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NOAA Technical Report NMFS SSRF-662

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

Seasonal Distribution of Tunas and Billfishes in the Atlantic

JOHN P. WISE and CHARLES W. DAVIS

SEATTLE, WA
January 1973

NOAA TECHNICAL REPORTS

National Marine Fisheries Service, Special Scientific Report--Fisheries Series

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For sale by the Superintendent of Documents, U.S. Government Printing Office
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CONTENTS

Figures

Tables

SEASONAL DISTRIBUTION OF TUNAS AND BILLFISHES IN THE ATLANTIC[1]

By

JOHN P. WISE and CHARLES W. DAVIS[2]

ABSTRACT

Charts of the Atlantic Ocean for each quarter of the year—January-March, etc.—show the distribution of 10 species and groups of species fished by the Japanese Atlantic longline fishery in the years 1956-68. These charts are based on detailed catch and fishing effort data published by the Japanese Government. Quarterly average catch per unit of effort was calculated for each 5° × 5° square, and contour lines were drawn through equal levels of catch per unit of effort. The text explains the calculation and contouring processes in detail, and has a section of remarks and explanation for each of the 10 species or groups.

INTRODUCTION

After World War II the Japanese longline fishery for tunas and billfishes began to expand from the area of the home islands. By 1953 the fishery had reached about long 160°W in the eastern Pacific; by 1956 the Pacific fishery extended at least to long 140°W (Rothschild, 1966), and the first commercial ventures had begun in the Atlantic. Subsequent expansion was rapid; in 1962 most of the world ocean between lat 25°N and 25°S was being fished by Japanese longliners. In 1969 the fishery had expanded so that most waters between lat 40°N and 40°S were being fished—the maximum north-south extension of the fishery reached from nearly the Arctic Circle to 55°S (Fisheries Agency of Japan, 1971).

The Japanese Government has collected detailed catch and effort data on this unique fishery for many years and has published most of the available information. The published data for the Atlantic begin with the inception of the Atlantic fishery in 1956; worldwide coverage starts in 1962. These data are of inestimable value from the point of view of understanding the fishery and also from the ecological standpoint by virtue of the information they contain on the distribution and abundance of the species caught. Many studies have been based on these data—the earliest were those published by the Nankai Regional Fisheries Research Laboratory on 1952 data (1954) and on 1958 data (1959). Both covered only the Pacific, as did Howard and Ueyanagi's (1965) atlas on the distribution of billfishes.

The data used here were taken from publications of the Nankai Regional Fisheries Research Laboratory (Shiohama, Myojin, and Sakamoto, 1965) and of the Research Division, Fisheries Agency of Japan (Fisheries Agency of Japan, 1965, 1966, 1967a, 1967b, 1968, 1969, 1970). Shiohama et al. reported on the longline fishery in the Atlantic for 1956-62; the Fisheries Agency publications cover the fishery in the world ocean for 1962-69. Among

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the data presented are the number of hooks set and the catch in numbers of 10 species or groups of species for each 5° × 5° square and each month. The data for 1969 became available as this report was in preparation (Fisheries Agency of Japan, 1971) and are summarized in Table 1 but not included in this analysis.

From 1956 through 1966 the values published are from the longliners from which logbooks were available. Conversion factors are provided to adjust these data to estimates for the whole Japanese fleet. The data from 1967 onward were adjusted before publication. The factors used to adjust the data to values for the whole Atlantic fleet are:

1956	1.00	
1957	1.15	
1958	2.57	
1959	1.97	
1960	1.34	
1961	1.29	
1962	1.72	
1963	1.60	
1964	1.52	(Longliners)
	1.47	(Motherships with longline boats)
1965	1.60	(Longliners)
	1.27	(Motherships with longline boats)
1966	1.54	(Longliners)
	1.17	(Motherships with longline boats)
1967	1.21	(Longliners)
	1.14	(Motherships with longline boats)
1968	1.61	(Longliners)
	1.16	(Motherships with longline boats)

Factors for 1961 and 1962 have been changed slightly from those indicated in Shiohama et al. (1965) because of the deletion of some suspect data on the advice of Dr. Akira Suda of the Far Seas Fisheries Research Laboratory of the Fisheries Agency of Japan. Shiohama (1971) has recently published a table of corrections which agrees almost exactly with Suda's letter—our data are very slightly at variance with the later corrections.

Table 1 summarizes the Japanese Atlantic catch and fishing effort for the period studied.

Through 1965 the Japanese fleet accounted for 90% or more of all Atlantic longline catches. The percentage decreased rapidly in 1966 and following years as the Japanese reduced their effort and the Chinese (Taiwan) and South Koreans increased theirs. In 1969 the Japanese fleet only took about 30% of the total Atlantic longline catch, but fishing operations were widely enough distributed in time and space that the Japanese fleet could still be considered a good sampling device for deriving indices of catch per unit of effort and abundance.

The tunas and billfishes were originally identified in the data reports only by their Japanese and English common names. Beginning in 1967 the names for the Atlantic tunas and billfishes are given as follows:

Japanese name	*Scientific name*	*English name*
Kuromaguro	*Thunnus thynnus*	Bluefin tuna
Minamimaguro	*T. maccoyii*	Southern bluefin
Binnaga	*T. alalunga*	Albacore
Mebachi	*T. obesus*	Bigeye tuna
Kihada	*T. albacares*	Yellowfin tuna
Mekajiki	*Xiphias gladius*	Swordfish
Nishimakajiki	*Tetrapturus albidus*	White marlin
Nishikurokajiki	*Makaira nigricans*	Blue marlin
Shirokajiki	*M. indica*	Black marlin
Nishibashokajiki	*Istiophorus albicans*	Sailfish
Kuchinagufurai	*Tetrapturus pfluegeri*	Longbill spearfish
Katsuo	*Euthynnus pelamis*	Skipjack tuna

METHODS

The area covered in this study is the Atlantic Ocean, exclusive of the Mediterranean Sea, but including the Gulf of Mexico and Caribbean Sea, from lat 45°N to 40°S, west of long 20°E. Twelve of the 6,045 observations in 1956-68, including some 72,000 hooks in 1965-68, occurred just north or south of this area and are not included in subsequent consideration. Two hundred fifty 5° × 5° squares all or part water are included. Two hundred thirty of these were fished at least once during the 13-year period. The 20 squares in which there was no fishing are in coastal areas or at the southern boundary.

The number of month-squares for which there are observations in a given year varies from 23 in 1956 to 1,053 in 1965. An average year has about 464 of a possible 2,760 (230 × 12) month-squares. When the data are grouped into quarters of the year, the range is from 19 quarter-squares in 1956 to 548 quarter-squares in 1965, with an average of about 264 of a possible 920 (230 × 4) quarter-squares. Since the mean density is 29% (264/920) for quarter-squares vs. 17% (464/2,760)

Table 1.--Number of observations*, estimated total numbers of hooks and estimated numbers of fish caught, Japanese Atlantic longline fishery, 1956-69.

Year	Observations*	Hooks	Bluefin**	Albacore	Bigeye	Yellowfin	Swordfish	White marlin	Blue marlin	Black marlin	Sailfish and spearfish	Skipjack
		Thousands										
1956	23	131	Ø	1	Ø	12	Ø	Ø	1	Ø	Ø	0
1957	134	3,376	Ø	32	9	259	1	1	9	Ø	3	0
1958	132	8,001	Ø	100	15	746	1	1	10	Ø	4	0
1959	241	15,312	3	357	45	1,098	2	7	23	Ø	6	Ø
1960	307	20,727	7	452	71	1,159	3	11	27	Ø	12	Ø
1961	401	26,660	4	430	243	980	11	38	43	1	28	Ø
1962	440	54,920	54	1,102	367	991	20	113	112	3	68	0
1963	586	55,004	67	1,133	285	886	24	87	96	1	51	1
1964	806	84,998	63	2,134	344	879	31	163	84	Ø	118	2
1965	1,058	97,580	60	1,769	650	927	44	129	45	Ø	118	3
1966	757	53,791	29	1,586	232	395	22	89	22	Ø	65	1
1967	609	31,154	5	688	181	366	16	43	11	Ø	59	1
1968	551	30,200	8	917	205	274	17	43	9	Ø	52	Ø
1969	588	29,676	32	390	264	242	58	27	13	Ø	26	Ø
Total	6,633	511,531	335	11,090	2,909	9,213	249	753	503	6	610	8

*An "observation" is a set of effort and catch data for a 5° square for a single month. A total of 24 observations in 1961 and 1962 have been eliminated and raising factors adjusted appropriately as stated in the text.
**Includes southern bluefin - previous to 1966 the published statistics do not separate the two species.
Ø Less than 500 fish.

for month-squares, the data were grouped into quarters for analysis.

The number of squares fished at least once in each quarter in the 13 years is:

January-March	176 squares
April-June	193
July-September	203
October-December	200

Squares not fished are shown in Table 2.

Table 2.--Five degree squares not fished by Japanese longlines, 1956-68, by quarter of the year. Each square is identified by the coordinates of its southeast corner.

Never fished*	First quarter** not fished	Second quarter not fished	Third quarter not fished	Fourth quarter not fished
40°N - 70°W	35°N - 75°W.	40°N - 15°W	40°N - 10°W	40°N - 65°W
40°N - 05°W	35°N - 70°W.	35°N - 20°W	35°N - 75°W	40°N - 60°W
40°N - 00°	35°N - 65°W.	35°N - 15°W	35°N - 45°W	40°N - 15°W
35°N - 05°W	35°N - 60°W.	35°N - 10°W	30°N - 80°W	40°N - 10°W
30°N - 85°W	35°N - 45°W.	30°N - 15°W	30°N - 75°W	35°N - 75°W
30°N - 10°W	35°N - 25°W.	25°N - 80°W	30°N - 30°W	35°N - 70°W
30°N - 05°W	35°N - 15°W.	25°N - 15°W	30°N - 15°W	35°N - 15°W
25°N - 10°W	35°N - 10°W.	20°N - 25°W	25°N - 15°W	35°N - 10°W
05°N - 60°W	30°N - 80°W.	05°N - 80°W	20°N - 25°W	30°N - 80°W
05°S - 50°W	30°N - 75°W.	05°N - 75°W	20°N - 15°W	30°N - 75°W
05°S - 45°W	25°N - 80°W.	05°N - 05°W	10°N - 10°W	30°N - 70°W
25°S - 45°W	25°N - 30°W.	20°S - 35°W	05°N - 05°W	30°N - 65°W
40°S - 60°W	25°N - 20°W.	20°S - 20°W	05°N - 00°	30°N - 50°W
40°S - 55°W	20°N - 80°W.	20°S - 15°W	05°N - 10°E	30°N - 15°W
40°S - 25°W	20°N - 75°W.	25°S - 40°W	25°S - 30°W	25°N - 80°W
40°S - 10°W	20°N - 45°W.	25°S - 35°W	25°S - 25°W	25°N - 75°W
40°S - 05°W	20°N - 30°W.	25°S - 20°W	25°S - 20°W	25°N - 65°W
40°S - 00°	20°N - 25°W.	25°S - 15°W	30°S - 30°W	25°N - 60°W
40°S - 10°E	15°N - 90°W.	25°S - 10°W	35°S - 50°W	25°N - 55°W
40°S - 15°E	10°N - 10°W.	25°S - 05°W	40°S - 50°W	25°N - 50°W

The mean catch per unit of effort taken as apparent abundance for a square for a quarter was computed as the arithmetic mean of the catch per unit of effort for each month in the quarter for each year—possibly 39 values had the square been fished in every month of the quarter in all of the 13 years. The method was selected over the alternative of dividing total catch by total effort because we desired to weight each unit of time equally to eliminate the possible biasing effects of large variations in fishing effort in different years. Over 70% of the fishing in the 13 years took place in the 5 years 1962-66 (Table 1).

Catch per unit of effort was estimated for most unfished squares, and they were "filled"

Table 2.--Continued.

Never fished*	First quarter** not fished	Second quarter not fished	Third quarter not fished	Fourth quarter not fished
	05°N - 10°E	25°S - 00°	40°S - 45°W	25°N - 40°W
	00° - 50°W	25°S - 05°E	40°S - 40°W	25°N - 35°W
	20°S - 00°	30°S - 45°W	40°S - 35°W	20°N - 75°W
	25°S - 00°	30°S - 35°W	40°S - 30°W	20°N - 50°W
	30°S - 30°W	30°S - 30°W	40°S - 20°W	20°N - 40°W
	30°S - 25°W	30°S - 25°W	40°S - 15°W	15°N - 95°W
	30°S - 00°	30°S - 20°W	40°S - 05°E	15°N - 90°W
	30°S - 20°E	35°S - 50°W		05°N - 10°E
	35°S - 35°W	35°S - 35°W		35°S - 50°W
	35°S - 30°W	35°S - 30°W		40°S - 50°W
	35°S - 25°W	35°S - 25°W		
	35°S - 20°W	35°S - 20°W		
	35°S - 10°W	40°S - 35°W		
	35°S - 05°W	40°S - 30°W		
	35°S - 00°	40°S - 20°W		
	40°S - 45°W	40°S - 15°W		
	40°S - 20°W	40°S - 05°E		
	40°S - 15°W			
	40°S - 05°E			

*These squares not included in listing by quarter.
**No fishing north of 40°N in this quarter.

since we felt that with certain limitations values in surrounding squares could be taken as estimators. The four adjacent squares and the four squares at the corners of each unfished square were considered. An unfished square was filled if there were data in at least: two adjacent squares, one adjacent square and two opposing corner squares, or four corner squares. Adjacent squares were assigned a weight of two, the corner squares a weight of one.

The catch per unit of effort of an unfished square was calculated by multiplying values in the adjoining squares by the appropriate weighting factors, summing the products, and dividing by the sum of the factors. The

Table 3.--Five-degree squares not fished and not filled, by quarter of the year. Each square is identified by the coordinates of its southeast corner.

Never filled*	First quarter** not filled	Second quarter not filled	Third quarter not filled	Fourth quarter not filled
40°N - 05°W	35°N - 75°W	35°N - 10°W	35°N - 75°W	40°N - 70°W
40°N - 00°	35°N - 70°W	30°N - 15°W	30°N - 85°W	40°N - 65°W
35°N - 05°W	35°N - 65°W	05°N - 80°W	30°N - 80°W	40°N - 15°W
30°N - 10°W	35°N - 10°W	05°N - 75°W	25°N - 15°W	40°N - 10°W
30°N - 05°W	30°N - 85°W	25°S - 45°W	35°S - 50°W	35°N - 75°W
25°N - 10°W	30°N - 80°W	25°S - 40°W	40°S - 50°W	35°N - 70°W
05°S - 50°W	35°S - 30°W	30°S - 30°W	40°S - 45°W	35°N - 15°W
40°S - 60°W	35°S - 25°W	30°S - 25°W	40°S - 40°W	35°N - 10°W
40°S - 55°W	35°S - 05°W	35°S - 35°W	40°S - 35°W	30°N - 85°W
40°S - 05°W	35°S - 00°	35°S - 30°W	40°S - 30°W	30°N - 80°W
	40°S - 25°W	35°S - 25°W	40°S - 25°W	30°N - 75°W
	40°S - 20°W	35°S - 20°W	40°S - 20°W	30°N - 70°W
	40°S - 15°W	40°S - 35°W	40°S - 15°W	25°N - 75°W
	40°S - 10°W	40°S - 30°W	40°S - 10°W	15°N - 95°W
	40°S - 00°	40°S - 25°W	40°S - 00°	35°S - 50°W
	40°S - 05°E	40°S - 20°W	40°S - 05°E	40°S - 50°W
	40°S - 10°E	40°S - 15°W	40°S - 10°E	
		40°S - 10°W		
		40°S - 00°		
		40°S - 05°E		
		40°S - 10°E		

*These squares not included in listing by quarter.
**No filling north of 40°N in this quarter.

procedure was reapplied to a single square, lat 20°-25°S, long 15°-20°W, in the second quarter only, which remained as a "hole" in the data field after the filling process. Table 3 shows the squares which remained without observed or assigned values after filling.

Contouring was done by computer, assigning the catch-per-unit-of-effort value for each square to a point in the geometric center of the square. Although our charts (Figures 1 and 4-13) are a square projection, the "squares" are, of course, not square. One degree of longitude is approximately equal to 60.722 nautical miles × cosine latitude.

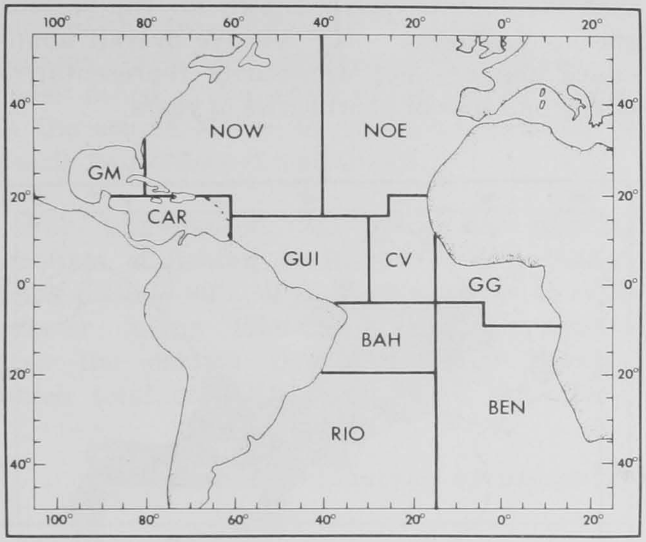

Figure 1. — Divisions of the Atlantic Ocean.

The program used for contouring could not effectively distinguish squares with no data from those with values of zero, and it contoured squares which are part water as if they were all water. For these reasons we edited the computer plots, terminating all contours at the coast and a half-square before the edge of the data field.

For the sake of clarity and simplicity the contours in Figures 4-13 are usually drawn at the levels of 2, 4, and 6, and the number of hooks is varied appropriately by orders of magnitude:

Fish per 100 hooks -	Albacore
	Yellowfin
Fish per 1,000 hooks -	Bigeye
	White marlin
	Blue marlin
	Sailfish and spearfish
Fish per 10,000 hooks -	Bluefin
	Swordfish
	Black marlin
	Skipjack

The level of 4 (per 100 or 1,000 or 10,000 hooks) is shown by a dashed line. In cases where the catch rates exceeded 6 (per 100, etc., hooks) in significant amounts, the fact is noted in the explanatory text for each species. Black marlin and skipjack are exceptions—their apparent abundance is so low that contours are drawn only at the single level of 1 per 10,000 hooks, roughly equivalent to comparison of presence vs. absence.

INTERPRETATION OF CONTOURS

The various species have shown differing apparent responses to exploitation, and these responses, of course, affect the mean abundance values. (Wise, 1968; Wise and Fox, 1969; Wise and LeGuen, 1969.) For this reason, in Figure 2, we show for each species the annual

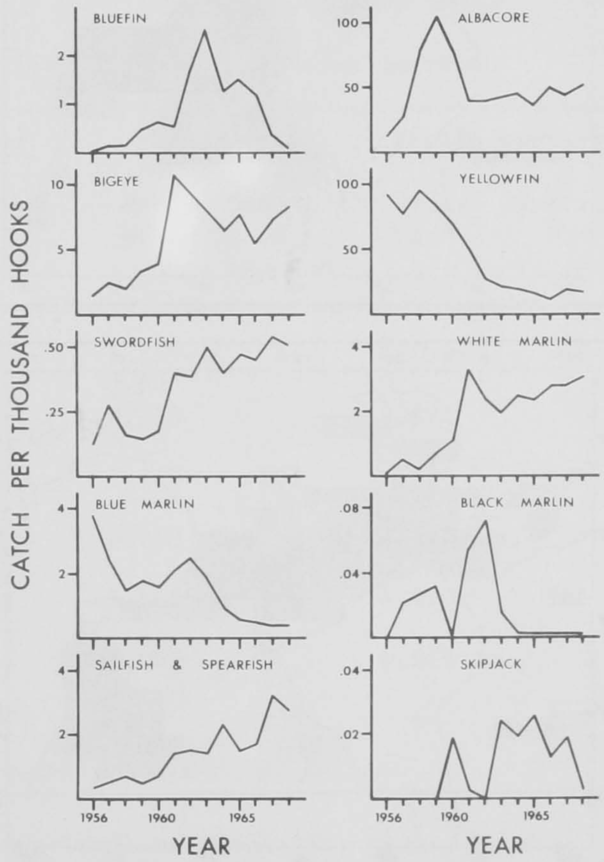

Figure 2. — Catch per thousand hooks, 1956-68, various tunas and billfishes in selected areas (see text) in the Atlantic Ocean.

catch per unit of effort only in the areas in which the catches of the species were greatest in 1956-68, dividing the Atlantic as shown in Figure 1. Catches were distributed as follows:

Bluefin	- 89% of the catch in NOW, GUI, and BAH
Albacore	- 86% of the catch in NOW, BAH, BEN, and RIO
Bigeye	- 86% of the catch in GUI, CV, GG, and BEN
Yellowfin	- 86% of the catch in GUI, CV, and GG
Swordfish	- 81% of the catch in GUI, CV, GG, BAH, and BEN
White marlin	- 72% of the catch in NOW, GUI, BAH, and RIO
Blue marlin	- 72% of the catch in NOW, GUI, GG, and BAH
Black marlin	- 73% of the catch in CV, GG, and BAH
Sailfish and spearfish	- 76% of the catch in GUI, GG, BAH, and RIO

Catch rates of skipjack are calculated for the whole ocean.

Examination of Figure 2 makes it clear that the contour levels shown for the various species can reflect only relative overall abundance and are not necessarily representative of any one year or short series of years.

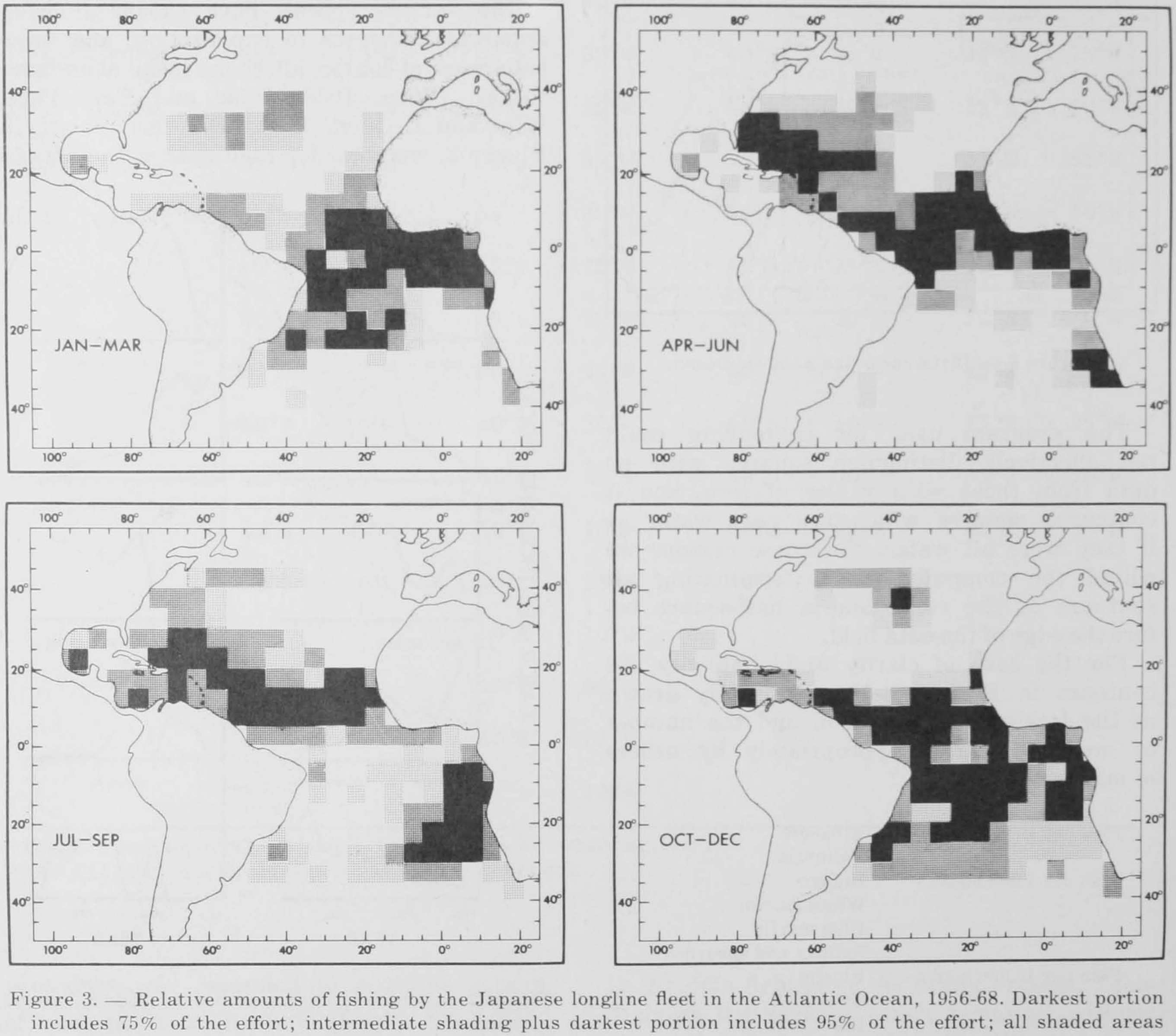

Figure 3. — Relative amounts of fishing by the Japanese longline fleet in the Atlantic Ocean, 1956-68. Darkest portion includes 75% of the effort; intermediate shading plus darkest portion includes 95% of the effort; all shaded areas include 99% of the effort.

Most, if not all, previous studies based on the Japanese longline data—e.g., Koto (1969); Mather, Jones, and Beardsley (1972); Sakamoto (1967)—have tacitly assumed that all observations are of equal value in delimiting distribution and abundance of the species taken by the fishery. The assumption probably is not correct because of the grossly unequal amounts of fishing in different parts of the Atlantic. For example, there were a total of some 7 million hooks fished in 1956-68 in each of the two most heavily fished 5° × 5° squares, vs. a total of only about a thousand hooks fished in the most lightly fished square in the course of the 13 years, a difference of nearly four orders of magnitude.

For this reason, we show the relative amounts of fishing in Figure 3. The shaded areas include 99% of the fishing effort in each quarter during 1956-68. Within the shaded area the darkest portion includes squares which total cumulatively 75% of the effort; the intermediate shading plus the darkest portion includes 95% of the effort. Table 4 shows the range of the percentages. The total fishing effort was approximately equal in each of the four quarters—first quarter 120.5 million hooks, second quarter 131.6 million hooks, third quarter 120.7 million hooks, fourth quarter 109.0 million hooks.

Thus, all of the squares outside of the shaded areas in any quarter taken together include no more than 1% of the fishing effort for that quarter, and no one unshaded square includes more than about 0.05% of the fishing for that quarter—at the maximum about 5,000 hooks total in 13 years (131.6 million hooks × 0.05%/13). Most of the squares outside the shaded area include less than 0.05% of the fishing; the average is less than 0.02%, or less than 2,000 hooks total in 13 years.

A recent publication by Shiohama (1971) shows graphically the distribution of Japanese longline fishing effort for each year in the 1956-68 period.

Table 4.--Distribution of percentages of fishing effort for each quarter.

	First quarter		Second quarter		Third quarter		Fourth quarter	
Effort level	Range of %	Number of squares	Range of %	Number of squares	Range of %	Number of squares	Range of %	Number of squares
75%	5.894-0.924	34	5.075-0.766	48	5.169-0.814	44	4.070-0.584	55
95%	5.894 0.176	78	5.075-0.225	88	5.169-0.163	101	4.070-0.208	109
99%	5.894-0.055	115	5.075-0.046	124	5.169-0.049	141	4.070-0.048	144
100%	-	176	-	193	-	203	-	200

Note: The number of squares shown for each effort level is cumulative--i.e., in the first quarter 95% of the fishing is included in the 34 squares which include 75% of the fishing, plus 44 others, or 78 squares.

The shaded regions include the areas in which we have reasonable confidence in the contours, with confidence increasing as the amount of fishing included increases. Contour lines outside of the shaded areas are related to very small amounts of fishing and should be interpreted with caution, especially where there are isolated peaks of high apparent abundance.

In evaluating the amount of confidence to be placed in the contour lines, however, we feel that giving consideration only to the amount of fishing is oversimplification. When a concentration repeats in more than one quarter, or when it appears to be coherent with one or more others appearing in other quarters, it can often be given more credence than that based simply on the amount of fishing. The ideal, of course, would be to have the fishing uniformly distributed over the ocean. An alternative would be to apply an objective statistical procedure to reject catch-per-unit-of-effort values derived from amounts of fishing below a critical value. The first is impossible and the second probably not practical, so a certain amount of subjectivity must remain in the interpretation of the contours.

BLUEFIN AND SOUTHERN BLUEFIN TUNAS

The published Japanese statistics did not separate the bluefin and the southern bluefin previous to 1966. In the period 1966-68 about 30% of the total catch of both species was southern bluefin, but less than 100 southern bluefin were caught north of lat 20°S. About 75% of the catch south of lat 20°S was reported as southern bluefin. We shall generally consider concentrations north of lat 20°S as bluefin and concentrations south of 20°S as southern bluefin.

Figure 4 shows the distribution of catches of bluefin for the four quarters of the year. The most consistent features are a concentration of bluefin off the easternmost part of South America all year round and another, probably of bluefin and southern bluefin (Talbot and Penrith, 1963), on or near the African coast south of lat 20°S, in every quarter but the first. There is a concentration in the first quarter just north of lat 20°S; it appears probable that this is related to the African coastal group.

There is a concentration around Cuba and Puerto Rico in the first quarter, extending into the northern Gulf of Mexico and along the east coast of North America in the second quarter. It is off the northeastern United States and Newfoundland in the third quarter and extends southward in open water from Nova Scotia and Newfoundland in the fourth quarter. This pattern is consistent with a migration pattern outlined by Rivas (1955). The migration hypothesis for northwest Atlantic bluefin was unsupported by any direct evidence for many years, but recently longliners off New England and Nova Scotia caught two bluefin tagged in the Bahamas (F. J. Mather, III, personal communication).

In the first through third quarters there are "spots" of bluefin extending eastward from the concentrations mentioned above, and in the fourth quarter there is a large concentration centered on long 30°W in the North Atlantic. These distributions may be related to the irregular transatlantic migrations of bluefin discussed by Mather (1969).

Although there are relatively important fisheries for bluefin on the European coast, in the Mediterranean, and on the northwest coast of Africa, nearly all of the large concentrations in Figure 4 occur west of long 20°W.

The apparent abundance of bluefin during the 1956-68 period increased from very low levels in the early years to a peak in 1962-66, then returned to low levels (Figure 2). A similar cycle may be seen in the purse-seine catches off New England (Wise, Beardsley, and Mather, 1971). While great changes in catch-per-unit-of-effort values with time make any absolute values questionable, average catches per unit of effort in the concentrations shown run over 50 per 10,000 hooks in the first quarter and over 100 per 10,000 hooks in the second quarter.

ALBACORE

The most obvious feature in the distribution of albacore for the four quarters of the year,

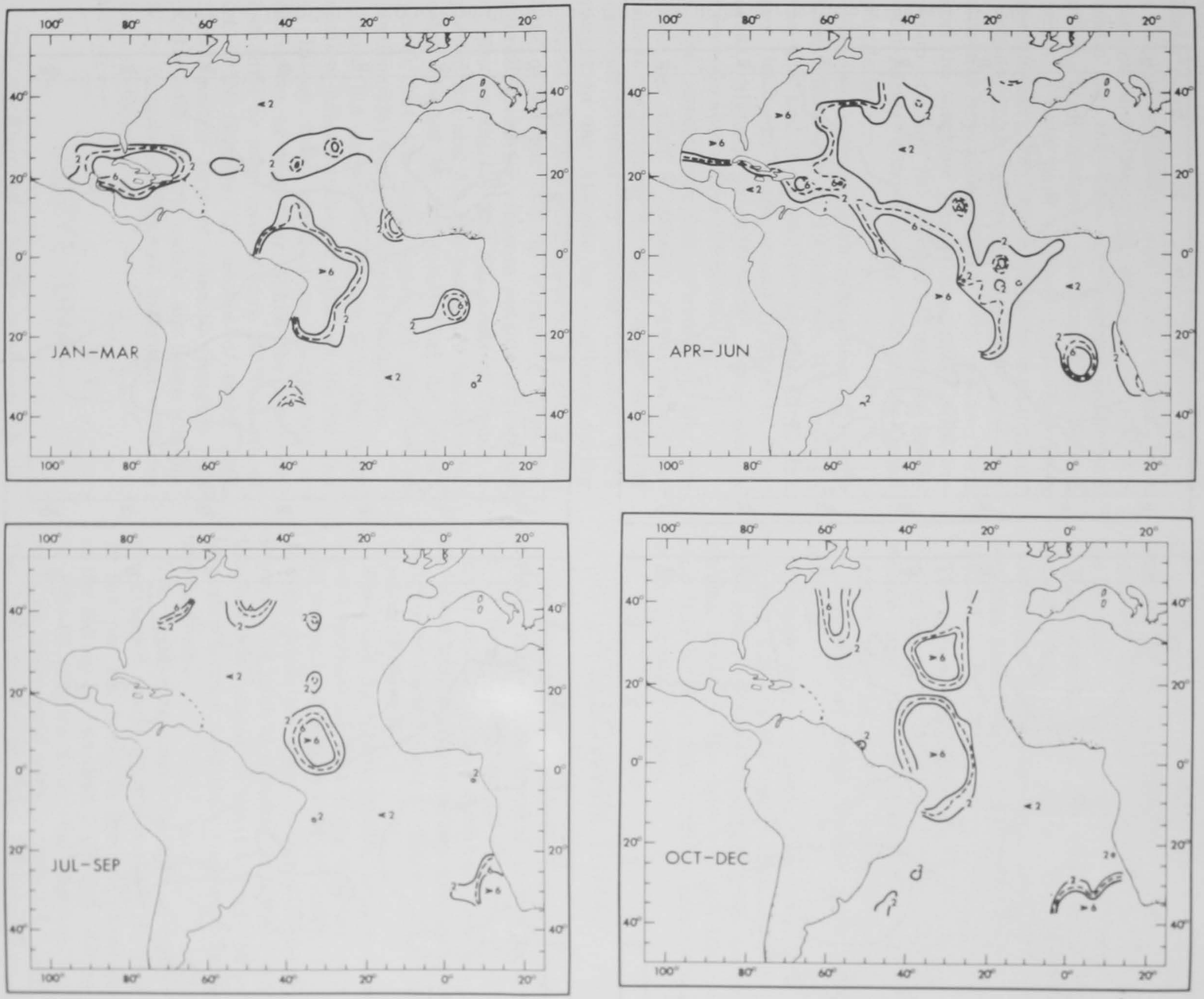

Figure 4. — Distribution of catches of bluefin tunas (per 10,000 hooks) in the four quarters of the year, 1956-68.

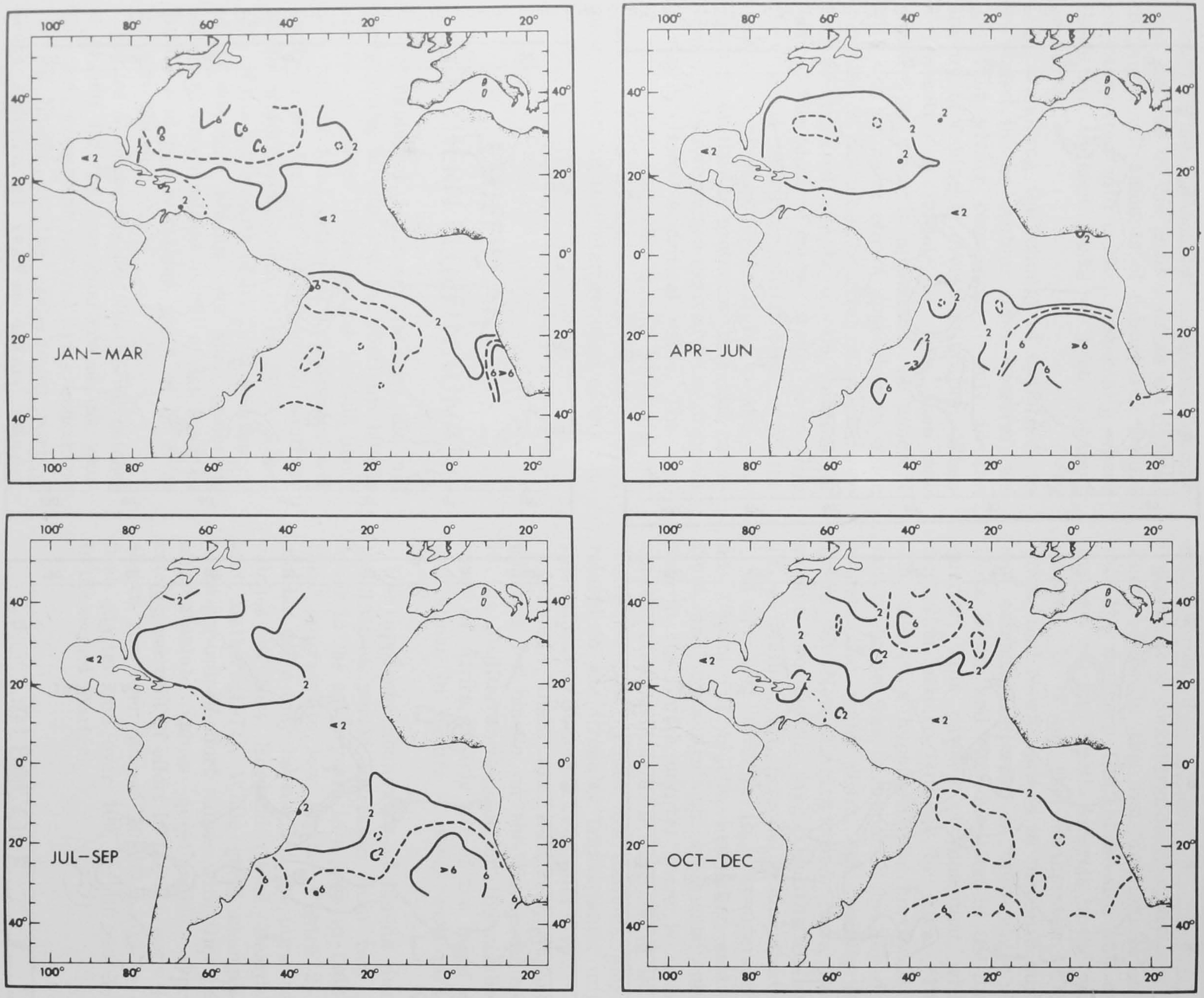

Figure 5. — Distribution of catches of albacore (per 100 hooks) in the four quarters of the year, 1956-68.

as shown in Figure 5, is the separated northern and southern distribution of the species, with very low catch rates between about lat 15°N and 5°S.

Beardsley (1969) and Koto (1969) both studied distribution of albacore in the Atlantic on the basis of longline catch and effort. Their analyses were based on shorter series of data than we have used—Beardsley used 9 years, 1957-65, while Koto used 5 years, 1961-65. Both agreed on generally east-west seasonal migrations within both the northern and the southern groups of albacore, with the group of small fish located off extreme southwest Africa interchanging with Indian Ocean populations.

Highest average catch rates occur off southwest Africa—up to 10 fish per 100 hooks in the first and third quarters and up to 17 fish per 100 hooks in the second quarter. In other areas, highest average catch rates almost never are above 7 per 100 hooks.

The almost complete absence of albacore from the Gulf of Mexico, although not apparent in Figure 5, is of some ecological interest. Almost 11 million albacore were caught in the Atlantic by longliners during 1956-68, but only 0.02% were caught in the Gulf of Mexico (GM in Figure 1). The two poorest areas for albacore outside of the Gulf of Mexico, the CV and GG areas of Figure 1, yielded 2.4 and 3.1 fish per 1,000 hooks (total catch divided by the total effort for the 13 years), but the same figure for the Gulf of Mexico (GM) was only 0.5 per 1,000 hooks.

Also not shown on Figure 5 is the large shallow concentration of albacore in the Bay of Biscay from about June to October or November of each year. While the longliners fish little or none east of long 20°W, north of lat 20°N (Figure 3), catches of more than 30,000 metric tons of albacore (roughly half of the total Atlantic catch) are taken annually by French and Spanish fishermen with live bait and by trolling.

BIGEYE TUNA

The distribution of bigeye is shown for the four quarters of the year in Figure 6. Two large concentrations are evident off the coast of west Africa, separated at or near the equator, changing their shapes and boundaries with the seasons. The northern concentration is not defined at its northern edge in any quarter except the third, and may extend all of the way across the Atlantic at about lat 35°-40°N in every quarter except the second.

These distributions are different in many respects from those outlined by Sakamoto (1967)—the differences may be due to the fact that Sakamoto used data only for 3 years, 1962-64.

The apparently anomalous minor concentration of bigeye along the east coast of southern Mexico and Central America in all four quarters may be due to misidentification by the fishermen of large blackfin tuna (*T. atlanticus*).

Average catches inside the contour of 6 fish per 1,000 hooks reach over 30 fish per 1,000 hooks in some cases along the southern African coast in the last two quarters, and near this level in the northern concentration in the first two quarters.

YELLOWFIN TUNA

Concentrations of yellowfin tuna are almost entirely confined to tropical waters between lat 20°N and 10°S, except for low or small concentrations in the northwest Atlantic in the third and fourth quarters and some concentrations in the Gulf of Mexico in all four quarters (Figure 7).

Wise and Le Guen (1969), among others, have hypothesized that there may be eastern and western populations of yellowfin in the tropical Atlantic. There is some evidence in Figure 7 of such a division, but the dividing line could be placed at about long 70°W, considerably farther west than suggested by Wise and Le Guen.

The catch per unit of effort of yellowfin has dropped markedly and steadily from 9 or 10 fish per 100 hooks in the first three years of the fishery to less than 2 fish per 100 hooks in 1964-68 (Figure 2) so that absolute values must be interpreted with considerable caution. The highest average value is nearly 19 fish per 100 hooks in the western Gulf of Mexico in the first quarter and nearly 12 fish per 100 hooks occur on the north coast of South

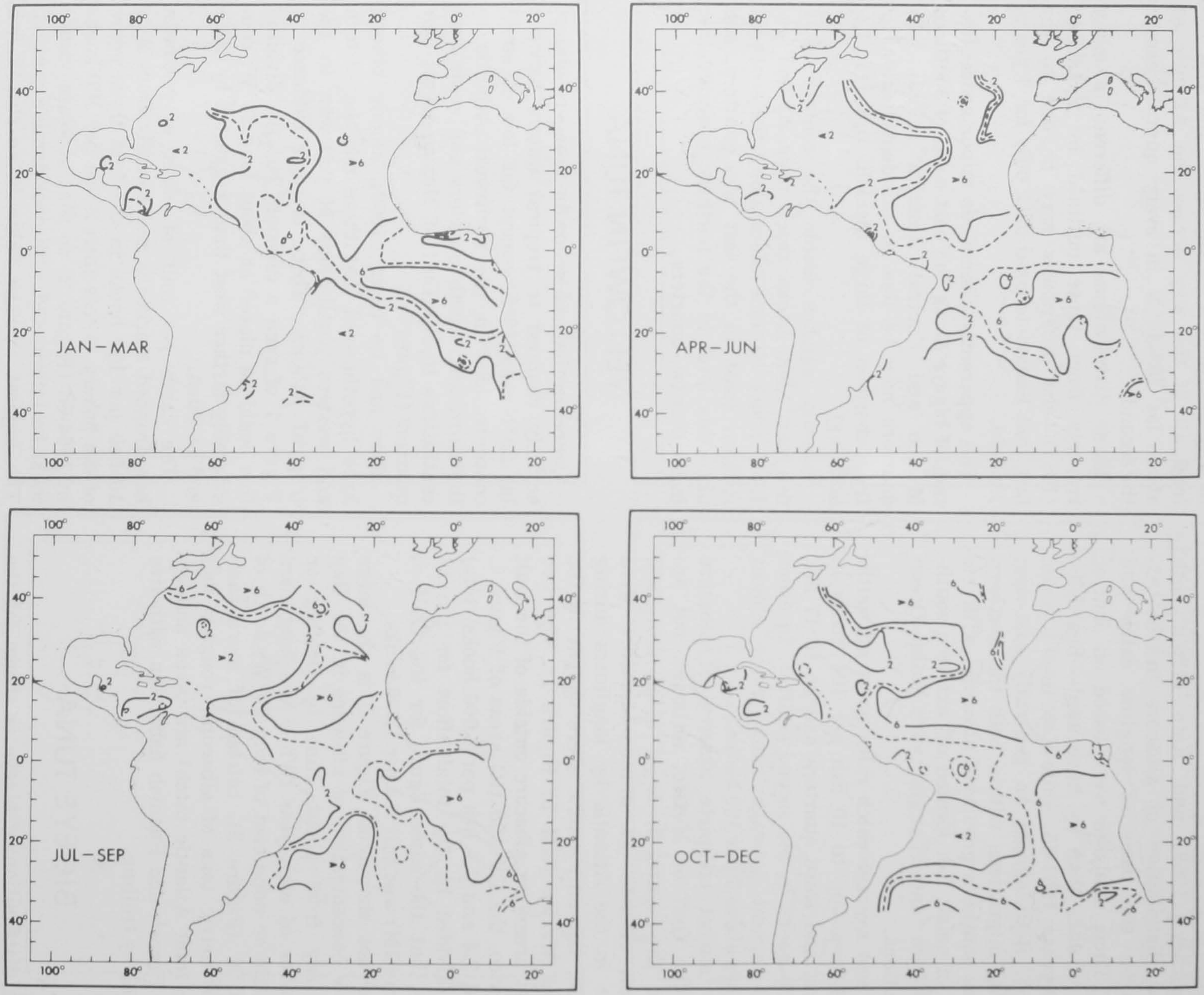

Figure 6. — Distribution of catches of bigeye tuna (per 1,000 hooks) in the four quarters of the year, 1956-68.

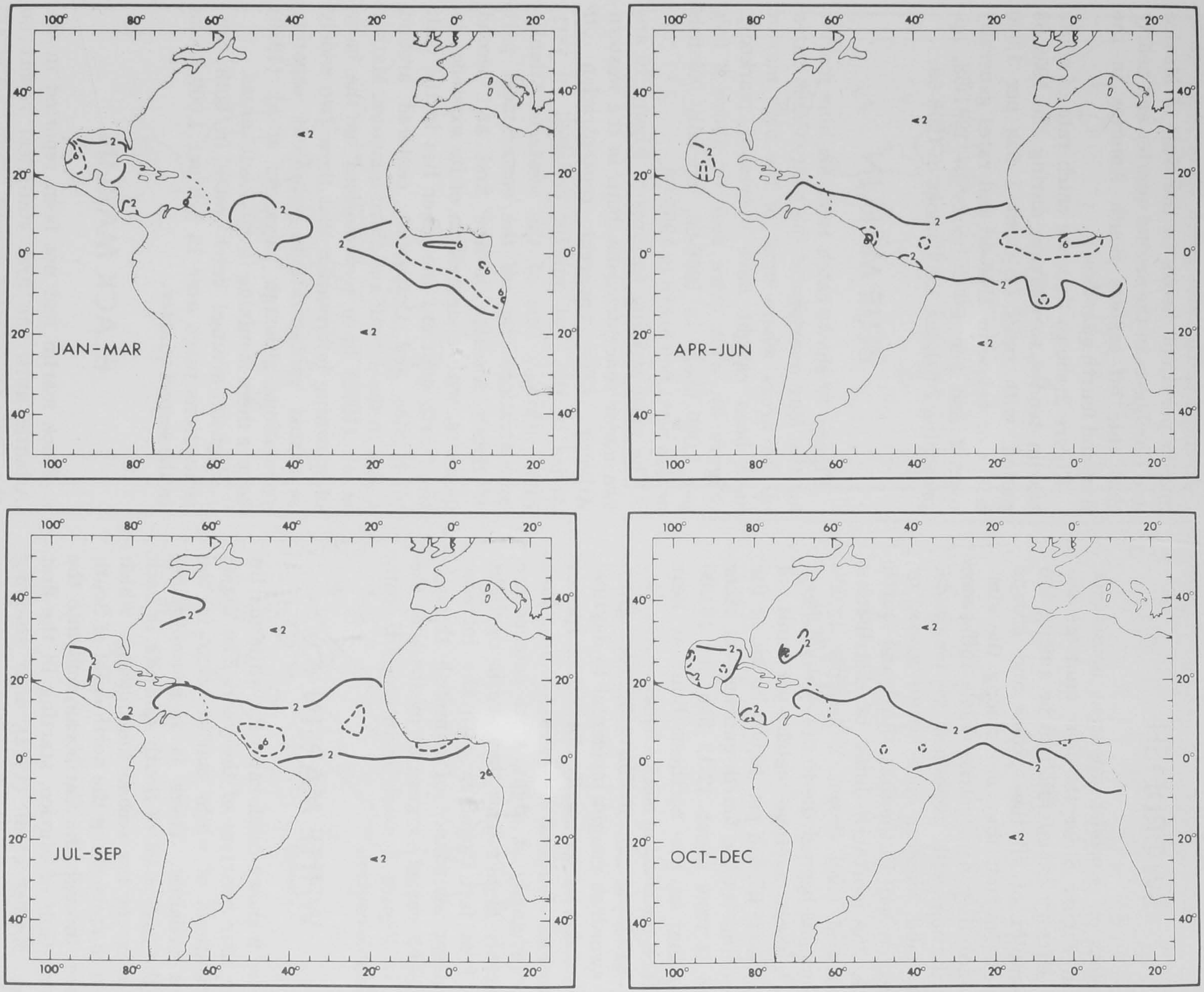

Figure 7. — Distribution of catches of yellowfin tuna (per 100 hooks) in the four quarters of the year, 1956-68.

America in the second quarter—in all other cases the contour of 6 fish per 100 hooks does not enclose values of much above 6.

SWORDFISH

The plots of swordfish apparent abundance shown in Figure 8 for the four quarters appear on cursory examination to be among the most complex of all the species and groups of species. In fact, they are among the simplest, since they demonstrate little difference in distribution with reference to longitude, latitude, land masses, open ocean areas, or even with season. In the first, third, and fourth quarters, the northern limit of distribution at the lowest level shown, 2 fish per 10,000 hooks, extends beyond the limits of the fishery.

The highest average catch per unit of effort is about 27 fish per 10,000 hooks, at the northern limit in the fourth quarter—in other quarters it runs about 12-19 fish per 10,000 hooks, either at the northern limit or near lat 10°N on the coast of west Africa.

The catch-per-unit-of-effort figures given are for swordfish caught incidental to daytime longline fisheries primarily for other species —commercial longline fisheries for swordfish operate primarily at night, since catches are considerably higher than they are in daylight hours. This fact, together with the increase in apparent abundance of swordfish through the 1956-63 period (Figure 2) means that the values in Figure 8 must be interpreted with considerable caution.

WHITE MARLIN

Figure 9 shows catch rates for white marlin for the four quarters of the year. The major concentrations of white marlin occur in the western Atlantic. There is a concentration along the east coast of South America in each quarter except the second and another which appears to move along the north coast of South America, through the Caribbean, and into the northern Gulf of Mexico, starting in the first quarter. Mather et al. (1972), after studying 65 tag returns, mostly from the commercial fishery, state that these shifts may be attributed to seasonal migration. They hypothesize that there are probably no major migrations of white marlin between the two western Atlantic concentrations and that they may be separate populations.

Average catch rates reach 30 or more white marlin per 1,000 hooks in the Gulf of Mexico and Caribbean in the second quarter and nearly that rate off eastern South America in the first and fourth quarters.

Figure 2 shows that the catch rate of white marlin tended to increase during the 1956-68 period, with rates of about 1 fish per 1,000 hooks or below in 1956-60 and rates generally over 2 fish per 1,000 hooks in 1961-68, approaching 3 fish per 1,000 hooks in 1966-68.

BLUE MARLIN

Figure 10 shows catch rates for blue marlin for the four quarters of the year. Catch rates in the areas where most of the blue marlin have been caught have decreased markedly (Figure 2), with rates near or above 2 fish per 1,000 hooks in 1956-63, but only 0.6 fish or less per 1,000 hooks in 1965-68.

The most striking features of Figure 10 are two major concentrations, both in the western Atlantic. (The apparent concentration off Africa in the first quarter is based on very little fishing.) One of the western Atlantic concentrations lies off the easternmost part of South America in the first and second quarters, with a suggestion of its existence in the fourth quarter. The other lies in the Gulf of Mexico and Caribbean, centered around Cuba, in the second and third quarters. Mather et al. (1972) have hypothesized on the basis of spawning information that these two widely separated concentrations represent separate populations although Ueyanagi et al. (1970) believe there is mixing in equatorial areas.

Highest average catch rates in both concentrations reach over 13 fish per 1,000 hooks in the second quarter.

BLACK MARLIN

Black marlin had not been reported in the Atlantic until the first statistical report on the Japanese longline fishery (Shiohama et al., 1965). Its existence in the Atlantic still has not been confirmed by examination of specimens by a qualified ichthyologist. Nonetheless,

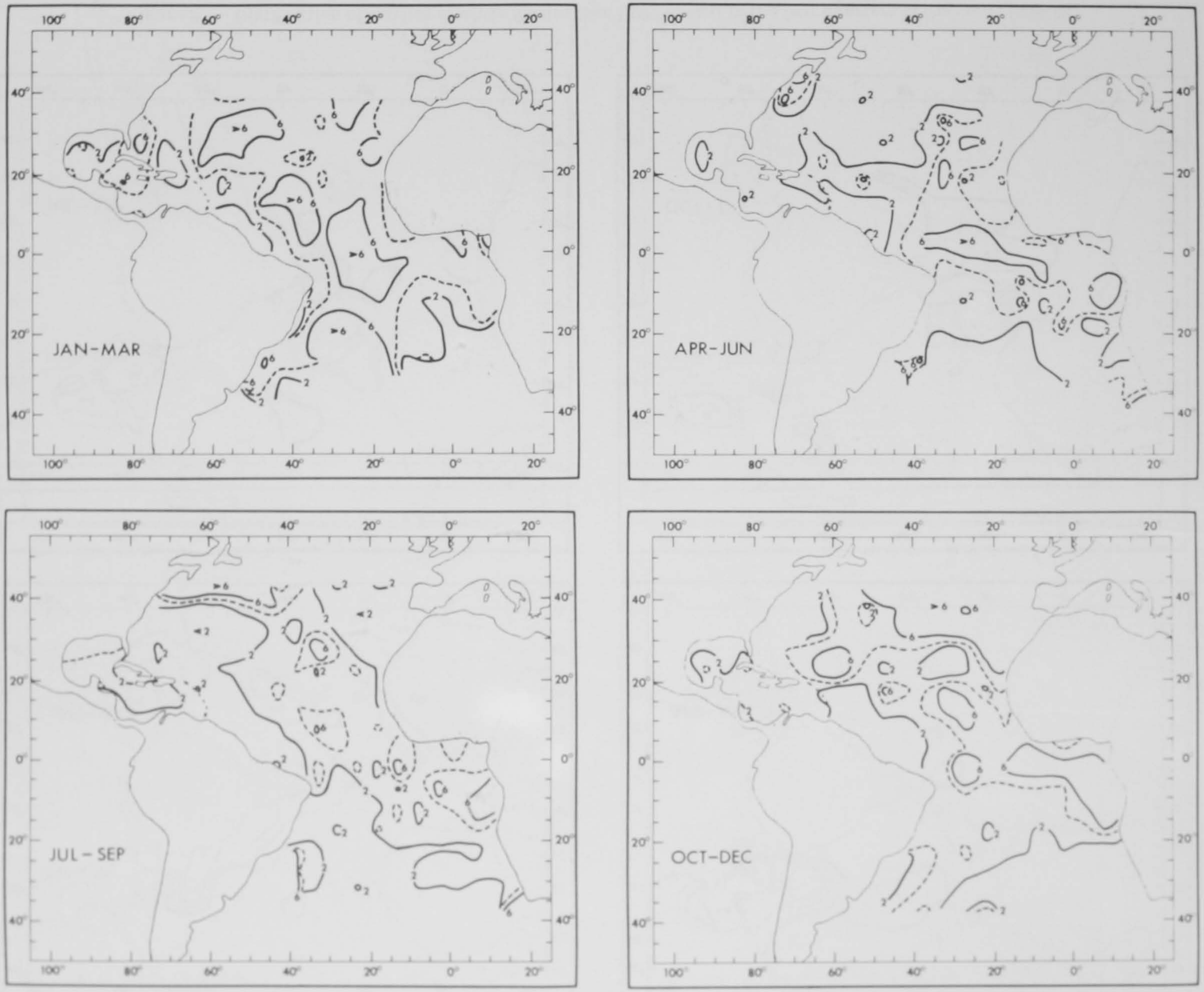

Figure 8. — Distribution of catches of swordfish (per 10,000 hooks) in the four quarters of the year, 1956-68.

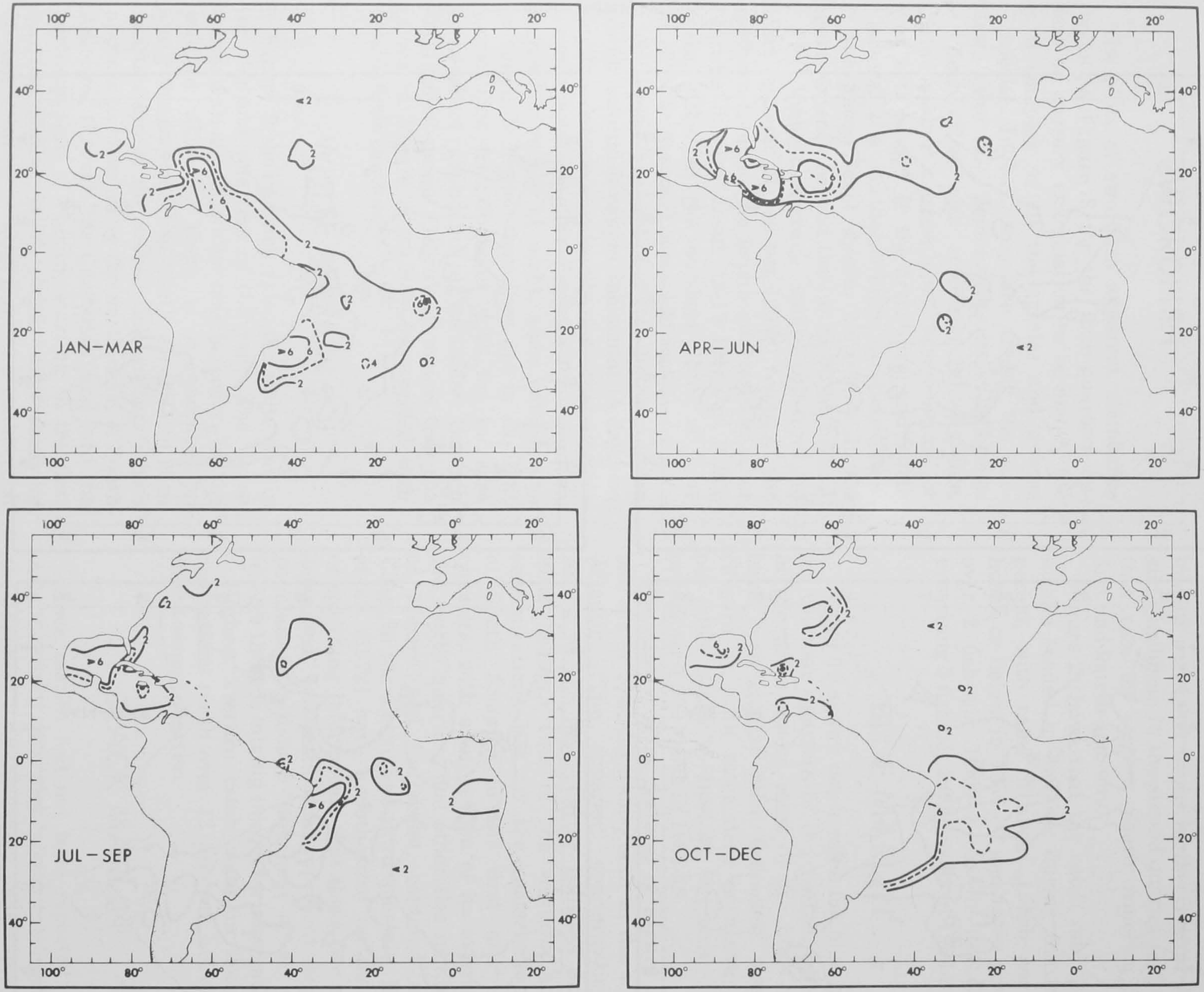

Figure 9. — Distribution of catches of white marlin (per 1,000 hooks) in the four quarters of the year, 1956-68.

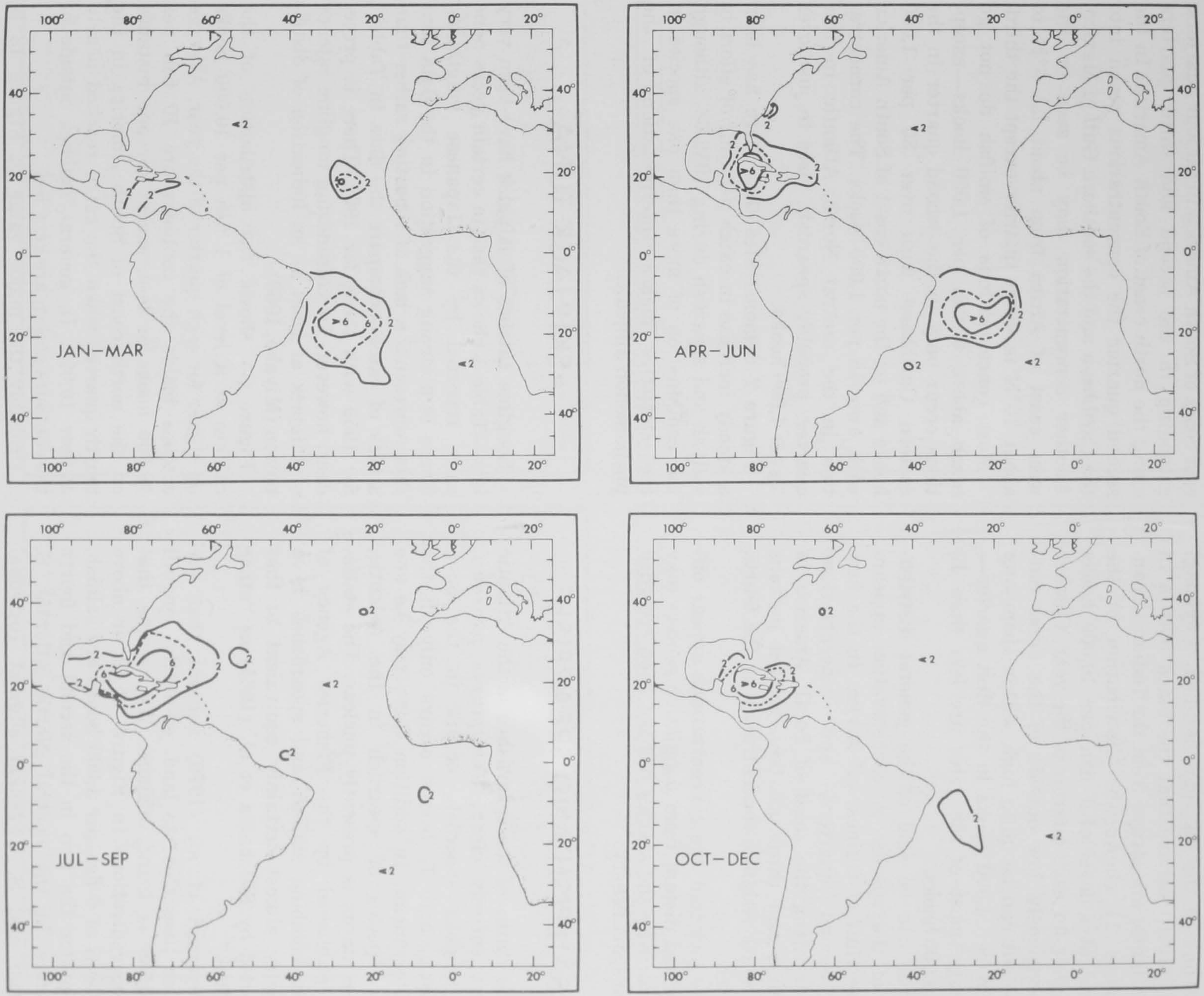

Figure 10. — Distribution of catches of blue marlin (per 1,000 hooks) in the four quarters of the year, 1956-68.

the Japanese longline fishermen, many of whom would be expected to recognize the species, have reported catches consistently in every one of the 13 years studied. Ueyanagi et al. (1970) believe that the black marlin in the Atlantic are strays from the Indian Ocean.

Figure 11 shows the distribution of the catches at a level of 1 fish per 10,000 hooks or higher for each quarter of the year. Catches are extremely low outside of the areas outlined, but can be quite high within them—up to 186 per 1,000 hooks in the first quarter—although most of the rates are less than 10 per 10,000 hooks.

Little can be said of the general distribution of the species. A concentration appears in the Gulf of Guinea, off Africa, in the first and second quarters, and concentrations appear along the coast of South America in the first and third quarters, related perhaps to a South Atlantic concentration in the fourth quarter.

The fact that the concentrations appear offshore and distant from population centers may explain why the species has not been recorded in the sport fishery.

SAILFISH AND SPEARFISH

The status of the spearfishes in the Atlantic is not entirely clear; *Tetrapturus pfluegeri*, the longbill spearfish, occurs in the open Atlantic, and *T. belone* occurs only in the Mediterranean. In addition there may be one other species of spearfish in the Atlantic, whose status is presently unclear. The statistics published by the Fisheries Agency of Japan combine sailfish and spearfishes in a category almost certainly equivalent to that reported by Shiohama et al. (1965) as "other marlins."

Ueyanagi et al. (1970) suggest that the sailfish lives close to land, while the longbill spearfish is found offshore. We assume that all concentrations in Figure 12 at or above the level of 6 fish per 1,000 hooks are sailfish, except for the two in the second and fourth quarters in the central North Atlantic. S. Hayasi and S. Ueyanagi suggest (personal communication) that all of the open sea concentrations shown in Figure 12 may reflect the distribution of spearfish rather than sailfish.

Concentrations of sailfish occur along the east coast of South America in all four quarters, extending in the second and third quarters along the north coast of South America. In the second quarter the concentrations reach into the Caribbean and the southern Gulf of Mexico. Another concentration may be seen on the west coast of Africa from about lat 5°N to about 10°N in every quarter except the third.

Most concentrations of sailfish do not go much above 6 fish per 1,000 hooks—exceptions occur only in the second quarter in the eastern Caribbean with over 35 per 1,000 hooks and on the north coast of South America with over 15 per 1,000 hooks. The concentration in the central North Atlantic in this quarter, probably spearfish, rises to just over 14 per 1,000 hooks.

Figure 2 demonstrates that there has been a steady increase in catch per unit of effort of sailfish and spearfish during 1956-68, although the combination of more than one species in the statistics makes interpretation of the phenomenon difficult.

SKIPJACK TUNA

Longline catches of skipjack have been very low—Table 1 shows that in certain years none were reported by the Japanese longliners. There is a strong suggestion in the data that this represents a lack of reporting rather than a lack of catch—compare the data in Table 1 for 1959 with those for 1962. There is precedent, however, for considering longline catches of skipjack at least as an indication of distribution (Miyake, 1968).

Figure 13 shows the distribution of the catches at a level of 1 fish per 10,000 hooks or higher for each quarter of the year. Average catches inside the contours are 10 fish per 10,000 hooks or less, except for one instance on the north coast of South America in the fourth quarter when the catch reached nearly 40 per 10,000. In general, catches outside of the contours shown are very low.

Probably the major value of Figure 13 is the indication that skipjack are very widely distributed in the Atlantic.

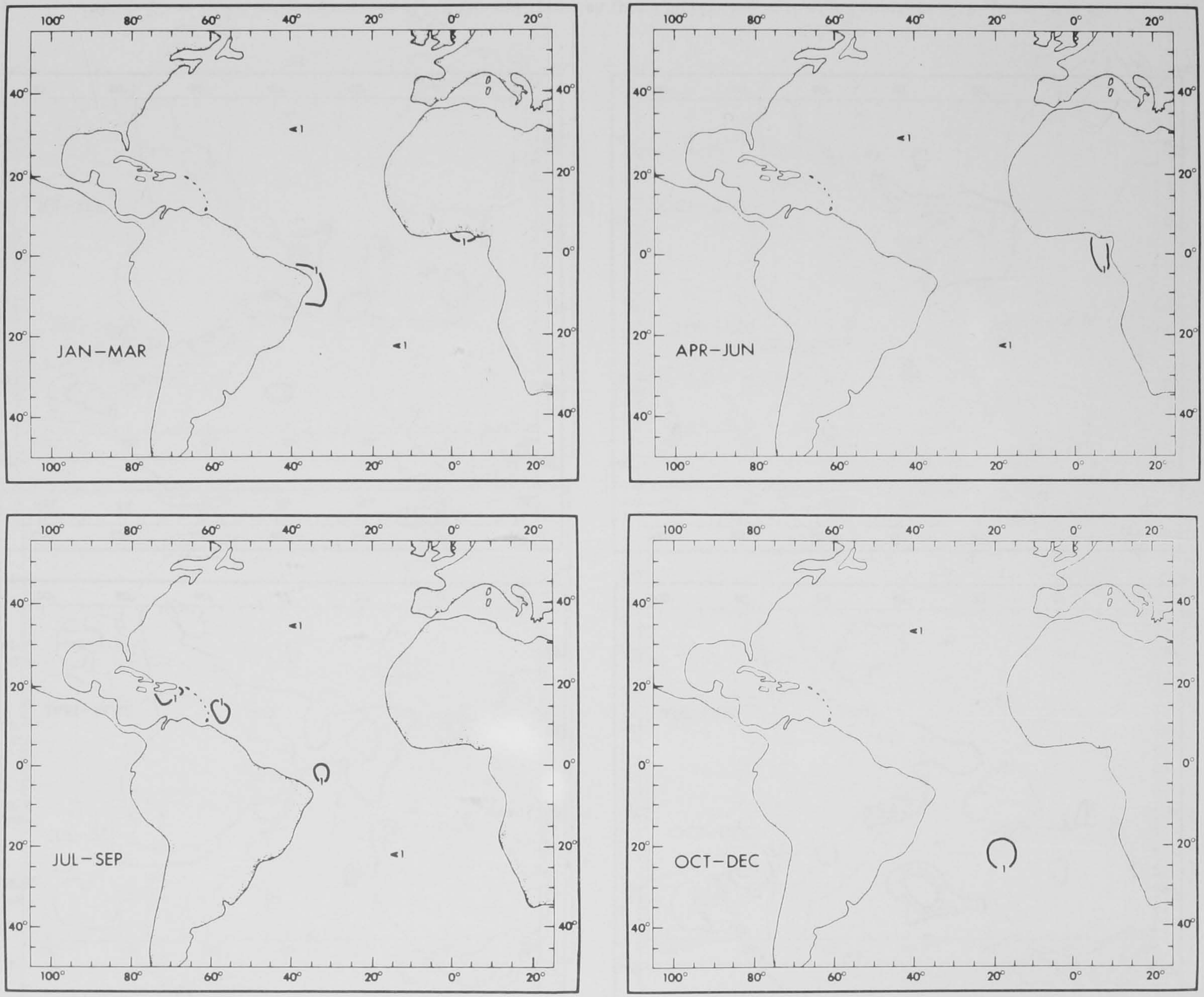

Figure 11. — Distribution of catches of black marlin (per 10,000 hooks) in the four quarters of the year, 1956-68.

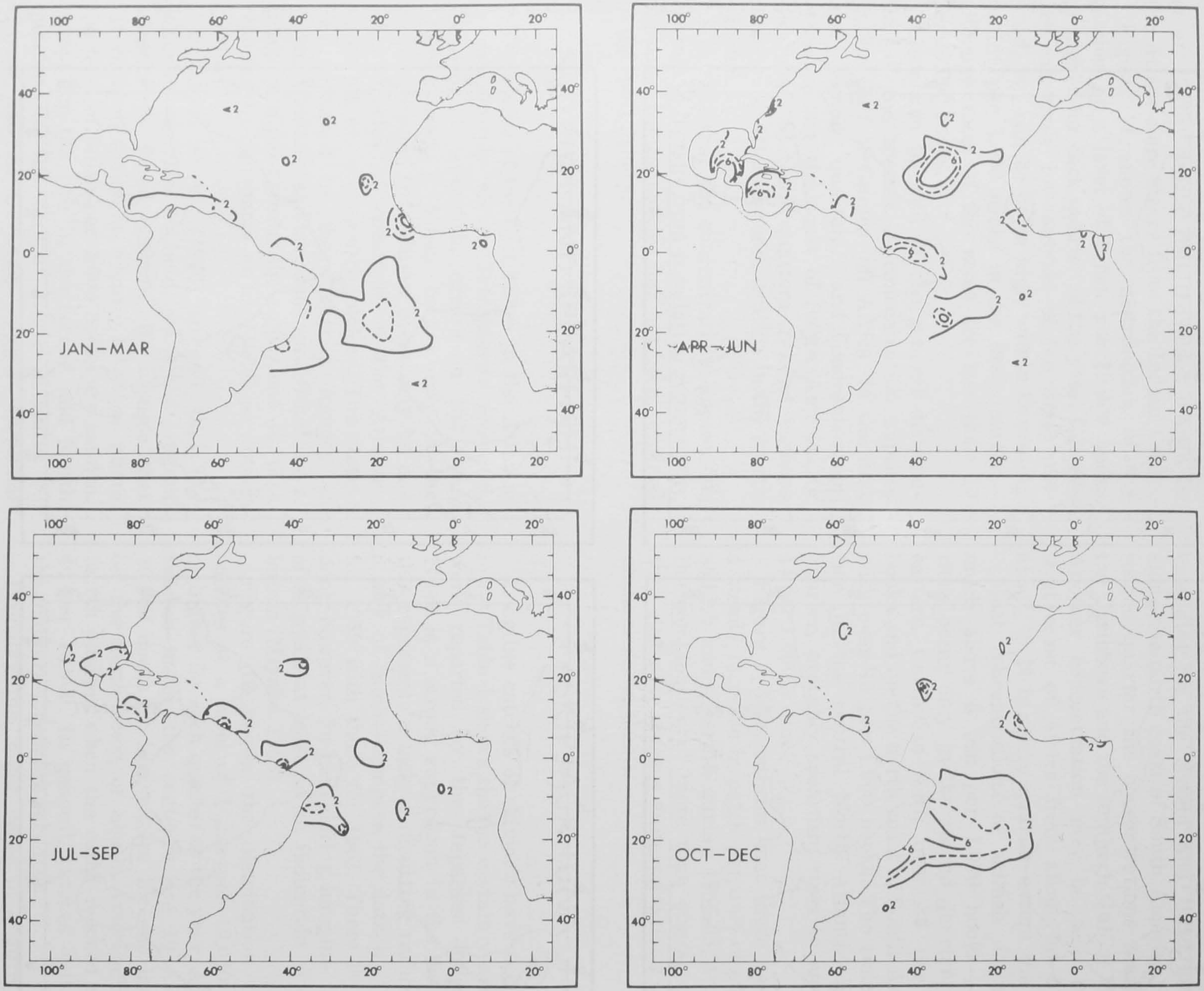

Figure 12. — Distribution of catches of sailfish and spearfish (per 1,000 hooks) in the four quarters of the year, 1956-68.

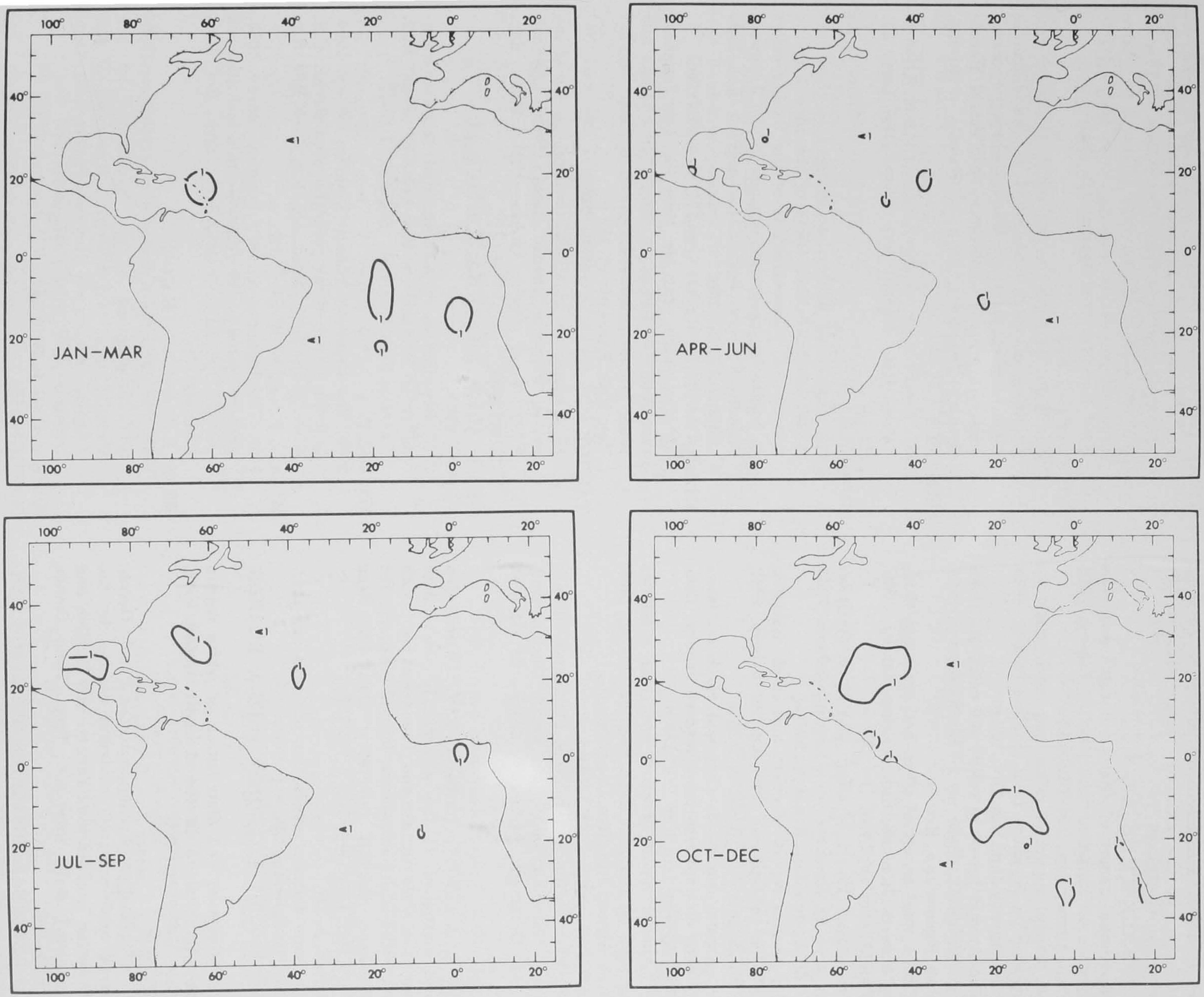

Figure 13. — Distribution of catches of skipjack tuna (per 10,000 hooks) in the four quarters of the year, 1956-68.

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639. A hydrographic survey of the Galveston Bay system, Texas 1963-66. By E. J. Pullen, W. L. Trent, and G. B. Adams. October 1971, v + 13 pp., 15 figs., 12 tables. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price 30 cents.

640. Annotated bibliography on the fishing industry and biology of the blue crab, *Callinectes sapidus*. By Marlin E. Tagatz and Ann Bowman Hall. August 1971, 94 pp. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price $1.00.

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