NOAA Technical Memorandum NMFS-SEFC-187

Species profile of Spanish sardine

(*Sardinella aurita*)

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August 1986

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U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Anthony J. Calio, Administrator
NATIONAL MARINE FISHERIES SERVICE
William G. Gordon, Assistant Administrator for Fisheries

I. Introduction

This report is a summary of available information on the biology, fishery, and marketing of Spanish sardines (Sardinella aurita). Emphasis is on the Gulf of Mexico with reference to other areas when particular information may have application to the Gulf of Mexico resource.

The purposes of this report are:

1. To provide a summary of the current knowledge of this species and the resource.

2. To point out the limitations of our current knowledge.

II. Taxonomy and Identification

The Spanish sardine (Sardinella aurita, Valenciennes 1847) is also called round sardinella (English), allache (French) and sardinela atlántica (Spanish). Other names of less common usage are sardina de España, false sardine, sardina, and bang. Previously used scientific synonyms of this species are: Sardinella anchovia, Clupea anchovia, Clupea pseudo-hispanicus, Clupanadon pseudohispanicus, Sardinia anchovia, and Sardinia pseudo-hispanica (Fischer 1978, Hildebrand 1963).

The adult form of this species has the typical sardine appearance (Fig. 1) with the following distinctive characteristics according to Fischer (1978), Robins and Ray (1986):

Body elongate and slender, sometimes cylindrical, but usually a little compressed; belly rounded, with scutes but without a prominent keel. Top of head with 8 to 10 longitudinal fronto-pariental striae on each side; no hypo-maxilla; hind border of gill opening with two fleshy out-growths; gill rakers fine and numerous, increasing with size of fish, anterior rakers on lower limbs of gill arches lying more or less flat. Dorsal fin a little before center point of body; pelvic fins with 9 rays, set below dorsal fin base; anal fin short and well behind dorsal (Fig. 1); last two anal fin rays enlarged, almost like a finlet. Color: back dark blue, changing rather abruptly to silver or brassy on sides; no spots or streaks; fins hyaline. Size: maximum, 29 cm; common to 25 cm.

Spanish sardines can be distinguished from other species in its range by the following characteristics:

Sardinella brasiliensis: anterior rakers on lower limbs of gill arches strongly curled when seen from above in S. brasiliensis (Fig. 2b); narrow bronzy line along upper part of side.

Opisthonema species: last dorsal fin ray filamentous in Opisthonema; also, only 8 pelvic fin rays (9 in Sardinella).

Harengula species: hypo-maxilla present (Fig. 2); also, only 8 pelvic fin rays in Harengula.

Etrumeus teres and Jenkinsia species: no scutes along belly as in Sardinella; also, 14 to 15 branchiostegal rays in Etrumeus (6 in Sardinella).

Lile piquitinga: only 8 pelvic fin rays, belly with sharp keel in L. piquitinga.

Prosvirov and Varea (1969) provided a table of morphometric features of Gulf of Mexico Spanish sardine which they classify as plastic (variable) (Table 1). Hildebrand (1963) using morphometric measurements expressed as percent of standard length from 32 fish (90 to 155 mm total length), also indicated that the morphometric characters of this species are variable (Table 2).

There may be more than one species in the Gulf of Mexico that is referred to as Spanish sardine (Klima 1971). Whitehead (1973) has provided information on several lectotypes, but not from the Gulf of Mexico. Heald and Griffiths (1967), in their paper on age determination of Spanish sardine from Venezuela, refer to two types of Sardinella anchovia from the Gulf of Cariaco. Research is needed to determine the number of species of Spanish sardine, their geographic distribution, and identifying characteristics. This review paper examines the information available on Spanish sardine as if there is only one species, Sardinella aurita.

The larval stages of Spanish sardine have been described by Fahay (1983), (Table 3 and Fig. 3). Jones et al. (1978) provided a series of larval illustrations compiled from various sources (Fig. 4).

III. Distribution

The Spanish sardine occurs throughout the Gulf of Mexico, northward to Massachusetts and southward to Rio de Janeiro, Brazil. This species is also common in the eastern Atlantic, Mediterranean Sea and the western Pacific Ocean (Fischer 1978). In the Gulf of Mexico it is found from along the shore, mainly over sandy bottom, to a depth of 40 meters in the summer, between 40 and 80 meters in spring and fall, and out to a depth of 200 meters in the winter (Fig. 5) (U.S. Dep. Commer. 1985, Houde et al. 1979).

The distribution of larval Spanish sardine for the eastern Gulf of Mexico (west coast of Florida) has been reported by Houde (1973) and Houde et al. (1979). Ichthyoplankton survey catches of 1971-74 (17 cruises) in the eastern Gulf of Mexico were dominated by the families Clupeidae and Gobiidae in water less than 100 m deep. The annual abundance of larvae of Spanish sardine varied by factors greater than 20 times between years in the area studied (Figs. 6-8). Since clupeid eggs hatch 20 to 45 hours after spawning at water temperatures of the eastern

Gulf of Mexico (Houde 1973), we assume the larvae originated near the area of capture. The greatest abundance occurred in the summer and fall (May-October) (Fig. 7).

Very little information is available on larval distribution of Spanish sardine in the western Gulf of Mexico. A few larvae have been collected in waters as deep as 180 m in surface ichthyoplankton sampling in March through December (Finucane et al. 1977, 1978).

The adult Spanish sardine is "normally found close to the coast, well within the 50-fathom curve, but it has been caught as far offshore as the 200-fathom line in the Atlantic" (Klima 1971). Low (1973) reported that Spanish sardine (40 to 160 mm total length) occurred along with H. pensacolae and O. oglinum over grassbeds in Biscayne Bay, Florida (east coast) from May into the fall, thus indicating this species will occur in shallow waters. The distribution is generally along the shoreline to water 100 fathoms (183 m) deep, (Figs. 5 and 9). The fish are generally in the upper 40 fathoms (74 m) of the water column (Tables 4 and 5). The species has been caught in waters 13° to 31°C surface temperature and 17° to 28°C bottom temperature (Tables 6 and 7). Commercial concentrations of sardines have been reported 90 miles from shore at depths of 40 to 80 m off western Florida (Tampa area) by Prosvirov and Varea (1969). Another area of high concentration that has been reported is Campeche Bank where 4.7 to 5.3 tons/hr (using bottom trawl) have been caught (Sal'nikov 1965).

The species appears to form schools which migrate in the surface layers along the continental shelf. This species makes diurnal vertical migrations (keep to the bottom during day and rise to midwater at dusk). This upward movement appears to depend on illumination (Prosvirov 1967). Seasonality of movements is not well defined. Hildebrand (1963) believed the fish made a southward migration along the Atlantic coast in the fall. Low (1973) reported fish in Biscayne Bay, Florida in fall and winter but not spring and summer.

IV. Biology

Reproduction

The reproduction of Spanish sardine has not been examined thoroughly. The following excerpt from Reintjes (1980) summarizes the current information on Spanish sardine.

> "Spawning occurs in the open waters of the Gulf, although the exact areas of spawning are difficult to determine. According to Houde et al. (1976, 1979), most spawning in the eastern Gulf occurs over wide areas where depths are between 10 and 50 m, although some eggs and larvae have been recovered where depths were 200 m. In the western Gulf, larvae have been reported from as far out as the Continental Shelf off Texas (Finucane, Collins, and Barger 1978). Eggs and larvae have been collected in the eastern Gulf in all

seasons, but are not abundant from May to September (Houde et al. 1976, 1979), and in the western Gulf from April to October (Finucane, Collins, and Barger 1978). Since spawning occurs over a long period, a given year class will have a wide range in lengths (Prosvirov and Varea 1969). Elsewhere, off the northeast coast of Venezuela, Lopez (1972) reported that eggs were most abundant from August to November and in February and May, while Simpson and Griffiths (1967) stated that spawning occurred year round but was most intense during the upwelling season from December to April.

Only a few larvae have been described. Houde and Fore (1973) show figures of a larvae 7.8 mm and 19.3 mm, while Simpson and Gonzalez (1967) show detailed illustrations of developing embryos but not larvae. Larvae from off Brazil that may have been Spanish sardine were described by Aboussouan (1969); larvae of S. aurita were described by D'Ancona (1956).

Fecundity estimates for Spanish sardine in the Gulf are sparse. For eight females, 14.4 to 15.5 cm SL, collected near Palm Beach, Florida in 1971, estimates ranged from 30,718 to 86,269 (Martinez 1972). In the Mediterranean fecundity ranged from 3,710 to 48,600 depending on size of females (Ben-Tuvia 1960); off West Africa it ranged from 10,000 to 270,000."

Martinez (1972) provided more detailed information on fecundity of Spanish sardine from the west coast of Florida (Biscayne Bay), which is summarized in Tables 8 and 9 and Figure 10. The most recent work on reproduction of Spanish sardine in Florida waters was by Grall (1984). She reported on gonad index, fecundity and maturation (summarized in Tables 10 to 13, Figures 11 to 15). She found that although sex ratios varied considerably from month to month, the overall sex ratio in the Gulf of Mexico in 1982 was 1:1. No specific information was found on factors influencing spawning or spawning behavior.

Population Parameters

The most recent data on population parameters were reported by Grall (1984) from fish of northwest Florida and southeast Florida.

The length frequency of Spanish sardine from commercial fisheries for the above areas are presented in Figures 16 and 17. Mean fork length and weight by month showing smaller and lighter fish being caught in the fall are presented in Figure 18 and Tables 14 and 15. The length-weight relationship is described in Figure 19 and Tables 16 and 17.

Age determination was made on Spanish sardine using marks (deposited October - April) on otoliths. This information and growth parameters are presented in Tables 18 to 22 and Figure 20. Comparisons of growth parameters are presented in Table 23.

Mortality and survival estimates using the above data were developed and shown along with yield-per-recruit estimates in Tables 24 and 25 and Figure 21.

Additional age and growth information on Spanish sardine has been developed by Scherbich (1981) for the southeast Atlantic and Heald and Griffiths (1967) for Venezuela using scales as the age determination structure. Scherbich reported ages up to 6 yrs old and Heald and Griffiths up to 5 yrs old.

Houde et al. (1979) provided information on larval Spanish sardine abundance and mortality. The annual abundance varied considerably from year to year off the west coast of Florida (Fig. 22). His mortality coefficient for larval Spanish sardine was 0.3909.

Ecological Associations

Little is known concerning the food habits of Spanish sardine. They apparently feed primarily on planktonic copepods (Hildebrand 1963, Böhlke and Chaplin 1968, Low 1973).

Predators of Spanish sardine are numerous. Manooch (1984) reported that little tunny (Euthynnus alletteratus), gag (Mycteroperca microlepis), and king mackerel (Scomberomorus cavalla) eat Spanish sardine. Other references to predators eating this species are provided in the papers by Saloman and Naughton, which are summarized in Table 26.

Behavior and Environmental Relationships

The behavior and environmental relationships of Spanish sardine have not been investigated in detail. Klima and Wickham (1971) reported that Spanish sardine were attracted to artificial structures. Maksimov (1976) reported that defensive behavior is taken by this species in response to trawls. This behavior is usually expressed in the "zone of critical narrowing" of the trawl and consists of fright, optomotor reaction, etc., which causes the fish to leave the trawl. Klima (1972) reported laboratory observations on Spanish sardine to different voltage and direct current pulse rates (1.5 to 3.0 v/10 cm at 15 to 45 pulses/sec with a duration of 1.0 m sec). Zei (1969) reported that this species could be attracted by artificial light at night and that high catches were associated with low temperature in the Gulf of Guinea. He also reported that successful purse seine catches were dependent on the fish being assembled in catchable numbers which was greater in periods of upwelling than in periods of thermal stability. Aleem (1972) reported decreases in catches of Spanish sardine because of construction of the Aswan high dam, which caused a drop in nutrients from the Nile River, resulting in the disappearance of phytoplankton blooms. This may indicate positive response on the part of Spanish sardine to food concentrations. Low (1973) also associated the appearance of this species with food concentrations. A complex environmental (temperature and predator-prey) interaction may exist off the west coast of Africa between Spanish sardine and gray triggerfish (*Balistes capriscus*) where cold upwellings and high salinity favor the sardine and the opposite favor the triggerfish which feeds on benthos and pelagic organisms, including clupeid eggs and larvae (FAO 1980).

Stocks

The identification of stocks has not been adequately examined for Spanish sardine in the Gulf of Mexico area. Prosvirov (1967) suggested that Spanish sardine in the Gulf of Mexico has a number of local populations. Johnson (unpublished ms-a) reported that 8.6% of 35 enzymatic loci (starch gel electrophoresis) were polymorphic and estimated that the maximum proportion of the genome heterozygous was 0.051. This indicates that protein polymorphism may be useful for stock separation. Other reports on electrophoretic polymorphism in serum proteins (from Guinea and Mauritania) suggest they may be useful to separate stocks (Baron 1972, 1973a, 1973b). Preliminary work on morphometrics by Johnson (unpublished ms-b) showed that stepwise discriminant analysis of multiple measurements could correctly classify fish 97.3% of the time between three collection areas (Panama City, Cortez, and Fort Pierce) in Florida, which indicated that more than one stock may occur in the southeastern U.S. waters. Latini and Pettorossi (1977) used meristics to separate various collections of Mediterranean Spanish sardines. Meristics have not been examined for fish from the Gulf of Mexico, but may be useful to separate stocks of fish.

V. Fisheries and Catching Methods

The commercial fishery for Spanish sardine can be briefly summarized by the following excerpt from Reintjes (1980).

> "The largest fishery in the western Atlantic is off Venezuela, where annual landings of more than 40,000 tons have been reported. Mexico has reported landings of 1,000 tons in some years, and Sal'nikov (1965) and Sokolova (1965) have reported Spanish sardine in catches from Campeche Banks. An estimated 1,000 tons are landed annually in a small seine fishery from May to October in the Florida panhandle from Port St. Joe to Pensacola. Most of this catch is used for bait."

The Spanish sardine supports the most important commercial fishery in Venezuela where the major gear type is the beach seine. Landings have averaged 40,000 mt annually from 1963 to 1967 having grown from 4,600 mt (Simpson 1971). Off Jamaica, Spanish sardines are caught by a variety of gear types (Fig. 23 and 24) - gill net, beach seine, lift nets, and cast nets (Harvey 1982).

In the northeastern Gulf of Mexico the Spanish sardine is caught by the coastal pelagic purse seine. The purse seine vessels average 45 to 65 ft. in length. They fish by means of a large net that encircles the school. The bottom of the net can be "pursed", thereby completely enclosing the fish. The net is slowly hauled in, and the fish are brought aboard by using a large brail or dip net. A detailed description of this operation can be found in Roithmayr 1983 (see Fig. 25). This source also gives the fishing grounds for the purse seine fleet as: from the Mississippi River to Apalachicola, Florida; also, west-central Florida from St. Petersburg, to Sarasota (Fig. 26). Principal ports for the purse seiners include Yscloskey, La.; Pascagoula, Miss.; and in Florida: Destin, Panama City, Port St. Joe, and Cortez. A drawback of this fishing method is some loss of fish quality, due to the abrasion that takes place while the fish are confined in the net.

Spanish sardine comprise a minor portion of the catch of this gear type (for example - Table 27); however, the amount of this species in a catch depends on the the vessel's target, based on market demands.

Additional information on exploratory purse seining is available in a report by Harrell (1982). She provides the cost of converting a 78 ft steel shrimp trawler (150,000 lb hold capacity) to a dual purpose drum seine/pair trawling vessel (Table 28). The result of fishing tests demonstrated that drum seining must produce 30,000 pounds of fish per day in order to be profitable (catch valued at 15 to 25 cents per pound) and can give a 21% return on investment (Tables 28, 29, and 30).

Centaur Associates (1981) provided the following excerpt which described the northern Gulf of Mexico fishery.

> "Most of the coastal herring catch is currently taken from inshore waters. Two types of gear are utilized in the directed fishery. Haul or beach seines are fished with boats ranging in size from 23 to 50 feet in length. The seines vary in length from 400 to 750 yards. Purse seines are the second gear type used. These are fished with vessels ranging from 45 to 65 feet in length. The nets are approximately 750 yards long and generally 45 to 60 feet deep. Approximately 6 purse seine boats were reported fishing these species in the Gulf of Mexico. Purse seine boats land greater quantities than haul seines.
>
> A total of 30 to 35 boats and vessels currently participate in the directed fishery for coastal herrings. According to Reintjes (1979), most of these are located on the west coast of Florida. Alabama is the primary landing area for coastal herrings in the northern Gulf. Thread herring and blue runners are reported in th Alabama commercial catch. However, most, if not all, of the landings of these species in the northern Gulf are catches incidental to other fishing activities, primarily the menhaden, shrimp and ground fish fleets....The resource potential for a directed coastal herring fishery in the northern Gulf appears good, but current processing and demand problems will have to be overcome. Development of a directed fishery in the northern Gulf would likely place a greater demand on port facilities for relatively small boats and vessels if the type presently used in Florida are fished in the

northern Gulf. Development of this fishery, however, would not result in a proportional increase in number of boats and vessels since many of the existing craft could expand into the fishery. many of the Florida boats and vessels who fish for bait also fish for other existing foodfish species such as pompano, mullet and the mackerel."

An example of the value of the purse-seine-caught fish was provided by Uebelhoer (1984), where Spanish sardine made up 11% of the return for 26 sets (purse seine catches) (Table 31).

Whether or not the abundance of, and markets for, Spanish sardine can support full development of this type of fishery is unknown, but Houde (1976) suggested that there may be about 250,000 metric tons of *Sardinella* sp. in the eastern Gulf of Mexico. Bullis and Carpenter (1968) suggested that 8,448 million pounds are available for harvest in the coastal pelagic fish resource (herring group) (Table 32). The coastal herrings can be broken down further into their respective components which are presented in Table 33 (Reintjes 1979).

VI. Composition and Marketing

Hale (1984) found the proximate composition of Spanish sardine from the gulf to be: protein, 20.90%; fat, 2.42%; moisture, 74.73%; ash, 2.69%.

The quality of a fish species with regard to oil, protein, usable meat, storage etc., greatly influences the desirability as a resource. Various sources have made studies on the quality of Spanish sardine (Table 34). The fatty acid and lipid classes and changes due to canning was studied by Hale and Brown (1983). They reported no significant changes in these traits as a result of canning; however, the vegetable oil used in packing had major effects on the fatty acid profile (increases in lenoleic acid). The chemical composition between raw and canned fish showed an increase in percent protein and lipid and a decrease in percent moisture in the canned product compared to the raw fish (Tables 35, 36, 37 and 38).

Another study showed that fish held in refrigerated sea water (brine spray system) were of higher quality than those held in chilled sea water (slush system) or ice during short-term storage. However, excessive saltiness and rancidness developed by the third day in refrigerated sea water and by the fourth day in chilled sea water and ice. Whole and headed and gutted fish stored frozen showed little deterioration for up to three months. Of the three holding methods, only chilled sea water produced an acceptable canned product for fish that were held for more than one or two days. Frozen fish could be made into good canned products even after two months of frozen storage. In order to produce a quality product, careful handling was required. Off loading by brailing was preferred over pumping (ABIC International Consultants, Inc. 1984).

Bushardt and Williams (1983) have examined the problems involved in the packaging of underutilized species for marketing. They stress the need for development of high quality, identifiable boxes and an industrial standard. They suggest that Spanish sardine be packed in 3-mil poly bags in banded 23" x 13-1/2" x 5-7/8" single wall, 200 lb, corrugated, water resistant cartons.

The current landings of Spanish sardine of 1,265 mt for the United States and 56,082 mt for the total area (FAO 1984) indicate that considerable amounts remain for harvesting. Combs (1978) indicated that in the United States, current use of this species is as bait and frozen animal food, but that Spanish sardine has potential for use as meal and as canned products and also as a substitute for menhaden and other sardine products. The constraints on this fishery have been the wide annual fluctuations in resource availability and the fact that the fish spoils quickly.

Perkins (1981) provided an economic assessment of the potential sardine fishery for the northern Gulf of Mexico. He reports very positive reaction to and high preferences for canned Gulf of Mexico Spanish sardines. Commercial fishermen can profitably produce large volumes of fish for a price of $160 to $200 per ton which would yield an ex-vessel value of 10.8 million dollars. This volume would yield a retail canned value of 37.7 million dollars and would generate an economic impact of 75 to 113 million dollars annually. His report also gives a detailed description of an experimental canning operation for Spanish sardine at an established seafood canning plant in Mississippi, using various packing mediums. Regarding demand, he states that the U.S. consumption of sardines is low, averaging only 0.4 pounds per capita per year over a seven year period (Table 39). However, it is expected that consumption would rise with some reduction in price (Figs. 27 and 28; Tables 40 and 41).

The number of firms exporting underutilized species from the Gulf of Mexico and south Atlantic area have been examined by Prochaska and Cato (1981) and Centaur Associates (1981). Their information is summarized in Tables 42 and 43.

The following are two personal communications about the market prospects of Spanish sardines from marketing specialists.

From M.E. Smith (National Marine Fisheries Service, Pascagoula, MS, April 16, 1985):

<u>Domestic Market</u> - Other than as bait for recreational fishermen and to lesser extent for zoos, Mr. Smith is not aware of any other use for the fish, fresh or frozen. From the standpoint of eye appeal and edibility, Spanish sardines from the Gulf of Mexico should be well received as a canned item. The same species is canned and imported from Venezuela, and has been seen on shelves in markets at prices as low as 40 cents per 4-ounce can. From the standpoint of size, the gulf species

should make a pack having as much or more eye appeal than Atlantic herring. With the traditional 4-ounce flat can of domestic sardines retailing at the competitive price of 55 cents to 58 cents, it would be more realistic to can the product in an existing facility rather than construct one that would be new. There are several shrimp canneries along the gulf coast that are in dire need of expanding their productivity. The only deterrent to their including sardines would be if the production season for Spanish sardines overlapped or interfered with the canning of small or medium shrimp. A shortage of the resource in New England would probably stimulate an investigation of the Gulf of Mexico stocks.

Export Market - Canned sardines have worldwide acceptance, and this is best seen by the number of inquiries that are received, especially from southeast Asia, about the availability of the product. In this area Japan is a major exporter of canned Spanish sardines, but the product is normally not canned until there is an oversupply, at which time the price on fresh sardines dips to 4 cents per pound. With such a low cost raw material, it is felt that U.S. canneries could not be competitive; this suggests that potential buyers are merely shopping for lower prices. Normally, fresh sardines in southeast Asia are used by low income groups and are also seen dried for the same purpose, wholesaling at approximately 30 cents per pound.

From Richard Raulerson (Southeast Regional Office, NMFS, St. Petersburg, FL, May 25, 1985): Spanish sardine has great potential for fishery development and has been canned for human food in the U.S. for 100 yrs. Currently the fish is used mostly as bait, but has greater potential value as a canned fish. There is a problem in canned fish with an unattractive color in the oil, but this could be worked out technologically. There is a substantial fishery in Cortez, Florida; the fishing industry there also uses it as a home canning product. There once was a canning plant in Pascagoula, Mississippi, run by a Brazilian firm. Major problems for development are competition with the better known canned sardine products, such as the Norwegian product, and trade and tariff restrictions. Spanish sardine is highly used as a canned product in South America.

Spanish sardine also shows potential for use as surimi or a minced fish product. Feasibility research showed that processing for minced fish provided a net yield of 42.6%; processing for surimi provided a net yield of 25.3%. Although the surimi provided a lower net yield, it was reported to have better flavor, color and texture than the minced fish product (Thrash 1985).

VII. Information Needs

The more important areas in which information is needed are:

1. Species identification and geographic distribution. Are there more than one species being called Spanish sardine in the Gulf of Mexico?

If so, what are the identification characteristics and ranges of the species?

2. Accurate estimates of abundance and location of resource, especially in the western Gulf of Mexico.

3. Stock identification, separation, ranges and biological parameters of each stock. Estimates of other resource user needs, so adequate resource allocation can be made. For example, if we take x amount of Spanish sardine, what effect does this removal have on king mackerel and other predators of Spanish sardine?

4. Fishing methods and how to locate this species accurately and effectively catch it. We need to apply innovative and new technology to this problem. For example, Harrell (1982) reported using night flying aircraft to spot groups of fish by the bioluminescent glow caused in the water around the fish.

5. Development of improved methods of handling this species to maintain a quality product. This includes improvements in ship board storage between catching and unloading, and standardization of an industrial "pack" (i.e., development of a universally accepted box for frozen storage of this product).

6. Test marketing of canned and other forms of this species to obtain an accurate evaluation of the consumer response to Spanish sardine. Additional information needs on this species were expressed in Christmas et al. (1985), which are summarized in (Figure 29).

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Table 1. Morphometric features of _Sardinella aurita_ (N = 100) in the Gulf of Mexico (Prosvirov and Varea 1969).

Character	Overall dimensions	M*	±M*	±S*
Body length (after Smith)*, (cm)	16.5-19.7	17.95	0.064	0.64
Weight, g	55.1-99.7	73.12	0.875	8.75
	In % of body length (after Smith)*			
Length of head	22.3-25.0	23.43	0.055	0.55
Maximal height of body	18.5-24.5	22.60	0.114	1.14
Minimal height of body	6.0-8.0	6.78	0.041	0.41
Antedorsal distance	38.9-44.5	41.56	0.126	1.26
Anteventral distance	43.6-52.5	47.87	0.134	1.34
Length of pectoral fin	10.8-16.4	15.16	0.083	0.83
Anteanal distance	65.0-77.4	73.26	0.170	1.70
Length of ventral fin	7.1-9.4	8.36	0.042	0.42
Distance between bases of anal and caudal fins	23.2-29.6	26.46	0.122	1.22
	In % of length of the head			
Length of snout	27.3-39.6	33.64	0.226	2.26
Diameter of eye	20.0-25.7	23.50	0.114	1.14
Postorbital section	44.4-55.0	50.20	0.182	1.82
Height of head	62.9-79.0	72.57	0.340	3.40
V				
A	16-18	17		
Number of rays B	9	9		
D	16-17			
Number of vertebrae	46	46		

* Abbreviations are not defined in original paper, and Smith is not referenced, in Prosvirov and Varea (1969).

Table 2. Morphometric measurements expressed as percent of standard lengths for S. aurita (Hildebrand 1963).

Body depth: 21-26.9	Pectoral fin: length 15-17.6
Caudal peduncle: depth 7.7-10	Distance from snout to origin of: dorsal fin 40-43.5
Head: length 22.3-27.2; depth 17.6-19.7	
Snout: length 6.0-7.5	Scales: about 41-46; often lost from preserved specimens
Eye: diameter 5.3-7.3	
Interorbital: width 4.2-5.3	Ventral scutes: 32-34
Maxillary: length 8.75-11	Fin rays: dorsal 17-19, occasionally 20; anal 16-18; pectoral 15 or 16
Anal fin: length of base 13.7-16	
Pelvic fin: length 8.5-11	Vertebrae: 45-57 (7 specimens)

Table 3. List of features of larval S. aurita (Fahay 1983).

Spawning: September - February off Florida

Eggs
- Pelagic, spherical
- Diameter: 0.94-1.40 mm
- Shell: smooth, transparent and thin
- Yolk: segmented
- Perivitelline space: moderate
- Oil globules: 1
- O.G. diameter: 0.12-0.16 mm

Meristic features

Myomeres:	45-48
Vert:	16+29-31
D :	(15)16-19(20)
A :	(14)16-17(19)
Plv :	8-10
C :	8+10+9+7

Larvae
- Hatching occurs at about 3 mm
- Body elongate with long straight gut; vent posterior to dorsal fin
- Flexion occurs at about 11 mm TL, and transformation at about 25 mm TL
- Last 2 anal rays become elongate in larger larvae
- Larvae uncommon north of Cape Hatteras

Important characters:
- Myomeres between dorsal and anal fins 5-8; predorsal myomeres decrease from 28-24
- Dorsal pigment absent from notochord tip, but ventral pigment present
- Anal fin ray count lower than in Opisthonema

Table 4. Summary of experimental midwater trawls (MWT) by U.S. research vessels in the northern Gulf of Mexico 1957-69.*

Cruise code	Month year	Location	Gear**	Depth	Size of fish school & catch	Genus
01 42	1/57	NE Gulf	30 ft, 50 ft MWT	20-90 fm	300 yds + dia	Anchoa Sardinella Decapterus Scomber
01 49	4/57	Cape San Blas to Fort Myers	40 ft MWT	10-30 fm	200 lbs/hr	Etrumeus Anchoa Scomber Sardinella
01 57	2-3/59	Mississippi River to Chandeleur Island Cedar Key to Cape Romano Cape San Blas	40 ft MWT " "	8-12 fm 10-30 fm 10-12 fm	up to 1000 lbs/tow " "	Harengula Opisthonema Anchoa Brevoortia Etrumeus Sardinella

* Information from Frederick Minkler, National Marine Fisheries Service, Pascagoula, MS, May 1985.
**Midwater trawl size in feet of headrope.

Table 5. Catch rate of *S. aurita* by depth and season*.

Depth (fathoms)	December-February		March-May		June-August		September-November	
	Number of tows	Hits**	Number of tows	Hits	Number of tows	Hits	Number of tows	Hits
1-10	457	6	1175	19	2101	46	2251	44
11-20	647	16	1933	24	1156	39	2970	29
21-30	455	9	1065	7	615	16	2008	13
31-40	278	2	613	3	298	0	1421	2
41-50	-	-	-	1	206	1	-	-

* Data from Frederick Minkler, National Marine Fisheries Service, Pascagoula, MS, May 1985.
** Number of tows in which Spanish sardine was found.

Table 6. Catch rate of *S. aurita* by surface temperature (°C) and season*.

Surface Temp. °C	December-February		March-May		June-August		September-November	
	Number of tows	Hits**	Number of tows	Hits	Number of tows	Hits	Number of tows	Hits
13	139	1	10	0	-	-	1	0
14	216	0	17	0	-	-	2	0
15	61	0	40	1	-	-	-	-
16	211	1	106	0	-	-	19	0
17	233	2	192	0	1	0	101	0
18	306	2	390	1	-	-	75	0
19	240	0	903	1	1	0	206	0
20	217	0	343	0	-	-	166	0
21	86	0	446	0	1	0	627	0
22	168	0	460	0	1	0	1088	0
23	134	0	298	6	17	0	1594	0
24	31	0	213	9	28	1	1244	0
25	1	0	48	2	26	1	384	1
26	-	-	77	2	279	0	699	8
27	-	-	109	1	549	6	538	15
28	3	0	25	1	1029	13	408	1
29	2	0	1	0	1009	17	392	0
30	-	-	-	-	367	1	64	1
31	-	-	-	-	236	4	21	0
32	-	-	-	-	41	0	1	0
33	-	-	-	-	4	0	-	-
34	-	-	-	-	1	0	-	-

* Data from Frederick Minkler, National Marine Fisheries Service, Pascagoula, MS, May 1985. Shrimp and fish trawl (40 ft head rope) data from Gulf of Mexico 1950-1985.

** Number of tows in which Spanish sardine was found.

Table 7. Catch rate of S. aurita by bottom temperature (°C) and season*.

Bottom Temp. °C	December-February Number of tows	December-February Hits**	March-May Number of tows	March-May Hits	June-August Number of tows	June-August Hits	September-November Number of tows	September-November Hits
17	45	0	129	1	42	0	35	0
18	84	0	249	0	75	0	58	0
19	64	0	294	0	147	0	78	0
20	19	0	148	0	123	0	58	0
21	35	0	149	0	281	0	145	0
22	54	0	53	0	238	1	303	1
23	87	0	59	0	219	8	448	0
24	93	0	18	0	164	5	517	0
25	5	0	-	-	86	0	131	0
26	9	0	3	0	266	3	163	2
27	-	-	2	0	164	1	82	2
28	-	-	-	-	118	0	15	1
29	-	-	-	-	60	2	3	0
30	-	-	-	-	9	0	2	0

* Data from Frederick Minkler, National Marine Fisheries Service, Pascagoula, MS, May 1985. Shrimp and fish trawl (40 ft head rope) data from Gulf of Mexico 1950-1985.

** Percent of total number of tows in which Spanish sardine was present.

Table 8. Data on size, ovary weight, gonad index, fecundity and relative fecundity for <u>Sardinella aurita</u> (Martinez 1972).

Fish	Standard length (cm)	Total length (cm)	Weight (g)	Ovary weight (g)	Gonad index (%)	Fecundity (no. ova)	Relative fecundity
1	14.4	15.8	51.02	1.2100	2.3	59,682	1,198.0
2	14.4	15.6	50.17	2.2929	4.7	56,826	1,187.0
3	14.4	15.6	46.70	1.5288	3.3	61,815	1,370.0
4	14.6	16.1	49.93	1.7493	3.5	30,718	637.0
5	14.7	16.2	50.90	.8847	1.7	45,824	916.0
6	15.0	16.2	53.81	2.1449	3.9	45,730	885.0
7	15.4	16.5	57.63	2.0681	3.5	86,269	1,552.0
8	15.5	16.8	63.91	2.7793	4.3	68,632	1,122.0

Table 9. Equations, standard deviations (S and S_b) and correlation coefficients (r) for the relations of fecundity (considering fecundity as the number of maturing and mature oocytes in the intermediate and most advanced mode) and relative fecundity to body weight and length in Spanish sardines, *S. aurita* (Martinez 1972).

Variables	Results
Fecundity (F) and body weight (W) g	F = 1,560 W - 25,764; S = 15,610; S_b = 1,086; r = .51
Fecundity (F) and standard length (SL) mm	F = 18,939 SL - 223,367; S = 15,575; S_b = 13,088; r = .26
Log_{10} fecundity and standard length (SL) mm	Log_{10} F = 2.789509 + 0.131643 SL; S = .13136; S_b = .1100388; r = .4382
Log_{10} fecundity and log_{10} standard length (SL) mm	Log_{10} F = 4.4593 log_{10} SL - .4799; S = .13169; S_b = 3.7953; r = .43
Relative fecundity (F_r) and standard length (SL) mm	F_r = 121.83 SL - 694.54; S = 307.45; S_b = 258.36; r = .19

Table 10. Length, weight, batch fecundity, relative fecundity and gonad index of *S. aurita* from the Gulf of Mexico (Grall 1984).

Fork length (mm)	Weight (g)	Batch fecundity (# of eggs)	Relative fecundity (eggs/g)	Gonad index (%)
146	45.9	21,214	505.1	8.50
154	57.0	31,737	623.5	10.70
162	60.5	26,721	476.3	7.27
165	67.7	45,099	733.3	9.16
166	74.5	34,462	500.2	7.52
168	67.7	67,433	1023.0	8.86
170	72.2	94,108	1484.4	12.19
175	88.4	69,550	899.7	12.56
177	73.8	36,842	545.8	8.54
179	80.6	92,405	1279.8	10.42
180	87.4	54,625	701.2	10.87
180	92.0	97,058	1202.2	12.17
182	87.1	80,816	1023.0	9.30
184	104.9	52,615	565.2	11.25
186	90.6	61,346	744.5	9.05
186	105.1	115,344	1227.1	10.55
187	107.6	98,449	1024.4	10.66
188	94.3	105,855	1232.3	8.91
188	107.5	146,728	1931.6	10.88
190	98.5	87,395	1232.3	9.24
193	98.7	40,022	443.7	8.61
195	114.5	41,541	399.0	9.08
195	118.9	47,802	437.0	7.99
198	120.9	139,800	1331.4	13.15
200	112.1	84,265	812.6	7.47
average		70,312	871.7	9.80

Table 11. Length, weight, batch fecundity, relative fecundity and gonad index of S. aurita from the Atlantic Ocean (Grall 1984).

Fork length (mm)	Weight (g)	Batch fecundity (# of eggs)	Relative fecundity (eggs/g)	Gonad index (%)
141	36.2	31,543	985.7	11.60
143	35.9	21,806	673.0	9.75
149	39.9	26,526	726.7	8.52
150	41.7	31,142	821.7	9.35
150	45.0	30,687	767.2	11.11
151	45.6	31,542	763.7	9.43
153	44.6	33,084	818.9	9.42
153	48.7	34,170	773.1	9.24
154	44.4	32,251	804.3	9.01
154	46.1	29,913	720.8	9.98
155	55.0	39,429	818.0	12.36
156	47.3	28,794	665.0	8.46
158	51.9	32,243	693.4	10.40
158	52.1	35,128	738.0	8.64
160	52.9	33,284	673.8	6.62
160	56.8	47,600	963.6	13.03
162	48.8	29,115	652.8	8.61
168	61.2	47,446	844.2	8.11
168	62.2	42,385	766.5	11.09
168	64.2	68,044	1195.8	11.37
168	65.5	40,822	684.9	9.01
176	77.6	41,186	580.1	8.51
average		35,825	778.7	9.71

Table 12. Relationship of batch fecundity (F) and fork length (L in mm) and weight (W in g) for female *S. aurita* from the Gulf of Mexico (Grall 1984).

Variables	Linear regression equation	Log-log linear regression equation
Batch fecundity vs fork length	$F=-165902.0 + 1317.5\ L$ $r = 0.52$ $r^2 = 0.27$ $n = 25$	$F=350.4 \times 10^{-7}\ L^{4.1}$ $r = 0.62$ $r^2 = 0.39$ $n = 25$
Batch fecundity vs fork length (adjusted*)	$F=-318472.9 + 2227.1\ L$ $r = 0.77$ $r^2 = 0.60$ $n = 20$	$F=118.8 \times 10^{-8}\ L^{6.1}$ $r = 0.83$ $r^2 = 0.68$ $n = 20$
Batch fecundity vs weight	$F=-12389.5 + 934.74\ W$ $r = 0.55$ $r^2 = 0.30$ $n = 25$	$F=158.4\ W^{1.3}$ $r = 0.63$ $r^2 = 0.40$ $n = 25$
Batch fecundity vs weight (adjusted*)	$F=-46568.8 + 1413.7\ W$ $r = 0.77$ $r^2 = 0.59$ $n = 20$	$F=20.99\ W^{1.8}$ $r = 0.81$ $r^2 = 0.66$ $n = 20$

(*) Adjusted data include only females less than 190 mm FL.

Table 13. Relationship of batch fecundity (F), and fork length (L in mm) and weight (W in g) for female *S. aurita* from the Atlantic coast (Grall 1984).

Variables	Linear regression equation	Log-log linear regression equation
Batch fecundity vs fork length	$F=-80413.3 + 740.2\ L$ $r = 0.67$ $r^2 = 0.45$ $n = 22$	$F=0.006\ L^{3.1}$ $r = 0.71$ $r^2 = 0.51$ $n = 22$
Batch fecundity vs weight	$F=-910.6 + 683.6\ W$ $r = 0.73$ $r^2 = 0.53$ $n = 22$	$F=779.8\ W^{0.97}$ $r = 0.79$ $r^2 = 0.63$ $n = 22$

Table 14. Mean fork length (FL) and weight (WT) of *S. aurita* in the Gulf of Mexico for 1981-1982 (Grall 1984).

Year	Month	Mean FL (mm)	Mean WT (g)	Number of fish in sample
1981	Apr	166.77	64.89	289
	May	160.57	59.54	286
	Jun	170.00	69.44	882
	Jul	167.64	66.39	496
	Aug	157.56	57.95	310
	Sep	159.36	53.64	201
	Oct	123.54	26.41	590
	Nov	153.59	51.28	102
1982	Apr	134.63	29.13	109
	May	149.92	44.62	411
	Jun	162.60	60.71	820
	Jul	163.22	59.63	587
	Aug	164.26	62.58	204
	Sep	113.53	18.52	133
	Oct	120.78	21.86	371
	Nov	138.18	33.49	118

Table 15. Monthly mean fork length (FL) and weight (WT) of *S. aurita* catch taken by purse seine and by beach seine from the west coast of Florida for pooled years, 1981 and 1982 (Grall 1984).

	Purse seine		Beach seine	
Month	FL (mm)	WT (g)	FL (mm)	WT (g)
April	144.21	42.00 *	168.21	67.09
May	155.09	49.25	157.78	55.47
June	162.57	58.34 *	168.19	67.65
July	161.74	56.89 *	165.97	63.94
August	163.36	54.27	162.22	61.19
September	-	-	141.11	39.66
October	126.80	26.16 *	120.93	24.59
November	-	-	148.23	44.80

* Significant difference in average length and weight between gear types at $P<0.05$.

Table 16. Summary of the length-weight relationships (mm-g) for *S. aurita* on the Gulf coast of Florida (Grall 1984).

Year	Sex	Equation	r^2	N
1981	Males	$W=12.80x10^{-6}\ FL^{3.01}$	0.94	504
	Females	$W=5.55x10^{-6}\ FL^{3.18}$	0.94	438
	Combined	$W=6.32x10^{-6}\ FL^{3.15}$	0.96	3157
1982	Males	$W=1.07x10^{-6}\ FL^{3.49}$	0.96	416
	Females	$W=0.87x10^{-6}\ FL^{3.54}$	0.97	421
	Combined	$W=1.37x10^{-6}\ FL^{3.45}$	0.96	2489
1981 + 1982	Males	$W=3.60x10^{-6}\ FL^{3.26}$	0.95	917
	Females	$W=1.73x10^{-6}\ FL^{3.40}$	0.96	884
	Combined	$W=3.45x10^{-6}\ FL^{3.27}$	0.96	5913

Table 17. Summary of the length-weight relationships (mm-g) for *S. aurita* on the Atlantic coast of Florida (Grall 1984).

Year	Sex	Equation	r^2	N
1981	Males	$W=24.99\times10^{-6}\ FL^{2.85}$	0.83	189
	Females	$W=3.08\times10^{-6}\ FL^{3.28}$	0.92	88
	Combined	$W=3.82\times10^{-6}\ FL^{3.23}$	0.97	327

Table 18. Estimated age at length, back-calculated from the fork length-otolith regressions for *S. aurita* (Grall 1984).

Year	Area	Sex	Length (mm) at		
			Age 1	Age 2	Age 3
1981	Gulf	Male	104.26	147.41	165.85
		Female	103.91	153.94	171.09
		Combined	104.01	150.86	169.84
1982	Gulf	Male	107.26	146.14	170.34
		Female	110.74	149.38	172.10
		Combined	110.36	147.01	170.12
1981 + 1982	Gulf	Male	104.98	146.86	168.32
		Female	105.96	151.71	171.11
		Combined	105.19	149.32	170.12
1981	Atlantic	Male	111.97	141.87	---
		Female	111.68	144.44	---
		Combined	110.20	142.75	---

Table 19. Distribution of back-calculated length (mm) at annulus (BC) and length (mm) at capture (AC) for S. aurita in the Gulf of Mexico, males and females combined in pooled years, 1981 and 1982 (Grall 1984).

Length class (mm)	Annulus 1 BC	Annulus 1 AC	Annulus 2 BC	Annulus 2 AC	Annulus 3 BC	Annulus 3 AC
70 - 79	10					
80 - 89	46					
90 - 99	80	1				
100 - 109	107	8				
110 - 119	86	45	5			
120 - 129	90	53	8			
130 - 139	39	73	39	1		
140 - 149	23	100	125	18	3	
150 - 159	10	182	88	87	7	1
160 - 169		191	59	187	19	1
170 - 179		51	19	143	24	25
180 - 189		11	1	64	2	37
190 - 199		1		6		12
200 - 209		1	1	1		
N	491	717	343	507	55	76
x	105.19	150.39	149.32	167.55	170.12	181.67
st. dev.	16.8	17.3	11.7	10.2	8.2	7.2

Table 20, Back-calculated length at age for *S. aurita* based on the premise that the annulus is formed at six months rather than one year (Grall 1984).

Year	Area	Sex	Length (mm) at		
			Age 1	Age 2	Age 3
1981	Gulf	Male	129.49	159.49	174.19
		Female	133.27	165.52	180.11
		Combined	131.68	163.43	178.55
1982	Gulf	Male	131.22	161.91	179.18
		Female	127.61	160.26	181.42
		Combined	129.11	160.99	179.93
1981	Gulf	Male	129.28	159.43	174.81
+		Female	132.82	164.49	179.68
1982		Combined	130.75	162.65	179.20

Table 21. Monthly age (in years) distribution by number of *S. aurita* for males (M) and females (F) (from Grall 1984).

Year	Month	Age 0.0 M	Age 0.0 F	Age 0.5-1.0 M	Age 0.5-1.0 F	Age 1.5-2.0 M	Age 1.5-2.0 F	Age 2.5-3.0 M	Age 2.5-3.0 F
1981	Apr	13	7	17	4	6	13	1	3
	May	18	12	29	28	14	9	3	9
	Jun	10	4	71	49	53	62	5	9
	Jul	0	2	35	41	20	55	2	6
	Aug	10	1	41	8	14	9	0	2
	Sep	8	1	25	11	8	3	0	0
	Oct	70	35	13	9	0	1	0	0
	Nov	9	6	5	2	3	3	0	0
Total		138	68	236	152	118	155	11	29
1982	Apr	12	9	7	2	0	0	0	0
	May	3	4	42	30	12	8	0	0
	Jun	3	1	46	31	46	57	16	13
	Jul	3	2	32	34	38	29	1	1
	Aug	1	1	10	7	20	11	1	0
	Sep	19	22	7	7	0	0	0	0
	Oct	6	11	19	29	0	0	0	0
	Nov	2	1	10	14	2	3	0	0
Total		49	51	173	154	118	110	18	14

Table 22. Length and estimated age at capture of *S. aurita* determined from the von Bertalanffy growth model for pooled years, 1981-1982 (Grall 1984).

Sex	Mean length at capture (mm)	Age (yrs)	Adjusted age*	Frequency
Males	132.6	1.63	1.08	187
	153.7	2.27	1.75	409
	164.8	2.37	2.28	236
	179.0	3.33	3.45	29
Mean		2.35	2.01	
Females	132.2	1.57	0.99	119
	154.0	2.03	1.58	306
	170.0	2.27	2.28	265
	183.1	3.23	3.38	43
Mean		2.22	2.10	
Combined	127.5	1.60	0.93	378
	151.2	2.10	1.56	779
	167.5	2.30	2.23	502
	181.6	3.30	3.22	73
Mean		2.24	1.90	

* The adjusted age is calculated from the von Bertalanffy curve which is based on the premise that the first annulus is formed at six months rather than one year.

Table 23. Growth parameters of S. aurita from different areas (Grall 1984).

Author	Area	L_{∞} (mm)	K	t_0
Boely, 1982	Senegal	306.3 FL	1.2060	-.0620
El-Maghraby et al., 1970	Egypt	260.0 FL	0.5310	.3395
Gheno, 1975	Congo	259.7 FL	1.0230	.0885
Gheno, 1975	Congo	260.0 FL	1.2090	-.0296
Heald, 1966	Venezuela	241.5 SL	0.3200	-----
Krzeptowski, 1981	Senegal	331.5 FL	0.2832	-.9890
Matsuura, 1977	Brazil	244.0 FL	0.4414	-----
Grall (1984)	Florida	F 220.1 FL M 197.1 FL	0.4708 0.6560	-.3810 -.6604

Table 24. Mortality rate estimates (M) and annual survival (S) of S. aurita based on the methods of Pauly (1980) and Ssentongo and Larkin (1973) for the years 1981-1982 (Grall 1984).

Method	Males	Females	Combined
Pauly	M = 0.5995 S = 0.5491	M = 0.5608 S = 0.5707	M = 0.5769 S = 0.5616
Pauly (*)	M = 0.7588 S = 0.4682	M = 0.8001 S = 0.4493	M = 0.7392 S = 0.4775
Ssentongo & Larkin	M = 0.8916 S = 0.4100	M = 1.009 S = 0.3646	M = 0.9894 S = 0.3718
Ssentongo & Larkin(*)	M = 0.7988 S = 0.4499	M = 0.7709 S = 0.4694	M = 0.8433 S = 0.4303

(*) Represents mortality and survival estimates based on the adjuste growth parameters.

Table 25. Yield-per-recruit, mean weight, length and age of *S. aurita* in the catch at A.) maximum fishing mortality, B.) optimum fishing mortality and C.) maximum exploitation rates (Grall 1984).

Data used	F	E	Yield per recruit (g)	Mean weight (g)	Mean length (mm FL)	Mean age (yr)
A.)						
original	6.7	0.87	24.14	27.70	129.28	1.49
adjusted	3.8	0.82	24.42	29.84	132.25	1.03
B.)						
original	1.5	0.60	21.91	36.52	140.80	1.58
adjusted	1.5	0.64	23.15	36.16	140.38	1.24
C.)						
original	1.0	0.50	19.87	39.58	145.60	1.92
adjusted	0.85	0.50	20.39	40.78	145.63	1.39

Table 26. Some predators of *S. aurita*.

Predator	Location studied	Spanish sardine occurrence in stomachs: Percent frequency	Percent volume	Reference
Bluefish	Carolinas to Louisiana	0 - 2.7	0 - 2.9	Naughton & Saloman 1984
Spanish mackerel	Carolinas to Texas	0.5 - 3.2	2.2 - 20.4	Saloman & Naughton 1983b
Crevalle jack	Florida to Texas	0 - 6.2	0 - 9.3	Saloman & Naughton 1984
King mackerel	Carolinas to Texas	0 - 9.0	0 - 24.3	Saloman & Naughton 1983a

Table 27. Species composition of purse seine catches, Florida, October, 1981 (Roithmayr 1983).

Species	Tons	Percent composition
Thread herring	121	41
Ladyfish	57	19
Spot	48	16
Menhaden	46	15
Spanish sardine and round scad	27	9
TOTAL	299	

Table 28. "Typical" drum seine conversion cost (projected) (Harrell 1982).

Deck Equipment	$ 27,500
Drum Seine	9,400
Spool Assembly	8,000
Miscellaneous Items	7,500
Net	50,000
Total Cost	$102,400
(3rd Quarter 1981 dollars are estimated)	

Table 29. Projected drum seine operating costs (Harrell 1982).

Assumptions (Basis):

1. Diesel Fuel Cost (Anderson Results): $1.18/gallon
2. Fuel Consumption (Clark Results): 0.023 gallons per pound
3. Life of Drum Seine Mechanical Equipment: 12 years
4. Life of Electronic: 7 years (Due principally to obsolesence)
5. Life of Net: 2 years
6. Original Cost of Mechanical Equipment: $50,000
7. Original Cost of Electronics: $30,000
8. Estimated Insurance Cost: $10,000
9. Ice Consumption: 0.765 pounds of ice per pound of fish (Clark actual results)
10. Ice Cost: $4.75 per block (~300 pounds)
11. Labor & Spotter Plane Cost: Divide Total Gross Stock as follows:

    48.6% - Vessel　　10% - Spotter Plane
    32.4% - Crew　　9% - Captain

12. Original Cost of Seine: $50,000
13. Estimated Maintenance Cost: $12 - 15,000 per year per boat (Use 2 boats)
14. Estimate Harvesting Rate: 33,000 pounds per day (Assume Clark Seafood's rate is typical)

Using these assumptions, the following operating costs can be expected (Note: per pound basis assumes boat produces 3,000,000 pounds of fish per year with 23 cents per pounds).

Cost Component	Annual Cost (Dollars)	(Cost per Pound (Cents)
Vessel depreciation	15,000	0.500
Mechanical depreciation	4,167	0.139
Electronic depreciation	4,285	0.142
Line depreciation	25,000	0.833
Vessel cost	69,000	2.300
cost	47,500	1.583
Insurance	10,000	0.333
Maintenance	15,000	0.500
Harbor & spotter plane (Percent of gross revenue)	292,560	9.752
Miscellaneous	5,000	0.167
TOTAL COST	$487,512	16.25 cents/lb

Table 30. Sample comparison of drum seine and shrimp trawl costs and earnings (Harrell 1982).

Cost component	Drum seine	Shrimp trawl
1. Vessel Characteristics:		
Gross Tonnage	80	108
Length	70	69
Horsepower	245	352
Crew Size	7	3
2. Gross Revenue	$450,000	150,000
3. Variable Costs:		
(a) Goods & Services	134,500	65,700
(b) Labor	145,800	50,000
(c) Opportunity Cost of Capital	2,018	985
Total Variable Costs	282,318	116,685
4. Fixed Costs:		
(a) Insurance	10,000	7,000
(b) Miscellaneous	5,000	2,086
(c) Depreciation (See Table #8)	48,452	8,667
Total Fixed Costs	63,452	17,753
5. Total Costs (3 ÷ 4)	345,770	134,438
6. Returns to operator's labor, management and capital (2-5)	104,230	15,562
7. Opportunity Cost of Management	36,000	15,000
8. Returns to Capital (6-7)	68,230	562
9. Total Investment	325,000	275,000
10. Return on Investment (%)	21.0	0.2

Drum seine assumptions:

Annual Catch: 3,000,000 pounds
Catch Value: 15 cents per pound

Table 31. Species composition, weight, and value of purse-seined fish in 1982 (Uebelhoer 1984).

Species	No. of sets	Amount harvested (lbs)		Unit value	Total value
Spanish Sardine	4	217,678	(15.9%)	6¢/lb.	$13,060.68(11.0%)
Ladyfish	5	425,050	(31.0%)	8¢/lb.	34,004.00(30.0%)
Mullet	1	7,100	(0.5%)	15¢/lb.	1,065.00(0.9%)
Bonito	3	172,706	(13.9%)	8¢/lb.	13,816.48(12.2%)
Jack Crevalle	6	198,440	(14.5%)	8¢/lb.	15,875.20(14.0%)
Menhaden	1	140,000	(10.2%)	4.25¢/lb.	5,950.00(5.3%)
Blue Runner	3	93,500	(6.8%)	17.0¢/lb.	15,895.00(14.0%)
Red Fish	2	72,000	(5.3%)	12.0¢/lb.	8,640.00(7.6%)
Blue Fish	1	26,000	(1.9%)	18.0%/lb.	4,680.00(4.1%)
Total	26	1,352,474		8.25¢/lb (Weighted Average)	$113,066.36

Table 32. Production and latent fishery resource potentials of the Gulf of Mexico in 1968 (Bullis and Carpenter 1968).

	Production (Millions of Pounds)	Latent (Millions of Pounds)	Expansion factor	Species of greatest potential
Coastal Pelagic Fish	1,064	8,448	8	Herring Sardine Anchovy
Bottomfish (industrial)	88	5,673	64	Croaker Spot Seatrout
Bottomfish (food)	54	1,005	19	Snapper Grouper
Shellfish	257	2,835	11	Scallops Squid Lobsters Crabs Shrimp
Mid-water Fish	None	2,148	100+	Butterfish Bumper Scad Harvest fish
High Seas Pelagic Fish	None	912	100+	Sharks Tuna Flying fish Dolphin
Total	1,463	21,021	14	

Table 33. Status of the coastal herrings and associated stocks in the Gulf of Mexico and south Atlantic (Reintjes 1979).

Species	Total estimated catch	Biomass	Potential Yield	Available for expansion
	thousand metric tons			
Atlantic thread herring[d]	25-50	110-370	60-120	35-70
Spanish sardine[d]	.5	110-370	60-120	60-120
Scaled sardine[d]	.5	185	46-92	46-92
Round herring	.25	130-700	50-250	50-250
Bay anchovy	b	a	a	a
Striped anchovy	b	a	a	a
Silver anchovy	b	a	a	a
Round scad[d]	1.	100-200	70-85	69-84
Rough scad	0	20-50	12-14	12-14
Atlantic bumper	2.5	a	a	a
Total[c]	30-55	655-1,875	298-681	272-630

[a] Unknown

[b] Shrimp discards represent about 17,000 tons of anchovies.

[c] Numbers rounded

[d] Directed fisheries primarily limited to Florida

Table 34. Composition of *S. aurita*.

Reference	Description		Moisture %	Protein %	Fat %	Ash %	Carbo-hydrates %	Calories Per 100 gm	Phosphorus mg/100 g	Chlorine mg	Arsenic parts per million
Sidwell 1981	Muscle Raw	$\bar{x}$	71.0	22.9	6.0	1.7	0	146	331	140	0.99
		Range	67.9-74.8	18.3-32.6	2.3-9.9	1.1-2.1					
		n	4	5	6	5					
	Whole Raw		71.6	19.0	3.6	6.5	0	108			
				18.3-19.6							
				2							
	Dried		23.9	57.0	5.7	14.5	0	279			
			22.8-24.9								
			2								
	Salted & smoked		23.3	56.3	5.4	14.2	0.8	277			
			22.5-24.1								
			2								
Herzberg and Pasteur 1969	Edible parts with skeletal frame			20.7	3.7	1.9					
				17.0-22.3	0.4-20.0	1.4-2.9					
Sidwell et. al 1974	Not listed		74.8	20.5	3.8	2.1					
			65.9-79.9	17.3-22.3	0.4-20.0	1.4-2.9					
			50	49	125	49					

Table 35. Major fatty acids of raw and canned *S. aurita* (weight percent composition) (Hale and Brown 1983).

Fatty acid	Sample form		
	Raw	Canned (F_o = 13.3)1/	Canned (F_o = 17.7)
14:0	3.9	3.5	4.1
16:0	22.2	21.8	22.8
17:0	1.6	1.5	1.5
18:0	7.5	7.7	7.3
16:1	5.7	5.4	6.1
18:1	11.3	10.2	11.4
20:1	1.3	1.2	1.1
22:1	0.1	--	0.1
18:2ω6	1.2	1.3	1.4
18:3ω3	0.7	0.8	0.8
18:4ω3	0.7	0.6	0.8
20:4ω6	1.8	1.9	1.8
20:5ω3	8.1	7.8	9.4
22:5ω6	1.2	1.4	1.2
22:5ω3	1.4	1.2	1.3
22:6ω3	22.7	25.1	22.1
Total saturated	37.7	37.3	39.0
Total monoenes	19.4	17.8	19.5
Total PUFA2/	42.9	44.9	41.6
Total HUFA3/	33.6	35.6	33.9

1/ F_o = measure of total heat exposure at the center of the can.
2/ PUFA = polyunsaturated fatty acids.
3/ HUFA = highly unsaturated fatty acids.

Table 36. Effect of packing media on concentrations of total lipids and selected fatty acids for canned *S. aurita* (Hale and Brown 1983).

Item	Raw, headed and gutted	Canned in 2% brine	Canned in soybean oil
		Sample	
		Percent	
Total lipids	1.3	2.05	9.64
		Fatty acids (% of total)	
16:0	25.18	25.38	13.81
18:0	8.09	8.48	5.04
18:1	9.71	11.74	21.42
18:2ω6	1.06	1.32	43.50
20:5ω3	4.86	4.29	0.84
22:6ω3	29.46	25.50	4.34

Table 37. Lipid class composition of raw and canned *S. aurita* (Hale and Brown 1983).

Lipid class	Raw	Canned (F_o = 13.3)	Canned (F_o = 17.7)
		Sample form	
		Percent of total	
Triglycerides	67	55	66
Free fatty acids	7	7	5
Sterols	2	3	2
Polar lipids	22	35	26
Unidentified	2	--	--

Table 38. Size data for whole *S. aurita*, and proximate chemical compositions for dressed, headed and gutted (H & G) fish, both raw and canned (Hale and Brown 1983).

Item	Size data (whole fish) Spanish sardine
Mean weight (g±SD)	71.5 ± 23.8
Mean length (cm±SD)	16.9 ± 1.7

	Proximate composition (dressed, H&G)	
	Raw	Canned
Moisture (%)	75.41	69.63
Protein (%)	20.09	24.52
Lipid (%)	3.22	4.21
Ash (%)	1.75	1.90

Table 39. Per capita consumption of sardines (Perkins 1981).

	Pounds per capita
1970	.4
1971	.4
1972	.4
1973	.5
1974	.4
1975	.2
1976	.3
1977	.3
1978	.3
1979	.3

Table 40. Hypothetical price and quantity demanded relationships with increased domestic production of canned sardines (Perkins 1981).

Quantity	Price	Total revenue
000 lbs.	Dol.	000 dol.
30,000	$1.50	$45,000
30,300	1.49	45,147
30,600	1.48	45,288
30,900	1.47	45,423
31,200	1.46	45,552

Table 41. Hypothetical per capita consumption of domestic sardines (Perkins 1981).

Production Mil. lbs.	Price Dol. per lb.	Consumption of sardines[1] lbs.
30,000	$1.50	.11
30,300	1.49	
30,600	1.48	
30,900	1.47	
31,200	1.46	
60,000	.91	.22

[1] Assuming unchanged consumption of imported canned sardines.

Table 42. Gulf of Mexico and south Atlantic export firms offering specified under-utilized species for export (Centaur Associates 1981).

Product for export	Export firms: Number	Export firms: Percent of firms surveyed
Black mullet	27	79
Bluefish	21	62
Jack crevalle	20	59
Little tunny	19	56
Bluerunner	18	53
Ladyfish	18	53
Spanish sardine	17	50
Sheepshead	15	44
Rock shrimp	15	44
Black drum	14	41
Atlantic thread herring	12	35
Sea catfish	10	29
Red porgy	9	26
Atlantic croaker	9	26
Blackfin tuna	7	21
Spot	7	21
Round herring	/7	21
Black mullet roe	6	18
Gulf quahog	2	6

Table 43. Locally produced seafood products exported from the southeast, 1980 (Prochaska and Cato 1981).

Seafood Product	Total	Percent of exporters reporting sales Large firms	Small firms
Mullet	62	100	29
Mullet Roe	46	67	29
Shrimp	31	33	29
Mackerel	23	50	0
Red Drum	23	50	0
Scallops	8	17	0
Monkfish	8	17	0
Squid	8	17	0
Butterfish	8	17	0
Ladyfish	15	33	0
Jack crevalle	15	33	0
Sardines	8	0	14
Porgy	8	0	14
King Mackerel	15	33	0
Lobster	15	33	0
Blue fish	8	17	0
Oyster stew	8	0	14
Black drum	8	17	0
Sheepshead	8	17	0

[a] Firm size based on total volume of sales and not sales of individual species. Small firms are those with sales less than one million pounds.

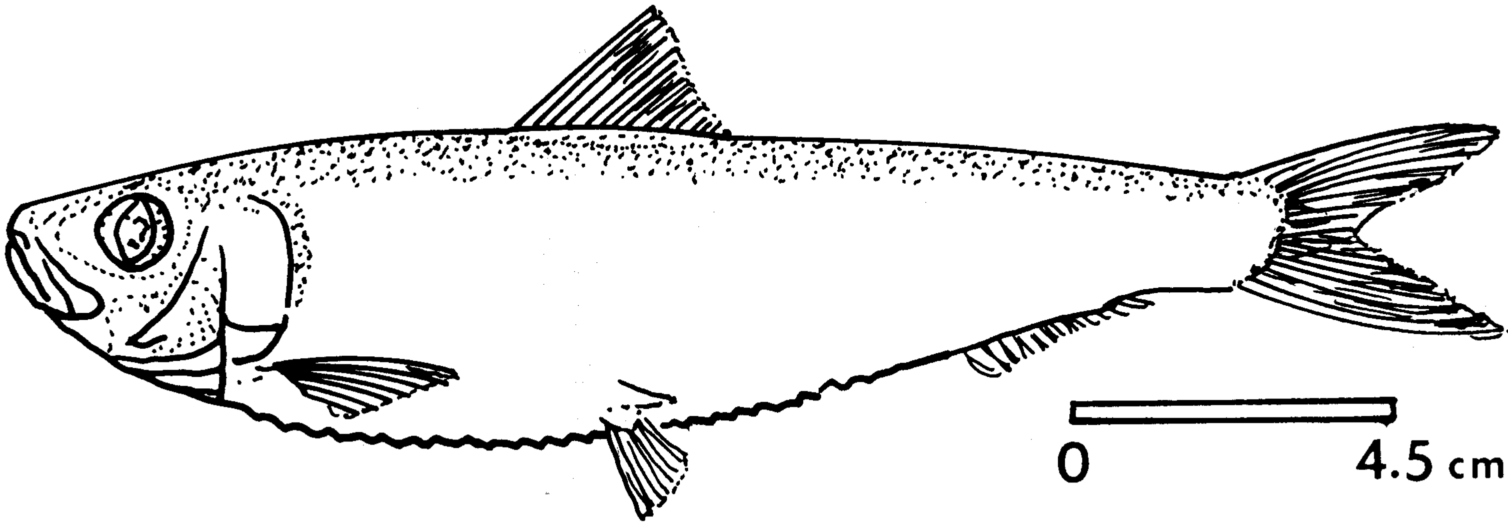


Figure 1. Diagram of a Spanish sardine, *Sardinella aurita* (Fischer 1978).

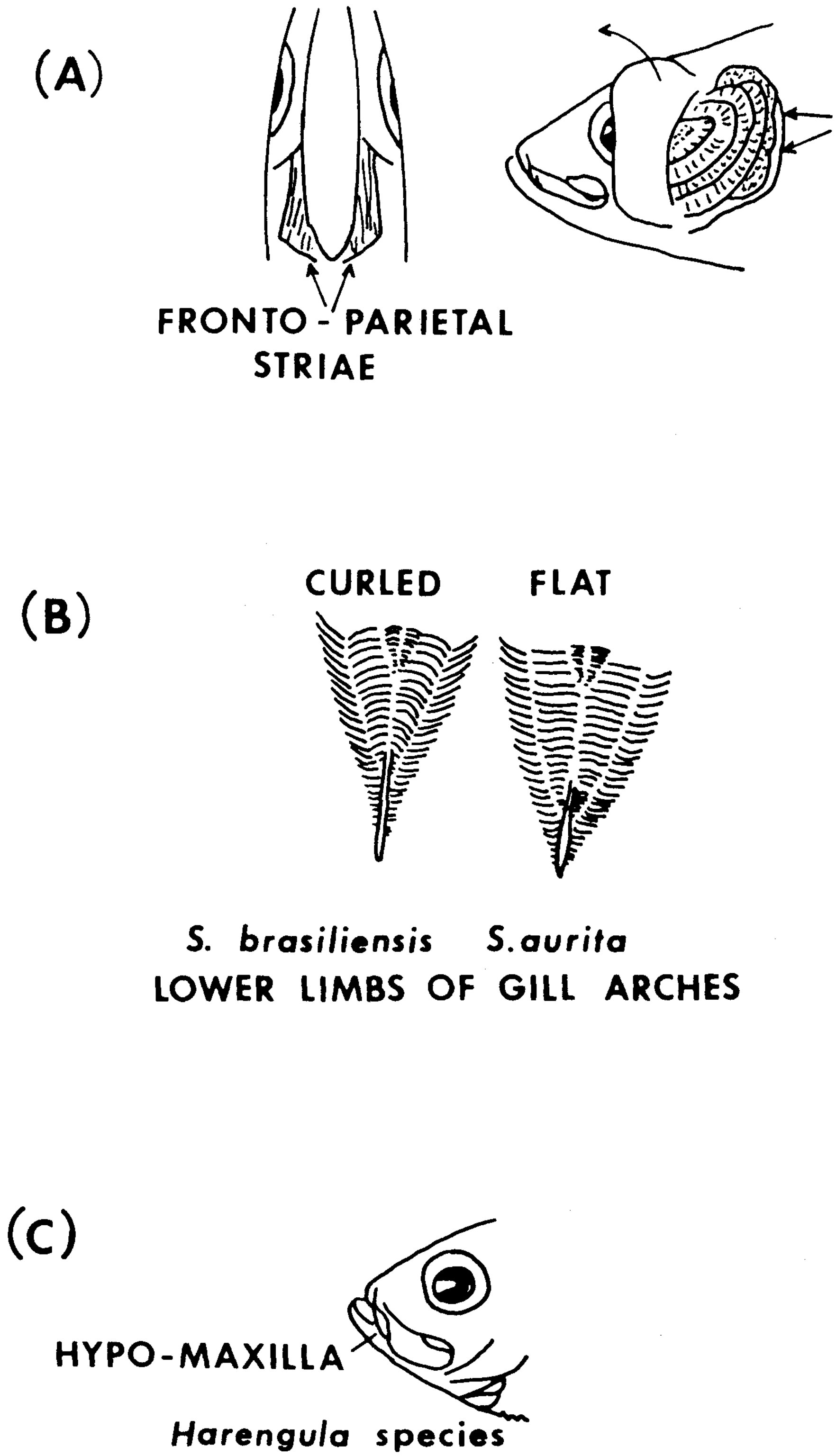


Figure 2. Identification characters for S. aurita (Fischer 1978).

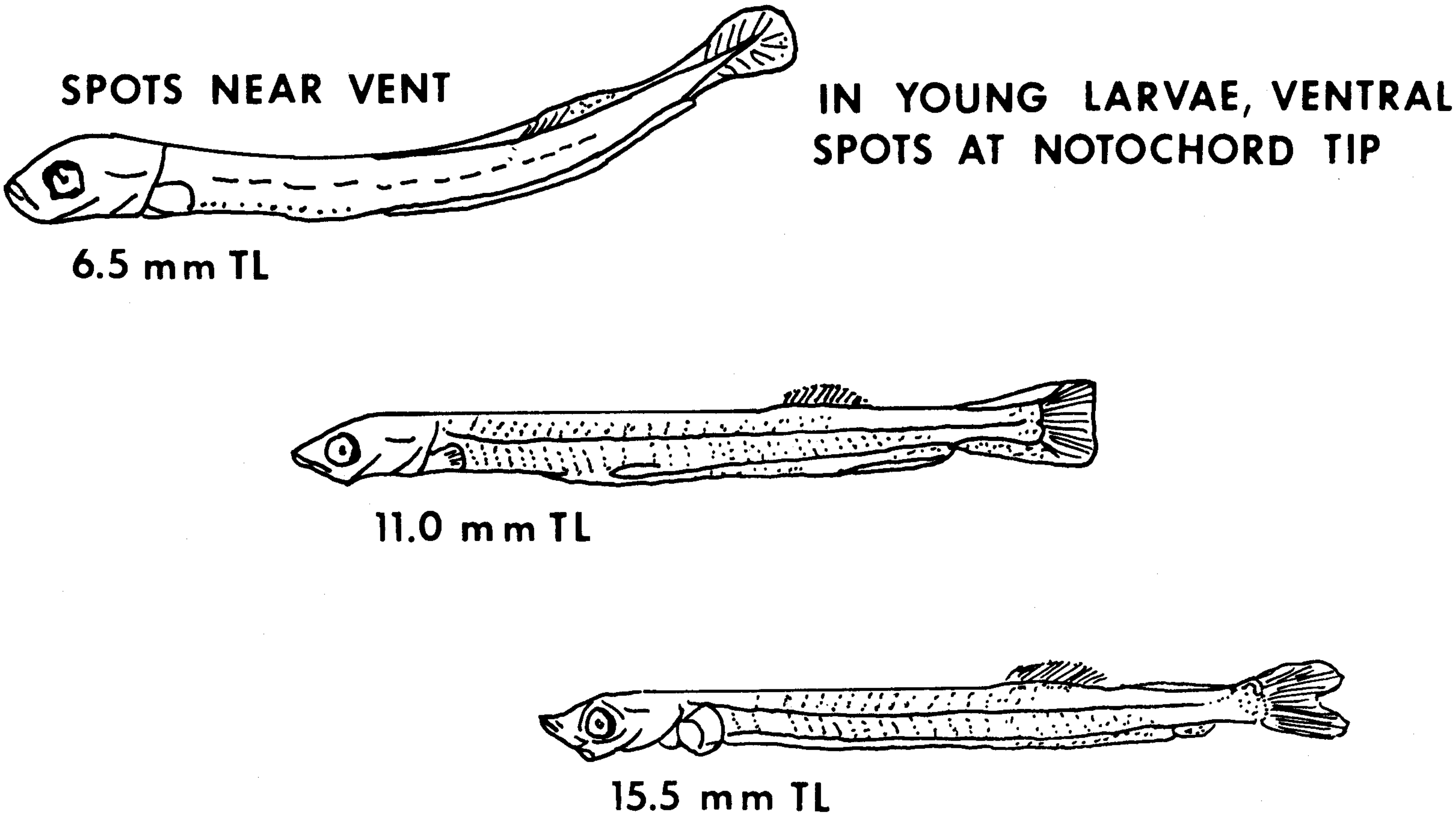


Figure 3. Larval S. aurita as illustrated by Fahay (1983).

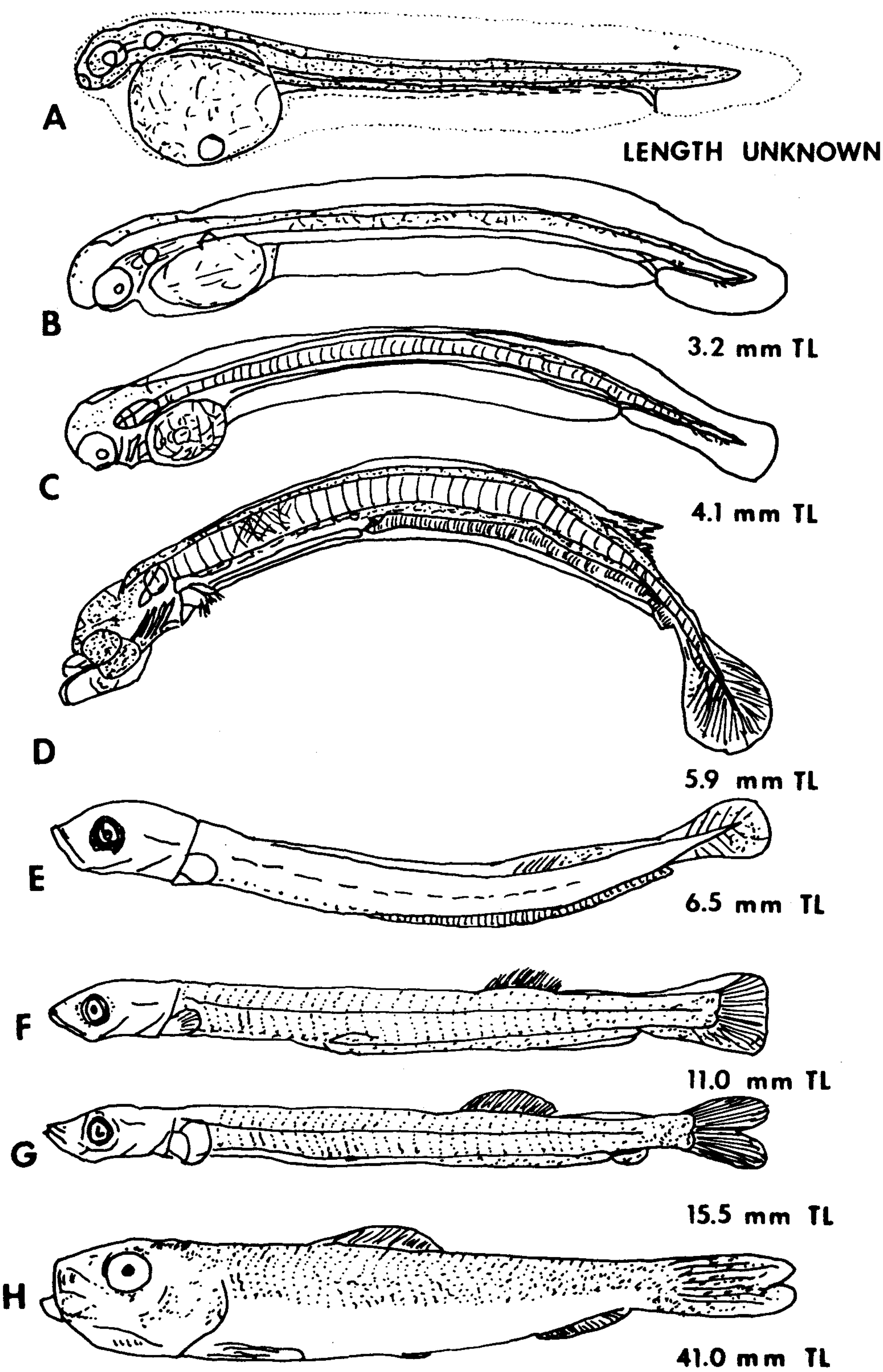


Figure 4. Larval S. aurita as illustrated by Jones et al. (1978).

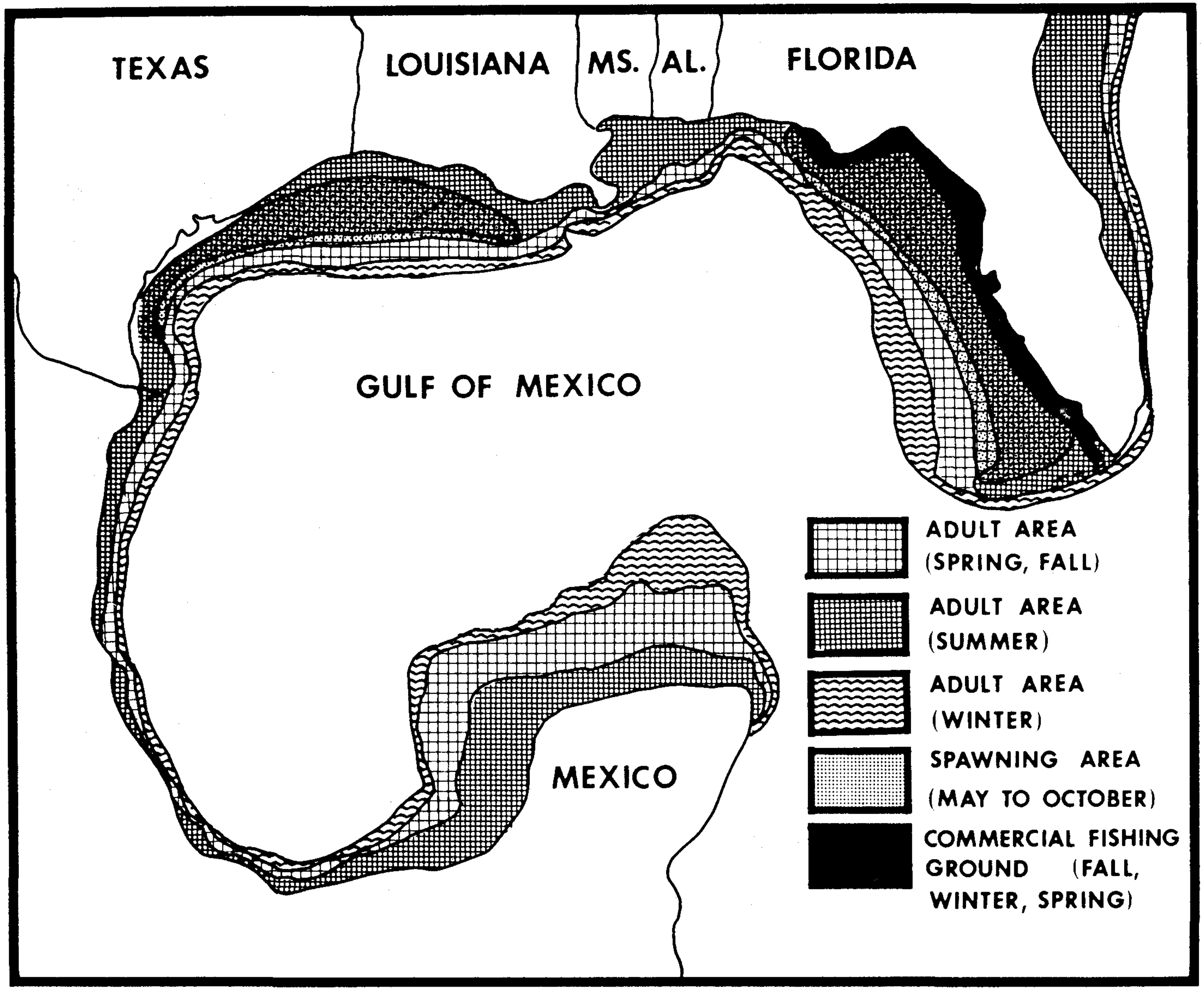


Figure 5. Distribution of *S. aurita* in the Gulf of Mexico and adjacent areas (U.S. Dep. Commer., NOAA 1985).

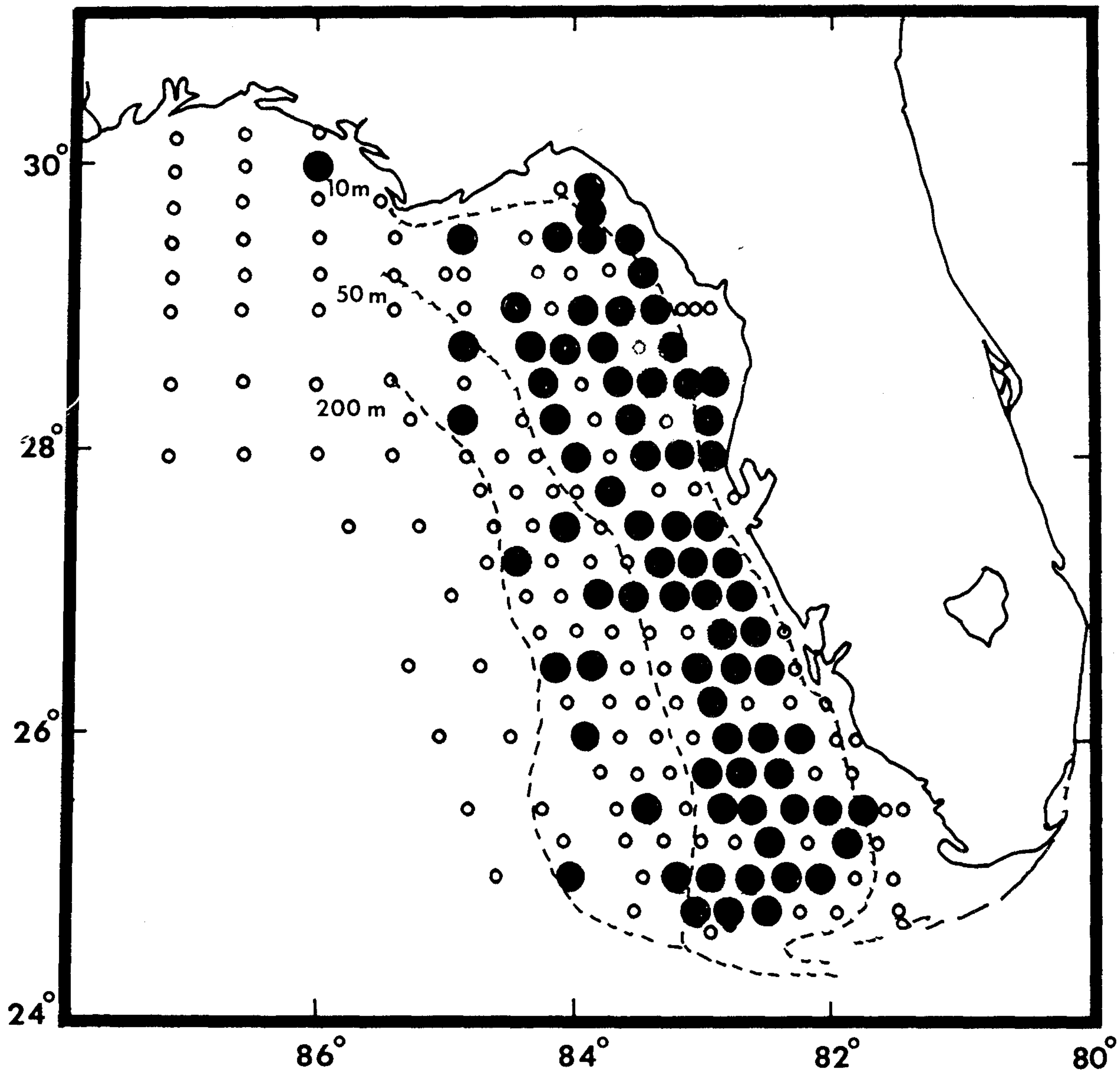


Figure 6. Stations (solid circles) at which <u>Sardinella aurita</u> (= <u>S. anchovia</u>) larvae occurred at least once during 17 cruises to the eastern Gulf of Mexico, 1971-1974 (Houde et al. 1979).

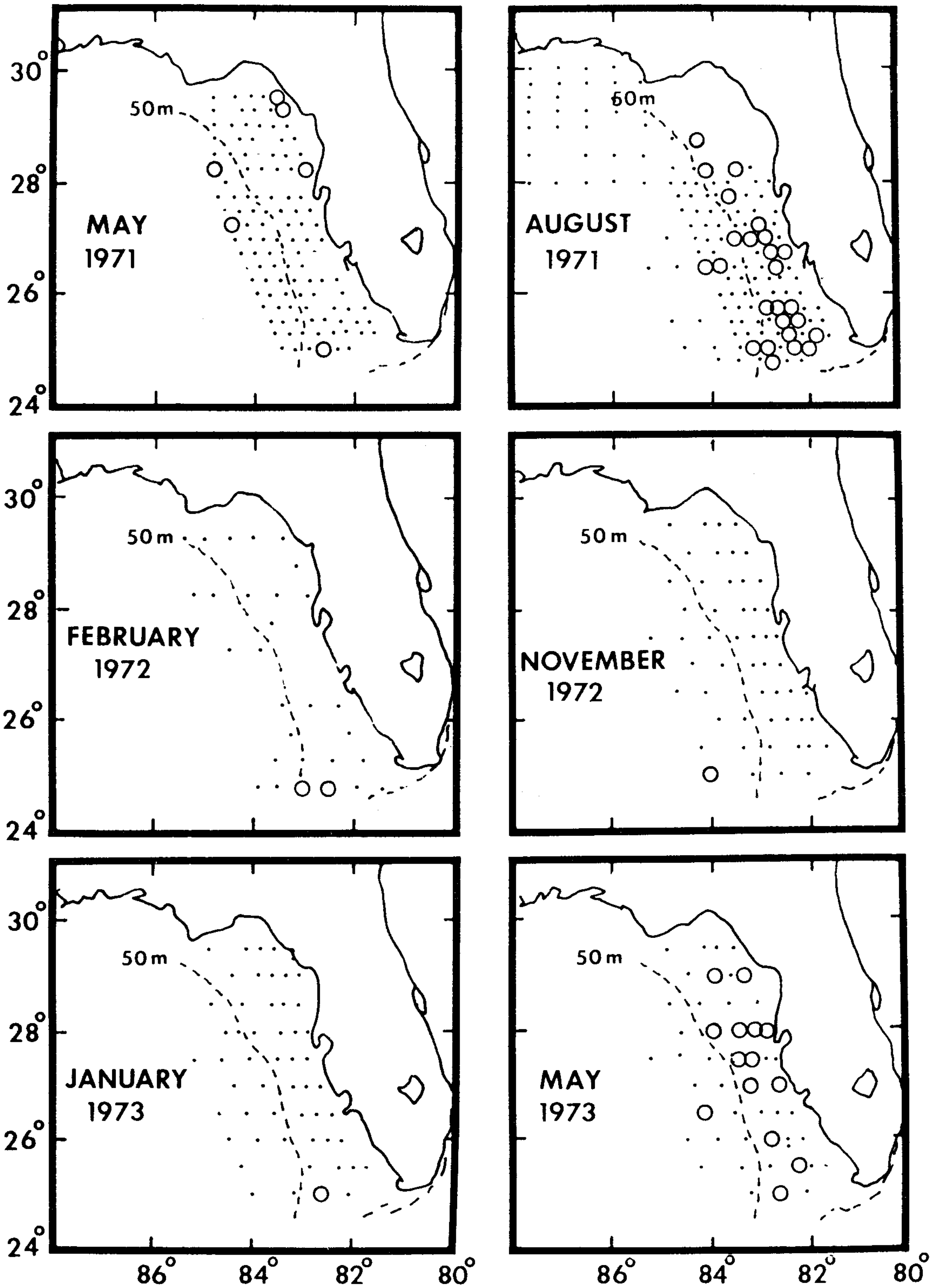


Figure 7. Distribution and abundance of S. aurita larvae in the eastern Gulf of Mexico, 1971-1974. 0 = tows in which larvae occurred (Houde et al. 1979).

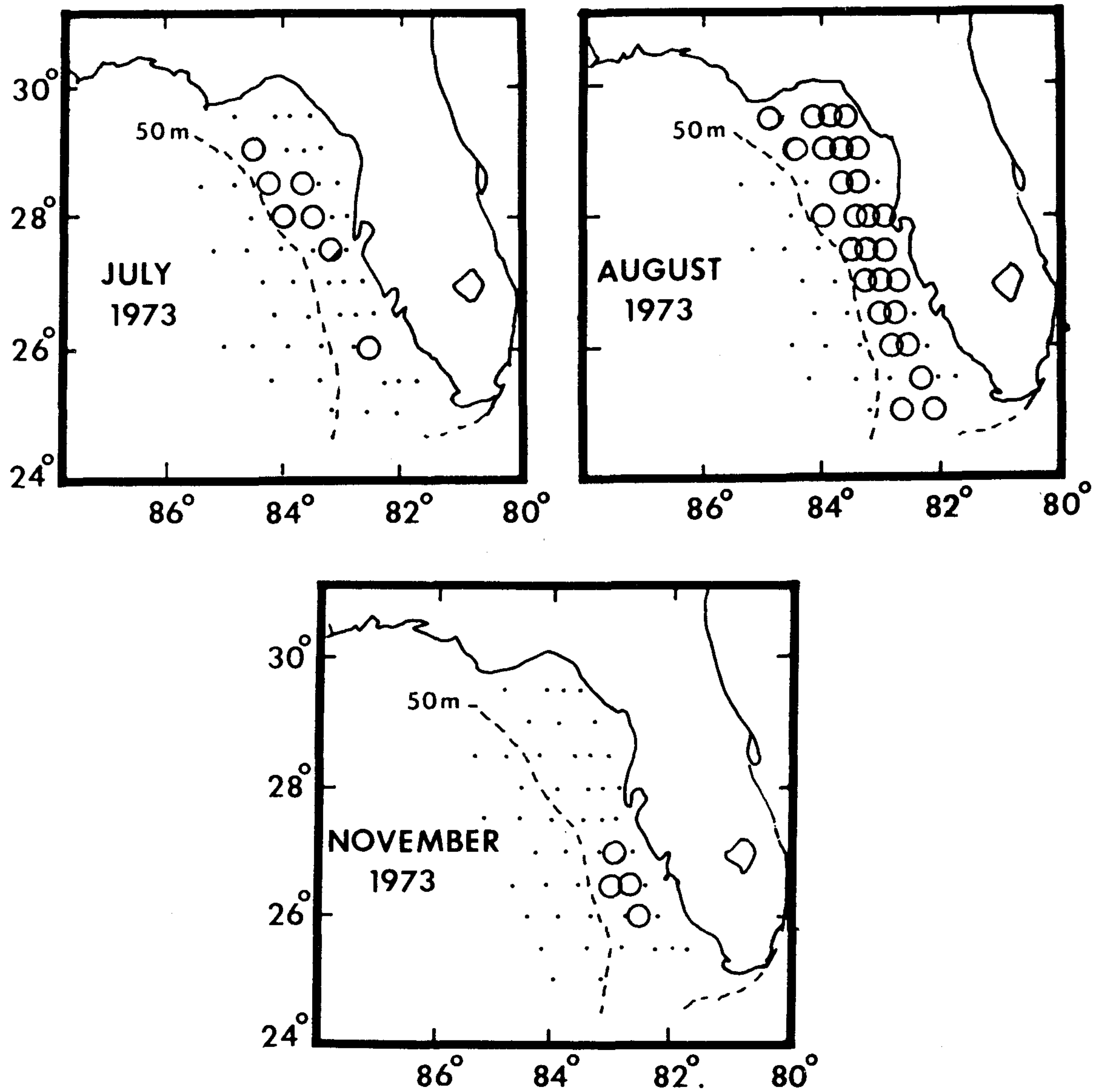


Figure 7. (Continued).

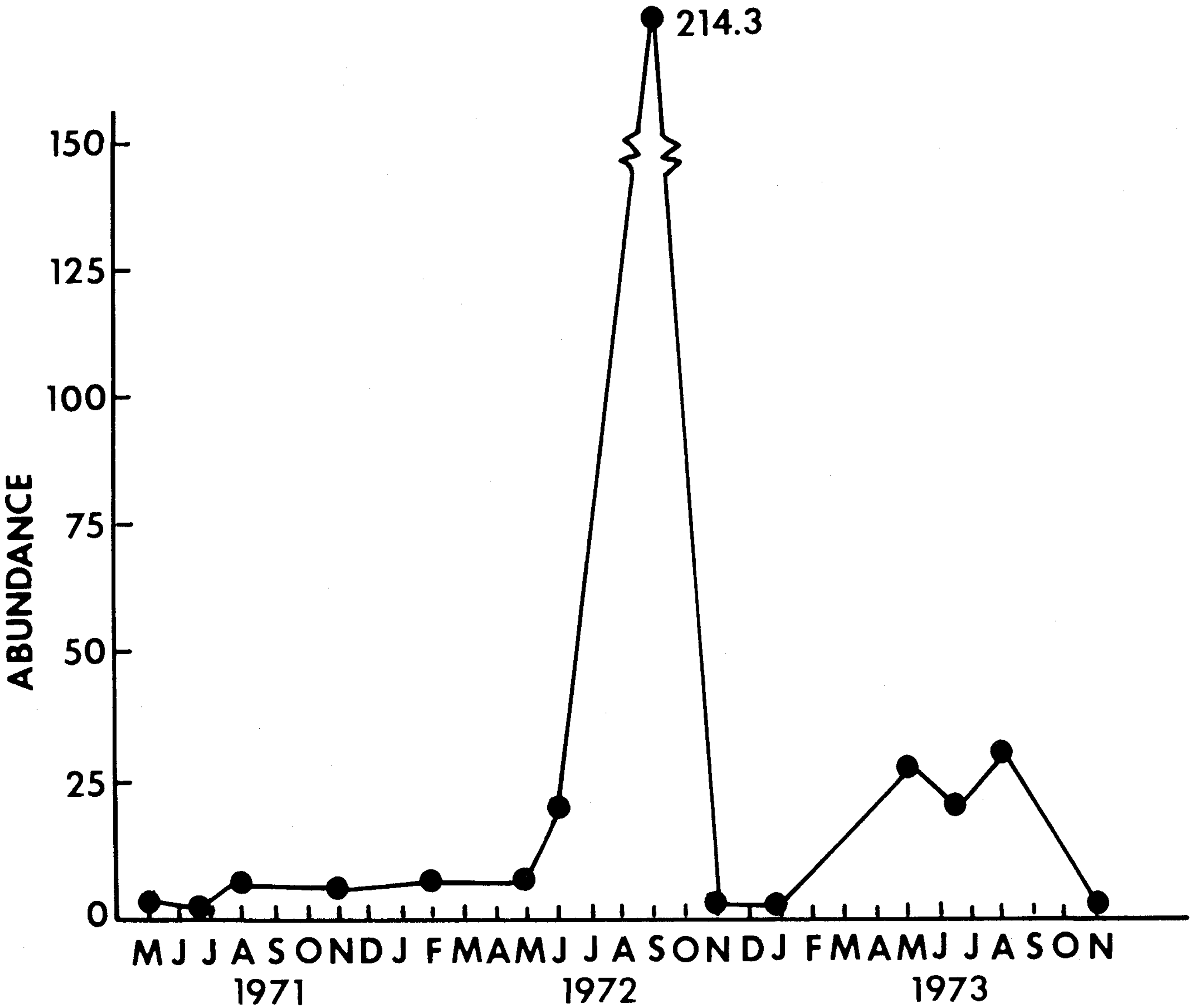


Figure 8. Estimated mean abundance (number under 10 m^2 of sea surface) of S. aurita larvae (Houde et al. 1979).

a

b

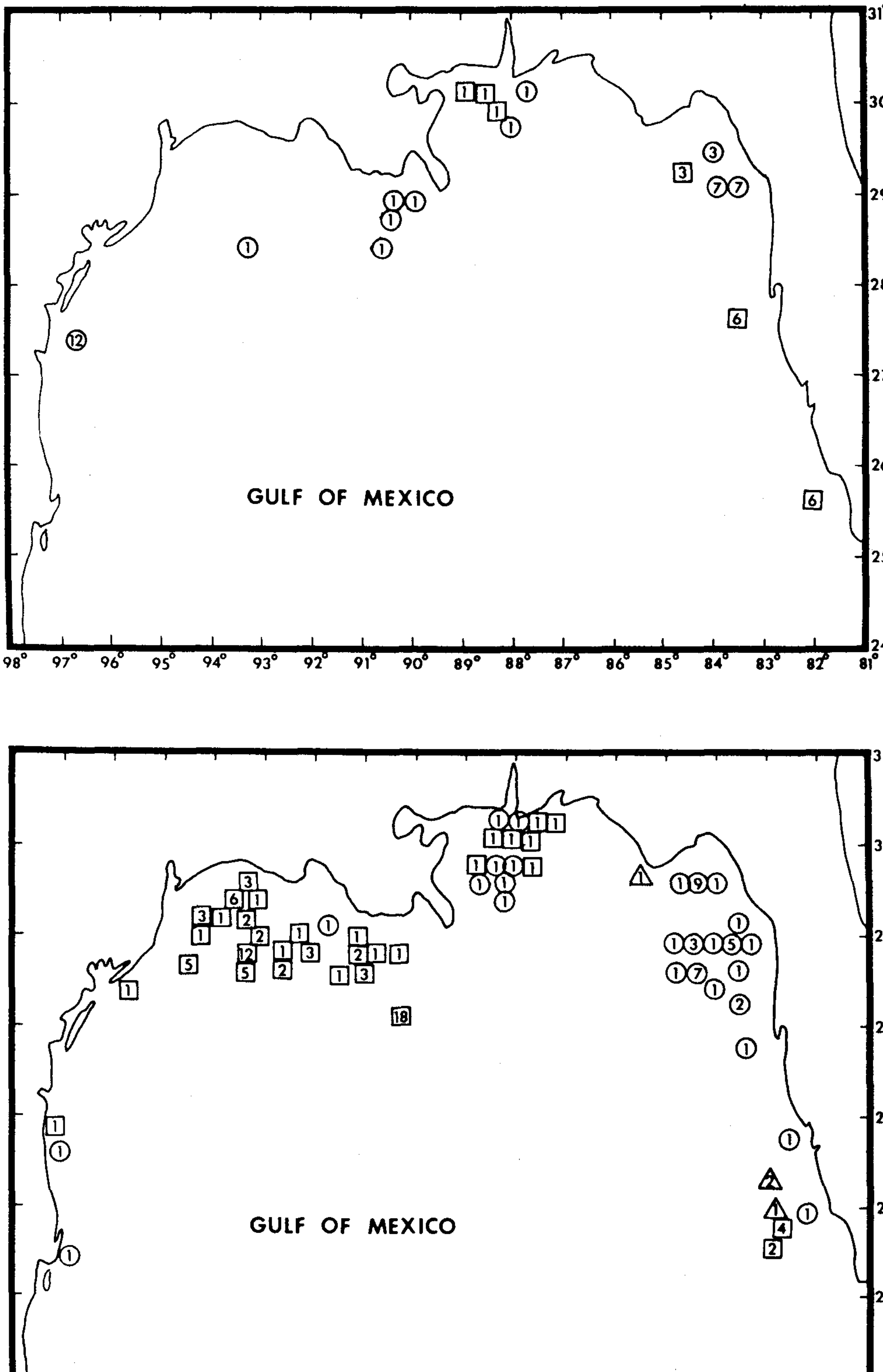


Figure 9. Catch rates for exploratory fishing for S. aurita, 1950 to 1985. a) Fall-winter (0=fall; □=winter) b) spring-summer (0=spring; □=summer). Also, 0 and □ are bottom trawls; △ are mid-water trawls. Numbers are pounds/hr. Information from Frederick Minkler, NMFS, Pascagoula Laboratory, Miss., May 1985.

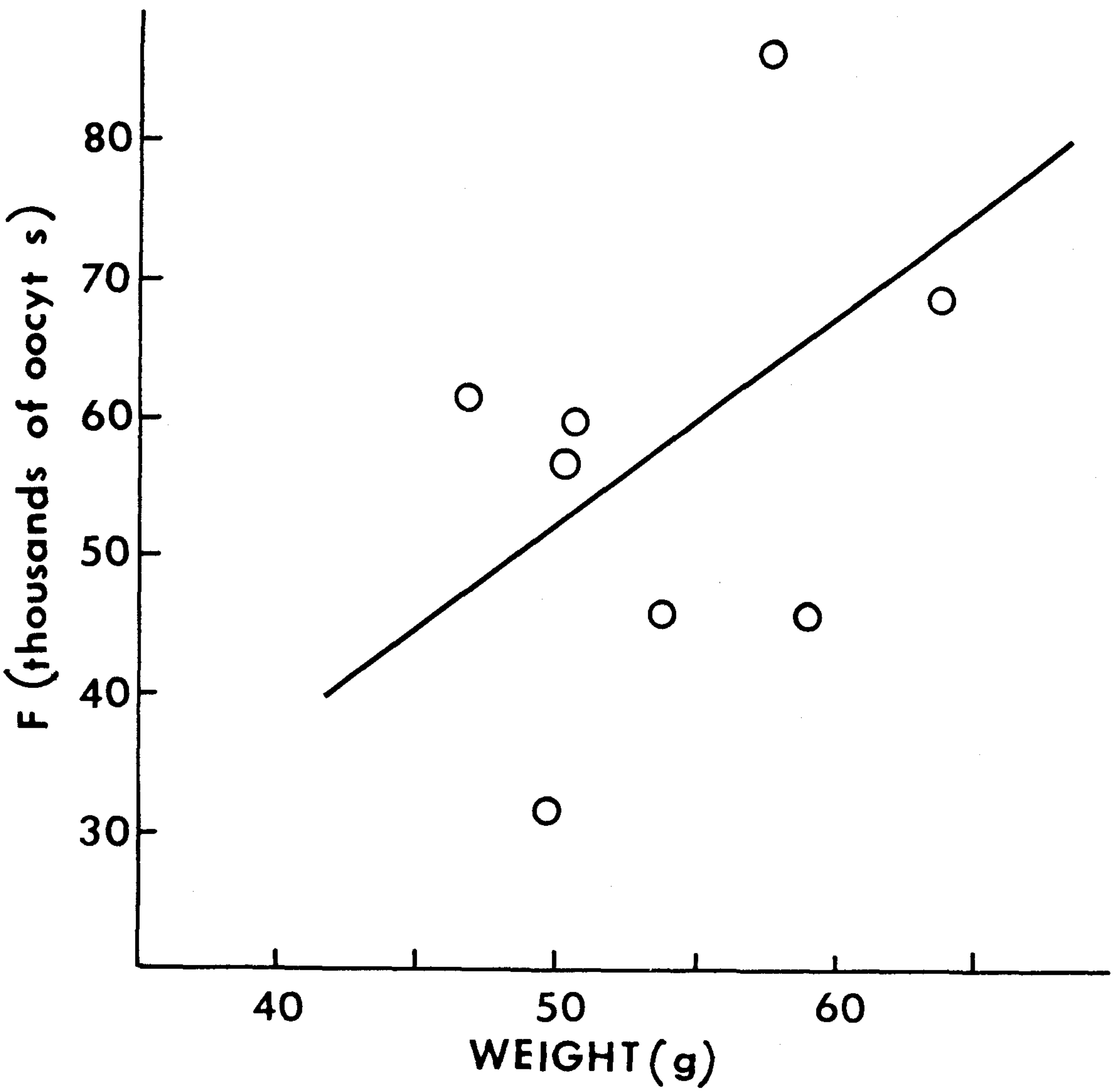


Figure 10. Regression of fecundity, F, on weight for *S. aurita* (Martinez 1972).

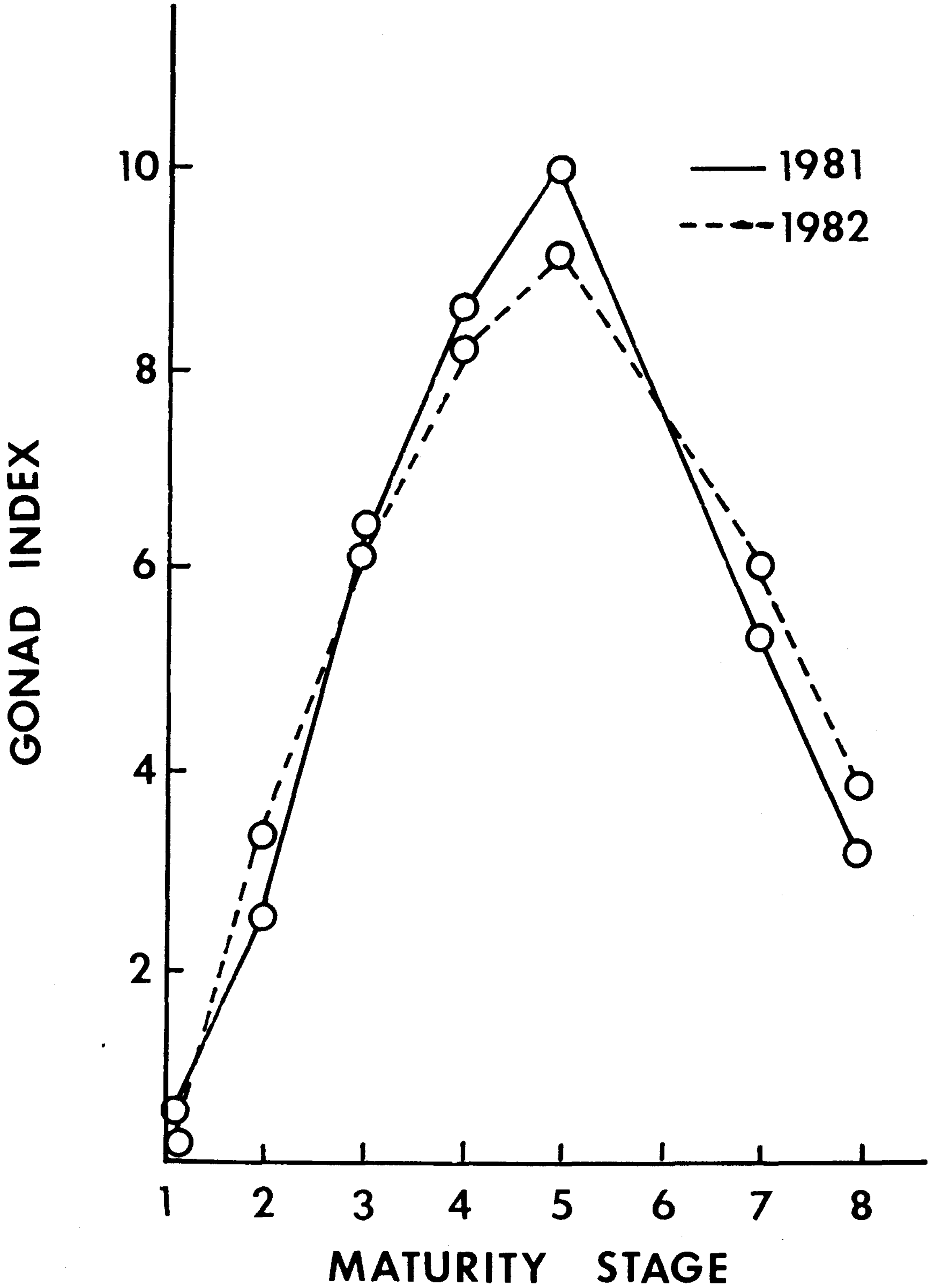


Figure 11. The relationship between the gonad index and the stage of maturity measured in 400 females of *S. aurita*. Maturity stage (6) was not plotted due to insufficient data (Grall 1984).

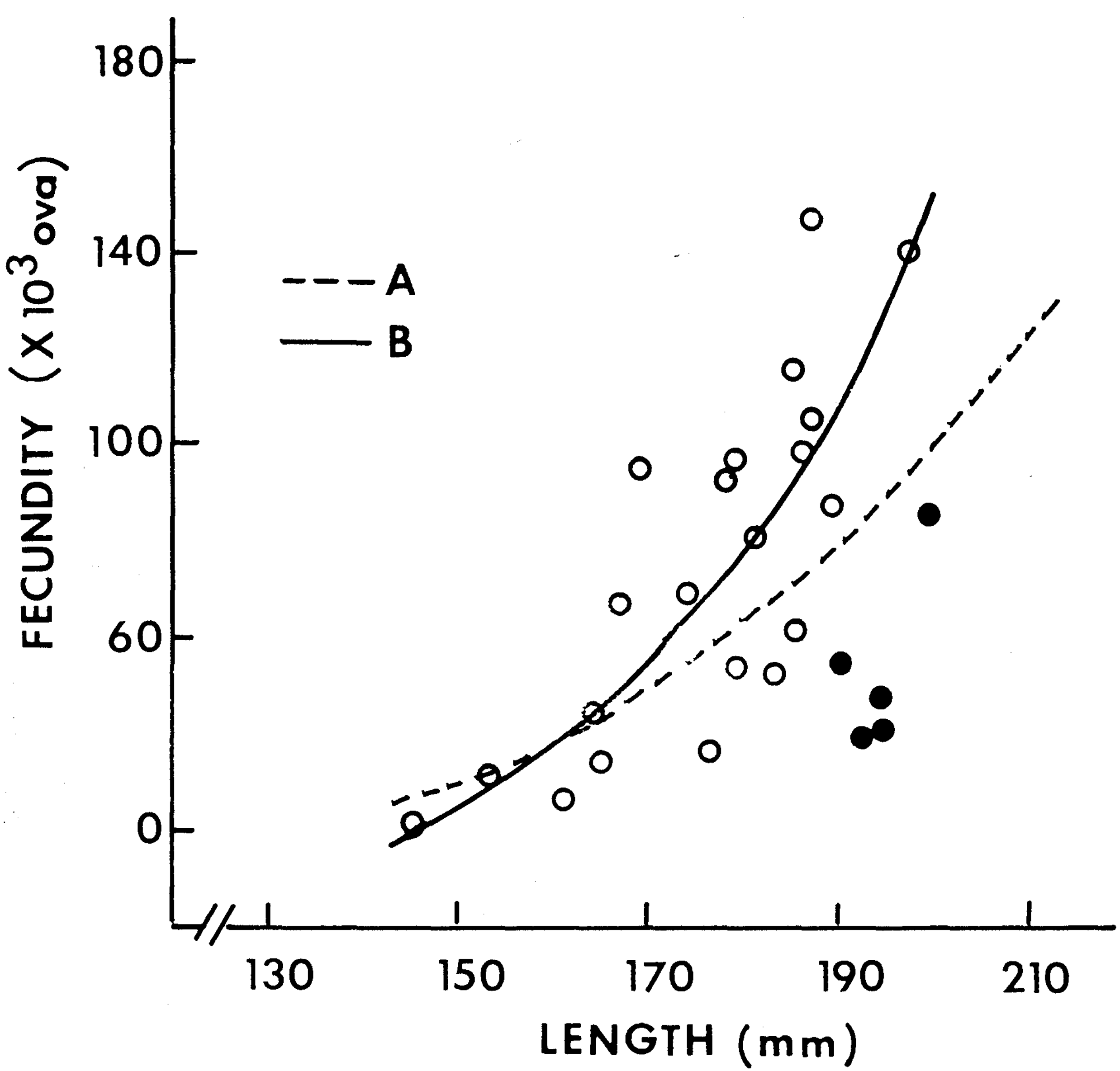


Figure 12. Graphic relationship between fecundity and fork length of 26 female S. aurita from the west coast of Florida. The dashed line (A) was fitted to all data points including females which were longer than 190 mm (indicated by solid dots). The solid line (B) was fitted to the open dots which represented females less than 190 mm (sic) in length (Grall 1984).

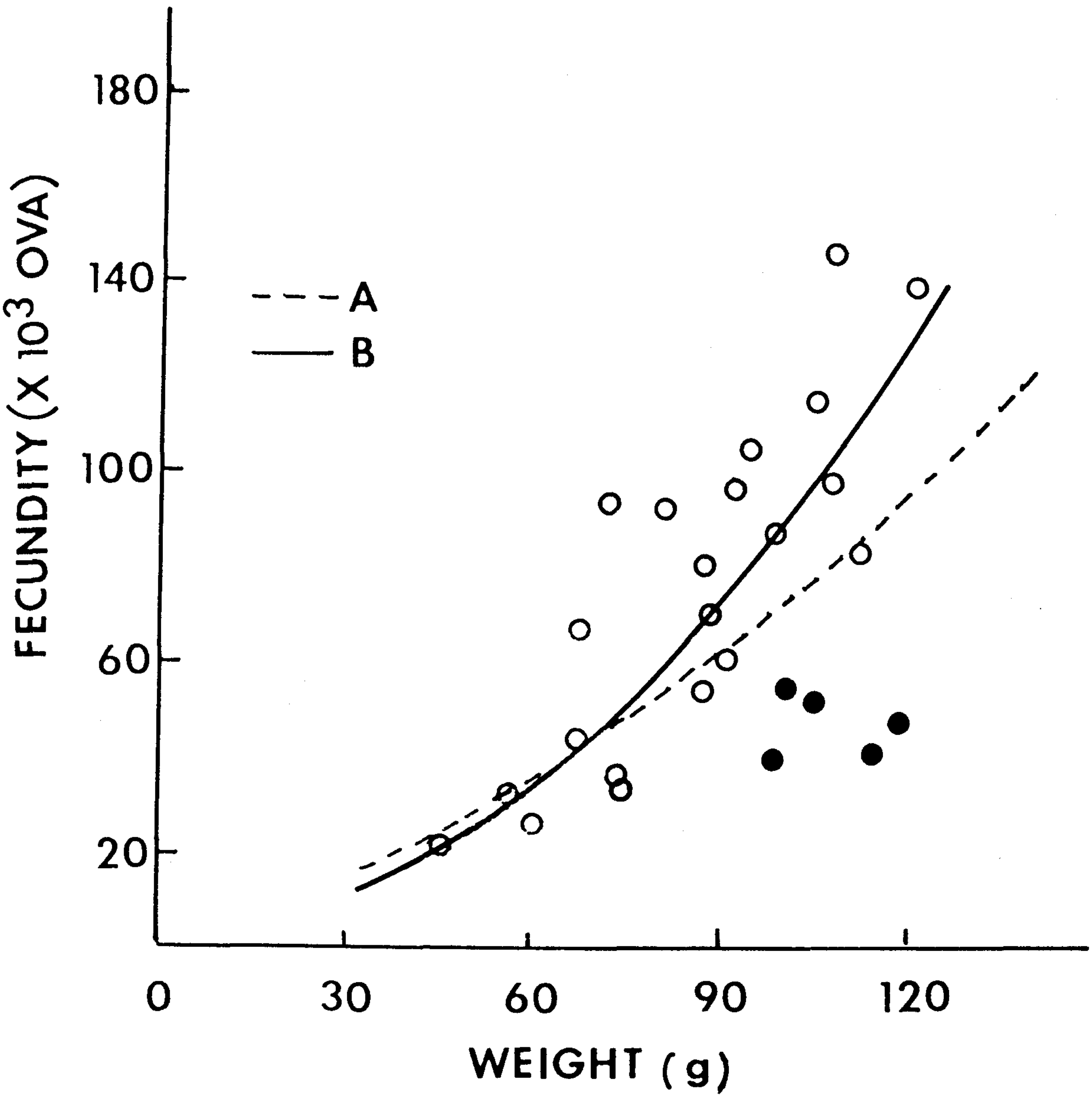


Figure 13. Graphic relationship between fecundity and weight of 26 female *S. aurita* from the west coast of Florida. The dashed line (A) was fitted to all data points including females which were longer than 190 mm (indicated by solid dots). The solid line (B) was fitted to the open dots which represented females less than 190 mm in length (Grall 1984).

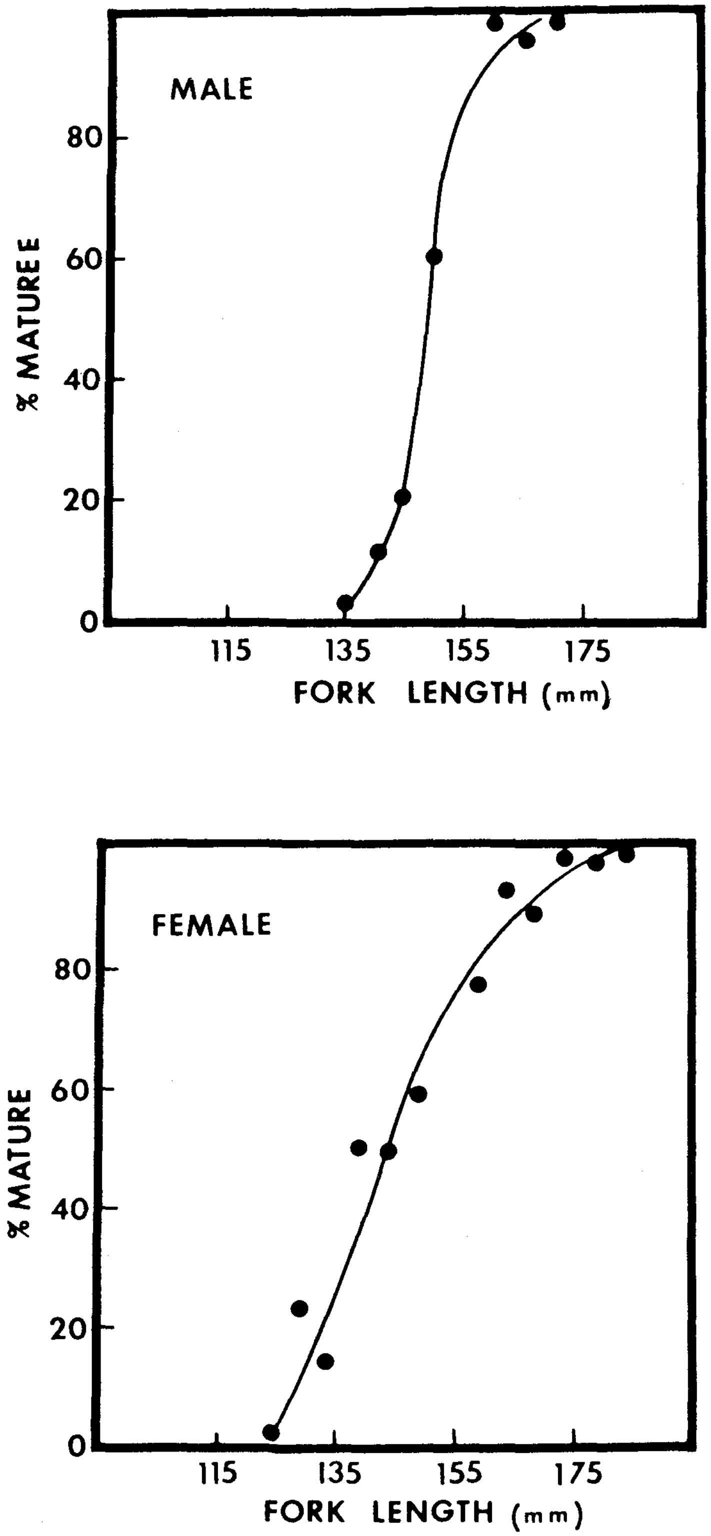


Figure 14. Frequency of mature S. aurita by fork length (Grall 1984).

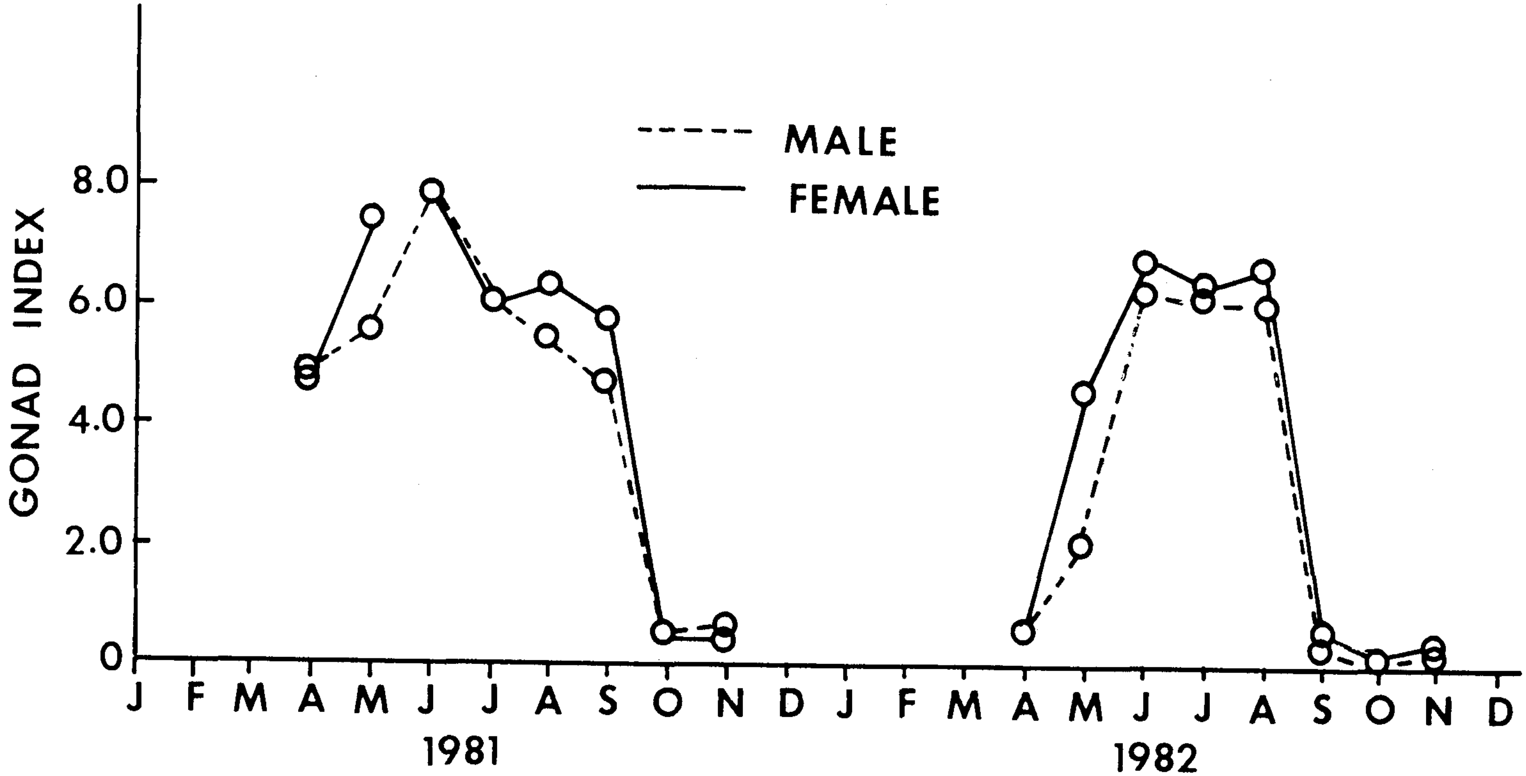


Figure 15. Mean gonad index by month for male and female S. aurita during 1981-1982 (Grall 1984).

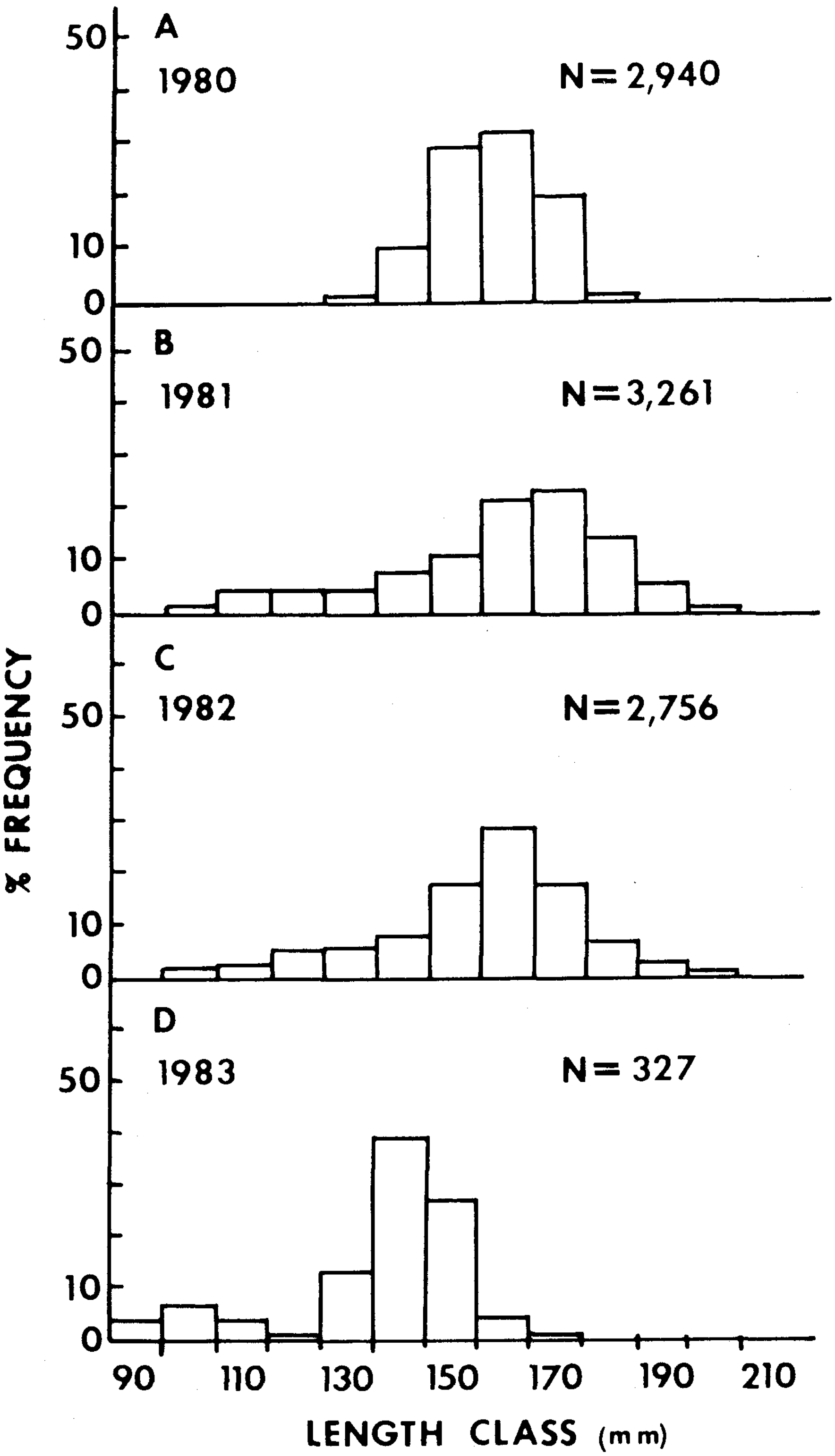
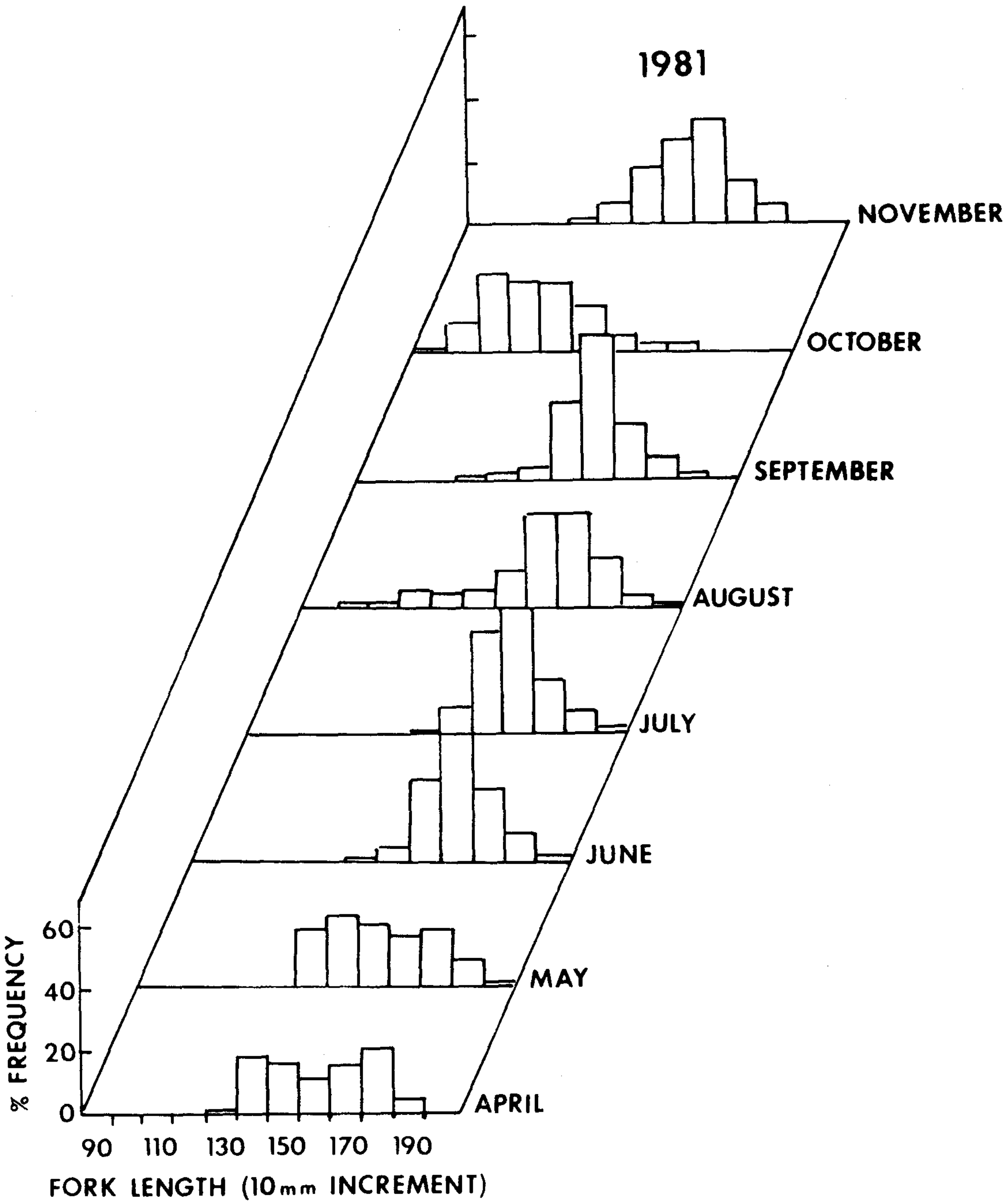
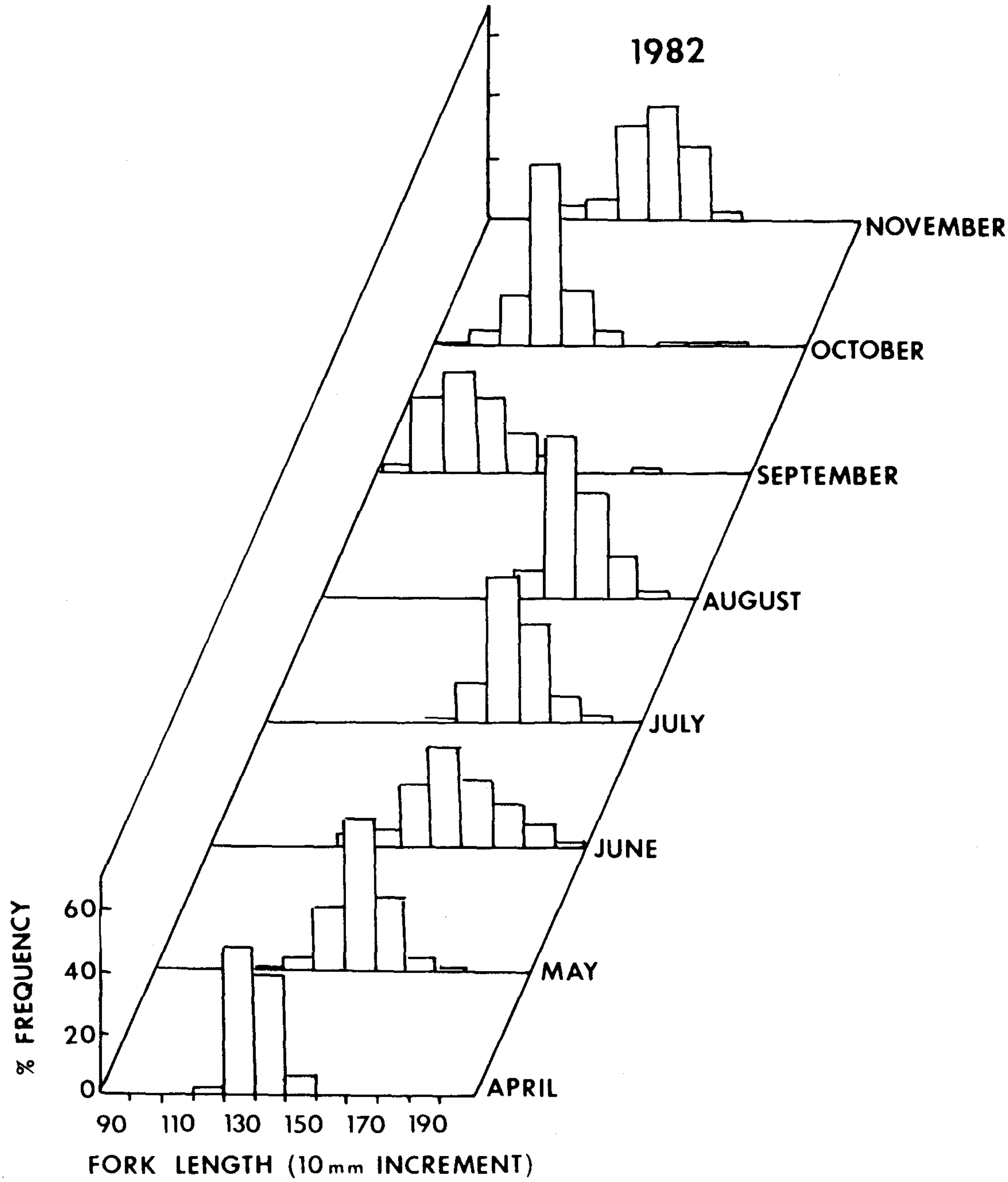


Figure 16. Annual length frequency of S. aurita for years 1980-1982. Distributions (A), (B) and (C) represent samples from the west coast of Florida and (D) represents samples from the east coast of Florida (Grall 1984).



17a. Monthly length frequencies of *S. aurita* collected from the west coast of Florida during 1981 (Grall 1984).



17b. Monthly length frequencies of S. aurita collected from the west coast of Florida during 1982 (Grall 1984).

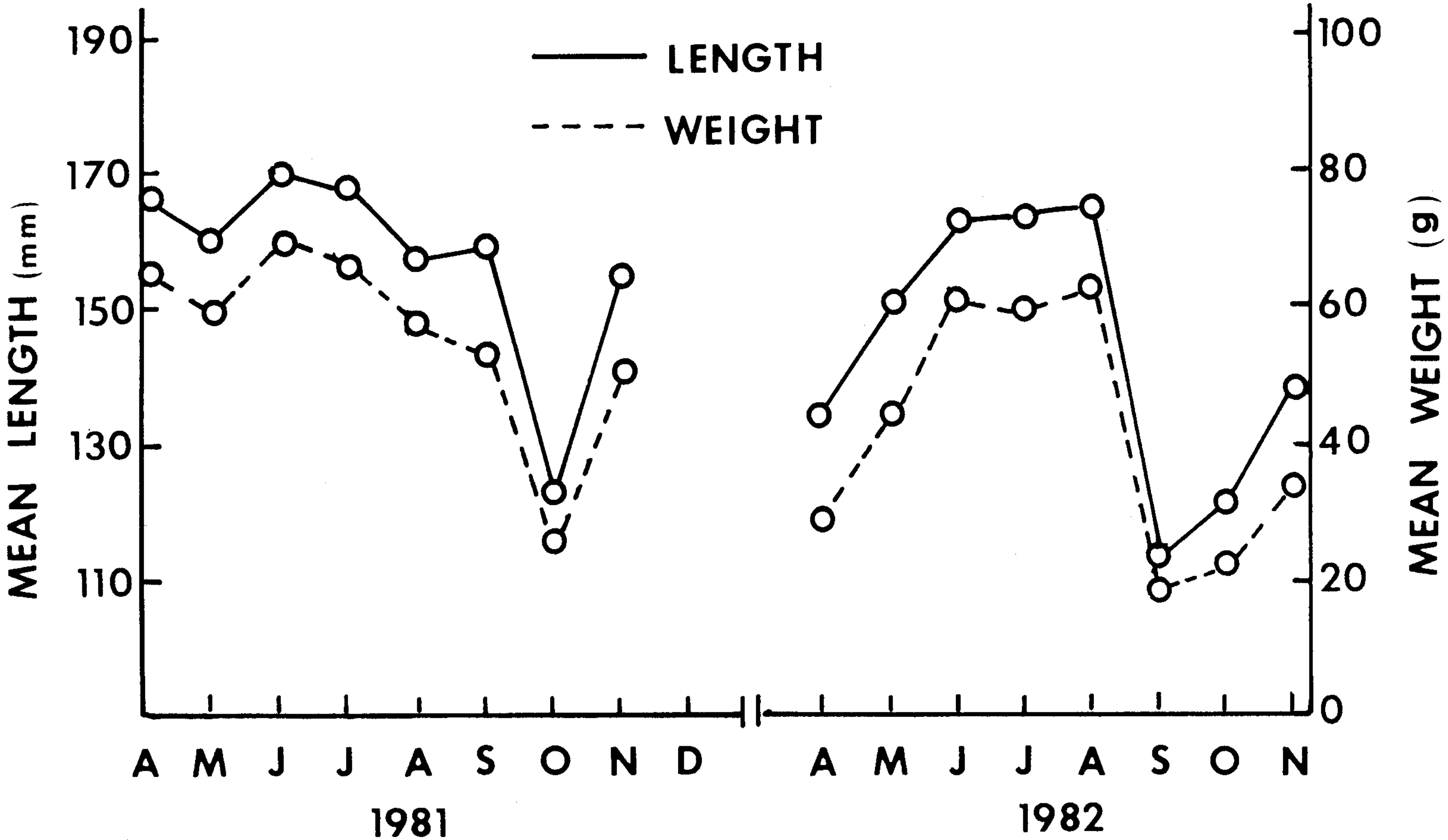


Figure 18. Mean fork length (mm) and weight (g) by month of S. aurita (Grall 1984).

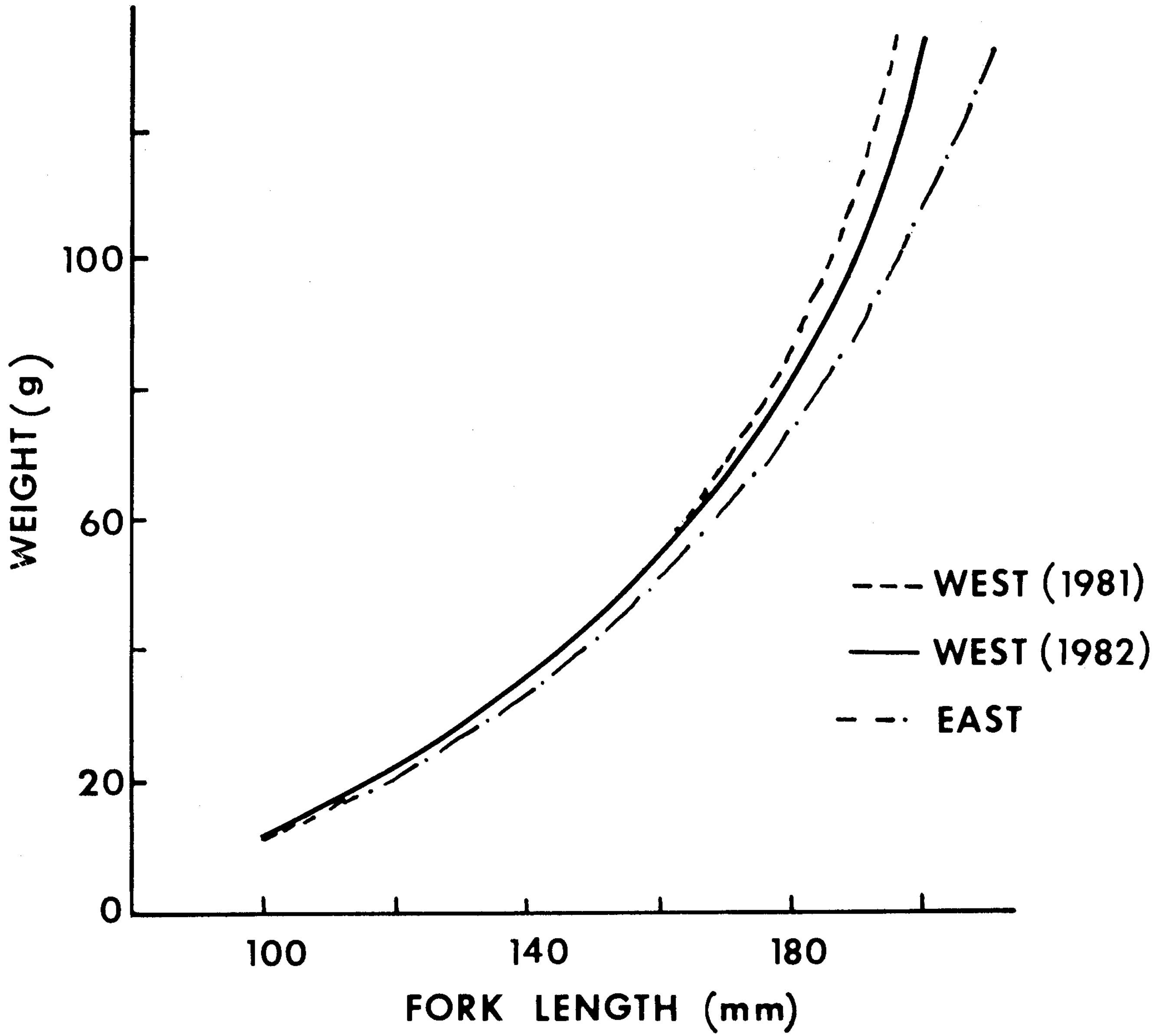


Figure 19. Length-weight relationships of S. aurita from the east and west coasts of Florida (Grall 1984).

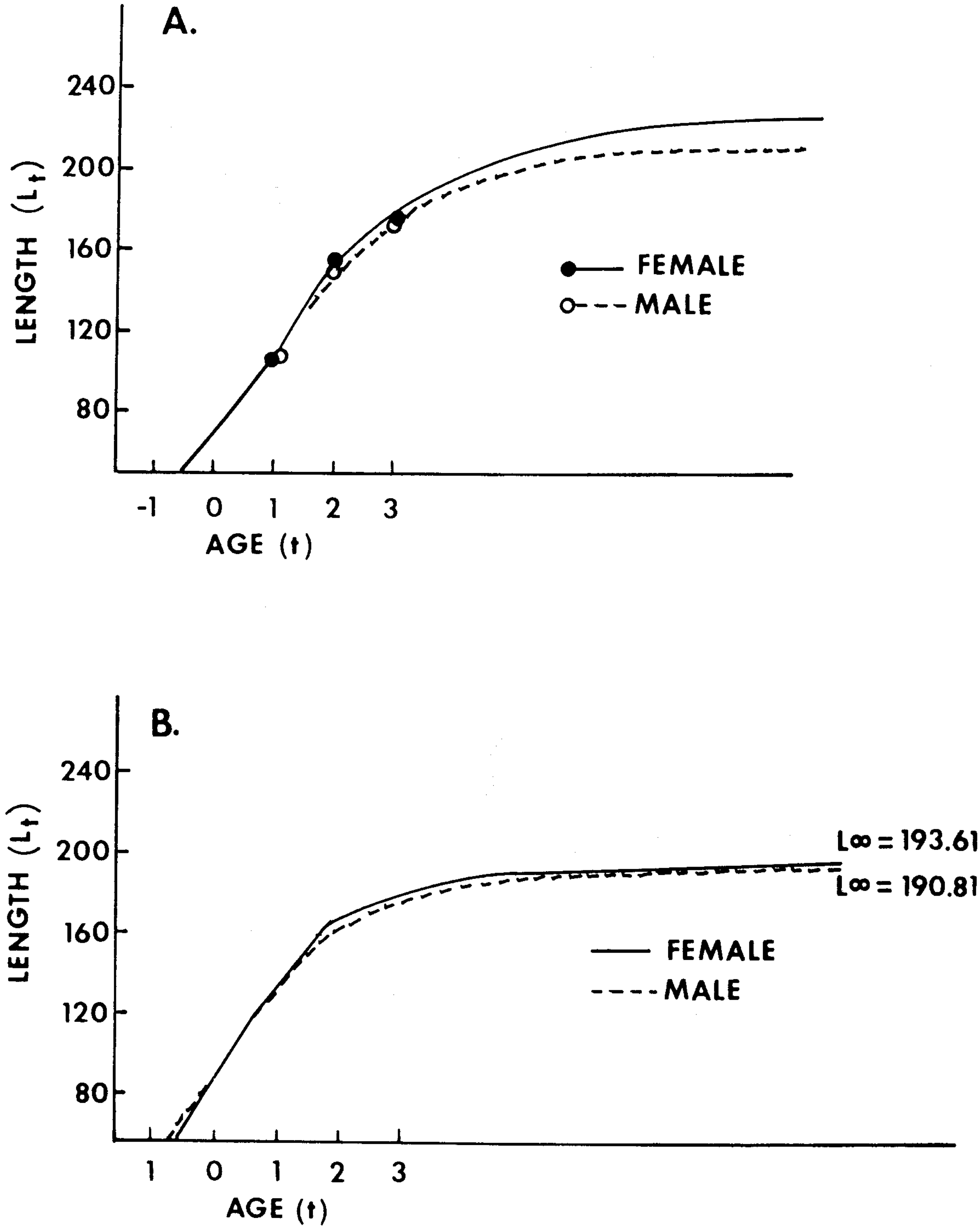


Figure 20. The von Bertalanffy growth curve fitted to age data based on first annulus formation at approximately (A) one year of age or (B) six months of age of S. aurita (Grall 1984).

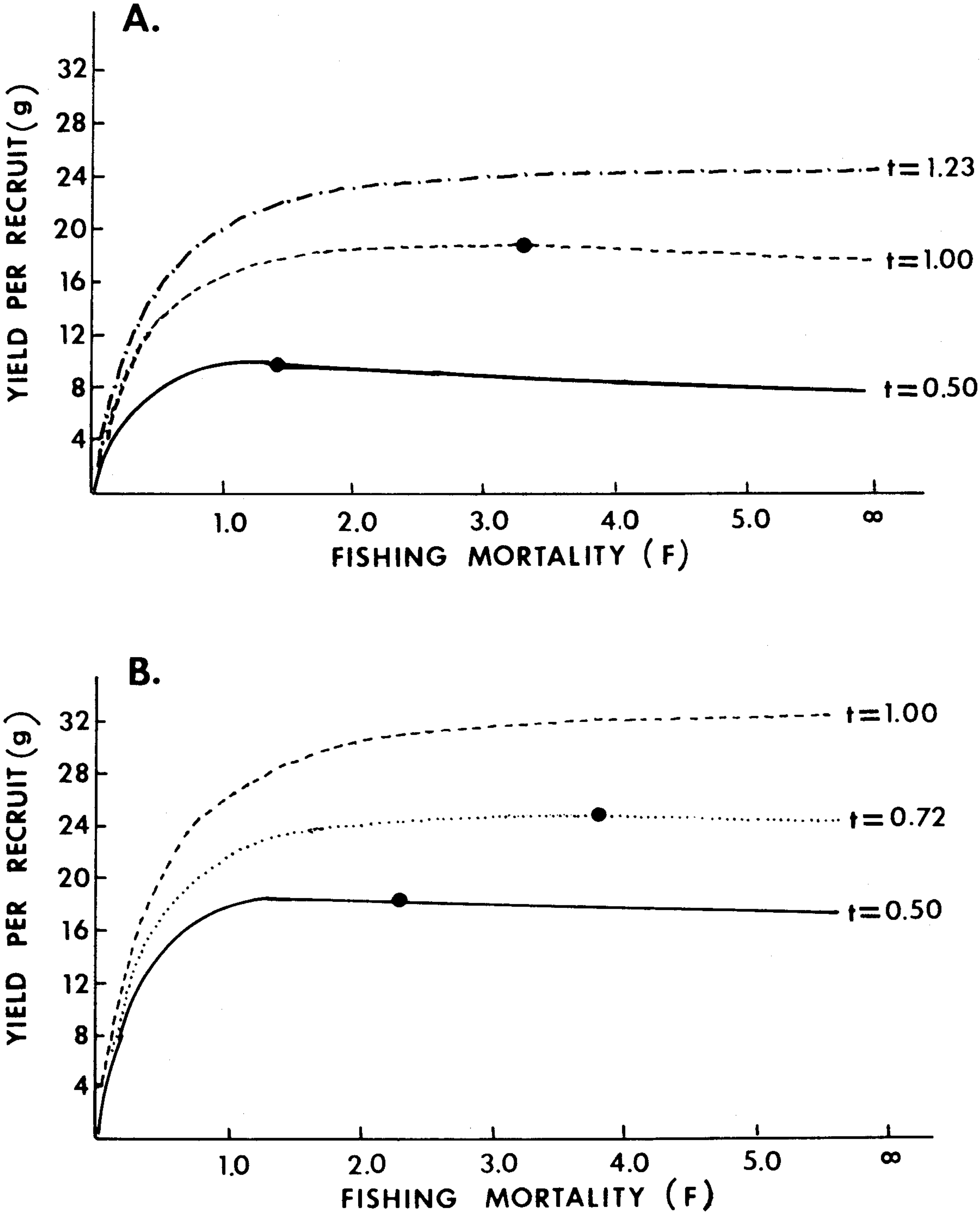


Figure 21. Yield-per-recruit curves assuming several ages at first capture (t) under various fishing mortalities (F) based on approximately first annulus formation at (A) one year of age or (B) six months of age of S. aurita (Grall 1984).

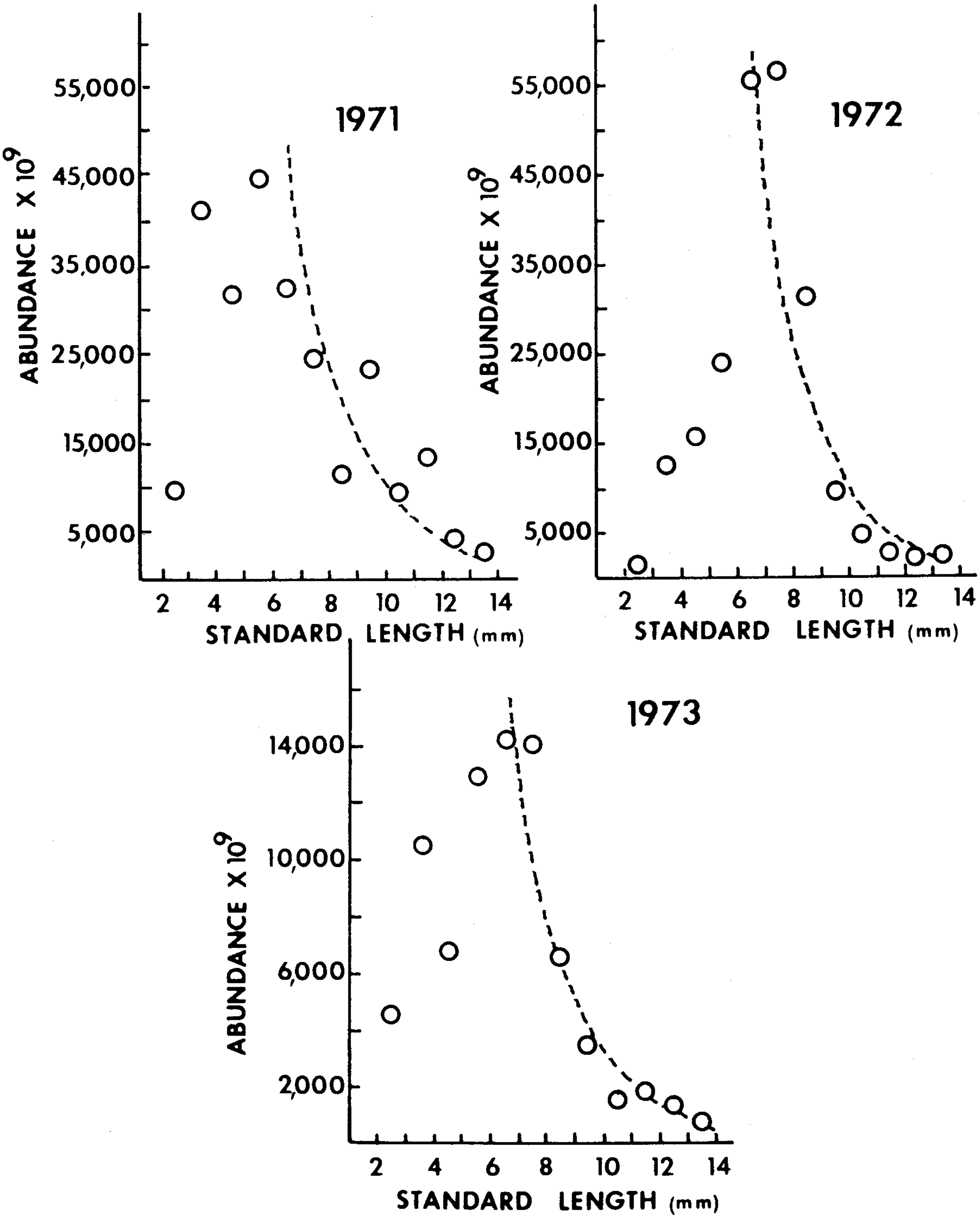


Figure 22. Apparent abundance by length of S. aurita larvae, collected on ichthyoplankton survey cruises to the eastern Gulf of Mexico, 1971, 1972, and 1973 (Houde et al. 1979).

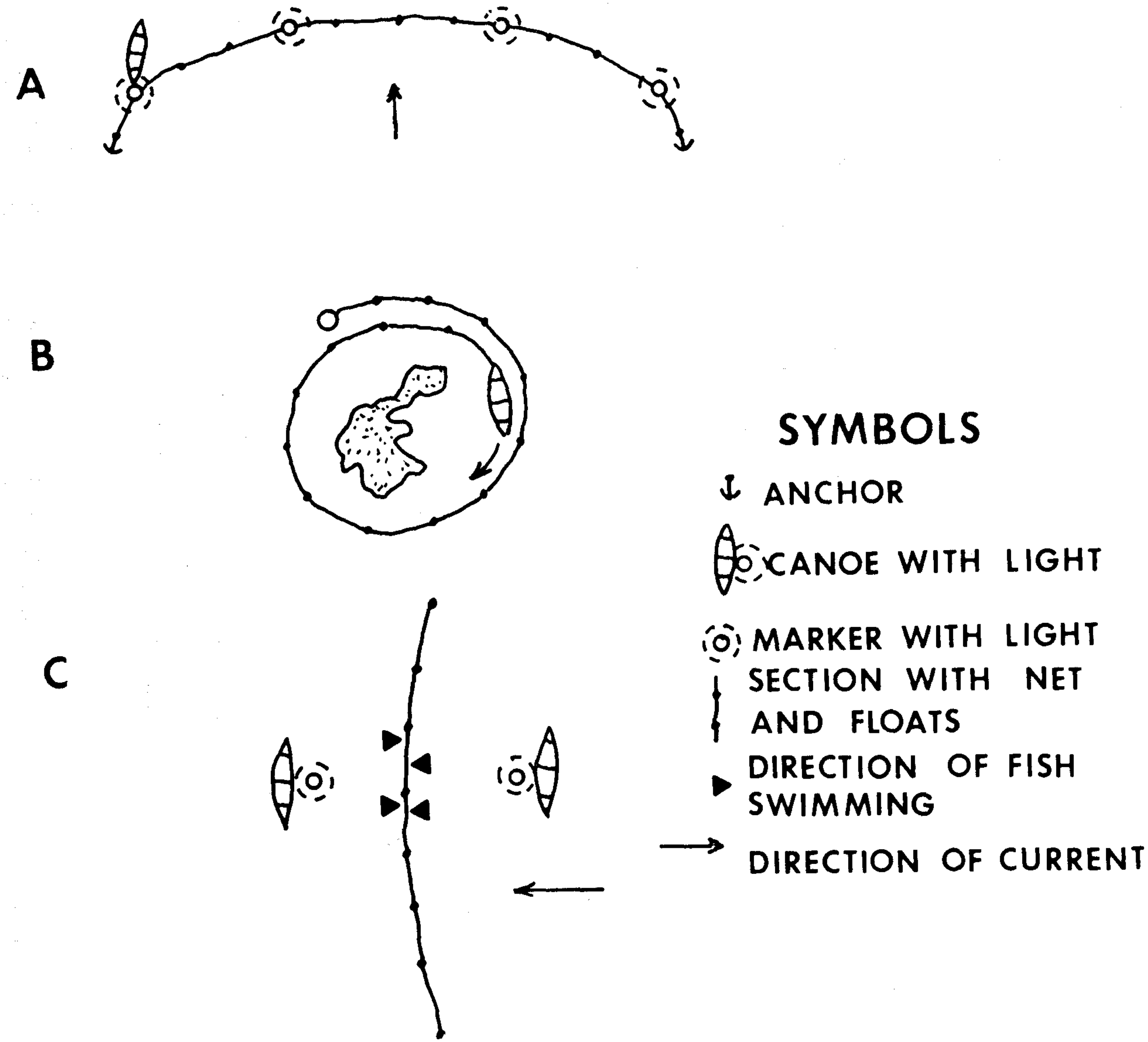


Figure 23. The use of gill nets for catching herring: A. standard surface floating gill net set at night; B. use of gill net to encircle herring during the day; C. use of lights to attract herring to net (Harvey 1982).

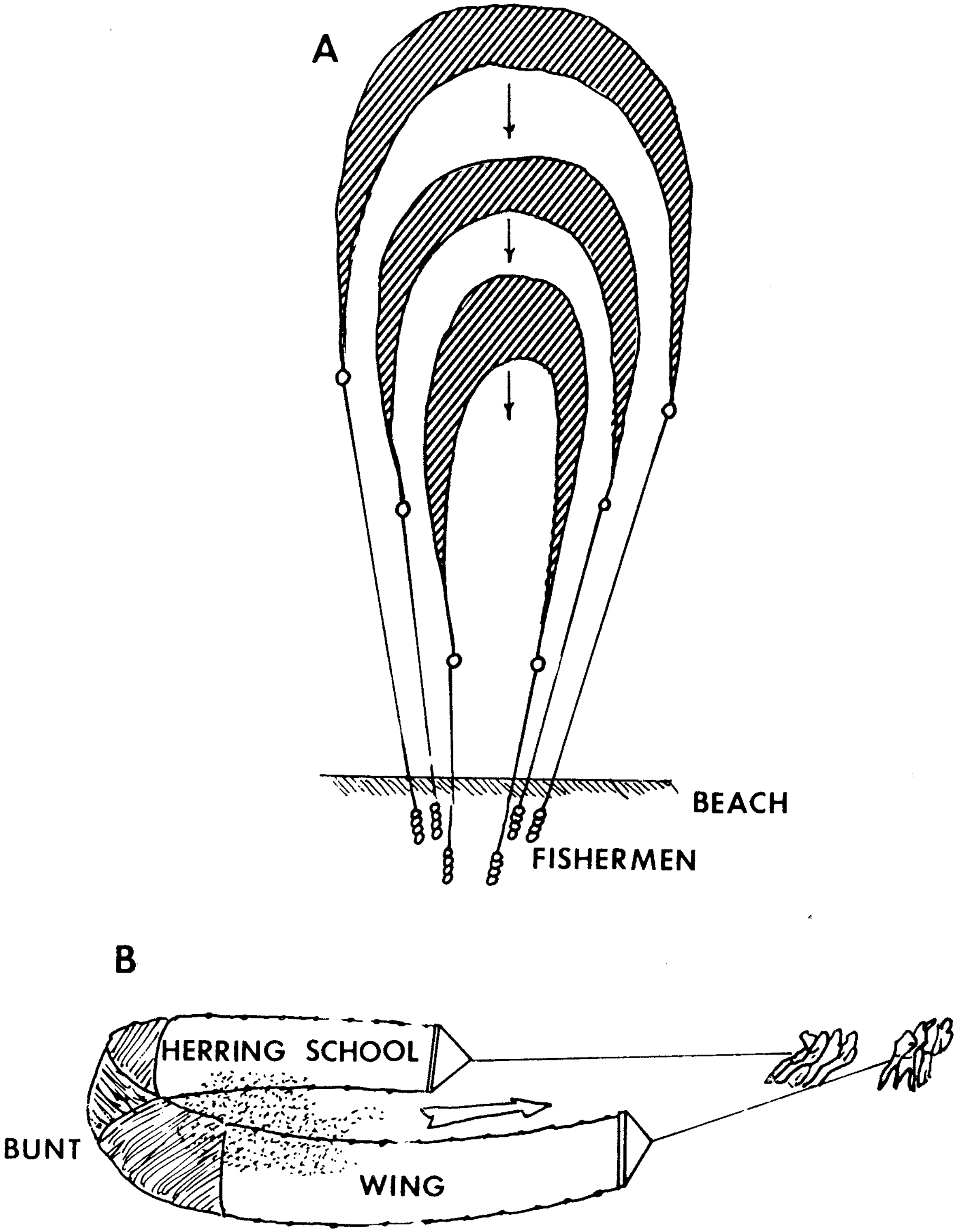


Figure 24. Beach seine in operation: A. plane view; B. lateral view (Harvey 1982).

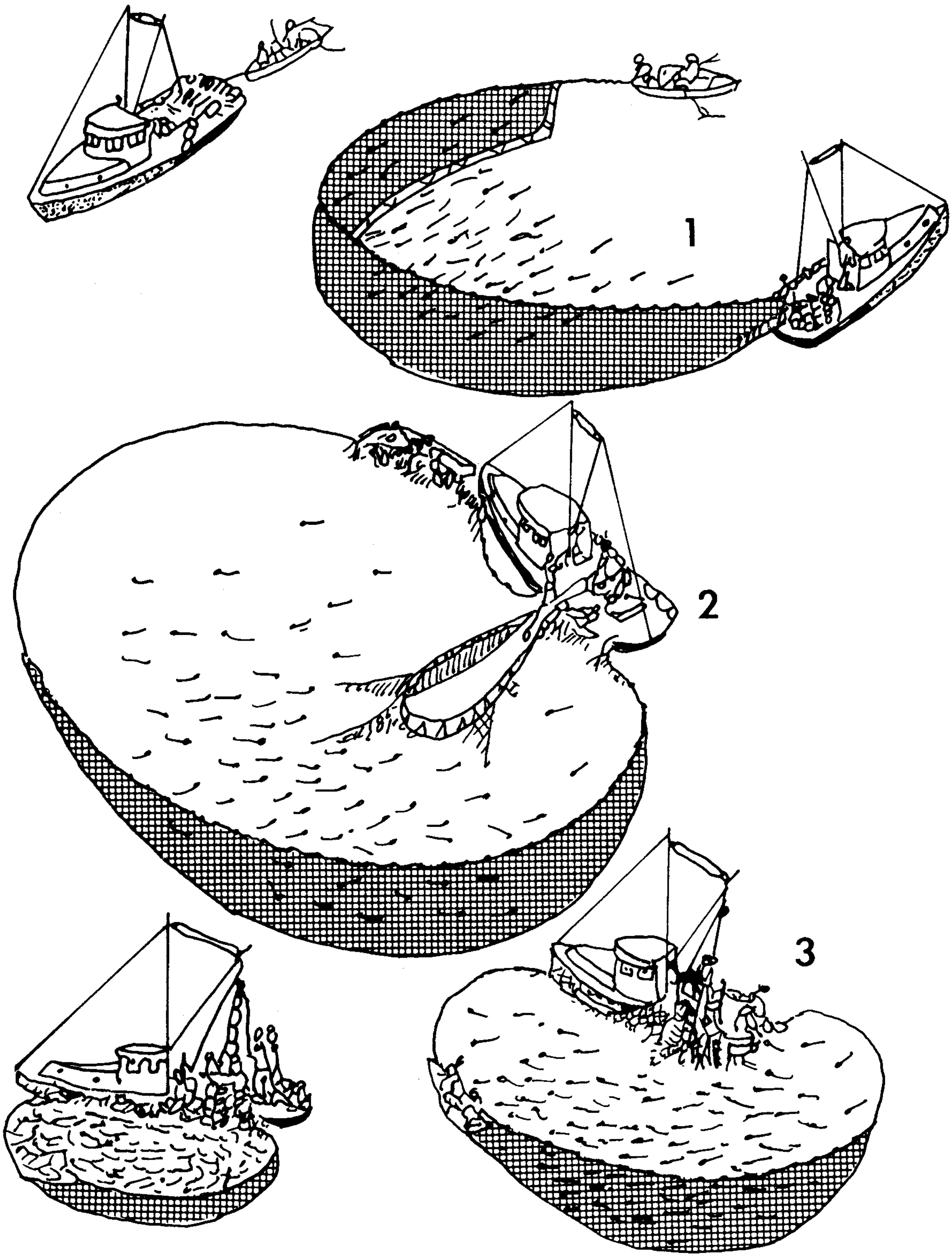


Figure 25. Sequence of purse seine operation: 1) setting the net 2) pursing 3) haul in purse seine rings and leadline (Roithmayr 1983).

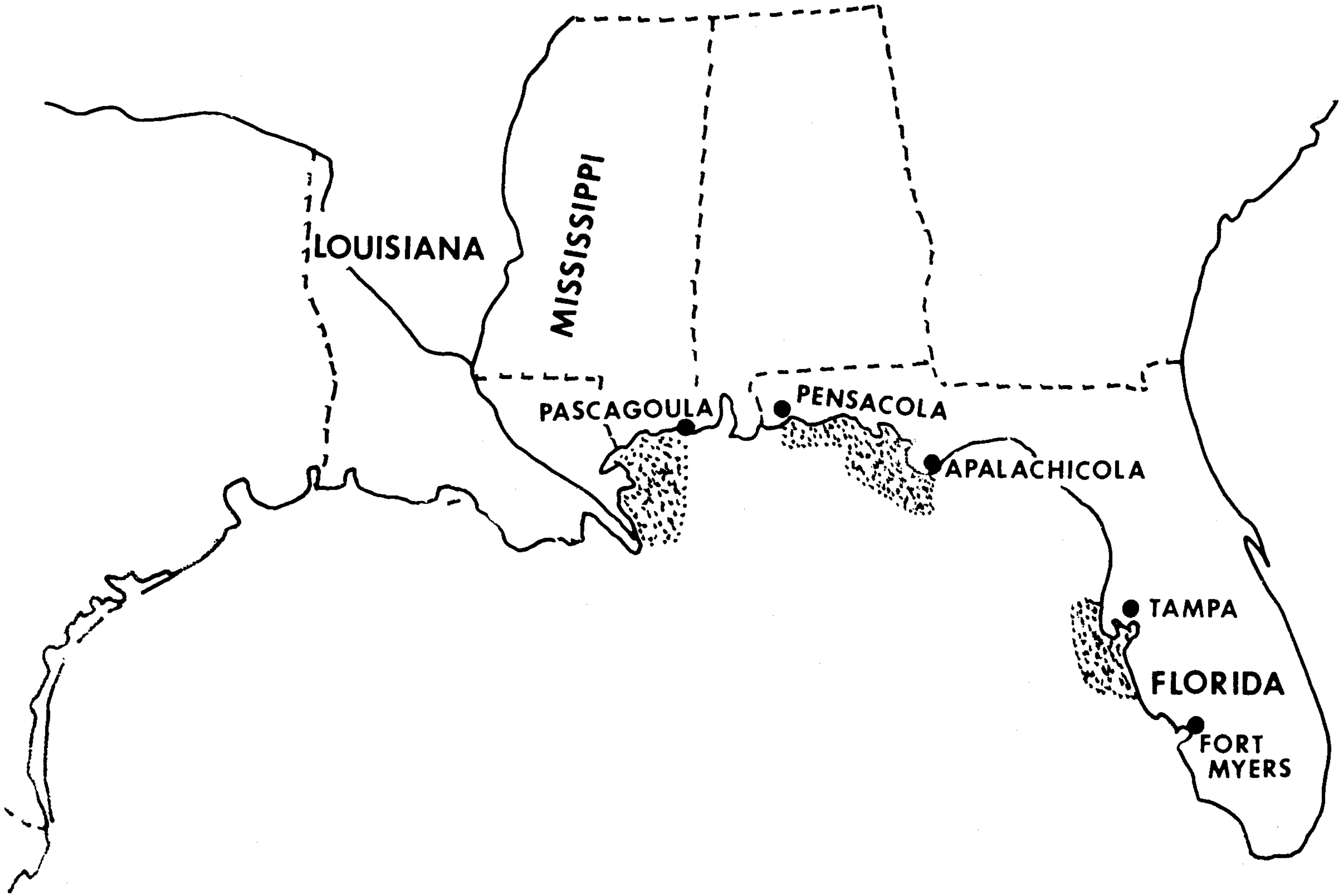


Figure 26. Commercial purse seine grounds (Roithmayr 1983).

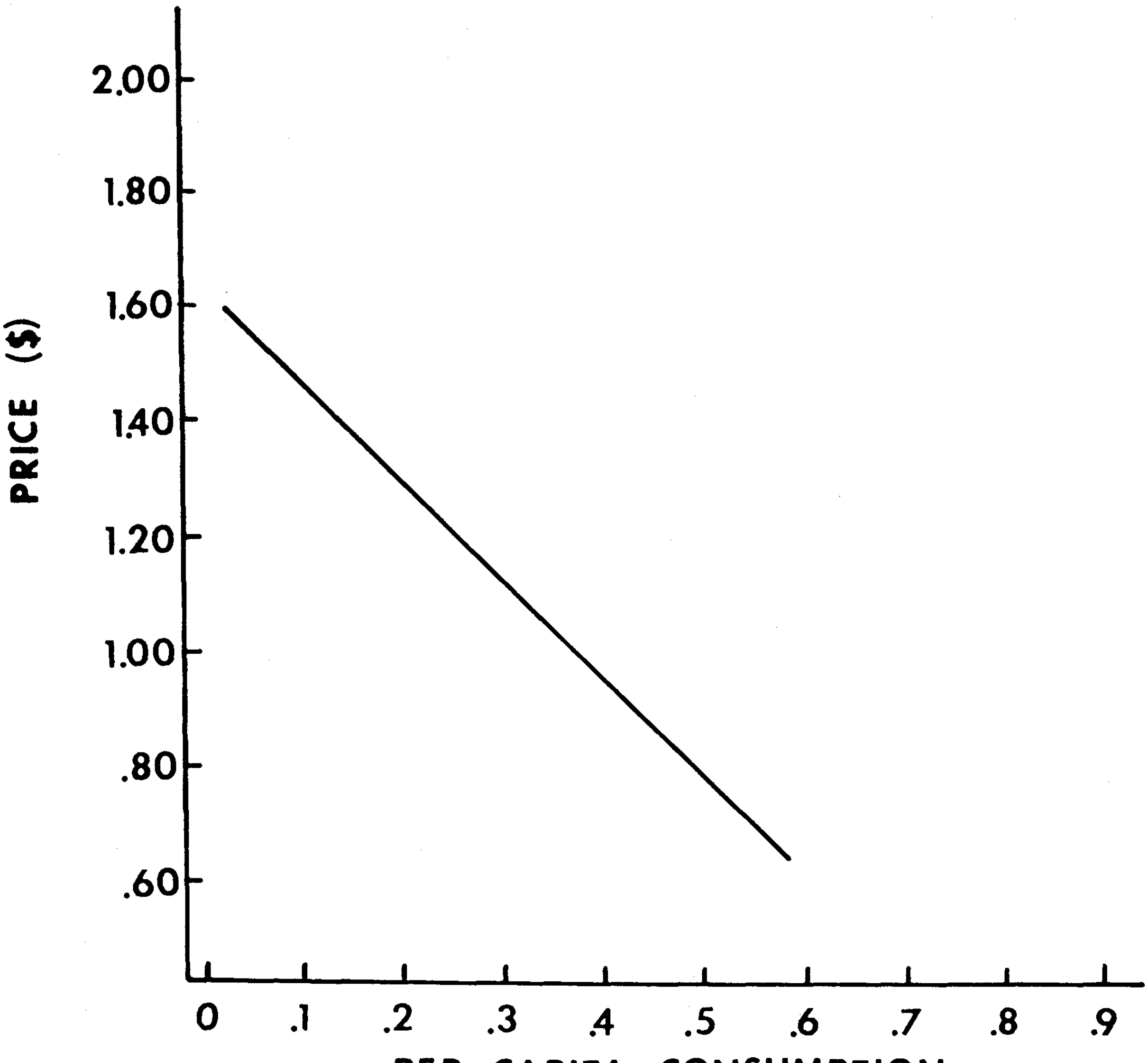


Figure 27. Price and per capita consumption of sardines, 1970-1979 (Perkins 1981).

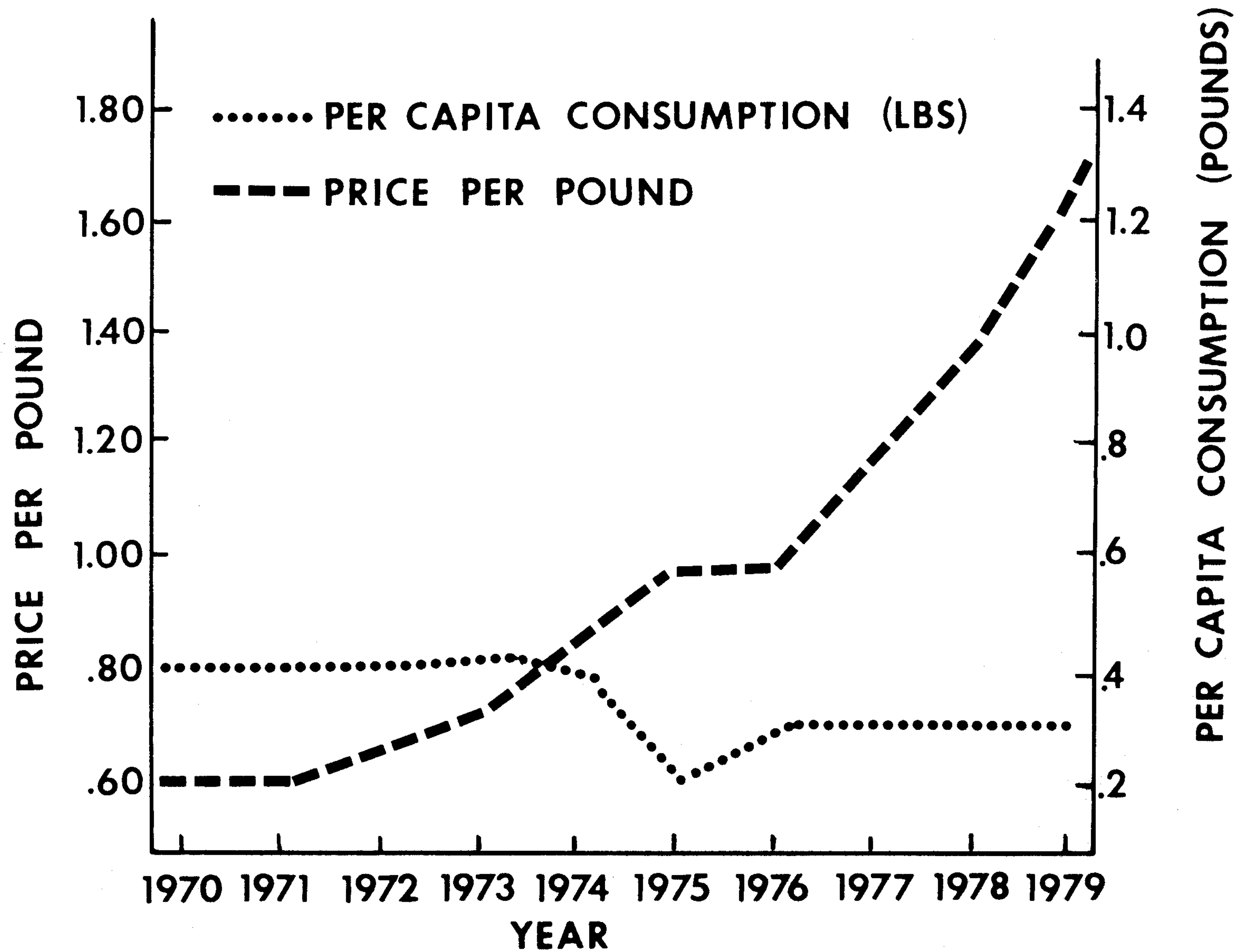


Figure 28. Demand curve for sardines (Perkins 1981).

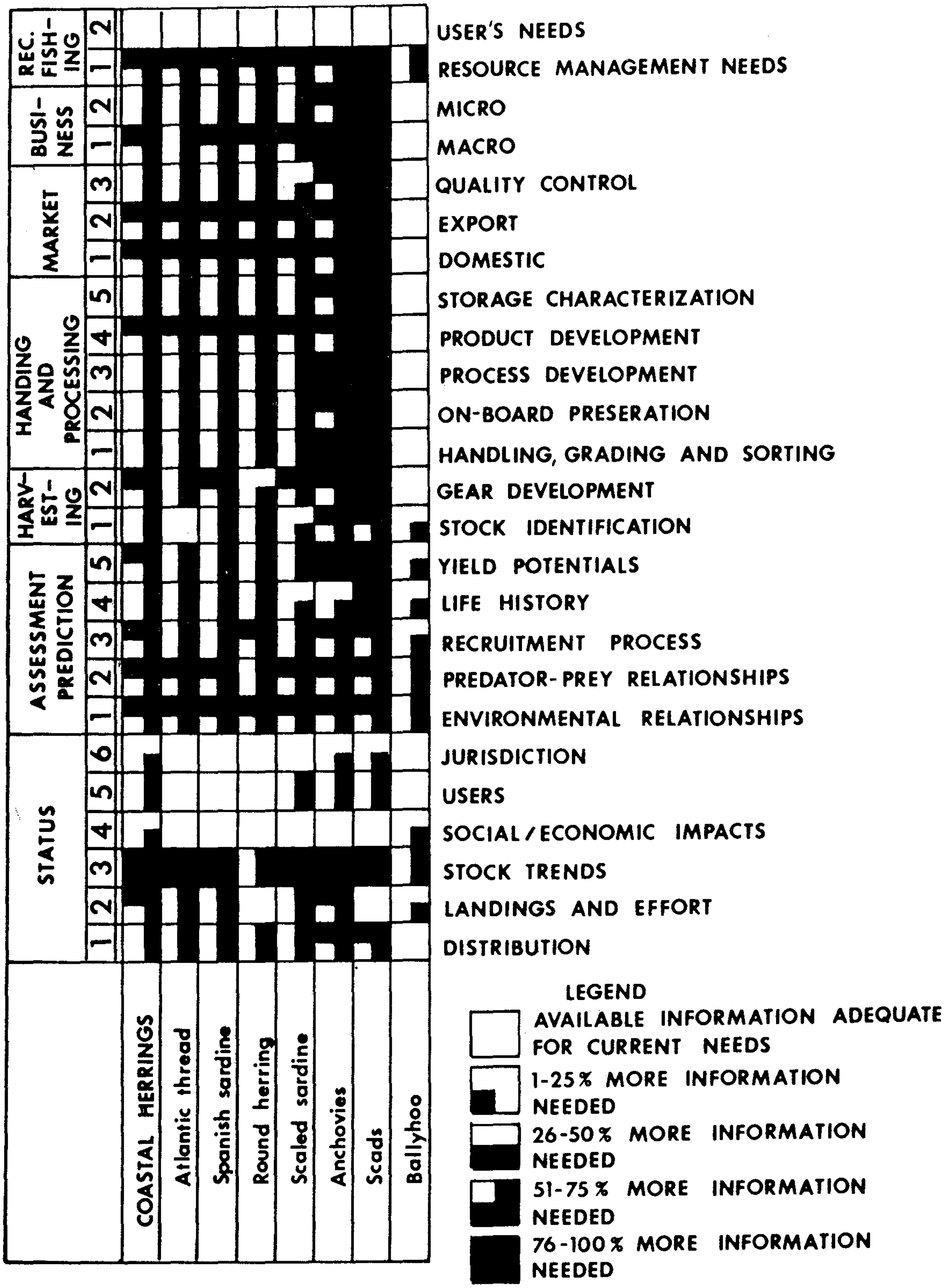


Figure 29. Summary of information needs concerning coastal herrings (Christmas et al. 1985).