ret.	Por.	Ret.	Por.
Gulf of Panama, 1961																												
F1	5	1.000	6	0.863	11	0.953	4	0.127	5	0.403	4	0.230	12	0.416	4	0.170	6	0.226	4	0.355	43	0.555	61	0.570	12	0.480	1	0.319
F2							28	0.474	26	0.449	48	0.281	90	0.193	3	0.060	7	0.407	1	0.213	1	0.049			7	0.204	2	0.269
F3							15	0.233	4	0.147	13	0.132	1	0.010	51	0.393	4	0.142	1	0.077	7	0.205	6	0.062				
F4															1	0.034	2	0.065	3	0.064					2	0.085		
F8																			6	0.264	6	0.153	1	0.040				
F10			1	0.137	4	0.047	11	0.165			5	0.357	11	0.381	11	0.342	16	0.160	1	0.026	4	0.039	11	0.328	11	0.232	3	0.412
Gulf of Panama, 1981																												
G1											2	0.014							2	1.000	1	0.497					2	0.186
G3																	1	0.758			1	0.503					1	0.236
G4									2	0.403																		
G5																							1	1.000	1	0.042		
G7					26	1.000			7	0.597	29	0.607													2	0.958	3	0.578
G8											8	0.360																
G9											3	0.019																
G10																	1	0.242										
southern Central America, 1979																												
G1	5	1.000			26	0.587	16	0.345	4	0.227	3	0.049	3	0.122			3	0.863										
G3									1	0.114	3	0.056																
G4							2	0.147			1	0.074							1	1.000			1	0.734				
G5					1	0.060					2	0.189									1	1.000						
G6																							2	0.266				
G7			21	0.547	3	0.073	9	0.303	1	0.168					2	0.205												
G8			6	0.364	34	0.159	12	0.149	24	0.344	7	0.308	3	0.168	2	0.793												
G9			4	0.089	23	0.120	5	0.057	5	0.147	8	0.325	7	0.179	1	0.002	1	0.137										
G10													10	0.531											2	1.000		
southern Central America, 1980																												
G1			44	1.000	4	1.000					1	0.025			2	0.638	4	0.892										
G2											3	0.873																
G3																	1	0.073					2	0.540				
G4																							1	0.460				
G6															1	0.125												
G8							2	1.000	1	0.763	1	0.102															1	1.000
G9									1	0.237			1	1.000	1	0.237												
G10																	1	0.035										
southern Central America, 1981																												
G1	134	1.000	85	0.473	2	0.103	3	0.082					2	0.878														
G3							1	0.159											1	0.322	1	1.000						
G4							1	0.059																				
G7			2	0.100					1	1.000																		
G8			6	0.093	3	0.629	1	0.521																				
G9			58	0.334	5	0.268	2	0.179			1	1.000							1	0.678								
G10													4	0.122	4	1.000												
northern Central America, 1979																												
G1	4	0.051	1	0.037	1	0.216			1	1.000																		
G3			4	0.701							3	0.436																
G4	12	0.949	2	0.190	1	0.605	1	0.866											1	0.873								
G5																					2	1.000			1	1.000		
G6											1	0.219			1	1.000			2	0.127								
G6											1	0.219																
G7			2	0.072																								
G8					4	0.179					1	0.345																
G9							1	0.134																				

TABLE 3. Returns and portions of returns weighted by fishing effort, in each area and month, from skipjack released in Areas H1 and I1. Ret. and Por. stand for Returns and Portion, respectively.

	April		May		June		July		August		September		October		November		December	
	Ret.	Por.	Ret.	Por.	Ret.	Por.	Ret.	Por.	Ret.	Por.	Ret.	Por.	Ret.	Por.	Ret.	Por.	Ret.	Por.
Gulf of Panama, 1959																		
H1			71	0.873			2	0.255			2	0.892					1	0.348
H2													3	0.740				
H4			2	0.127			2	0.710									2	0.565
H6							4	0.035			4	0.108	6	0.260	5	1.000	7	0.087
Gulf of Panama, 1961																		
H1			5	0.742	4	0.921			1	0.072					1	0.213		
H2							2	0.538	23	0.505	11	0.283	18	0.847				
H4							1	0.356	1	0.343	1	0.717			1	0.678		
H6			1	0.258	3	0.079	1	0.106	1	0.080			4	0.153	3	0.110		
southern Central America, 1979																		
I1	8	0.880	6	0.056	4	0.084			2	0.103								
I3			5	0.046	7	0.167	5	0.310			2	0.293						
I4			42	0.719	123	0.476	24	0.503	27	0.337	5	0.164						
I5	1	0.120	30	0.179	68	0.273	10	0.187	6	0.152	2	0.061	4	0.195				
I6									1	0.251	1	0.360	3	0.304				
I7									2	0.157	3	0.122	1	0.501				
southern Central America, 1980																		
I4					4	0.857	16	0.644	2	0.557	1	0.404						
I5							10	0.356	5	0.443	2	0.251			2	0.617		
I6					1	0.143					1	0.344	1	0.079	1	0.096		
I7													7	0.921	1	0.287		
southern Central America, 1981																		
I1	87	0.990	24	0.323														
I3			3	0.315														
I4			6	0.166	3	0.498												
I5	1	0.010	17	0.195	5	0.209												
I6					3	0.293												

TABLE 4. Numbers of small and large yellowfin released off southern Central America during April 14-15 and 26-27, 1979, and moving in Directions 1-2 and 3-4.

Length at release (cm)	Date of release	Direction of movement 1-2	3-4	1-4
<40	April 14-15	3	30	33
	26-27	5	43	48
	Sum	8	73	81
>40	April 14-15	1	3	4
	26-27	23	44	67
	Sum	24	47	71
Total	April 14-15	4	33	37
	26-27	28	87	115
	Sum	32	120	152

TABLE 5. Numbers of small and large yellowfin released at Clipperton Island during October 17-21, 1981, and recaptured in the vicinity of Clipperton Island and elsewhere.

Length at release (cm)	Recaptured near Clipperton Island	Recaptured far from Clipperton Island	Total
54-63	101	8	109
64-84	100	12	112
Total	201	20	221