

absent in *Hy. melanochir*. The fourth specimen is intermediate with a faint rostral groove.

Vertebral counts also indicate hybridization. The small *Hy. melanochir* had 60 vertebrae, at the high end of the range for nine Victorian specimens (Table 1). The two *Hy. australis* had 57 and 58 vertebrae, comparing well with 50 New South Wales specimens. The fourth specimen was intermediate with 59 vertebrae.

Based on its intermediacy in gill-raker and vertebral counts, pigmentation, upper jaw length, and otolith structure, I conclude that the fourth specimen is a hybrid between *Hy. australis* and *Hy. melanochir*. The two species are essentially allopatric and show character displacement as their ranges approach, that is, the Victoria population of *Hy. melanochir* differs more from the neighboring New South Wales population of *Hy. australis* than do populations of *Hy. melanochir* from further west, in South Australia and Western Australia (Collette, see footnote 1).

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## CONTRIBUTION ON THE SPAWNING OF *AUXIS* SP. (PISCES, SCOMBRIDAE) IN THE ATLANTIC OCEAN

The frigate mackerel (*Auxis* sp.) are apparently among the most abundant scombrids in the tropical Atlantic Ocean. They form a substantial part of the diet of skipjack tuna, *Katsuwonus pelamis*; yellowfin tuna, *Thunnus albacares* (Dragovich, 1970a); and bluefin tuna, *T. thynnus* (Dragovich, 1970b); and, therefore, it is important to understand their life history and their role in the trophodynamics of tropical ocean ecosystems. We report on the examination of ovaries from 76 frigate mackerel collected from the eastern and western tropical Atlantic, and off Cape Hatteras, N.C. (Figure 1).

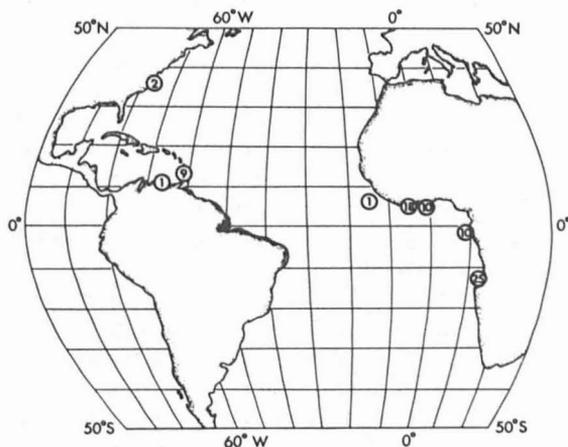


FIGURE 1.—Location and number of *Auxis* sp. captured (in circle) from which ovaries were examined.

The genus *Auxis* may be composed of two species, *A. thazard* (Lacépède) and *A. rochei* (Risso). We were not able to assign the specimens in our study to either species because the published diagnostic characters were not reliable for species identification. More taxonomic work is needed on the genus (William J. Richards, Southeast Fisheries Center, Miami Laboratory,

<sup>1</sup> Contribution No. 222, Southeast Fisheries Center, Miami Laboratory, National Marine Fisheries Service.

National Marine Fisheries Service, pers. comm.).

The ovaries were removed from specimens that had been fixed in 10% Formalin<sup>2</sup> and stored in 40% isopropanol. A wedge-shaped sample was taken from each ovary and about 200 eggs, 0.25 mm (one micrometer unit) in diameter or greater, were measured, following the method described by Clark (1925). The eggs were selected along an edge of the sample corresponding to the radius of the ovary. We determined that eggs below 0.25 mm formed most of the egg-stock present in all mature females throughout the year. In some ovaries, eggs about 0.25 mm in diameter appeared to be in the early stages of yolk accumulation because they were more opaque than the stock eggs. Each ovary was classified according to the following stages:

Stage 1. This stage corresponds to stage 1-S described by Schaefer and Orange (1956): "The gonads are small and ribbon-like. At this stage it is not possible to determine the sex by gross examination. Presumably these are virgin fish that have never yet reached sexual maturity."

Stage 2. The ovaries contained eggs which formed most of the egg-stock. In some ovaries the larger eggs may have been in the early stages of yolk accumulation but did not form a distinct modal group.

Stage 3. The ovaries contained one group of eggs distinctly separated from the egg-stock. Modal diameters of this group were from 0.375 to 0.675 mm.

Stage 4. The ovaries contained two groups of eggs distinctly separated from the egg-stock. Modal diameters of the group formed by the larger eggs were from 0.875 to 0.975 mm.

Selected egg diameter frequency distributions from stages 2, 3, and 4 are shown in Figure 2.

Our evidence indicates that *Auxis* from the tropical Atlantic mature at about 290 mm fork length (Table 1). Fish with ovaries in stages 2, 3, or 4 were considered mature; fish which contained stage 1 ovaries were considered immature. The smallest mature fish (stage 3) from the eastern Atlantic was 270 mm and the largest

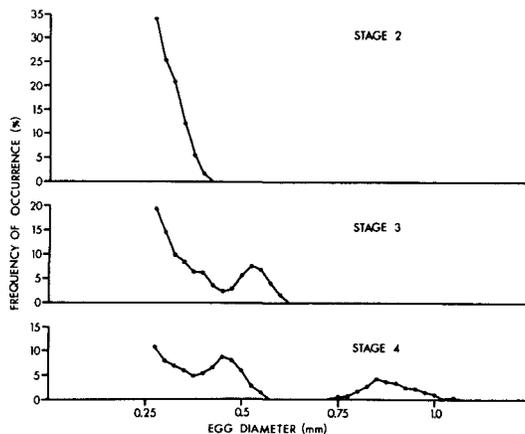


FIGURE 2.—Percent egg diameter frequency distribution from selected ovaries in stages 2, 3, and 4 (smoothed by a moving average of 3).

TABLE 1.—Number of mature and immature *Auxis* examined from the eastern and western tropical Atlantic by 10-mm length intervals.

Length interval (mm)	Eastern Atlantic		Western Atlantic	
	Immature	Mature	Immature	Mature
210-219	1	--	--	--
240-249	2	--	--	--
250-259	1	--	--	--
260-269	2	--	--	--
270-279	1	2	2	--
280-289	1	12	--	--
290-299	--	6	--	--
300-309	--	2	2	1
310-319	--	1	--	2
320-329	--	1	--	--
330-339	--	1	--	--
340-349	--	2	--	2
350-359	--	1	--	--
360-369	--	6	--	--
370-379	--	2	--	--
380-389	--	1	--	--
390-399	--	3	--	--
400-409	--	2	--	--
410-419	--	2	--	--
420-429	--	1	--	1
430-439	--	2	--	--
440-449	--	3	--	--
450-459	--	3	--	--
460-469	--	3	--	--

<sup>2</sup> Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

immature fish was 285 mm. From the western Atlantic, the smallest mature fish (stage 3) was 309 mm and the largest immature fish was 307 mm. There is an indication from the specimens we examined that the eastern Atlantic *Auxis* mature at a slightly smaller size than the western Atlantic *Auxis*. It is possible, however, that this is an artifact resulting from our sample size. Table 1 also indicates the length distribution of specimens used in our study. The two specimens captured off Cape Hatteras were 458 and 459 mm and both had stage 3 ovaries. These are not included in Table 1.

Ovaries in stages 3 and 4 were taken as evidence that spawning was imminent. *Auxis* with ovaries in a spawning condition were captured from the eastern Atlantic in February, March, April, June, September, and October, and from the western Atlantic in March and April. The two specimens from off Cape Hatteras were captured in July and August, and both contained ovaries in spawning condition. The number of *Auxis* examined in each stage of ovary development by month and area of capture is shown in Table 2.

TABLE 2.—Number of *Auxis* examined in each stage of ovary development by month and area of capture.

Area	Stage	Feb.	Mar.	Apr.	June	July	Aug.	Sept.	Oct.
Eastern Atlantic	1	--	--	--	--	--	--	--	8
	2	--	4	2	--	--	--	--	10
	3	1	12	7	2	--	--	10	2
	4	--	--	--	--	--	--	--	6
Western Atlantic	1	--	--	4	--	--	--	--	--
	2	--	--	1	--	--	--	--	--
	3	--	2	3	--	--	--	--	--
Cape Hatteras, N.C.	3	--	--	--	--	1	1	--	--

The number of eggs released per spawning is estimated for five specimens that contained stage 4 ovaries. These were captured off the Ivory Coast on 15 October 1967 at lat 4°31'N, long 5°18'W. The method used to determine the number of eggs released per spawning was to estimate the number in the most mature modal group, assuming that these eggs would be released at next spawning (Simmons, 1969).

The results show that *Auxis* from 360 to 455 mm fork length release from 56,000 to 148,000 eggs (Table 3). Rao (1964) determined

TABLE 3.—Estimated number of eggs in the most advanced mode for *Auxis* of different lengths.

Fork length (mm)	Eggs in the most advanced mode
360	95,000
361	58,000
396	56,000
440	148,000
455	103,000

that a 442-mm frigate mackerel captured off the southwest coast of India would have released 280,000 eggs at next spawning. A large variation should be expected due to the small sample size. The equation describing our regression line calculated by the method of least squares is

$$Y = -127.262 + 0.542X,$$

where  $Y$  is the number of eggs in the most advanced mode in thousands and  $X$  is the fork length of the fish in millimeters.

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