DISTRIBUTION OF TUNA LARVAE (PISCES, SCOMBRIDAE) IN THE NORTHWESTERN GULF OF GUINEA AND OFF SIERRA LEONE[1]

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ABSTRACT

Investigations of tuna larvae distributions in the northwestern Gulf of Guinea and off Sierra Leone were made during February-April 1964, August-October 1964, and February-April 1965. Larvae of the yellowfin tuna, bigeye tuna, skipjack tuna, little tunny, and frigate mackerels were collected and studied. Analyses of the data indicated that larvae of yellowfin tuna and bigeye tuna migrate to the surface during the day, skipjack tuna migrate to the surface during the night, and frigate mackerels do not seem to migrate at any time. Our data for little tunny were inconclusive. All species were widely distributed over the area but larvae of the commercially important tunas—yellowfin, bigeye, and skipjack—were restricted to waters where surface temperatures were higher than 24° C.

The distribution of tunas varies seasonally in the eastern Atlantic Ocean (Richards, 1969). In 1964 and 1965, the Bureau of Commercial Fisheries research vessel *Geronimo* (cruises 3, 4, and 5) collected tuna larvae in the northwestern Gulf of Guinea and off Sierra Leone. These collections were part of extensive investigations intended to relate the spatial and temporal distributions of tunas to the environment. Cruise 3 was in the northwestern Gulf of Guinea between 10 February and 26 April 1964, which is within the winter-spring "warm season" in the Gulf of Guinea, when sea-surface temperatures are higher than during summer and fall. Cruise 4 was in the northwestern Gulf of Guinea between 5 August and 13 October 1964, which is within the summer-fall "cool season" in the Gulf of Guinea, when sea-surface temperatures are lower than during winter and spring. During cruise 5, collections were made in two areas: the northwestern Gulf of Guinea and off Sierra Leone. The northwestern Gulf of Guinea area was generally the same as that covered in cruises 3 and 4 and collections were made from 14 March to 19 April 1965 within the winter-spring "warm season." The area off Sierra Leone, which is immediately northwest of the areas covered in cruises 3, 4, and part of 5, was studied from 10 February to 2 March 1965 (see Figure 1).

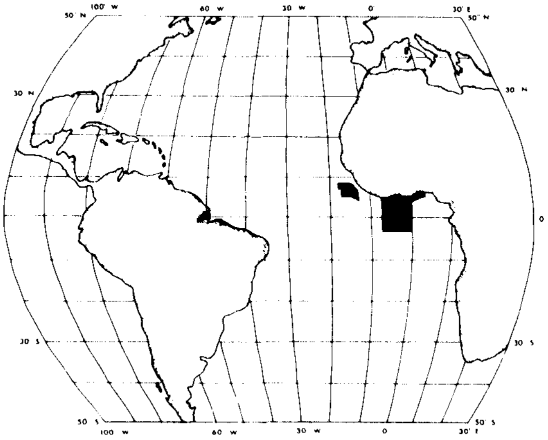

FIGURE 1.—Reference map for the areas studied. The shaded area east of long 10° W was surveyed on *Geronimo* cruises 3, 4, and part of 5; the shaded area west of long 10° W was surveyed on part of cruise 5.

The purposes of this study are to (1) analyze the time the collections were made, (2) describe the distribution of the tuna larvae, and (3) discuss the relations of the tuna larvae to oceanographic features. In addition to the collecting of larvae on each cruise, sightings of surface

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Manuscript accepted February 1971.

schools of tuna were recorded and several oceanographic features—temperature, salinity, and dissolved oxygen—were measured. The distributions of these oceanographic features were published in a series of atlases (Goulet and Ingham, 1968; Ingham, Goulet, and Brucks, 1968; Brucks, Ingham, and Leming, 1968a, 1968b).

The northwestern Gulf of Guinea is affected by the general meteorological and oceanic conditions of the Gulf of Guinea and by some unique local features. Ingham (1970) concluded that two types of upwelling occur in this region—a seasonal wind-driven upwelling (July through October) and a current-induced upwelling that is present most of the time. The mixed surface layer is rather thin in the coastal area (less than 10 m near the coast, grading to 30 to 40 m offshore) and is influenced by current-induced upwelling, wind-driven upwelling, and advection. Ingham (1970) reported that during the period of *Geronimo* cruises 3, 4, and 5, advection was the most effective of the three factors.

The species collected were the yellowfin tuna, *Thunnus albacares* (Bonnaterre); the bigeye tuna, *Thunnus obesus* Lowe; the bluefin tuna, *Thunnus thynnus* (Linnaeus); the skipjack tuna, *Katsuwonus pelamis* (Linnaeus); the little tunny, *Euthynnus alletteratus* (Rafinesque); and the frigate mackerel, *Auxis* sp. Larvae of the albacore, *Thunnus alalunga* (Bonnaterre) were not collected. Numbers of larvae, their location, and the methods used to collect, sort, identify, and compute the numbers of larvae have been treated by Richards et al. (1969a, 1969b, 1970) for each cruise. Larvae were collected by an ICITA (International Cooperative Investigations of the Tropical Atlantic) 1-m plankton net, towed at the surface.

ANALYSIS OF COLLECTION TIME

The relative apparent abundance of some fish larvae is complicated by diel variations. Oblique plankton collections that sample the entire vertical distribution of a species tend to catch fewer fish larvae during the day (Ahlstrom, 1959), presumably a result of increased net avoidance. In surface collections, such as those taken during *Geronimo* 3, 4, and 5, diel vertical migrations also could be an important factor in abundance variations.

We used the Mann-Whitney U test (Siegel, 1956) to determine the probability of equal catches of tuna larvae in day and night surface tows. A ranked test such as this should minimize the effects of patchiness. Tows with local apparent midtimes from 0600 through 1759 hr were designated as day tows and those with local apparent midtimes from 1800 through 0559 hr as night tows. Included in our calculations were all successful tows (those that captured tuna larvae) and unsuccessful tows (those that did not capture tuna larvae), except those unsuccessful tows outside the temperature-salinity ranges of the species (Table 1). These temperature-salinity ranges are a composite from Richards (1969) and the present study and should not be considered absolute. The unsuccessful tows were included because of the implication that larvae were not captured for some reason other than intolerance to temperature or salinity. In calculating the statistics, a correction for the tied (equally ranked) unsuccessful tows was used (Siegel, 1956).

TABLE 1.—Temperature-salinity ranges for larvae of yellowfin tuna, bigeye tuna, skipjack tuna, little tunny, and *Auxis* sp. These data are a composite from Richards (1969) and the present study.

Species	Temperature range	Salinity range
	° C	‰
Yellowfin tuna	23.6-29.7	33.5-36.8
Bigeye tuna	23.6-30.5	31.8-36.4
Skipjack tuna	23.4-29.7	31.4-36.9
Little tunny	22.7-29.3	32.7-35.4
Auxis sp.	21.6-30.5	33.2-35.9

The resulting probabilities (Table 2) indicate that yellowfin and bigeye tunas were collected more often at the surface during the day, and skipjack tuna and little tunny more often at the surface at night. No difference was apparent between day and night tows for *Auxis*.

Also analyzed was whether tuna larvae were better able to dodge the plankton net during the day than at night. The question was considered because we naturally assumed that tuna larvae should be able to see a plankton net more clearly during the day and therefore avoid it more

TABLE 2.—Probabilities of equal catches of larvae in day and night plankton tows.

Species	Number of day tows	Number of night tows	Total number of standardized larvae per number of successful tows		Probability of equal catches
			Day	Night	
Yellowfin tuna	263	194	1701.7/113	645.8/57	<0.01
Bigeye tuna	265	197	409.6/68	186.4/32	=0.02
Skipjack tuna	267	206	33.3/12	364.7/38	<0.01
Little tunny	274	209	303.5/28	362.2/36	=0.03
Auxis sp.	280	218	3637.8/128	2812.3/93	=0.99

easily. We also reasoned that large larvae, being better swimmers than smaller larvae, should have been captured less frequently in day collections than in night collections. Thus, if net avoidance was demonstrable, the lengths of larvae caught during the day should have been smaller.

Percent length frequencies of each species of larvae collected in the day and night were plotted from the following data: Yellowfin tuna, 1,009 day-caught larvae, 340 night-caught larvae (Figure 2); bigeye tuna, 271 day, 84 night (Figure 3); skipjack tuna, 22 day, 197 night (Figure 4); little tunny, 134 day, 72 night (Figure 5); and *Auxis*, 1,636 day, 1,082 night (Figure 6).

The length frequencies of night-caught larvae tended to be skewed more toward the larger sizes than did the day-caught larvae. The bimodal frequency of skipjack tuna captured during the day could have been due to the small sample size. The Mann-Whitney U test (Siegel, 1956) was applied to the frequencies to determine if night-caught larvae were significantly larger than day-caught larvae. Probabilities of less than 0.01 that larvae were the same length were found for yellowfin tuna, little tunny, and *Auxis*; bigeye and skipjack tunas had probabilities of 0.06 and 0.22, respectively. It should be noted also that the largest larvae of every species but bigeye tuna were captured at night. We tentatively conclude that there was greater net avoidance during the day for yellowfin tuna, little tunny, and *Auxis*, but little net avoidance for bigeye and skipjack tunas.

A differential vertical migration on the basis of size also should be considered as a possible explanation for the capture of larger larvae at night. Certain evidence causes us to reject this possibility, however. Ueyanagi (1969) found that the size composition of tuna larvae taken in night surface tows resembled the size composition of those taken during both day and night at depth. Smaller larvae were more numerous in catches made at the surface during the day. The implication is that net avoidance of larger larvae is greater at the surface during the day, and there is no indication of a vertical migration of the two size groups in opposition to one another.

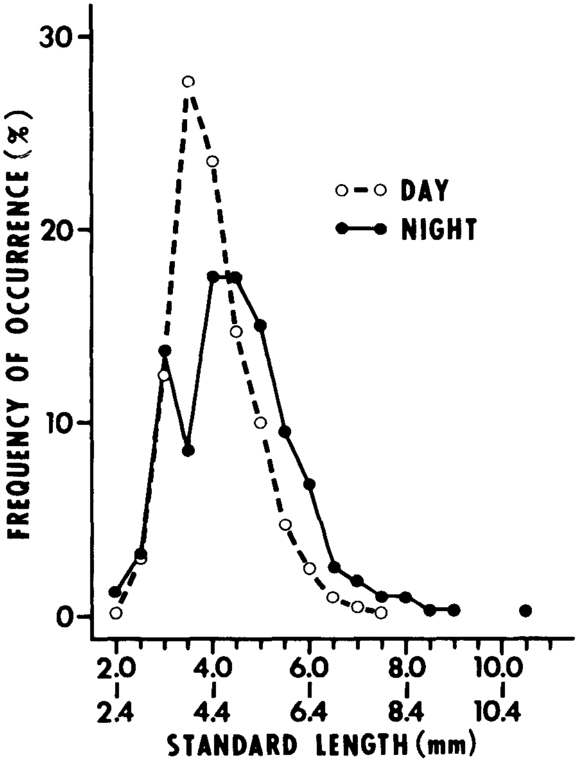

FIGURE 2.—Percent length frequencies of yellowfin tuna larvae captured during the day (broken line, 1,009 specimens) and night (solid line, 340 specimens).

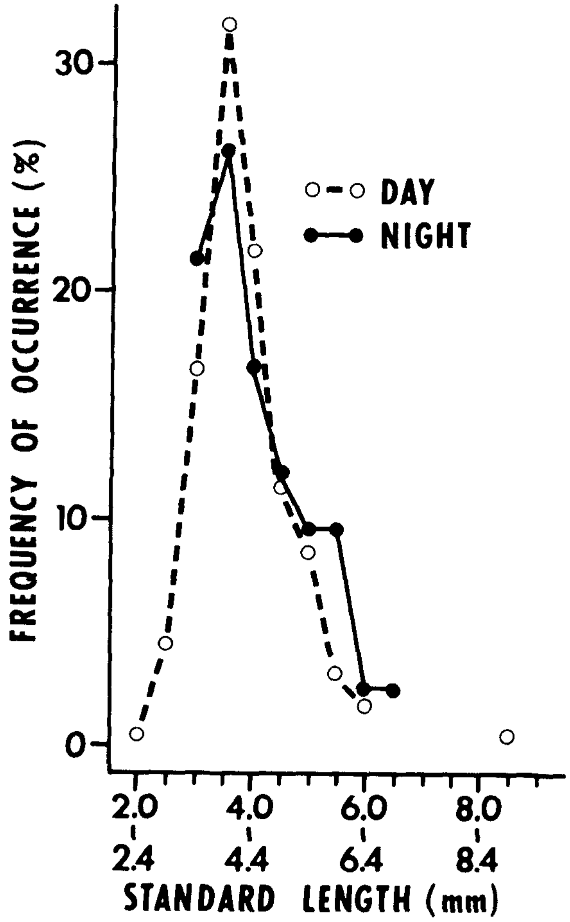

FIGURE 3.—Percent length frequencies of bigeye tuna larvae captured during the day (broken line, 271 specimens) and night (solid line, 84 specimens).

Analyses of our data show that yellowfin tuna larvae were more successfully captured in day tows than at night, even though greater net avoidance during the day was indicated. Had net avoidance been the major factor in day-night differences in abundance, more larvae should have been captured at night. Apparently —since the opposite is indicated—yellowfin tuna larvae migrate to the surface in the day and net avoidance is of minor importance, in terms of numbers collected. Ueyanagi (1964) suggested that istiophorid larvae behave similarly; other workers (Wade, 1951; Strasburg, 1960; Klawe, 1963; Ueyanagi, 1969) found no decisive evidence to show that yellowfin tuna larvae perform a vertical diel migration to the surface.

Our study indicated that bigeye tuna larvae —like those of yellowfin tuna—migrate vertically to the surface in the day, but the probabilities were not as significant ($P = 0.02$ compared with $P < 0.01$ for yellowfin tuna). Net avoidance was negligible for bigeye tuna larvae. Ueyanagi (1969) reported a greater larval ocurrence of bigeye tuna at the surface during the day than at night.

Our evidence showed that skipjack tuna larvae migrate vertically to the surface at night and that net avoidance was apparently negligible. A vertical migration to the surface at night also was suggested by Wade (1951) and Strasburg (1960). Ueyanagi (1969) reported a scarcity at the surface during the day, but increased abundance at night.

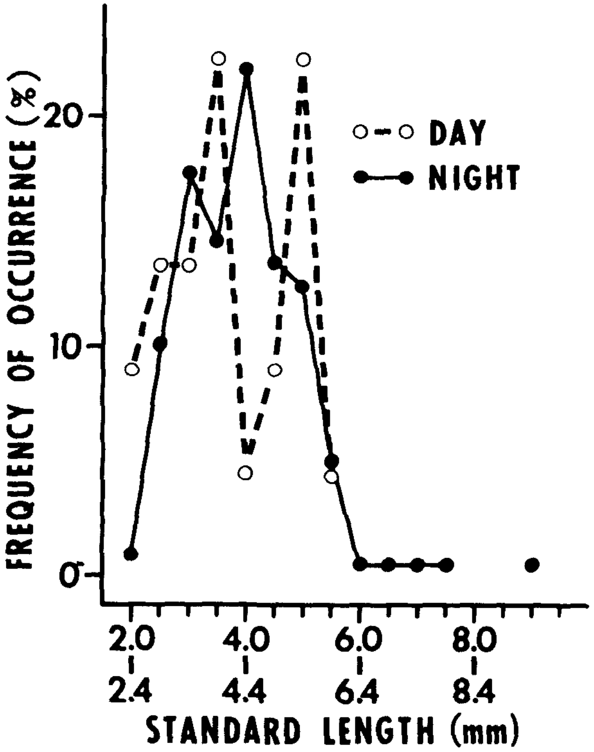

FIGURE 4.—Percent length frequencies of skipjack tuna larvae captured during the day (broken line, 22 specimens) and night (solid line, 197 specimens).

Our night tows caught little tunny larvae more successfully than day tows, but differences were not as pronounced as they were for skipjack tuna larvae ($P = 0.03$ compared with $P < 0.01$ for skipjack tuna larvae). Since a greater ability to dodge the net during the day was indicated, day-night differences could have been caused by migration to the surface at night, net avoidance, or a combination of both. Among larvae of yellowfin tuna, bigeye tuna, skipjack tuna, and *Auxis*, net avoidance was negligible or ineffective in detecting day-night differences in abundance. The higher frequency of night captures of little tunny larvae, therefore, was probably caused primarily by vertical migration to the surface at night. Vertical migration to the surface at night also was suggested for the closely related *Euthynnus yaito* (=*E. affinis*) by Wade (1951).

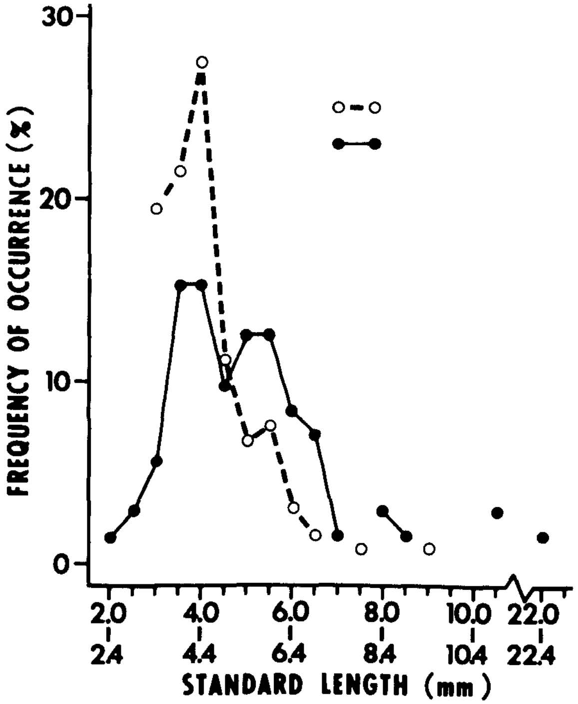

FIGURE 5.—Percent length frequencies little tunny larvae captured during the day (broken line, 134 specimens) and night (solid line, 72 specimens).

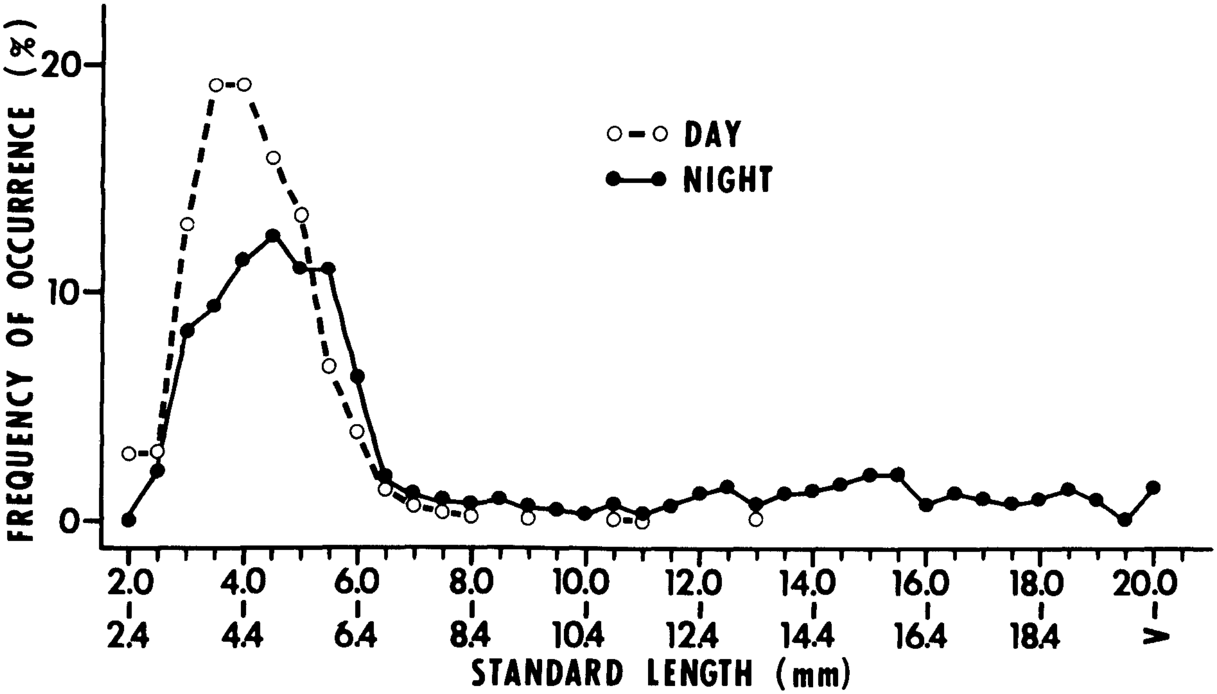

FIGURE 6.—Percent length frequencies of *Auxis* larvae captured during the day (broken line, 1,636 specimens) and night (solid line, 1,082 specimens).

Auxis larvae were equally abundant in day and night tows, indicating that this species does not migrate to the surface. The indication of net avoidance during the day had no detectable effect on apparent abundance, but if *Auxis* larvae were more abundant at the surface during the day and net avoidance had a significant effect on abundance, the same results could be obtained. Larval *Auxis* were almost equally abundant at the surface in day and night collections according to Wade (1951). Strasburg (1960) captured more *Auxis* larvae in 0 to 60 m tows at night and stated that Matsumoto (1958) also captured more specimens in night surface tows. Klawe (1963) reported greater success in catching *Auxis* larvae at night in surface and 300-m oblique tows but not in 140-m oblique tows; he suggested that net avoidance may be primarily responsible for decreased day catches. In a more recent study, Klawe, Pella, and Leet (1970) concluded that *Auxis* larvae did not exhibit a diel vertical movement; they also found no indication of net avoidance.

DISTRIBUTION OF LARVAE

Because all our collections were made by surface tows, it was not possible to directly compare our totals with the number of larvae collected during the Equalant surveys (Richards, 1967, 1969). The two multiship Equalant surveys covered most of the tropical Atlantic Ocean. Equalant I took place at the same time of year as *Geronimo* cruises 3 and 5 ("warm season"), Equalant II corresponded to the time of *Geronimo* cruise 4 ("cool season"). The average number of tuna larvae collected per 1,000 m^3 of water strained on each *Geronimo* cruise herein discussed and the average under 1 are (100 m^2) of sea surface for Equalant I and Equalant II (Richards, 1969) are shown in Table 3. The average numbers of larvae collected on the *Geronimo* cruises were corrected for diel variations in abundance. This was computed by the following formula:

$$\frac{a/b + a'/b'}{2}$$

where a = total number of standardized day-caught larvae
a' = total number of standardized night-caught larvae
b = total number of day tows
b' = total number of night tows.

The correction was applied to all species except *Auxis* because that species was equally abundant in day and night collections. The averages for *Auxis* were obtained by dividing the total number of standardized larvae by the total number of tows. The Equalant averages were not corrected for diel variations in abundance because most of the collections were oblique and sampled the entire vertical range of all tuna larvae. Calculations for the average number of larvae collected were similar to those used for *Auxis* but were expressed as the number under 1 are of sea surface. In the following separate accounts we report on our detailed findings concerning each species of larval tuna.

TABLE 3.—The average number of tuna larvae collected on *Geronimo* cruises 3, 4, and 5 and the two Equalant surveys.

Species	*Geronimo* cruise				Equalant survey	
	3	4	[1]5	[2]5	I	II
	Number per 1000 m^3				*Number under 1 are*	
Yellowfin tuna	11.4	5.2	1.1	1.0	7.82	5.05
Bigeye tuna	2.9	0.9	0.4	0.6	3.00	1.24
Skipjack tuna	2.3	0.3	0.1	0.2	13.71	7.85
Little tunny	3.5	0.8	0.4	0.4	--	--
Auxis sp.	12.6	9.9	6.5	18.8	--	--

[1] 14 March to 19 April 1965 in northwestern Gulf of Guinea.
[2] 10 February to 2 March 1965 off Sierra Leone.

YELLOWFIN TUNA LARVAE

The distribution of yellowfin tuna larvae in the northwestern Gulf of Guinea is shown in Figure 7. During *Geronimo* cruise 3, yellowfin tuna larvae were common throughout most of the area, averaging 11.4 larvae per 1000 m^3 of water strained. During cruise 5 (in the Gulf of Guinea a year later), a smaller area was sampled and an average of 1.1 larvae was collected per 1000 m^3 of water strained. During Equalant I, no larvae were found north of about lat 2° N in the same area, in contrast to the distribution found during *Geronimo* cruise 3. We presume

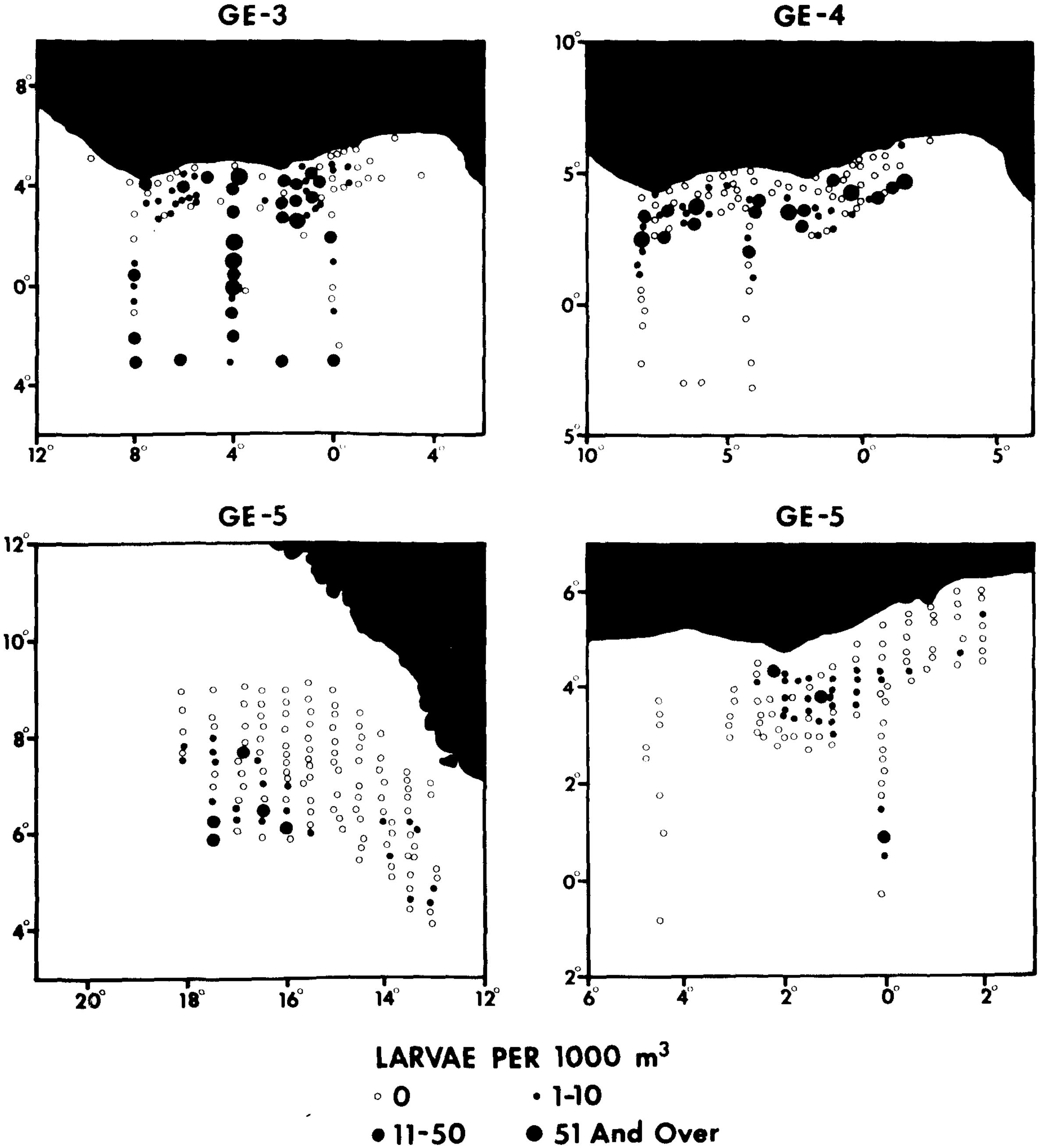

FIGURE 7.—The distribution of yellowfin tuna larvae in the northwestern Gulf of Guinea based on collections during *Geronimo* cruises 3 (10 February to 26 April 1964), 4 (5 August to 13 October 1964), 5 (14 March to 19 April 1965), and cruise 5 off Sierra Leone (10 February to 2 March 1965).

that the difference was because of increased sampling intensity on *Geronimo* cruise 3. Widespread spawning was seen near the equator, however, on both Equalant I and *Geronimo* cruise 3. An indication of this equatorial spawning is evident in cruise 5 (Figure 7). During *Geronimo* cruise 4, the distribution of larvae was reduced from that seen on cruise 3, averaging 5.2 larvae per 1000 m^3 of water strained. Again the situation differed from that found in Equalant II during which almost no larvae were taken, probably because of light sampling.

Richards (1969) found no yellowfin tuna larvae in waters with temperatures lower than 26° C, and indicated that the presence of yellowfin tuna larvae may depend on water temperature. During the *Geronimo* cruises, with one exception, yellowfin tuna larvae were collected in waters warmer than 24° C. Hence, the lower limit of 26° C for surface temperature set for the presence of yellowfin tuna larvae by Richards (1969) should be lowered to 24° C. Surface water temperatures were above 27° C at all stations sampled during cruise 3, and yellowfin tuna larvae were found between 27.9° and 29.7° C. During cruise 5 (also the "warm season"), surface temperatures ranged from 22.5° to 29.9° C but yellowfin tuna larvae were found within a range of 24.9° to 29.5° C. During cruise 4 (the "cool season"), surface temperatures ranged from 19.3° to 25.5° C; yellowfin tuna larvae were found only in water with temperatures higher than 24° C except at one station with a temperature of 23.6° C. During cruises 3, 4, and 5, surface salinity values ranged from 33‰ to 36‰. The yellowfin tuna larvae were rarely encountered when salinity fell below 34‰ but were common between 34‰ and 36‰.

In the area off Sierra Leone, yellowfin tuna larvae were encountered in water temperatures higher than 25° C (Figure 7), the area south of the 25° C isotherm. That area was not covered during the "cool season" by *Geronimo* cruises but did receive minor coverage on Equalants I and II, which resulted in the collection of some tuna larvae, particularly on Equalant II. Water temperatures were 26° C or higher at the Equalant stations where collections were made. Conand (1970) found yellowfin tuna larvae in waters warmer than 27° C off Senegal.

The Gulf of Guinea and contiguous waters account for much of the Atlantic tuna catch. Beardsley's (1969) discussion of the relation of oceanographic features to adult yellowfin tuna distributions in that area is of interest to the present study. In his summary charts of adult yellowfin tuna distributions, some catch rates are high in areas of cool water where the larvae do not occur, which indicates that an abundance of adults may not indicate abundance of larvae. Surface fishing was carried out by the *Geronimo* during cruises 3, 4, and 5 and it was interesting to note that there was no apparent relation between sightings of surface schools and location of larvae.

BIGEYE TUNA LARVAE

The distribution of bigeye tuna larvae in the northwestern Gulf of Guinea approximated that of yellowfin tuna larvae (Figure 8), but the average number per 1000 m^3 of water strained was less than for yellowfin tuna larvae. (A similar pattern was noticed on the Equalant surveys). Off Sierra Leone, the species was collected as often as yellowfin tuna (29 bigeye tuna stations compared with 28 yellowfin tuna stations), but the average number of bigeye tuna larvae collected was less than that of the yellowfin tuna. Larvae of bigeye tuna—like the yellowfin tuna larvae—were collected offshore, south of the 25° C isotherm. The apparent abundance of bigeye tuna larvae, compared with yellowfin tuna larvae, closely resembles that of the adults, as shown in the Japanese Atlantic longline data (Wise[3]). During the Equalant surveys, 3.0 times more yellowfin tuna larvae than bigeye tuna larvae were captured. In 1963 (the year of Equalants I and II) 3.4 times more yellowfin tuna adults than bigeye tuna adults were captured by Japanese longliners in the same general area (Wise, see footnote 3). During the *Geronimo* surveys 3.9 times more yellowfin tuna larvae than bigeye tuna larvae were captured. In 1964 (the

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[3] Wise, J. P. 1969. Some basic statistics of the Atlantic tuna fisheries. B.C.F. Tropical Atlantic Biological Laboratory, [Miami, Fla.,] Data Summary No. 8, 14 p. [Processed.]

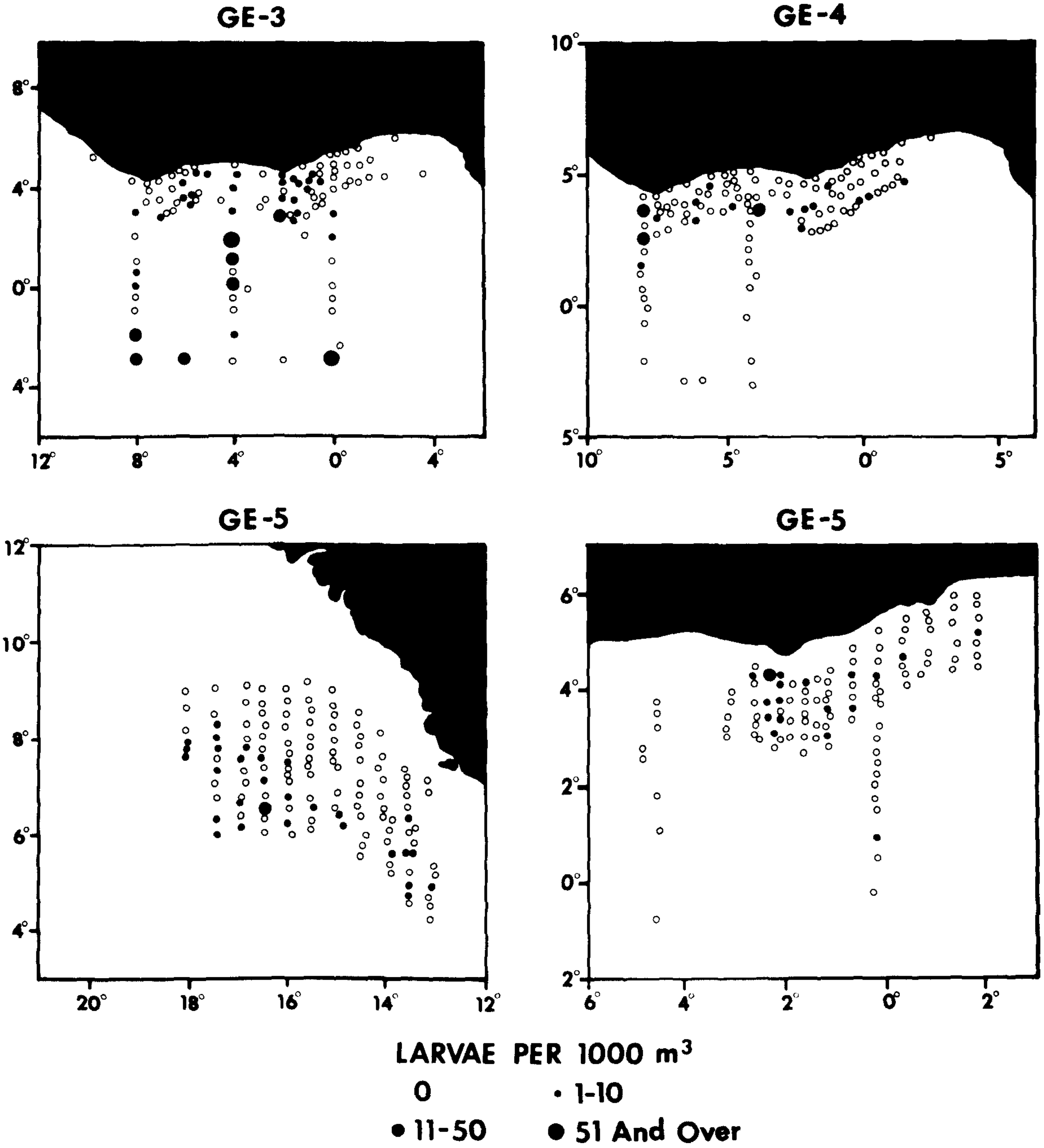

FIGURE 8.—The distribution of bigeye tuna larvae in the northwestern Gulf of Guinea based on collections during *Geronimo* cruises 3 (10 February to 26 April 1964), 4 (5 August to 13 October 1964), 5 (14 March to 19 April 1965), and cruise 5 off Sierra Leone (10 February to 2 March 1965).

predominant year of the *Geronimo* surveys), 3.7 times more adult yellowfin tuna than adult bigeye tuna were captured by Japanese longliners in the same general area (Wise, see footnote 3).

SKIPJACK TUNA LARVAE

Richards (1969) found that distributions of skipjack tuna larvae differed from those of yellowfin and bigeye tunas, particularly when surface temperature values were below 26° C. Apparently skipjack tuna larvae are able to tolerate lower temperatures than the other two tunas. In the area covered by *Geronimo* cruise 3, distributions of larval skipjack tuna (Figure 9) were similar to those of yellowfin tuna larvae, but fewer were caught. The lesser quantities may have resulted from the sampling method used; surface collections may not adequately sample the species.

On *Geronimo* cruise 3, skipjack tuna larvae were collected in water temperatures that ranged from 27.6° to 29.7° C and salinities from 34.4‰ to 35.5‰. On *Geronimo* cruise 4 (Figure 9) the species was infrequently collected, although larvae had been commonly collected in the same region on Equalant II. Skipjack tuna larvae were found in the warmer water (24.4°-25.8° C) on *Geronimo* cruise 4, which was also true of Equalant II (see Richards, 1969: 298). On *Geronimo* cruise 5 (Figure 9) larval skipjack tunas were taken at only four stations, presumably an artifact of the sampling method. Off Sierra Leone, these larvae were found at only seven stations, perhaps again an artifact of sampling.

LITTLE TUNNY LARVAE

Little tunny larvae were collected during the Equalant surveys but the data have not yet been evaluated. In the northwestern Gulf of Guinea and off Sierra Leone, little tunny larvae were collected during each *Geronimo* cruise (Figure 10). Unlike the other species, they were not collected on the outer transects near the equator. The distribution of the larvae of this species, as it related to temperature and salinity, was also noticeably different from that of the other tuna species. The temperatures for the larvae ranged from 22.7° to 29.3° C and the salinities from 32.7‰ to 35.4‰. Apparently little tunny larvae can tolerate a wider range of physical conditions than can the larvae of the more oceanic tunas—skipjack, yellowfin, and bigeye.

Auxis sp.

Larvae of *Auxis* (frigate mackerels) are unquestionably the most abundant scombrid larvae found in these tropical waters. This abundance holds true for the eastern Pacific (Klawe, 1963), as well as for the eastern Atlantic (Figure 11). (We are aware that *Auxis* may be two species, but as yet methods for distinguishing their larvae have not been satisfactorily developed.) In the northwestern Gulf of Guinea, *Auxis* larvae were collected mostly nearshore, though a few specimens were found offshore. *Auxis* was the only species widely distributed off Sierra Leone. One reason for its abundance may be the wide tolerance of the larvae for temperature and salinity—*Auxis* larvae were found in water with temperatures as low as 21.6° C and as high as 30.5° C, the widest temperature range found for any tuna larvae we studied. The salinity range of the species was 33.2‰ to 35.9‰.

ACKNOWLEDGMENTS

This manuscript was reviewed by Elbert H. Ahlstrom, National Marine Fisheries Service, La Jolla, Calif.; Witold L. Klawe, Inter-American Tropical Tuna Commission, La Jolla, Calif.; and Walter M. Matsumoto, National Marine Fisheries Service, Honolulu, Hawaii. We appreciate their efforts in our behalf.

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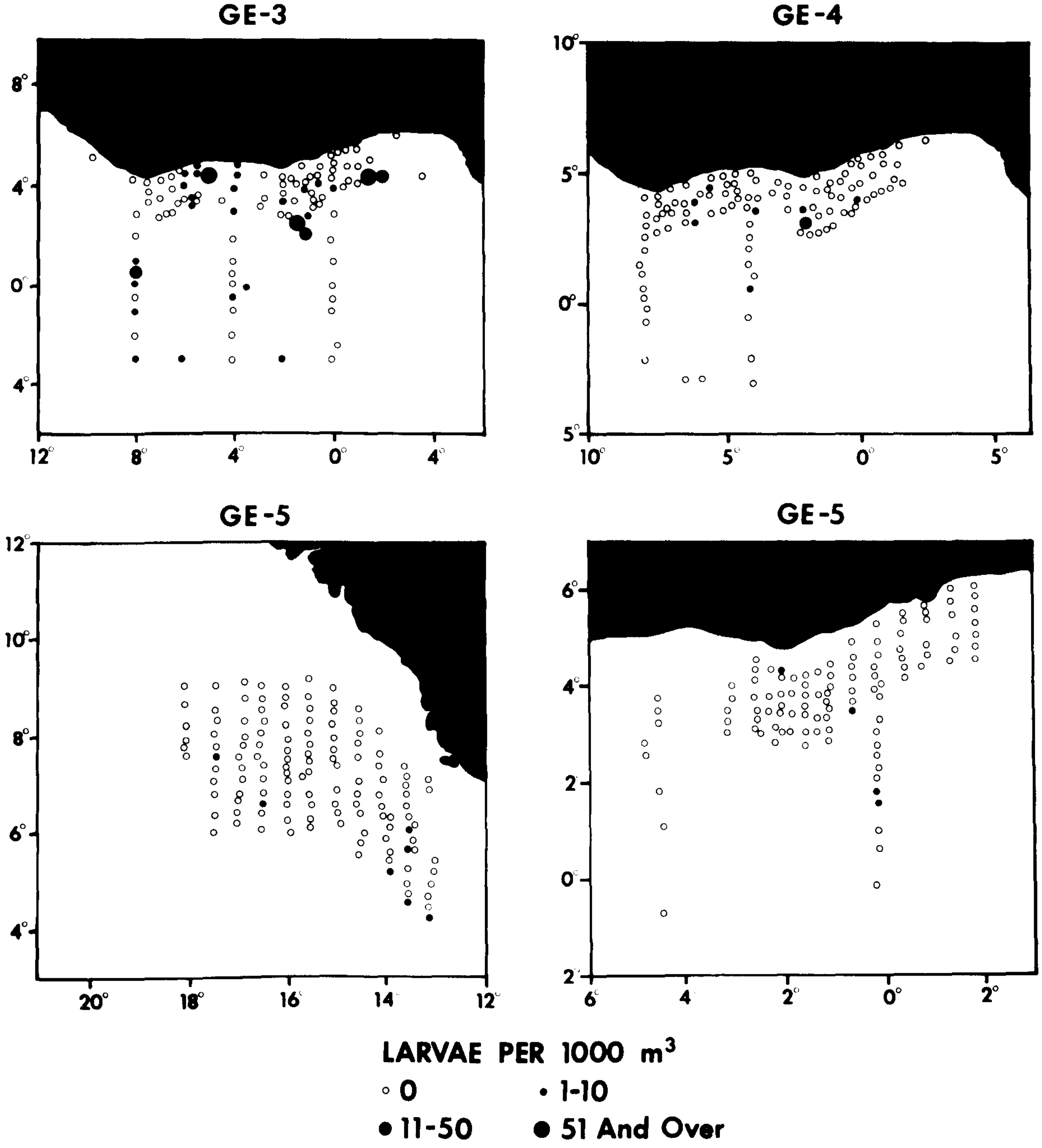

FIGURE 9.—The distribution of skipjack tuna larvae in the northwestern Gulf of Guinea based on collections during *Geronimo* cruises 3 (10 February to 26 April 1964), 4 (5 August to 13 October 1964), 5 (14 March to 19 April 1965), and cruise 5 off Sierra Leone (10 February to 2 March 1965).

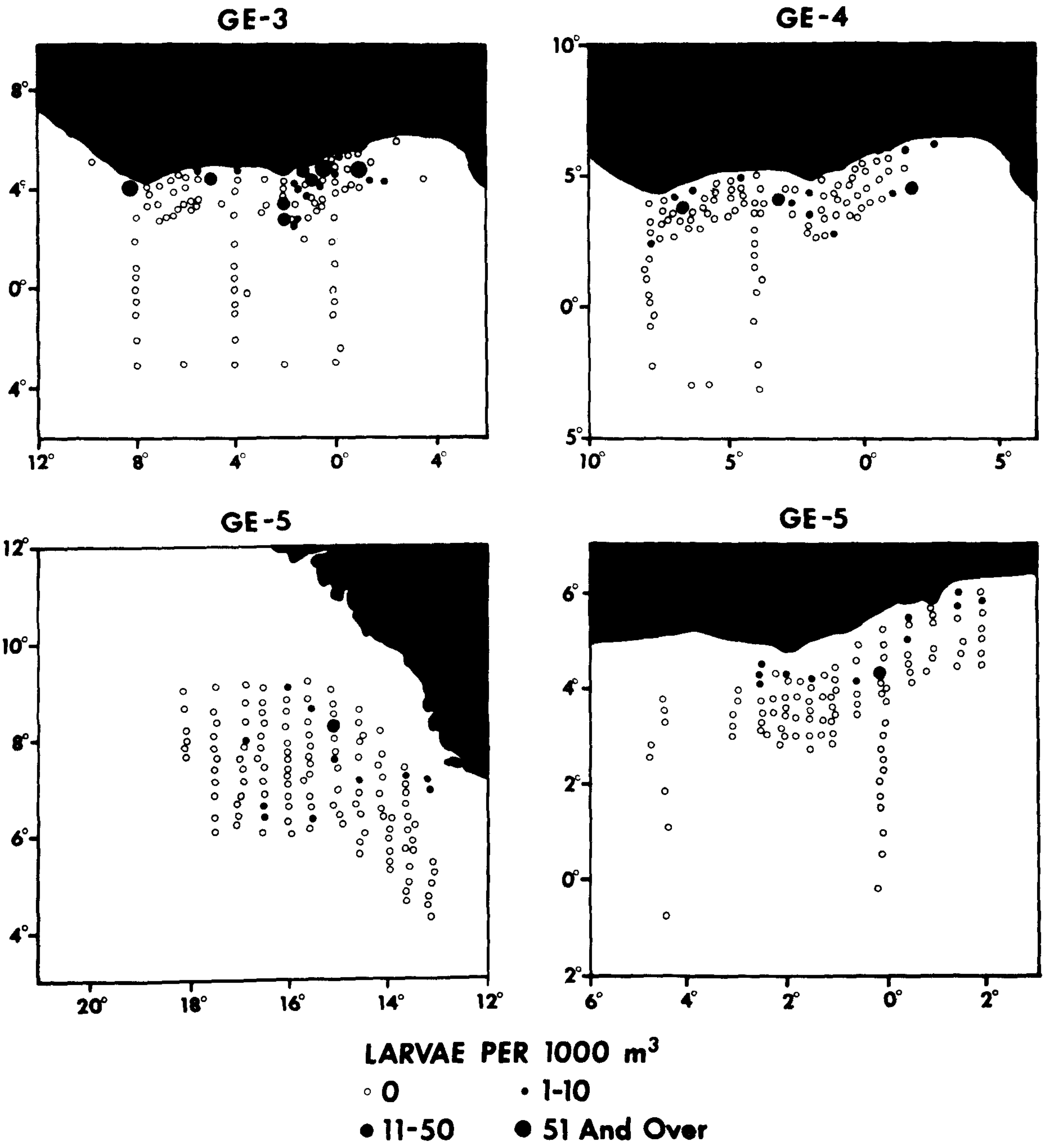

FIGURE 10.—The distribution of little tunny larvae in the northwestern Gulf of Guinea based on collections during *Geronimo* cruises 3 (10 February to 26 April 1964), 4 (5 August to 13 October 1964), 5 (14 March to 19 April 1965), and cruise 5 off Sierra Leone (10 February to 2 March 1965).

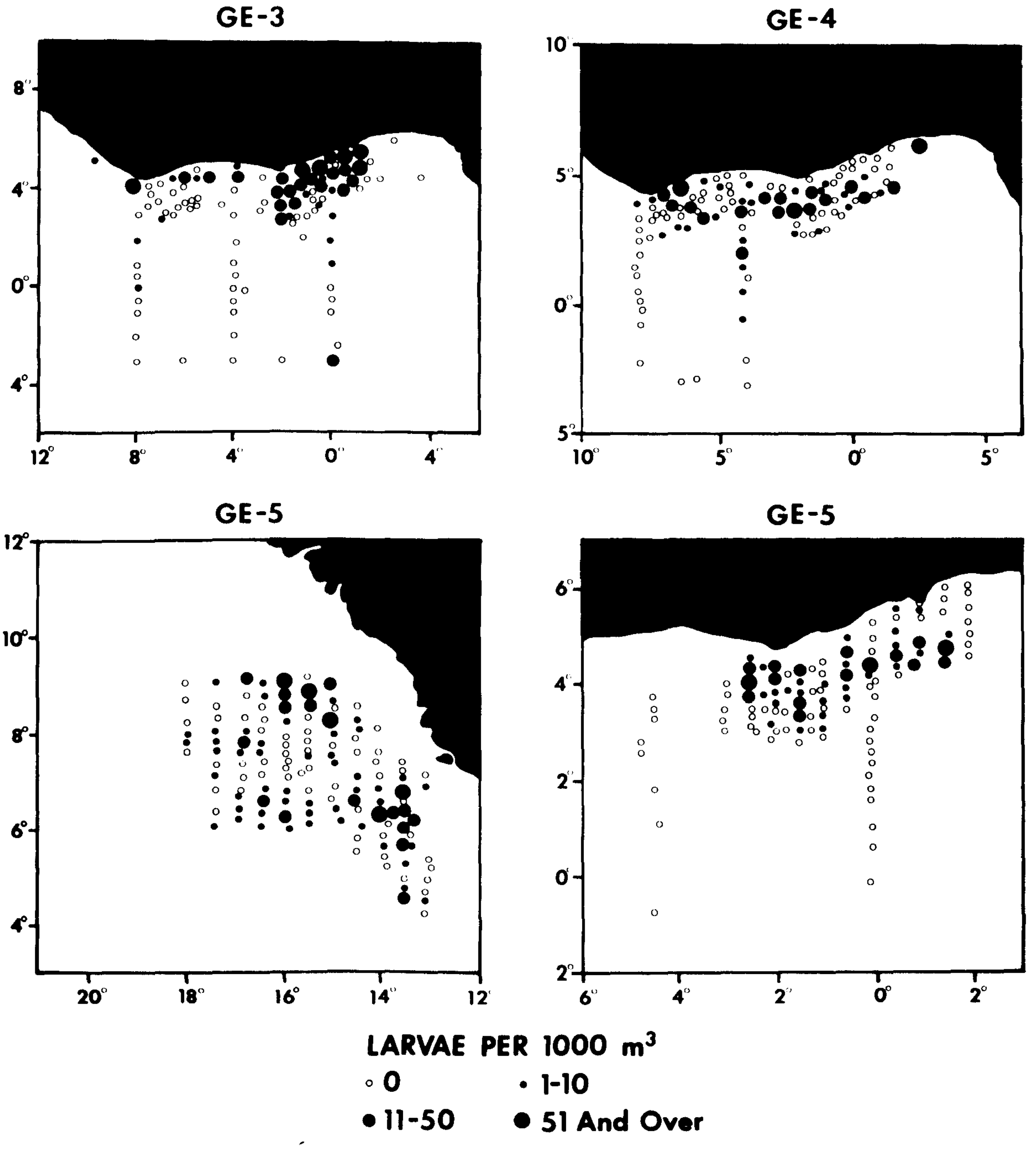

FIGURE 11.—The distribution of frigate mackerel larvae, *Auxis* sp., in the northwestern Gulf of Guinea based on collections during *Geronimo* cruises 3 (10 February to 26 April 1964), 4 (5 August to 13 October 1964), 5 (14 March to 19 April 1965), and cruise 5 off Sierra Leone (10 February to 2 March 1965).

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