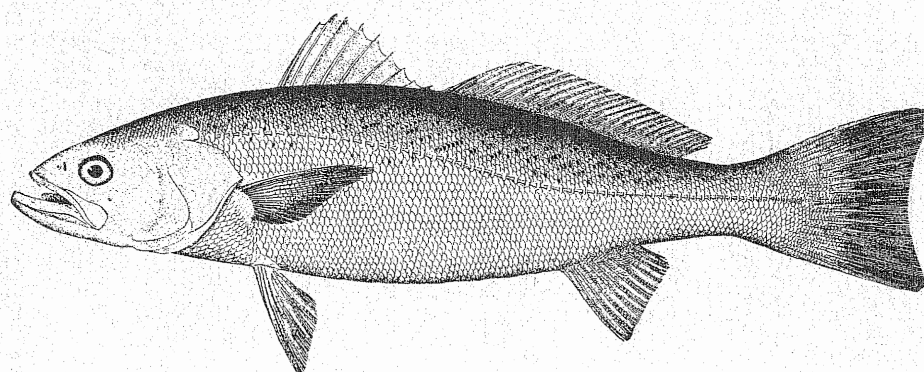

BIOLOGICAL & FISHERIES DATA
ON
WEAKFISH, *Cynoscion regalis* (Bloch and Schneider)

FEBRUARY 1979

Biological and Fisheries Data

on

weakfish, *Cynoscion regalis* (Bloch and Schneider)

by

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PREFACE

This technical report attempts to review and synthesize approximately 100 years of existing literature as well as National Marine Fisheries Service raw data files, personal communications, and my own observations.

In many cases I have taken the liberty of directly quoting or paraphrasing the works of others and where applicable have duplicated their figures and tables.

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1. IDENTITY

1.1 Nomenclaturee

1.1.1 Valid Name

Cynoscion regalis (Bloch and Schneider) 1801 (Figure 1).

1.1.2 Synonymy

Johnius regalis Bloch and Schneider, 1801

Roccus comes Mitchill, 1814

Labrus squeteague Mitchill, 1815

Otolithus regalis Cuvier and Valenciennes, 1830

Cynoscion regale Gill, 1862

Cestreus regalis Jordan and Eigenmann, 1889

This synonymy is after Jordan and Evermann (1896-1900).

1.2 Taxonomy

1.2.1 Affinities

Classification follows Greenwood et al. (1966). Taxa higher than superorder are not included:

Superorder: Acanthopterygii
  Order: Perciformes
    Suborder: Percoidei
      Family: Sciaenidae
        Genus: *Cynoscion*
          Species: *Cynoscion regalis*

1.2.2 Taxonomic Status

The weakfish is one of more than 30 members of the family Sciaenidae found along the Atlantic, Gulf, and Pacific coasts of the United States (Bailey, 1970). This group is commonly known as drum fishes or croakers since many of the species produce drumming or croaking sounds by vibrating their swim bladders with special muscles (Jordan and Evermann, 1896-1900; and Bigelow and Schroeder, 1953). The genus Sciaenidae is phylogenetically placed between the Sparidae (porgies) and Mullidae (goatfishes) by both Greenwood et al. (1966) and Bailey (1970).

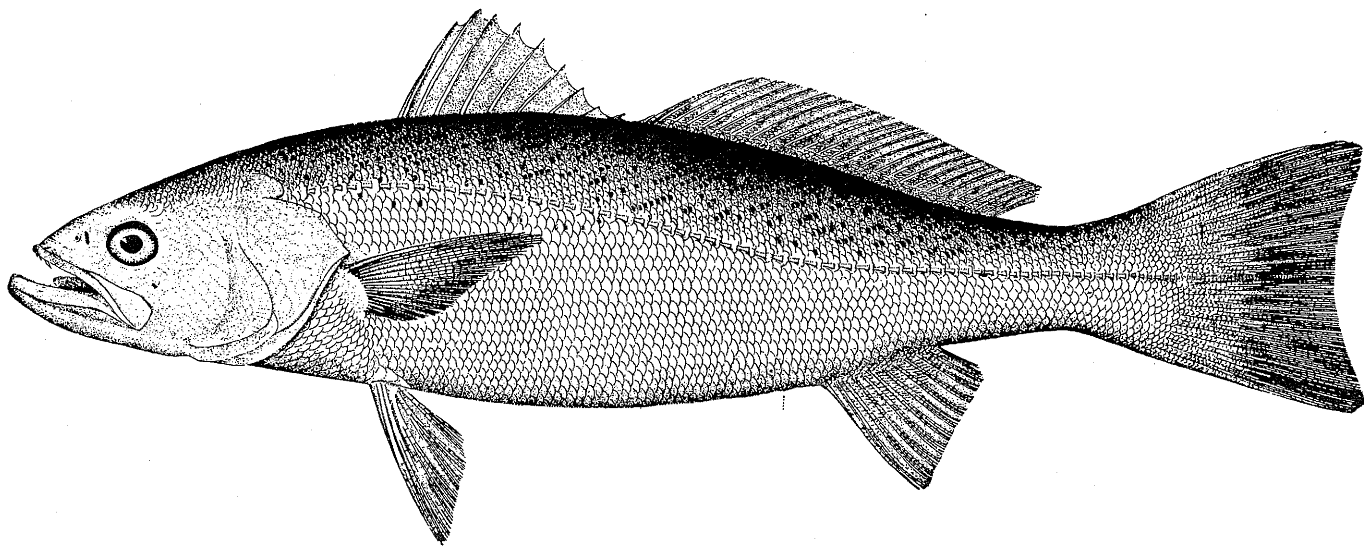


FIGURE 1. Weakfish, Cynoscion regalis (Bloch and Schneider), 1801 (illustration by H. L. Todd from: Goode, 1884).

The weakfish belongs to the genus *Cynoscion* of which there are six other members found along the United States coasts; these are the seatrout, *Cynoscion arenarius*; spotted seatrout, *C. nebulosus*; white seabass, *C. nobilis*; silver seatrout, *C. nothus*; shortfin corvina, *C. parvipinnis*; and orangemouth corvina, *C. xanthalus* (Bailey, 1970).

1.2.3 Subspecies

Alperin (1953), based on meristic data, theorized that *C. arenarius* is a clinal subspecies of *C. regalis*.

Weinstein and Yerger (1976) indicate that *C. arenarius* should be regarded as a subspecies of *C. regalis* on the basis of electrophoretic patterns and the valid occurrence of *C. regalis* in the Gulf of Mexico (Marco Island, Florida).

1.2.4 Standard Common Name, Vernacular Names

Weakfish is the common name given *Cynoscion regalis* by the American Fisheries Society (Bailey, 1970). Some of the names now in common use are weakie, squeteague, trout, seatrout, squit, sheantts, chickwick, salt-water trout, gray seatrout, tide runner, and gray trout (Jordan and Evermann, 1896-1900; Jordan et al., 1930; Hildebrand and Schroeder, 1927; Bigelow and Schroeder, 1953; and Leim and Scott, 1966).

1.3 Morphology

1.3.1 External Morphology

The following classical descriptions are those of Jordan and Evermann (1896-1900) for the family Sciaenidae, genus *Cynoscion*, and species *Cynoscion regalis*.

FAMILY Sciaenidae

"Body compressed, more or less elongate, covered with rather thin scales which are usually more or less ctenoid. Lateral line continuous, usually more or less concurrent with the back, extending on caudal fin. Head prominent, covered with scales; bones of the skull cavernous, the muciferous system highly developed, the surface of the skull, when the flesh is removed, very uneven. Suborbital bones without a backward projecting "stay". Chin usually with pores, sometimes with barbels. Mouth small or large, the teeth in one or more series, the outer of which are sometimes enlarged; canines often present. No incisor nor molar teeth; no teeth on vomer, palatines, pterygoids, nor tongue. Maxillary without supplemental bone, slipping under the free edge of the preorbital, which is usually broad. Premaxillaries protractile, but not very freely movable. Nostrils double. Pseudobranchiae usually large, present in most of the genera. Gills 4, a slit behind fourth. Gill rakers present. Branchostegals 7.

Gill membranes separate, free from the isthmus. Lower pharyngeals separate or united, often enlarged, the teeth conic or molar. Preopercle serrate or not. Opercle usually ending in 2 flat points. Dorsal fin deeply notched or divided into 2 fins, the soft dorsal being the longer, the spines depressible into a more or less perfect groove. Anal fin with 1 or 2 spines, never more than 2. Ventral fins thoracic, I, 5, below or behind pectorals. Pectoral fins normal. Caudal fin usually not forked. Ear bones or otoliths very large. Pyloric caeca usually rather few. Air bladder usually large and complicated (wanting in Menticirrhus). Most of the species make a peculiar noise, called variously croaking, grunting, drumming, and snoring; this sound is supposed to be caused by forcing the air from the air bladder into one of the lateral horns."

GENUS Cynoscion

"Body elongate, little compressed, the back not elevated. Head conical, rather pointed; mouth very large, terminal, not very oblique, the lower jaw projecting, the symphysis produced, the angle at base of maxillary not prominent. Maxillary very broad. Teeth sharp, not closely set, in rather narrow bands; tip of the lower jaw without canines; upper jaw with 2 long canines, 1 of which is sometimes obsolete; canines tapering from base to tip; lateral teeth of lower jaw larger than anterior. Preopercule with its membranaceous edge serrulate, the bones entire. Lower pharynegeal bones separated, their teeth all pointed. Gill rakers strong, rather long. Vertebrae about 14 + 10 (instead of 10 + 14 as in Sciaenoids generally). Pseudobranchiae well developed; dorsal spines slender, the fins closely contiguous; anal spines 1 or 2, very feeble, the soft rays 7 to 13; second dorsal long and low, more than twice length of anal; ventrals inserted below pectorals, the pubic bone long and strong; caudal fin subtruncate or lunate."

Cynoscion regalis

"Head 3 1/3; depth 4 1/4; eye about 1 1/3 in snout, 5 to 7 in head; snout 4 to 4 1/3. D. X-I, 26 to 29; A. II, 11 to 13; scales 6-56-11. Maxillary reaching to beyond pupil, 2 1/6 in head; teeth sharp, in narrow bands; canines large. Pectorals short, scarcely reaching tips of ventrals, a little more than 1/2 length of head; longest dorsal spine as long as maxillary, not 1/2 length of head; soft dorsal and anal scaly, the scales caducous. Gill rakers long and sharp, 5 + 11 in number. Color silvery, darker above and marked with many small, irregular dark blotches, some of which form undulating lines running downward and forward; back and head with bright reflections; dorsal and caudalefins dusky; ventrals, anal, and lower edge of caudale yellowish, sometimes speckled. Atlantic and Gulf coast of the United States from Cape Cod southward to Mobile; very abundant on sandy shores, not found about rocks. It is highly valued as a food fish, the flesh being rich and delicate. Its flesh, like that of most species of the genus, is very tender and easily torn, hence the common name Weakfish."

The following less formal description of the weakfish is from Bigelow and Schroeder (1953):

"The relative size and shapes of the fins of the weakfish, and its color, are such ready field marks that it is one of of our most easily identified fishes. Among Gulf of Maine species with separate spiny and soft-rayed dorsal fins, it is distinguishable from the mullet by the considerable length of its dorsals as well as by many other characters; its slightly emarginate tail distinguishes it from any mackerel or pompano; this same character, combined with a short anal fin and a first dorsal fin higher than the second dorsal gives it an appearance quite different from a bluefish; and the fact that its second dorsal is much longer than the first, and that it has only 2 anal spines and a slender body obviate all possibility of confusing it with striped bass or white perch. The shape of its dorsal and caudal fins and of its head, and the absence of a chin barbel make it distinguishable at a glance from the kingfish, the absence of barbels on the chin separates it from a drum; it has nothing in common with such bizarre fishes as the John Dory, triggerfish or any member of the sculpin tribe."

"The weakfish is a slim, shapely fish, about four times as long as deep (to the base of the caudal fin), only slightly flattened sidewise, with rather stout caudal peduncle; a head about one-third as long as body, moderately pointed snout, and large mouth. Its upper jaw is armed with two large canine teeth and its lower jaw projects beyond the upper. The first dorsal fin (10 spines), originating a little behind the pectorals, is triangular; the second dorsal (26 to 29 rays), originating close behind the first, is more than twice as long as the first and roughly rectangular. The caudal fin is moderately broad and only slightly concave in outline. The anal fin (2 very slender spines and 11 or 12 rays) is less than half as long as the second dorsal, under the rear part of which it stands. The ventrals are below the pectorals, which they resemble in their moderate size and pointed outline."

"Dark olive green above with the back and sides variously burnished with purple, lavender, green, blue, golden, or coppery, and marked with a large number of small black, dark green, or bronze spots, vaguely outlined and running together more or less, especially on the back; thus forming irregular lines that run downward and forward. The spots are most numerous above the lateral line, and there are none on the lower part of the sides or on the belly. The lower surface, forward to the tip of the jaw is white either chalky or silvery. The dorsal fins are dusky, usually more or less tinged with yellow; the caudal is olive or dusky with its lower edge yellowish at the base; the ventrals and the anal are yellow; and the pectorals are olive on the outer side, but usually yellow on the inner side."

Recently Chao (1978) assessed the phylogenetic relationships of all western Atlantic Sciaenidae genera on the basis of swim bladder, otoliths (sagitta and lapillus), and external morphology. He also provides a tested key to all species and genera of western Atlantic sciaenids which includes approximate range of distribution and some counts for each species.

Miller and Jorgenson (1973) give meristic characteristics from radiographs for 10 small weakfish. These data are summarized in Table 1. Alperin (1953) gives detailed meristic data for dorsal fin rays and spines (range 35-41), anal fin rays and spines (range 12-15), and pectoral fin rays (range 16-20) based on specimens collected in New York and Virginia. In addition, he provides morphometric data pertinent to head, body length, tail, and caudal peduncle.

Moshin (1973) discusses the comparative osteology of the four Cynoscion species found along the Atlantic and Gulf coasts of the United States. He hypothesizes, based on osteological relationships, that there are two phyletic lines within the genus Cynoscion: One line contains C.enebulosus and C. arenarius; with the second line containing C. nothus and C. regalis. Table 2 summarizes thee similarities and differences between the bones of thee four Cynoscion species.e

1.3.2 Cytomorphology

No data available.

1.3.3 Protein Specificity

Weinstein and Yerger (1976) give serum and muscle protein electropherograms as well as diagrammatic representations of serum, eye lens, and myogen protein bands based on

TABLE 1. Meristic characteristics of 10 weakfish, *Cynoscion regalis*, ranging in size from 28-165 mm SL. (from: Miller and Jorgensen, 1973).

VERTEBRAE	
Total	25
Precaudal	13
Caudal	12
DORSAL FIN	
Spines	11
Rays	24-28
ANAL FIN	
Spines	2
Rays	10-12
CAUDAL FIN	
Total	29-33
Dorsal secondary rays	7-9
Dorsal primary rays	9
Ventral primary rays	8
Ventral secondary rays	5-7

TABLE 2. Similar and different bones of four species of the genus Cynoscion found along the Atlantic and Gulf coasts of the United States. Like symbols indicate similarities, different symbols indicate differences in some discernible characteristic. Only those bones exhibiting significant variation among the four species are listed (from: Mohsin, 1973).

Character	SPECIES			
	C.e nebulosuse	C. arenarius	C. nothus	C. regalis
Lachrymal	+	+	*	+
Suborbital	+	+	*	=
Postorbitals	+	+	*	+
Parietal	+	+	*	=
Sphenotic	+	+	*	*
Sagitta	+	+	*	* (partly)
Articular	+	+	*	=
Mesethmoid	+	*	+	+
Nasal	+	*	=	+
Postorbital	+	+	=	+
Supraoccipital	+	*	+	+
Preorbital	+	*	+	=
Lateral ethmoid	+	*	=	#
Frontal	+	*	=	#
Dentary	+	*	=	#
Hyomandibular	+	*	=	#
Basihyal	+	*	=	#
Urohyal	+	*	=	=
Opercle	+	*	=	#
Postcleithrum	+	*	=	#

acrylamide gell electrophoresis for *C. arenarius*, *C. nebulosus*, *C. nothus*, and *C. regalis*. They, based on their overall results, draw the following three taxonomic conclusions: "First, with the exception of a single taxonomic distance (d_{jk}) value calculated in the phenetic analysis, the relationships established by electrophoresis reflect the phyletic relationships proposed by Ginsburg. This "aberrant" value is believed to result from the small sample size and the possibility of ecological convergence. Second, the data indicate that *Cynoscion nebulosus* is the most divergent of the four forms, supporting previous morphological and ecological conclusions. Third, as suggested by previous studies, the taxonomic status of *C. arenarius* as a distinct species is again questioned. Electrophoretic patterns indicate that it should be regarded as a subspecies of *C. regalis*."

Sullivan et al. (1975) have electrophoretically examined the amino acid composition of parvalbumins from the weakfish. Their results are summarized in Table 3.

2. DISTRIBUTION

2.1 Total Area

Weakfish are found along the Atlantic coast of the United States from southern Florida to Massachusetts Bay, straying occasionally to Nova Scotia (Hildebrand and Schroeder, 1927; Bigelow and Schroeder, 1953; Leim and Scott, 1966; and Chao, 1978) (Figure 2). The capture and documentation of two adult weakfish (266 and 298 mm SL) off Marco Island, Florida validate the occurrence of this species in the Gulf of Mexico (Weinstein and Yerger, 1976).

2.2 Differential Distribution

2.2.1 Spawn, Larvae, and Juveniles

Spawning occurs in the near-shore and estuarine zones along the Atlantic coast from May to October with peak production during May and June for most fish (Welsh and Breder, 1923; Pearson, 1941; Bigelow and Schroeder, 1953; and Merriner, 1976).

Massmann et al. (1958) describe the distribution and movements of young-of-the-year weakfish in the York River estuary based on monthly otter trawl collections. In July they found young weakfish in greatest numbers in the upper York River; in August they were most numerous in the nearby fresh waters of the Paumnkey River; during September, October, and November a return migration took place, and by December most young weakfish had left the river and bay. This pattern is probably similar in most estuaries where young-of-the-year weakfish occur, such as the Delaware Bay complex.

TABLE 3. Amino acid composition of parvalbumins from weakfish, _Cynoscion regalis_ (from: Sullivan et al., 1975).

Amino Acid	_Cynoscion_ slow	_Cynoscion_ fast
Lysine	10.90	10.10
Histidine	1.13	-
Arginine	1.05	1.10
Aspartic acid	8.38	14.00
Threonine[1]	6.44	4.27
Serine[1]	6.00	9.80
Glutamic acid	11.0500	10.40
Proline	2.28	-
Glycine	13.0500	8.98
Alanine	18.60	21.40
Valine[2]	3.85	3.93
Methionine	0.990	-
Isoleucine[2]	4.53	4.33
Leucine	9.86	8.79
Tyrosine	-	1.10
Phenylahanine	9.30	9.55
TOTAL	108.0310	107.75

[1]Extrapolated to zero time of hydrolysis.

[2]Value reported from 72 hour hydrolysis.

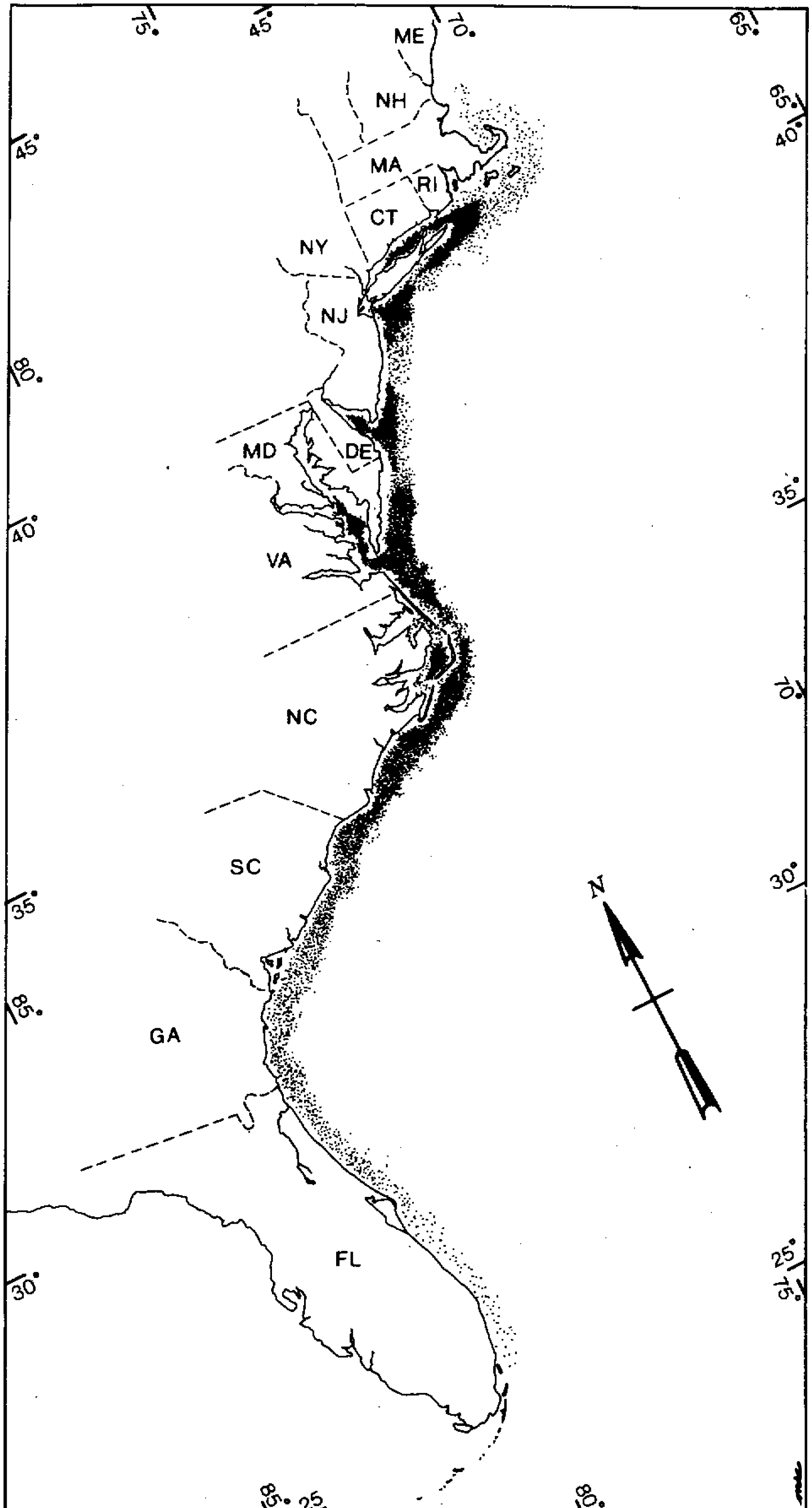


FIGURE 2. General distribution of the weakfish, Cynoscion regalis, along the Atlantic coast of the United States. Density of stippling indicates areas where weakfish tend to congregate (from: Wilk, 1976).

2.2.2 Adults

Although most of our knowledge is limited to that part of their lives spent in coastal and estuarine waters, the distribution of weakfish as indicated by offshore commercial trawlers, NMFS groundfish surveys, and recorded literature (Bigelow and Schroeder, 1953; Nesbit, 1954; and Pearson, 1932) is probably much wider and extends further out on the continental shelf than has been generally believed.

Young weakfish, less than four-years-old, move out of the near-shore and estuarine zones and south along the coast in fall and winter, some as far as Florida, and north in spring and summer. The older and larger fish, usually greater than four-years-old, move south but offshore in the fall, probably no farther than North Carolina, and then return to their inshore northern grounds with the advent of spring warming (Nesbit, 1954; Massmann et al., 1958; Wilk, 1976; and Wilk and Silverman, 1976a) (Figures 3 and 4). The larger fish, some larger than 15 pounds, appear to move fastest and tend to congregate in the northern part of their range (Wilk and Silverman, 1976a; and Wilk et al., 1977).

2.3 Determinants of Distribution Changes

Weakfish appear to congregate along the beaches, in the mouths of inlets, and in larger estuaries during spawning. The young also use these areas as nursery grounds during their first months of life.

As is the case with many migratory fishes, photoperiod, water temperature, and food supply may play a large role in their movements within a given area and during coastal or inshore-offshore migrations. See sections 2.2.1 and 2.2.2 for additional information.

2.4 Hybridization

Moenkhaus (1911), the only reference listed by Schwartz (1972), attempted to hybridize a _Fundulus heteroclitus_ female with a _Cynoscion regalis_ male. A tabulated outline of the development compared with the normal is as follows:

Time	Fundulus x Fundulus	Fundulus x Squetegue
3:40 p.m., July 17	-Fertilizationo	-Fertilizationo
5:50 p.m., July 17	-2 cellso	-2 cellso
6:35 p.m., July 17	-4 cellso	-4 cellso
7:25 p.m., July 17	-8 cellso	-8 cellso
7:45 p.m., July 17	-Begin. 16 cellso	-Begin. 16 cellso
8:10 p.m., July 18	-Late cleavageo	-Late cleavage
12:20 p.m., July 18	-Begin. germ ringo	-Begin. germ ringo
7:00 p.m., July 18	-Blast. closed; optico vesicles plainlyo formedo	-Blast. closed; optico vesicles poorly formedo notochord; somites.o Behind normals.o

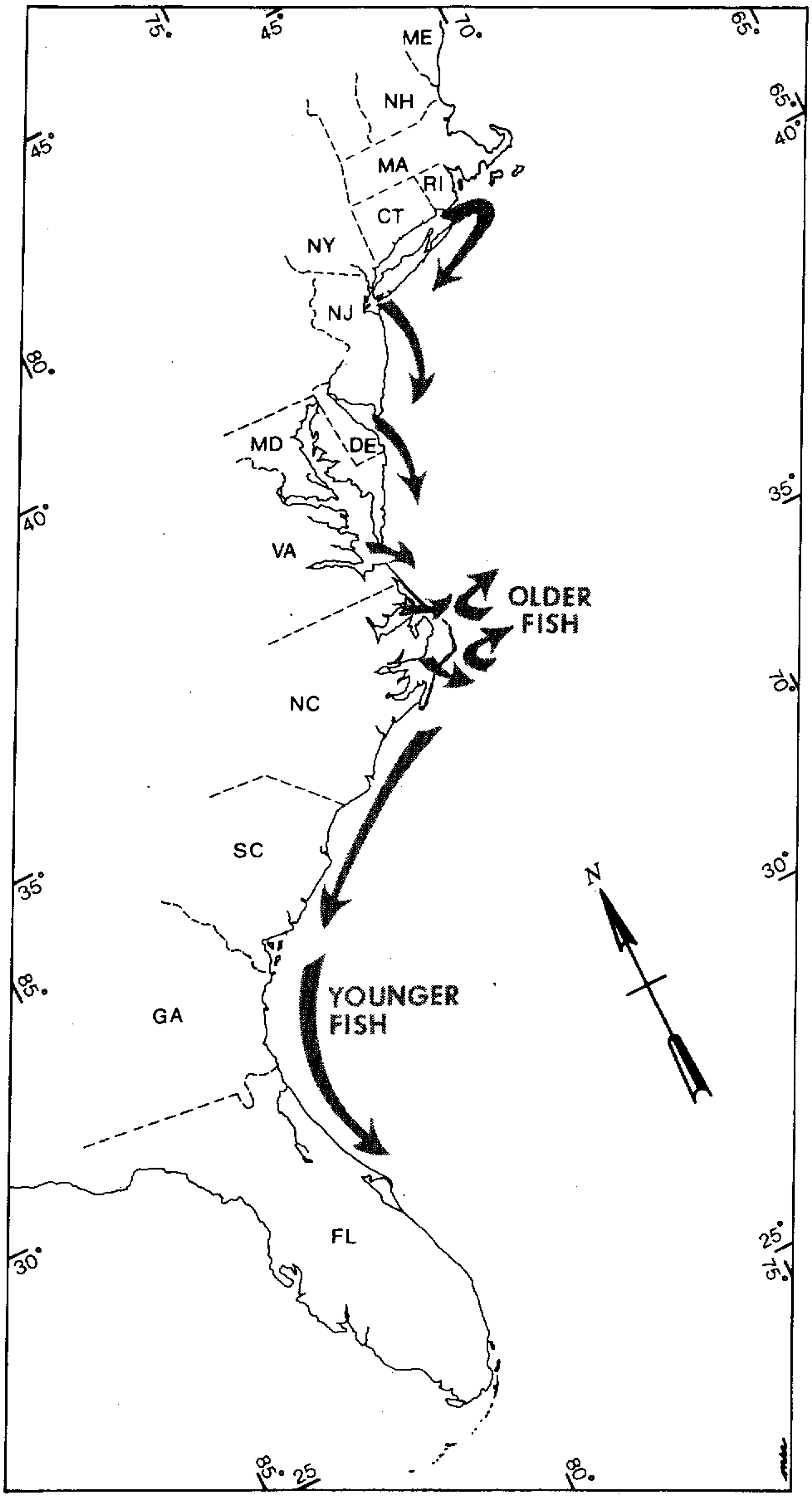


FIGURE 3. Movements of the weakfish, *Cynoscion regalis*, along the Atlantic coast of the United States during fall and winter (from: Wilk, 1976).

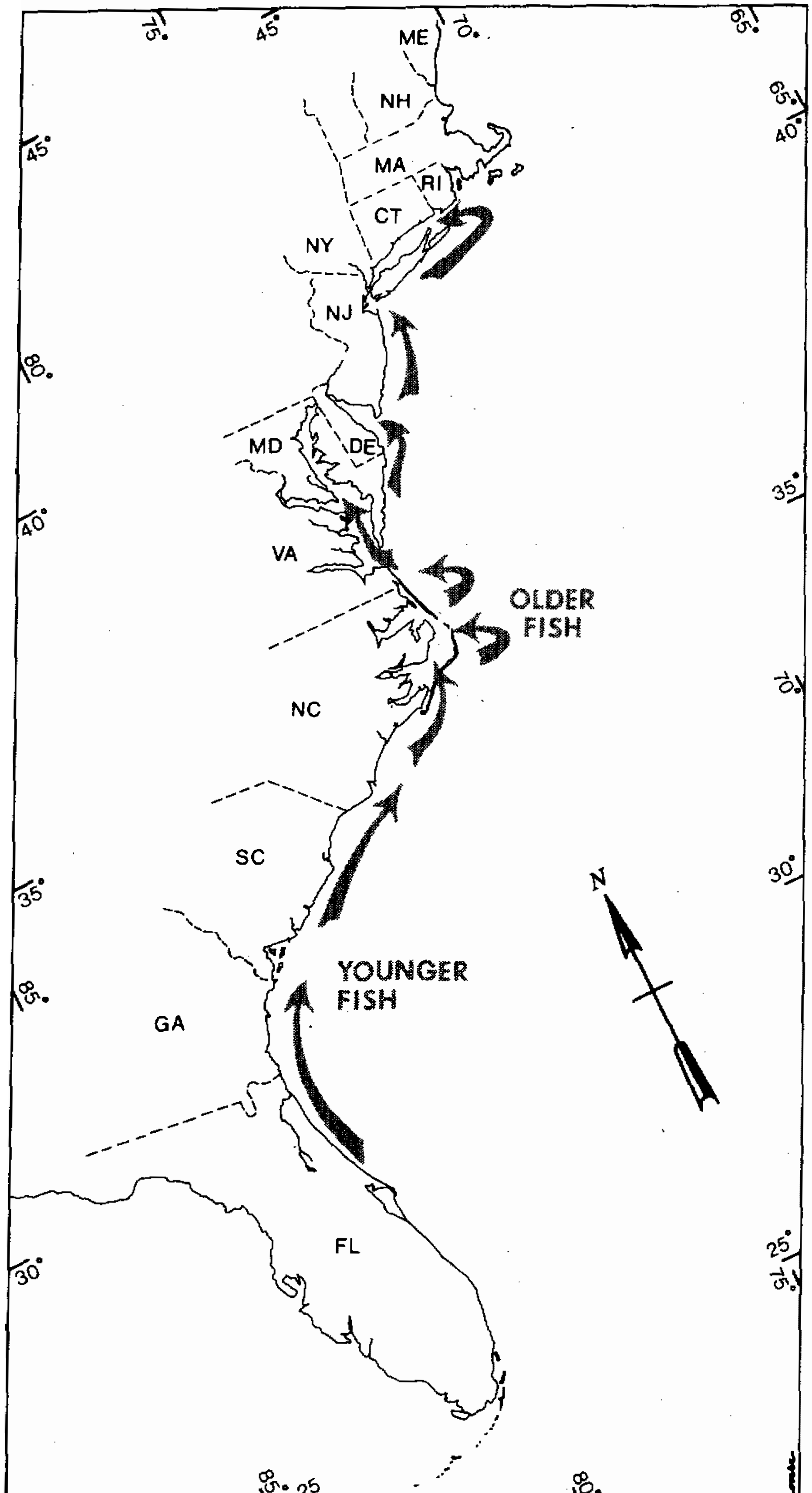


FIGURE 4. Movements of the weakfish, Cynoscion regalis, along the Atlantic coast of the United States during spring and summer (from: Wilk, 1976).

Time	Fundulus x Fundulus	Fundulus x Squetegue
7:00 p.m., July 18	-Blast. closed; optice vesicles plainlye formed.e	-Blast. closed; optic vesicles poorly formed notochord; somites. Behinde normals.e
2:15 p.m., July 19	-Optic vesicles ande lens; brown partse showing.	-Optic vesicles showing; behind normals.e
	-Hatchede	-No further alonge

3.e BIONOMICS AND LIFE HISTORYe

3.1 Reproductione

3.1.1 Sexuality

Weakfish are heterosexuals. They possess no external accessory organs, and there is no visual way to distinguish the sexes externally. The male weakfish has drumming muscles along the length of the body and makes assorted croaking and drumming sounds, the female does not (Fish and Mowbray, 1970). This developed drumming muscle allows one to differentiate between the male and the softer bodied female by applying external pressure on the abdomen (Merriner, pers. comm.). Hermaphroditism in weakfish is unknown.

3.d.2 Maturitye

Both male and female weakfish captured in North Carolina waters become sexually mature at age I with a few at age II according to Merriner (1976). From our (NMFS) observations, most, ife not all, weakfish are sexually mature by age II.

3.1.3 Mating

Mating in the literal sense is not known to occur nor is there parental care of eggs or larvae.

3.1.4 Fertilization

Fertilization is external.

3.1.5 Gonads

According to Merriner (1976) weight and length are better indicators of fecundity than is age. He gives the following fecundity (F) equations for standard length (SL), total length (TL), and weight (W):

$$Fe = 0.116\ SL^{2.7755} \quad (r^2 = 0.85)$$

$$Fe = 0.152\ TL^{2.6418} \quad (r^2 = 0.86)$$

$$Fe = 21{,}198 + 1{,}279\ W \quad (r^2 = 0.88)$$

Using the equation for total length, a female weakfish 500 mm will produce slightly over two million eggs (Merriner, 1976) (Figure 5).

3.1.6 Spawning

Spawning, hatching, and early larval development take place in the near-shore and estuarine zones along the coast from May to October with peak production during late April through June (Welsh and Breder, 1923; Hildebrand and Schroeder, 1927; Higgins and Pearson, 1928; Parr, 1933; Hildebrand and Cable, 1934; Pearson, 1941; Bigelow and Schroeder, 1953; Nesbit, 1954; Daiber, 1954; Perlmutter et al., 1956; Harmic, 1958; Massmann, 1963a, b; Thomas, 1971; and Merriner, 1976).

Poole (N. Y. State Department of Environmental Conservation, pers. comm.) indicates that a "milling" behavior during spawning has been observed in Great South Bay, Long Island on the Heckshir Flats. At times, the "milling" occurs simultaneously at many locations on the flats with the dorsal portion of the weakfish breaking the surface. To date, it has not been determined how many individuals are in each "milling" group.

3.1.7 Spawn

Lippson and Moran (1974) describe the eggs of weakfish as follows: pelagic and highly buoyant, 0.74-1.3 mm in diameter, spherical, transparent with thin horny membrane, 1-4 (rarely 5 or 6) amber oil globules in yolk which coalesce with development, and very thin perivitelline space (Figures 6A, B, and C). Harmic (1958) also describes the eggs of the weakfish.

3.2 Pre-Adult Phase

Lippson and Moran (1974) give the following description of weakfish embryos, prolarvae, larvae, and juveniles:

Larvae

"Hatching size: Ca. 1.5-1.75 mm TL [Figure 6D]

"Characteristics: Yolk usually absorbed at ca. 1.8 mm [Figure 6E], large gaping mouth, elongated slender body (less deep anteriorly than in spotted sea trout, *C. nebulosus*), series of melanophores along

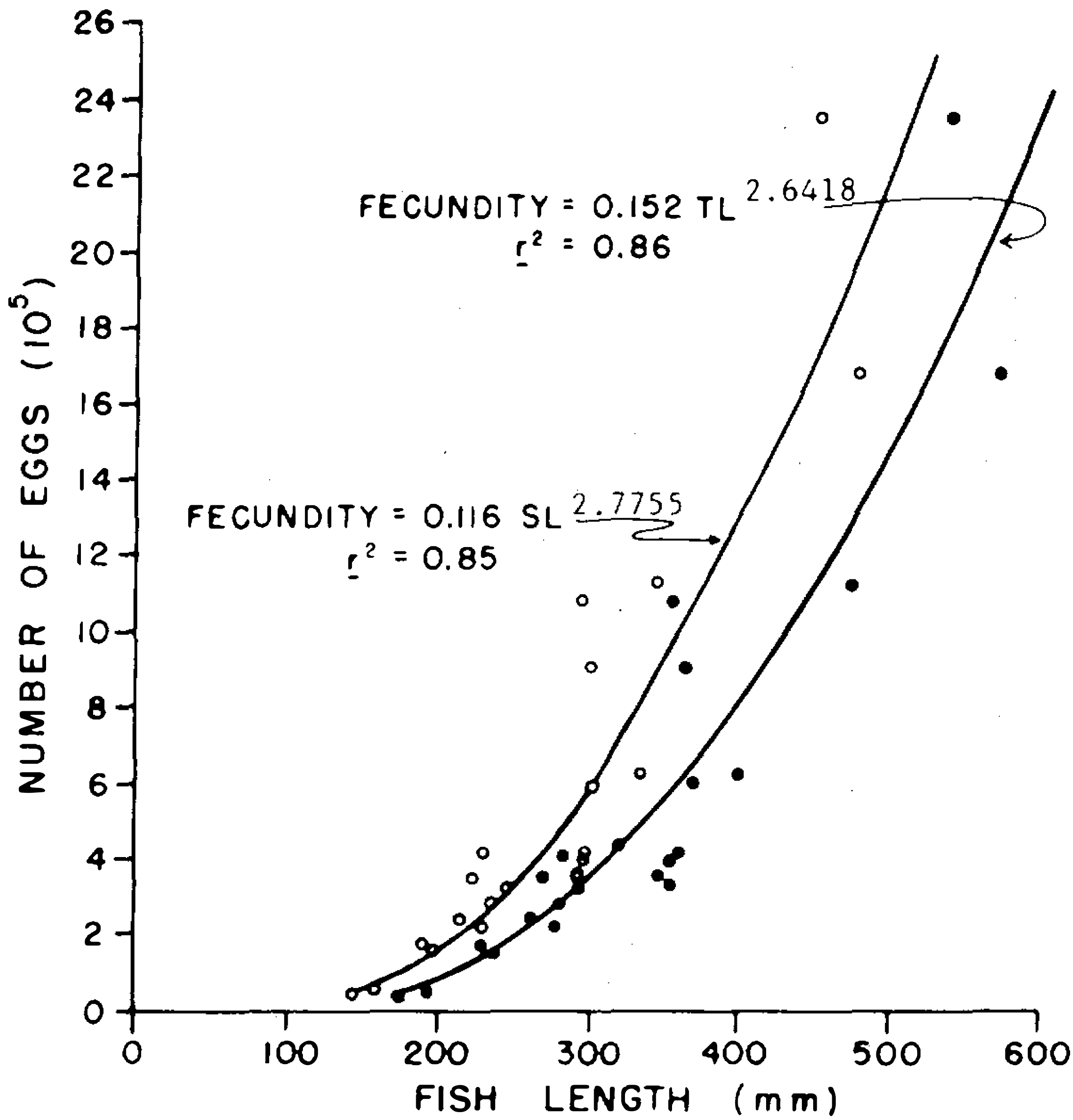


FIGURE 5. Relationship of weakfish, *Cynoscion regalis*, fecundity to total length (TL) and standard length (SL) based upon data from 22 females (illustration from: Merriner, 1976).

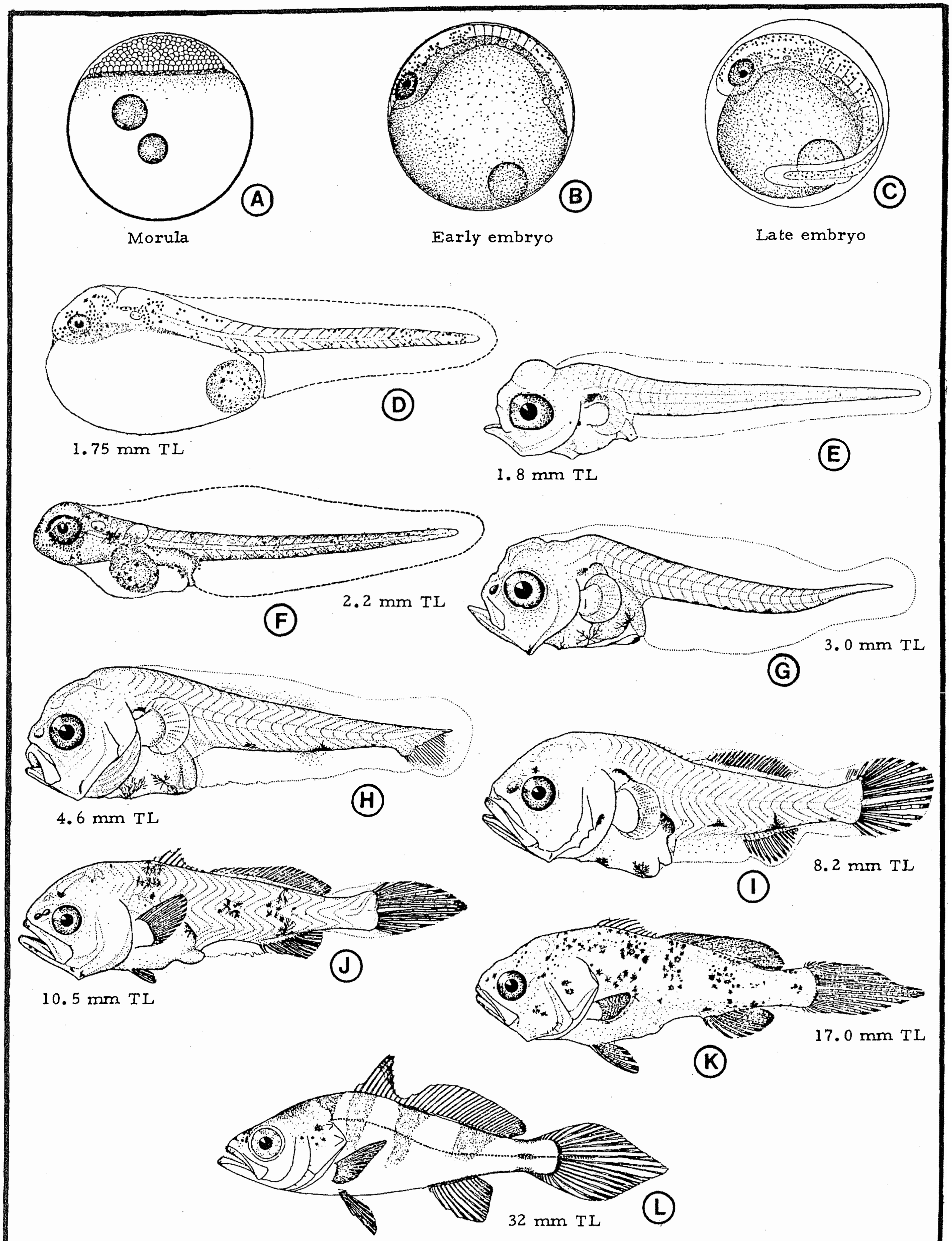


FIGURE 6. Stages in the development of weakfish, Cynoscion regalis, eggs, prolarvae, larvae, and juveniles (illustrations from: Lippson and Moran, 1974).

ventral surface from vent to tail with one pronounced spot at base of primitive anal fin. A specimen of 2.2 mm [Figure 6F]; 24 hours after hatching (Welsh and Breder, 1923) still retained yolk. This variability can be attributed to differences in developmental rates between laboratory reared and field collected specimens. At 3.0 mm [Figure 6G], body depth increased, melanophores more prominent, especially anterior to vent and at base of anal fin, minute teeth at this stage distinguish weakfish from silver perch and Atlantic croaker, M. undulatus.

"At ca. 4.6 mm [Figure 6H], soft rays of all fins apparent. Distinguishable from spotted sea trout of same size by relative lack of body pigmentation except for prominent spot anterior to vent and melanophores along gut.

"At 8.2 mm [Figure 6I], snout noticeably more blunt than in spotted sea trout and lower jaw does not project noticeably beyond upper; all fins but pelvic formed. By 10.5 mm [Figure 6J], melanophores present along lateral line and upper lip; caudal fin centrally elongate; dorsal fins almost complete."

Juveniles

"Tail pointed at 32 mm [Figure 6L], ca. 4 lateral bands or saddles of pigmentation along back and sides (amount and intensity varies with environment), prominent anal melanophore gone. After 170 mm, body progressively longer and more slender, caudal becoming less pointed."

Lippson and Moran (1974) give the following references for the weakfish section of their manual for identification of early developmental stages of fishes of the Potomac River estuary: Welsh and Breder, 1923; Hildebrand and Schroeder, 1927; Hildebrand and Cable, 1934; Pearson, 1941; Miller and Jorgensen, 1973; and Scotton et al., 1973. Wilk (1976), using the above references, also illustrates the weakfish metamorphosis from egg to adult (Figure 7).

Chao and Musick (1977) describe and illustrate in great detail the functional morphology of six juvenile sciaenid fishes including the weakfish. They found mouth position, dentition, gill rakers, digestive tract, pores and barbels, nares, and body shape to be important in locating and ingesting prey in the water column.

3.3 Adult Phase

3.3.1 Longevity

Personnel of the National Marine Fisheries Service's Northeast Fisheries Center, Sandy Hook Laboratory, have aged several thousand weakfish, collected between New York and Florida, with the oldest being 9-years-old (12 pounds, 14 ounces); however, larger and presumably older fish have been recorded: 17 pounds, 8 ounces (September, 1944, New Jersey - Bigelow and Schroeder, 1953); 16 pounds (May, 1921, Virginia - Hildebrand and Schroeder, 1927); and 30 pounds (Welsh and Breder, 1923).

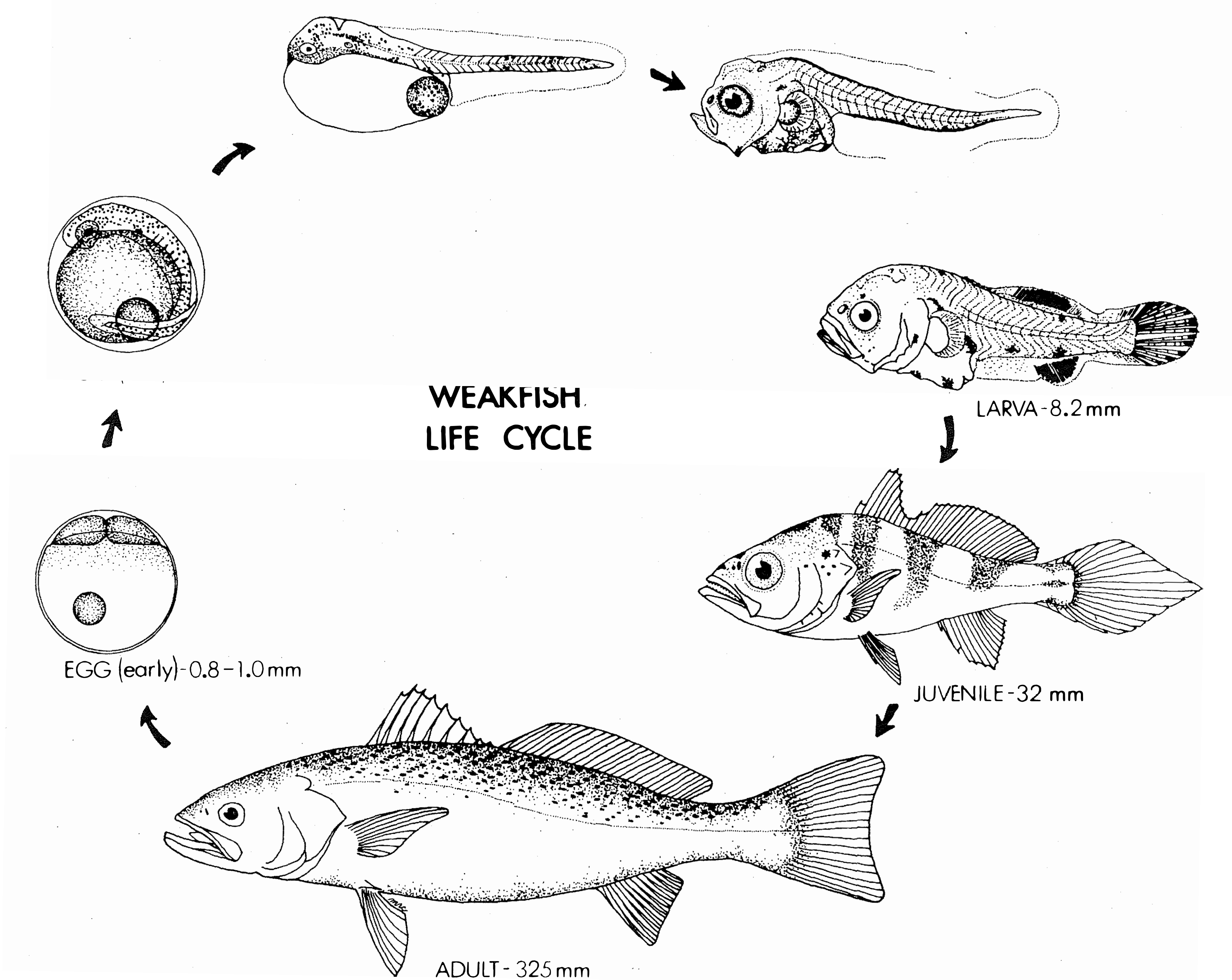


FIGURE 7. Weakfish, Cynoscion regalis, life cycle, from early egg to adult (from: Wilk, 1976).

3.3.2 Hardiness

No data available.

3.3.3 Competitors

Adult weakfish, owing to their predatious nature, are in competition with other high predators such as striped bass and bluefish. See section 3.4.1 for additional information.

3.3.4 Predators

Weakfish are in turn preyed upon by other predators such as bluefish, striped bass, and larger weakfish.

3.3.5 Parasites, Diseases, Injuries, and Abnormalities

Merriner (1973) lists the following parasites and their location from weakfish:

PROTOZA -- Sinuolind dimor ha (urinary bladder); Myxidium sp. (gall bladder ; Chloromyxa sp. (gall bladder); Henneguya sp. (fins and mesentery).

CESTODA -- Tetraphyllidae, 2 unknown species (intestine and galle bladder); Tr anorhyncha, 2 unknown species (mesentery); Otobothrium sp. mesentery); Nybelinia sp. (mesentery).

ACANTHOCEPHALA -- 2 species (intestine and mesentery).

TREMATODA -- Cynoscionicola seudoheteracantha (gills); Neoheterobothrium c noscioni gills); Pleorchis americanus (intestine ; Hemiuridae, 3 unknown species (stomach, mesentery, and ovary).

NEMATODA Contracaecum sp. (stomach, mesentery, and intestine); Capillaria sp. (intestine); Goezia sp. (stomach).

COPEPODA -- Lernaeenicus sp. (skin); Lernanthropus sp. (pectoral fin).

ISOPODA -- Livoneca sp. (gills).

Mahoney et al. (1973) report weakfish to be one of the most susceptible to the "fin rot" disease of marine and euryhaline fishes in the New York Bight. The most consistent and striking feature of this disease is the necrosis of one or more of the fins (Figure 8). It has been suggested that this disease is limited to the heavily polluted New York Bight. A summary of

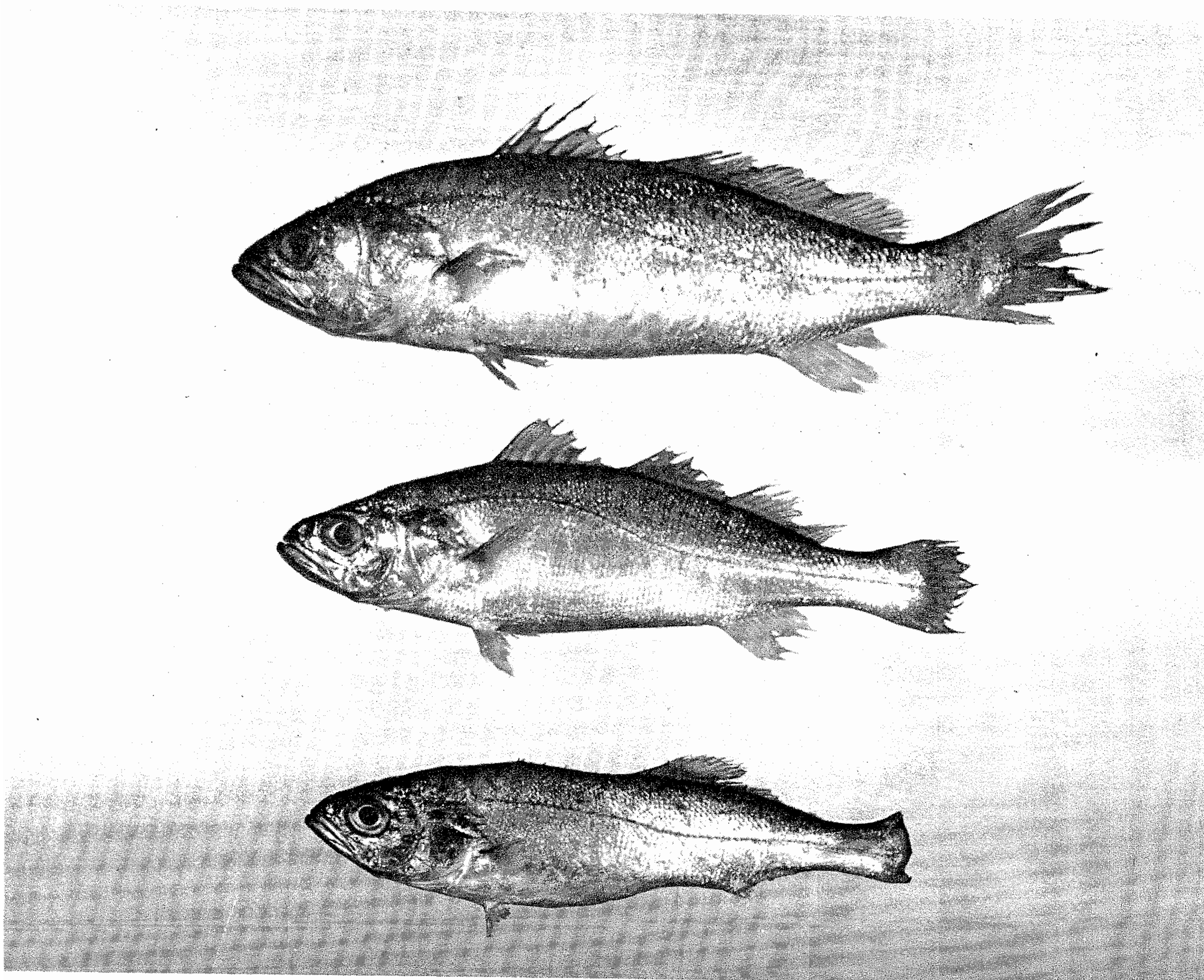


FIGURE 8. Young weakfish, *Cynoscion regalis,* 13-16 cm (SL), showing progressive stages of fin necrosis (photograph from: Mahoney et al., 1973).

Mahoney et al. (1973) findings of disease incidence among weakfish taken in the Raritan, Lower, and Sandy Hook bays, July-August, 1967-1971 is as follows:

Year	Size (SL)	No. Examined	% Diseased
1967	>20 cma	40	35
1968	>20 cma	25	15
1969	>20 cma	199	15
1969	≤20 cma	24	60
1970	>20 cma	326	3
1971	>20 cma	576	10
1971	≤20 cma	39	5

3.4 Nutrition and Growth

3.4.1 Feeding

Weakfish feed throughout the water column with the size of the individual dictating the size of the prey. Merriner (1975) found a transition in food with size of individual; larger individuals tended to eat larger fishes and did not feed as heavily on the smaller invertebrate forms. Chao and Musick (1977) indicate that young weakfish feed mainly off the bottom and therefore are able to coexist with other species which have more benthic feeding habits in the same habitat. Chao (1978) classifies the weakfish, among western Atlantic sciaenids, as an "upper midwater feeder" on the basis of external morphology.

3.4.2 Food

Weakfish feed on a large variety of fishes and invertebrates throughout their range. Peck (1896), Eigenmann (1901), Linton (1904), Tracy (1910), Welsh and Breder (1923), Nichols and Breder (1926), Hildebrand and Schroeder (1927), Bigelow and Schroeder (1953), Thomas (1971), Merriner (1975), Stickney et al. (1975), Chao (1976), and Chao and Musick (1977) give accounts of the food items observed in various areas along the Atlantic coast. Among the fishes most frequently observed are butterfish, herrings, sand lance, silversides, anchovies, weakfish (young), Atlantic croaker, spot, scup, and killifishes. Among the invertebrates are assorted shrimps, squids, crabs, annelid worms, and clams.

3.4.3 Growth Rate

Many investigators during the last 78 years have estimated age composition and rate of growth from annual rings on scales, otoliths, vertebrae, and from length frequencies (Eigenmann, 1901; Tracy, 1908; Taylor, 1916; Welsh and Breder, 1923; Higgins and Pearson, 1928; Hildebrand and Schroeder, 1927; Hildebrand and Cable, 1934; Daiber, 1954, 1956, and 1957;

Nesbit, 1954; Perlmutter et al., 1956; Massmann, 1963a, b; McHugh, 1960; Wolff, 1972; and Merriner, 1973). These estimates vary considerably not only from one investigator to another, but from season to season, year to year, and area to area. Published data give the following approximate age-length information:

Age	Length (mm) Range	Average
1	130-315e	191
2	221-361e	264
3	240-400e	310
4	260-480e	375
5	340-555e	435
6	419-645e	480
7-8e	427-686e	495

These variations probably result from the existence of several groups along the coast which have different growth rates. In the course of their migrations these groups mix, and the proportions of the mix in any given area varies. The possibility of two or even three distinct populations of weakfish have been postulated by several investigators. However, the evidence is at best only tentative. Statistical studies of ova diameters; scale peculiarities; counts of gill rakers, fin rays, and vertebrae; and various measurements along the body are highly suggestive but only marginally significant (Welsh and Breder, 1923; Hildebrand and Cable, 1934; Perlmutter, 1939; Nesbit, 1954; Daiber, 1954; Perlmutter et al., 1956; and Sequin, 1960). Limited tagging studies by the U. S. Fish and Wildlife Service from 1931 to 1938 have demonstrated the fact of mixing as well as variation in the proportion of mix, but have not defined the populations in the mix (Nesbit, 1954).

3.4.4 Metabolism

No data available.

3.5 Behavior

3.5.1 Migrations and Local Movements

See section 2.2.2 and Figures 3 and 4 for a general description of seasonal movements. See section 2.3 for information pertinent to local movements.

3.5.2 Schooling

Usually school by size and begin to school as pre-adults.

3.5.3 Responses to Stimuli - Experimental Studies of Weakfish Behavior

Until recently, information about the behavior of marine fish species has come mainly from indirect evidence of anglers, commercial fishermen, and researchers. This kind of information still leaves many questions unanswered as to the precise role played by various environmental stimuli on normal patterns of behavior. One approach to answering these questions is to study the behavior of selected species, such as weakfish, under controlled conditions in the laboratory. The following is a synopsis of preliminary studies carried out on a small school of adult weakfish, held under controlled conditions in a 32,000 gallon multi-windowed sea-water aquarium (Olla et al., 1967) located at the National Marine Fisheries Service's Sandy Hook Laboratory (B. L. Olla, pers. comm.).

Schooling - when fright or stress stimuli (increased temperature) were introduced schooling became more frequent with the school tighter.

Feeding - weakfish are highly visually oriented when feeding; in addition they have a highly developed chemo-sensing response mechanism.

Responses to temperature - as temperature was gradually increased (0.05°C/h) from the fishes acclimated temperature range of 19-20°C to almost 29°C the animals exhibited a 35% increase in activity (swimming speed) accompanied by tight schooling and more frequent schooling; however, as the animals became acclimated to 29°C their activity decreased to a point similar to that before temperature was increased. This increased activity may serve to move the animals from regions of adverse temperature. Also of note, the experimental weakfish, although they may not have preferred it, could acclimate to a temperature of approximately 29°C after initially wanting to leave the area of increasing temperature.

4.0 POPULATION

4.1 Structure

During the period 1968-1976 the Northeast Fisheries Center's Sandy Hook Laboratory regularly obtained information on the sex, age composition, growth rates, size composition, and distribution and abundance of weakfish from New York to Florida by regularly sampling commercial and recreational fisheries and by extensive bottom trawling aboard research vessels (Wilk and Silverman, 1976a, b; and Wilk et al., 1977).

4.1.1 Sex Ratio

Our (NMFS) information indicate that the sex ratio at each age remains essentially the same from area to area and from year to year. There are equal numbers of males and females at all ages and weakfish do not appear to school by sex during any time of life.

4.1.2 Age Composition

See sections 2.2, Differential Distribution; 3.4.3, Growth Rate; and 3.1.2, Maturity.

4.1.3 Size Composition

Owing to the extended period of spawning activity and the possibility of several distinct coastal groups, there are large variations in length and weight within each age group. The length-weight relationship for weakfish from the New York Bight is illustrated in Figure 9 (Wilk et al., 1975). Included are the number of specimens weighed (n), slope (b), and y-intercept (a) values, and correlation coefficient (r). Wilk et al. (1978) found no difference between male and female length-weight relationships. They give the following data for males, females, and total sample based on the formula $\log_{10}$ weight = $\log_{10}$ a + b $\log_{10}$ length; where weight is in grams and the length is in millimeters total length:

Sex	n	log a	b	r	Size Range (mm)
male	55	-4.2815e	2.7310	0.99	210-673e
female	40	-4.1983e	2.6992	0.99	193-768e
total	666	-4.9189e	2.9631	0.99	59-768e

The following sections under "POPULATION" will be combined:

4.2 Abundance and Density

4.3 Natality and Recruitment

4.4 Mortality and Morbidity

Murawski (1977) recently formulated a preliminary assessment of weakfish in the Middle Atlantic Bight. His results, which are based on reported commercial and recreational landings, National Marine Fisheries Service research cruise data, and creel survey estimates, tentatively indicate that under present harvest conditions optimum exploitation rate has been reached. In addition, he further concludes that if age at first selection (capture) is increased from 1- to 2-years-old for all fisheries an increased in yield-per-recruit of approximately 30% could be anticipated.

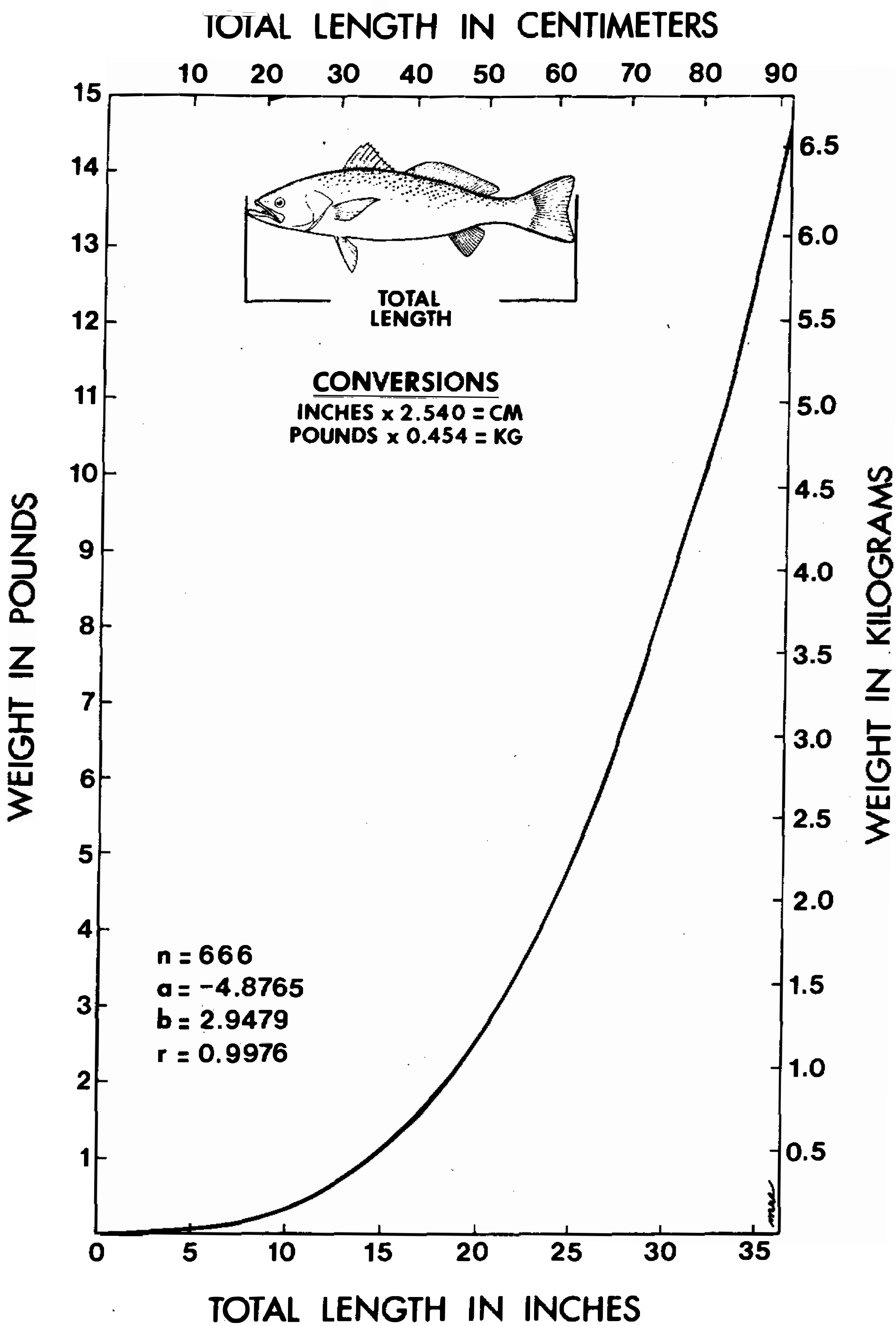


FIGURE 9. Length-weight relationship of weakfish, *Cynoscion regalis*, collected in the New York Bight, June 1974 to June 1975 (from: Wilk et al., 1975).

4.5 Dynamics of the Population(s)

Assessment with a view towards meaningful fishing management planning must take account of the different populations of weakfish on the Atlantic coast. These vary in abundance independently of each other. At present, there may be two or three principal ones and others which are evidently relatively small, or which might simply be at a low period in the cycle of their numbers. The identification of Atlantic coast populations, mapping of their distribution in time and space, and measurements of their respective abundance, and determination of the contribution of each to the fishery, require further studies of age and growth, fecundity, movements and migrations, scale and chemical characteristics, meristic and morphometric variations continuously over the entire range of the species for several years.

To measure the age composition and relative abundance of the various weakfish populations, we need continuous biologically representative sampling. So far we have not been able to achieve this over the entire range by sampling fishermen's catches. We cannot obtain it from commercial fishermen, for their individual catches are fairly minimal, highly selective, and opportunistic, and they land them at numerous small ports along the coast. Neither can we obtain it from recreational fishermen, for even though they take as much as or more than commercial fishermen, their individual catches are small and they too land them at many places along the coast and at all hours of the day and night.

Until the problem of biologically significant sampling is solved, questions related to year class strength, age composition of the populations, and status of the stocks will remain cloudy at best. If management of weakfish fisheries were to be indicated, it would require cooperation of all the Atlantic coastal states.

4.6 The Population in the Community and the Ecosystem

No data available.

5. EXPLOITATION

The following sections under "EXPLOITATION" will be combined:

5.1 Fishing Equipment

5.2 Fishing Areas

5.3 Fishing Seasons

5.4 Fishing Operations and Results

Commercial fishermen take weakfish with gill nets (Figure 10A), haul seines (Figure 10B), pound nets (Figure 10C), hook and lines, otter

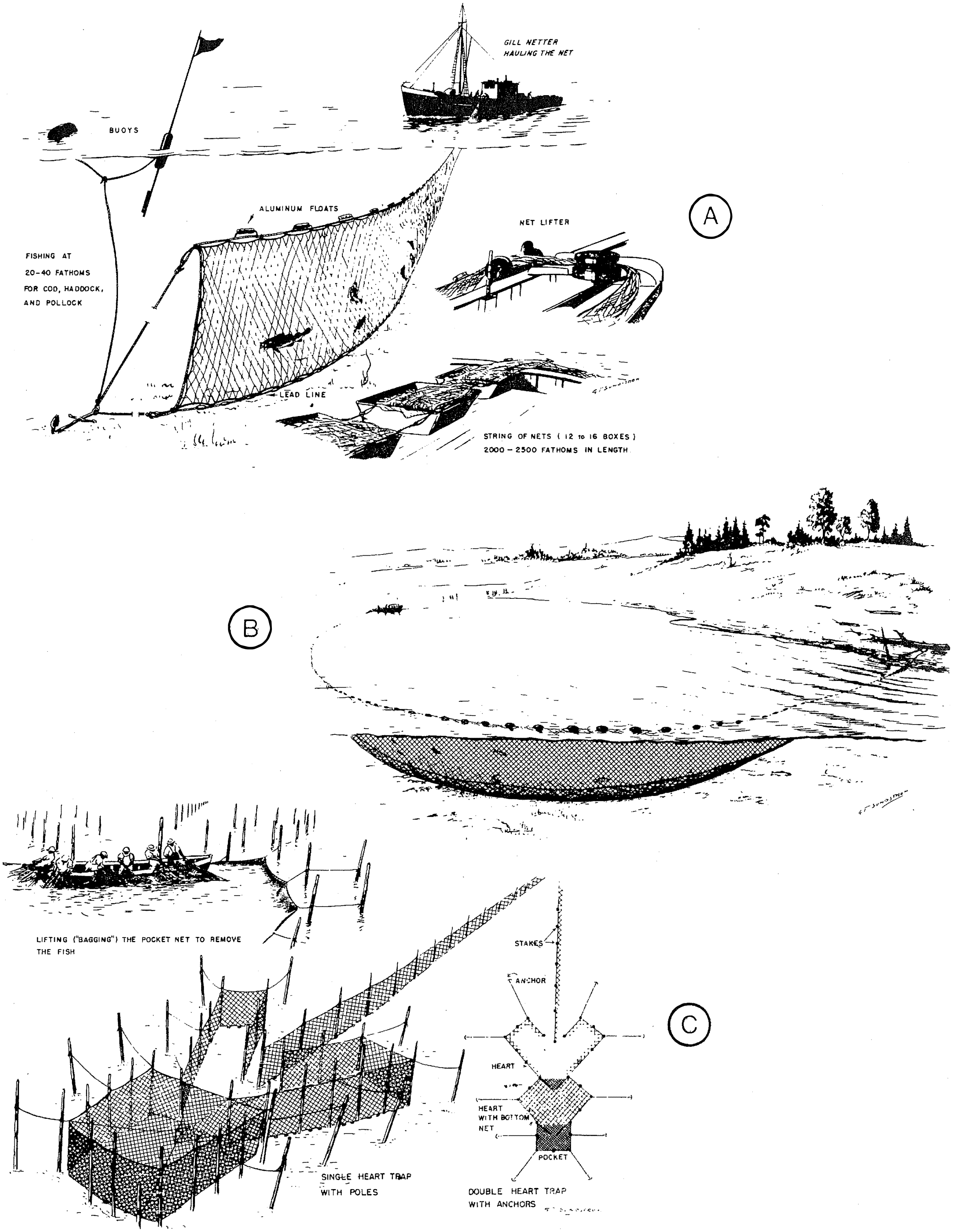


FIGURE 10. Commercial fishing gear used to capture weakfish, Cynoscion regalis: A. gill net; B. haul seine; and C. pound net (illustrations from: Sundstrom, 1957).

trawls (Figure 11A), purse seines (Figure 11B), and in olden days, they also took them with fyke and hoop nets (Figure 12A, B). The commercial landings by states from 1930 to 1977 are tabulated in Table 4 and summarized and graphically represented in Figure 13. Figure 14 illustrates the five-year averages of commercial landings for both geographic and fisheries management areas from 1930 to 1977. The commercial landings of weakfish might be significantly higher if the "scrap" landings of the species were included in the totals (McHugh, 1960; and Wolff, 1972).

McHugh (1977) gives an excellent historical review of both the commercial and recreational fisheries for weakfish in the New York Bight from the 1800's to the present. He indicated that the resource has increased in recent years with anglers taking an increasing share of the catch, while commercial landings have declined slightly. He concludes that although weakfish are presently relatively abundant, the resource has historically fluctuated widely in abundance and without effective management the present period of abundance may only be temporary.

According to Freeman and Walford (1974a, b, c, d; and 1976a, b) anglers take weakfish from boats while trolling, chumming, casting live-bait fishing, jigging, still fishing, and drift fishing. They also catch them from shore while casting, still fishing, live-bait fishing, jigging, and chumming. Figures 15, 16, and 17 based on data given by Clark (1962), Deuel and Clark (1968), Deuel (1973), and Deuel (pers. comm.), summarize and graphically illustrate the recreational fishery for weakfish along the Atlantic coast. Miller (Division Fish Wildl., Del., pers. comm.) based on creel surveys conducted in Delaware during 1968, 1971-1973, and 1976, indicates that the aforementioned recreational statistics may have underestimated the recreational importance of the weakfish in Delaware waters.

6.e PROTECTION AND MANAGEMENTe

6.1 Regulatory (Legislative) Measurese

There are state regulations in effect regarding the capture of weakfish. The state regulations are given in Table 5.

The purpose of the aforementioned state regulations (Table 5) are to insure successful year classes by limiting the capture of young-of-the-year and yearling fish (9-12 inches). The state laws, in most cases, have been on the books for many years and probably have little or no effect on the fishery due to lack of enforcement and the inconsistency of the regulations or lack of regulations from state to state.

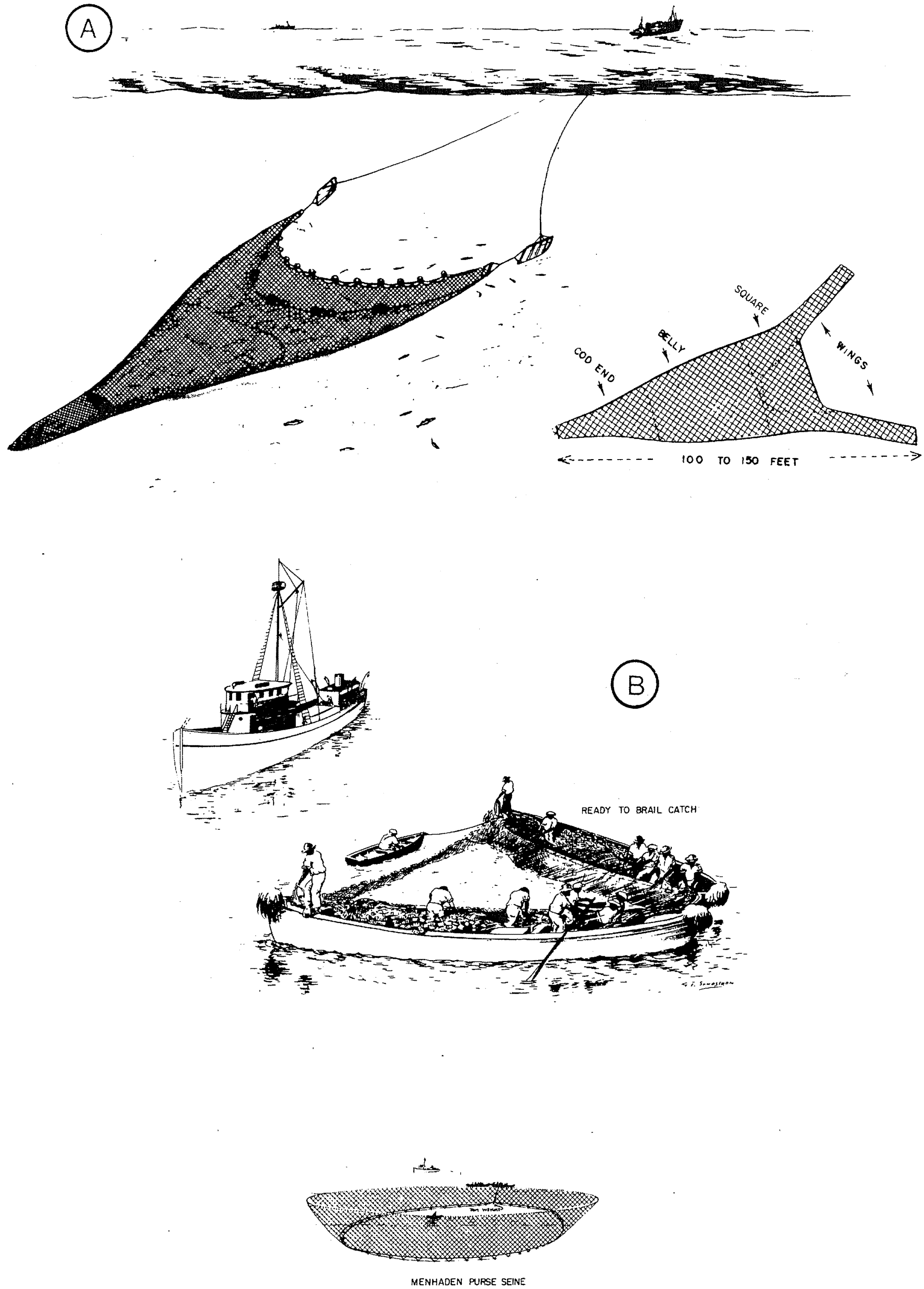
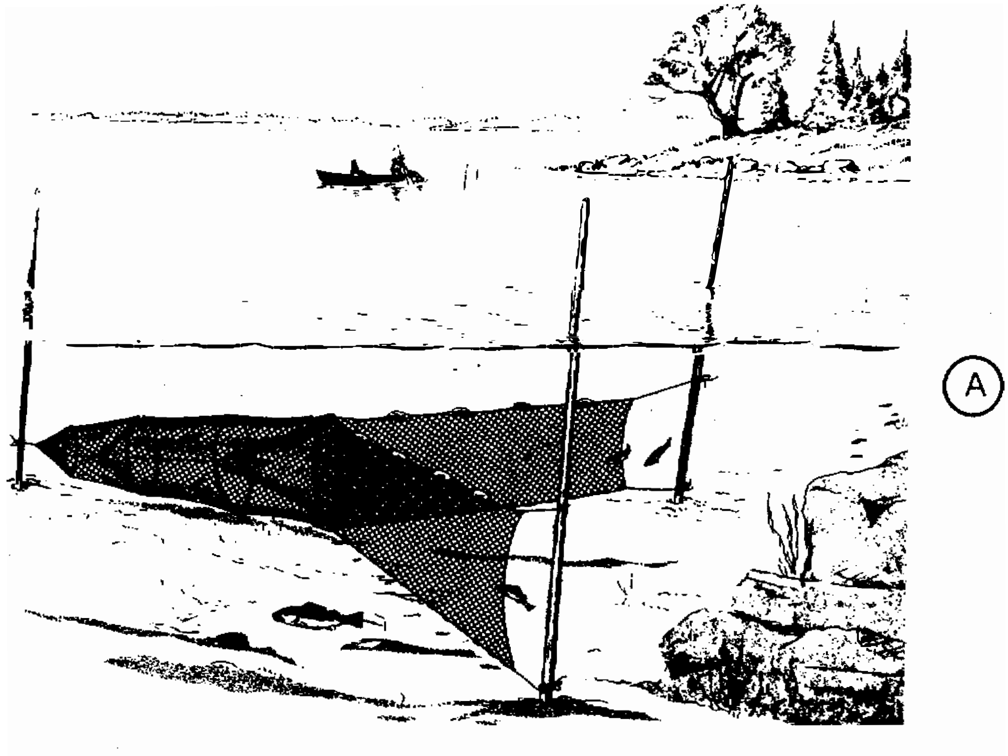


FIGURE 11. Commercial fishing gear used to capture weakfish, Cynoscion regalis: A. otter trawl; and B. purse seine (illustrations from: Sundstrom, 1957).



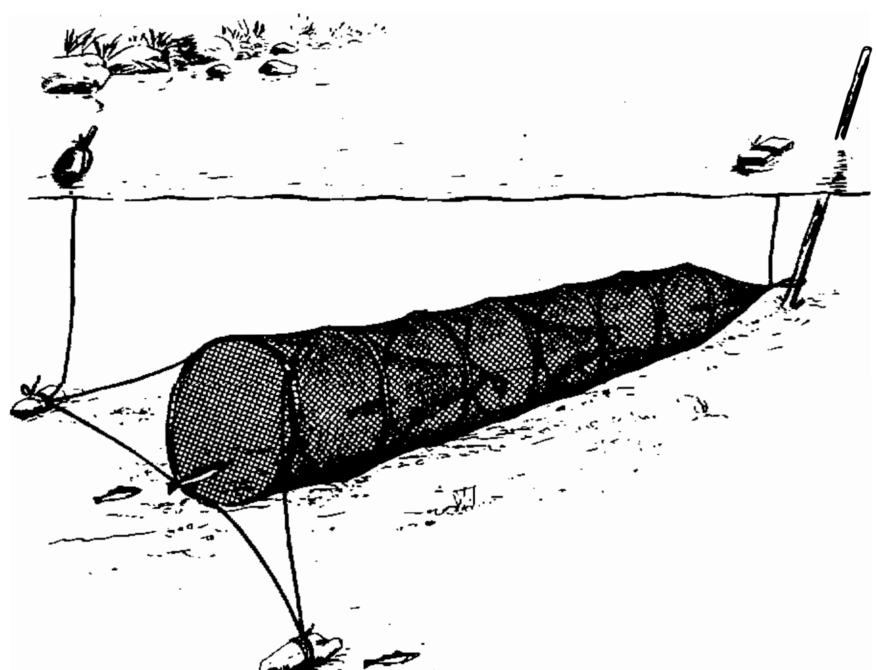


FIGURE 12. Commercial fishing gear used in the past to capture weakfish, Cynoscion regalis: A. fyke net; and B. hoop net (illustrations from: Sundstrom, 1957).

TABLE 4. Commercial landings of weakfish, Cynoscion regalis, by state, 1930-1977 (thousands of pounds). A dash (-) indicates information not available or no catch reported, and an asterisk (*) indicates less4 than 500 pounds taken.

Year	ME	MA	RI	CT	NY	NJ	DE	MD	VA	NC	SC	GA	FL (East Coast)	Total
1930	-	14	1414	43	950	11098	1235	3754	15512	2333	24	3	599	35693
1931	*	150	524	28	1467	11685	400	2159	10279	2994	4	-	24	29242
1932	*	574	58	17	677	8305	106	1806	11974	3636	2	2	21	26661
1933	-	2874	634	20	824	6927	123	1154	12310	-	-	-	-	21708
1934	-	-	-	-	-	-	-	1478	13406	7729	2	-	10	22625
1935	-	2614	384	29	1640	8075	428	1313	13443	-	-	-	-	25227
1936	-	-	-	-	-	-	-	1340	10349	8969	3	-	-	20661
1937	-	1284	644	9	1457	10515	292	10904	126074	7525	6	-	*	33693
1938	-	2724	614	6	1057	6289	197	10694	125474	5095	5	-	-	26598
1939	-	1244	574	10	1425	6089	413	1459	121004	2840	2	1	1	24521
1940	-	1084	374	9	1508	2983	300	1368	123064	3629	2	-	-	22250
1941	-	-	-	-	-	-	-	1219	72324	-	-	-	-	8451
1942	-	4	534	17	1810	4200	171	1468	61264	-	-	-	-	13849
1943	-	22	464	25	2095	5071	218	-	-	-	-	-	-	74774
1944	-	38	2154	68	1509	4719	272	2069	10313	-	-	-	-	19203
1945	-	44	2984	41	2109	9124	286	2369	22379	4739	-	-	33	41422
1946	-	42	4004	151	2305	-	-	2266	18291	-	-	-	-	23455
1947	-	60	3264	69	1544	5691	582	1638	17678	-	-	-	-	275884
1948	-	13	1584	85	1002	3306	640	1109	11854	-	-	-	-	18167
1949	-	1	164	3	406	2518	1038	614	6062	-	-	-	-	106584
1950	-	14	44	1	1424	1083	573	592	4011	-	-	-	-	64074
1951	-	-	1	2	1524	1965	666	233	1979	1263	-	-	81	63424
1952	-	-	24	44	1674	2176	281	281	1508	1626	-	-	43	6088
1953	-	-	17	74	1084	2162	732	252	2032	1897	-	-	20	7227
1954	-	-	84	34	1274	2003	369	263	2122	2381	26	-	59	7361
1955	-	*4	5	6	2054	1877	1579	412	3831	1356	-	1	15	9287
1956	-	-	124	11	2114	2002	958	477	3258	1842	-	1	7	87794
1957	-	-	234	224	1994	2025	1282	340	2019	2210	11	-	19	8150
1958	-	-	9	2	884	546	325	209	1567	3810	6	-	29	6591
1959	-	-	1	1	454	372	182	109	682	2913	7	-	34	4346
1960	-	-	24	14	894	526	8	271	810	2240	13	-	54	4014
1961	-	-	14	2	534	418	134	279	1194	2308	25	-	57	4471
1962	-	-	7	5	484	650	143	193	1489	2160	11	-	26	4732
1963	-	-	2	14	864	333	148	94	1098	1761	6	*	724	3601
19644	-	-	1	*	564	545	127	172	1593	1966	7	-	1074	4574
19654	-	-	4	*	734	596	221	248	2007	1959	23	2	2984	5431
19664	-	-	14	-	264	344	90	150	1040	1896	20	1	1844	3761
19674	-	-	2	-	30	456	8	85	600	1769	3	*	1284	30814
19684	-	-	3	-	63	532	5	153	1120	2286	1	*	2194	4382
19694	-	-	14	-	117	1869	21	175	870	1539	6	*	1444	47554
1970	-	-	21	-	296	1961	147	322	2142	2441	4	*	2924	74794
19714	-	-	183	-	1280	3081	213	408	2332	3645	-	-	1444	11073
19724	-	-	174	-	1831	3179	406	313	2544	7372	*	-	1754	15588
19734	-	3	178	-	1269	2563	334	540	5099	6222	2	*	2064	16082
19744	-	48	458	-	1427	2686	281	410	3063	6056	2	-	1294	14279
19754	-	7	466	-	1368	4370	290	887	4090	6726	2	2	1134	18031
19764	-	13	326	-	1345	5709	246	432	3975	8714	1	-	89	20604
19774	-	10	328	-	1708	3222	332	207	4326	8671	-	1	-	184734

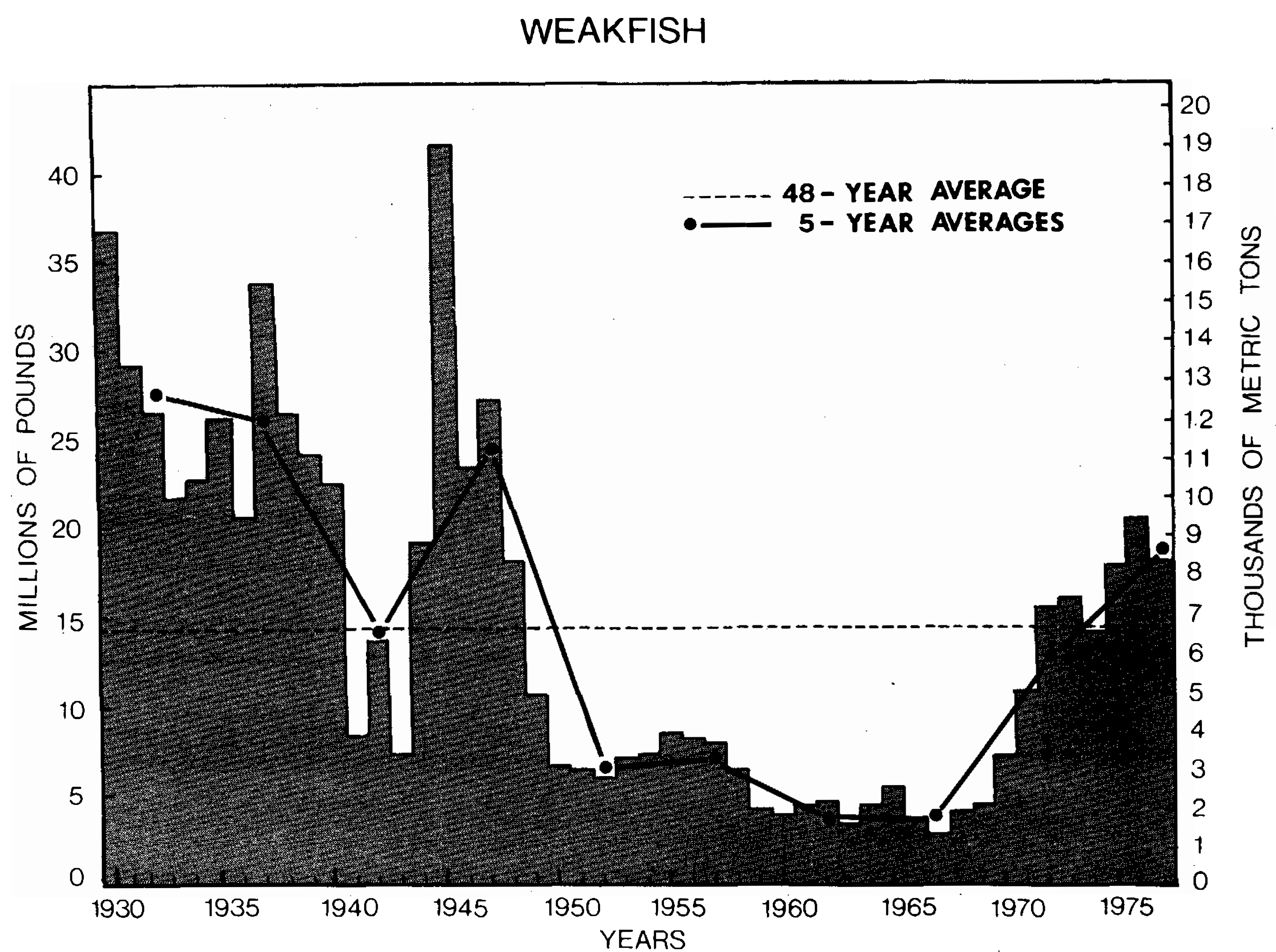


FIGURE 13. U. S. commercial landings of weakfish (*Cynoscion regalis*) 1930-1977, including 5- and 48-year averages.

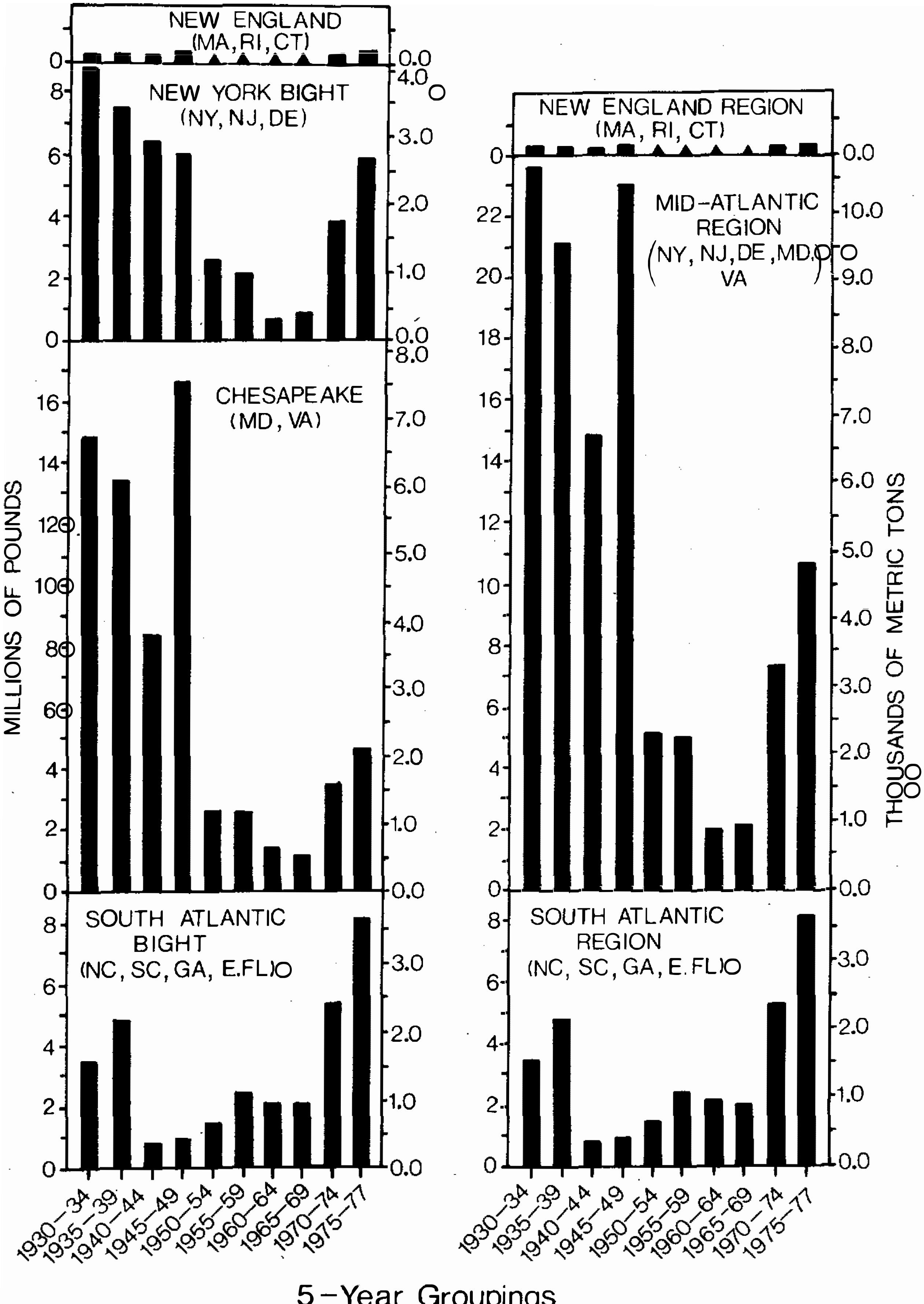


FIGURE 14. U. S. commercial landings of weakfish (*Cynoscion regalis*) 1930-1977, 5-year averages by geographic areas and fishery management regions.

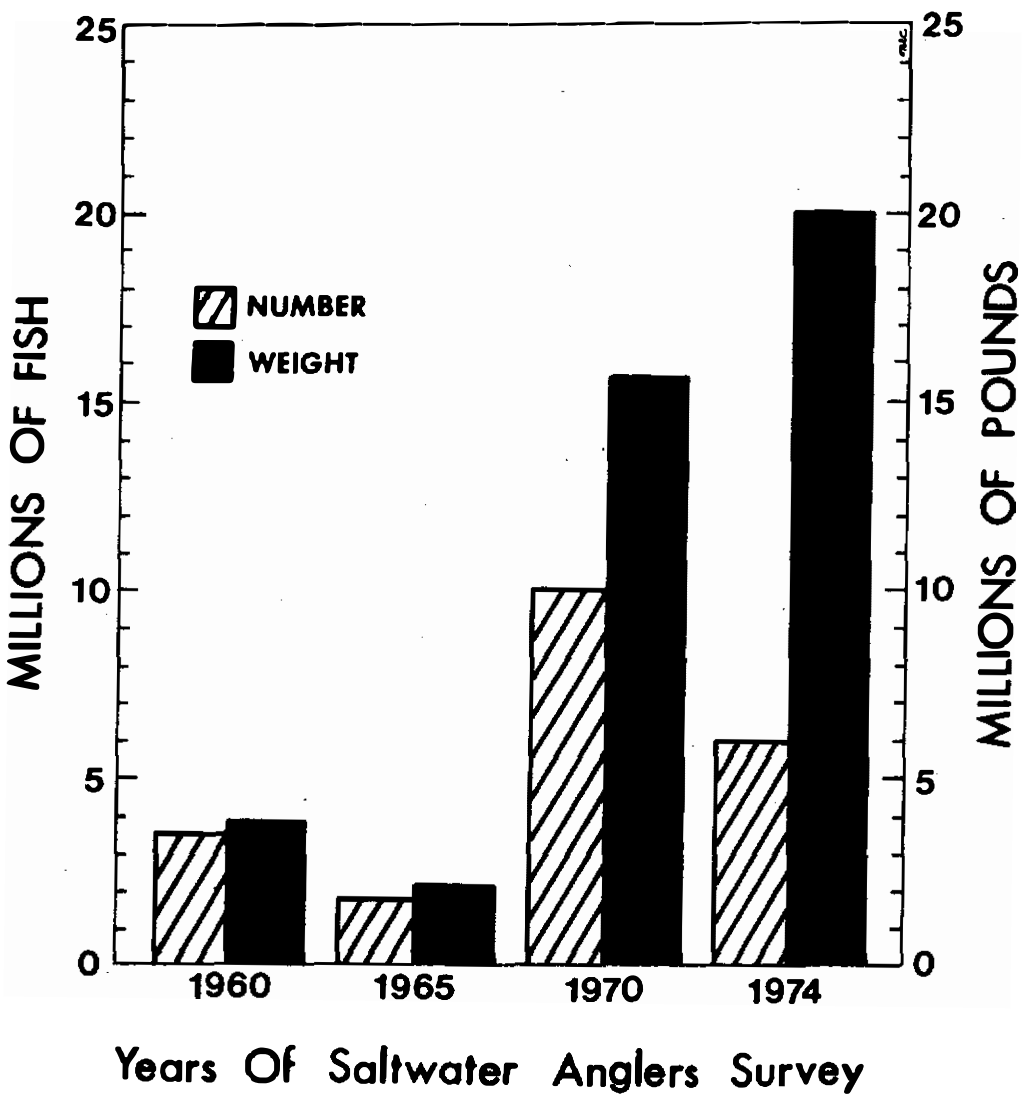


FIGURE 15. Recreational catch (no. and wt.) of weakfish (Cynoscion regalis) during 1960, 1965, 1970, and 1974 (from: Clark, 1962; Deuel and Clark, 1968; Deuel, 1973; and Deuel, pers. comm.).

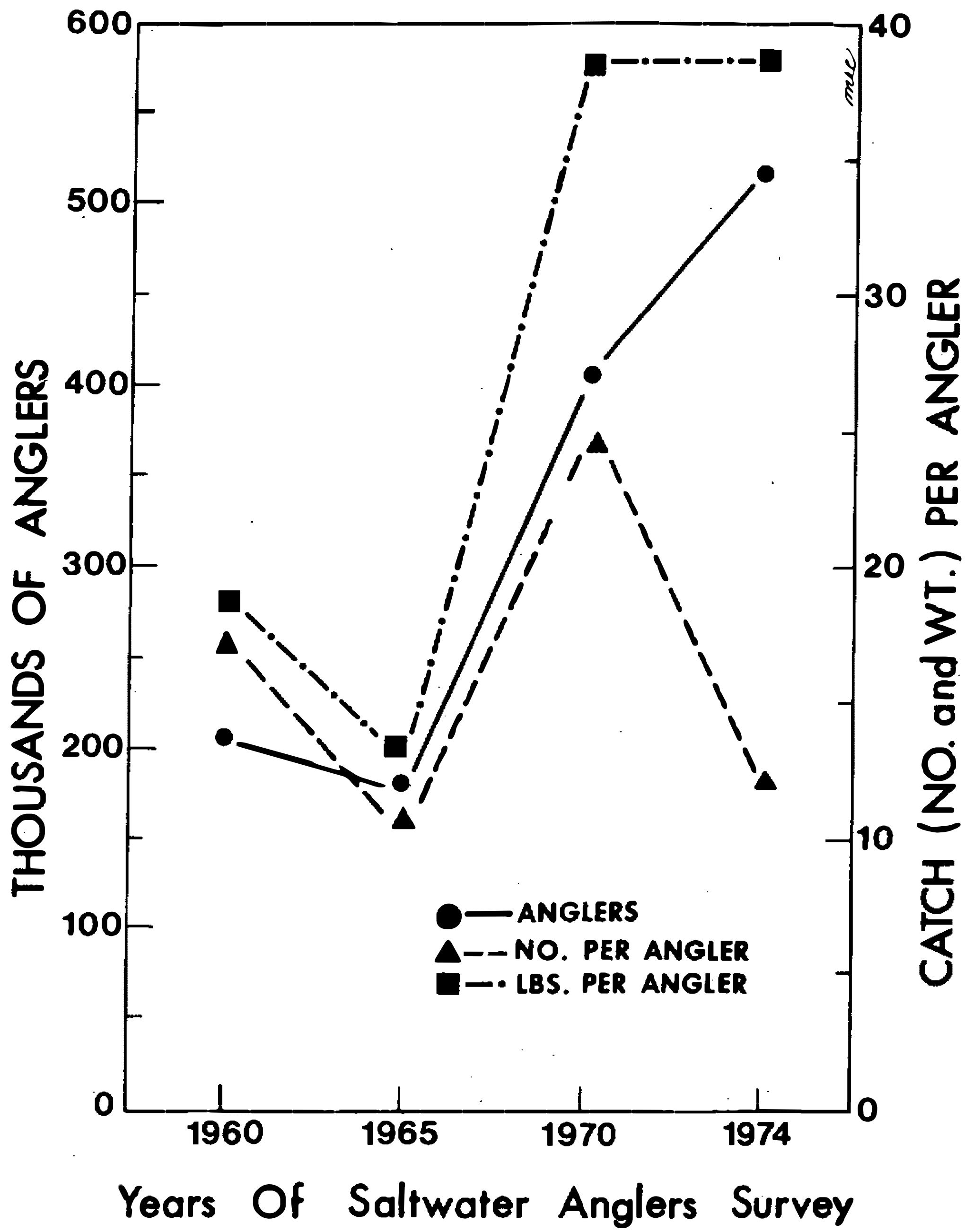


FIGURE 16. Number of anglers fishing for and their average catch (no. and wt.) of weakfish (*Cynoscion regalis*) 1960, 1965, 1970, and 1974 (from: Clark, 1962; Deuel and Clark, 1968; Deuel, 1973; and Deuel, pers. comm.).

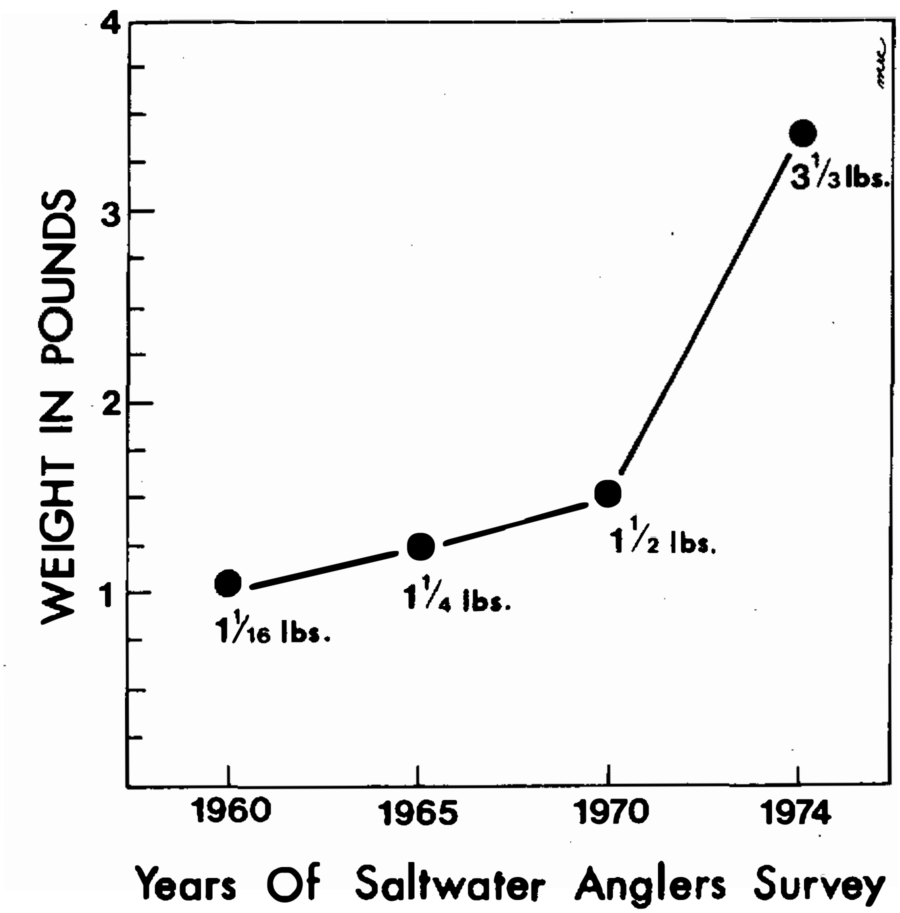


FIGURE 17. Average weight of weakfish (*Cynoscion regalis*) taken by anglers during 1960, 1965, 1970, and 1974 (from: Clark, 1962; Deuel and Clark, 1968; Deuel, 1973; and Deuel, pers. comm.).

TABLE 5. State commercial and recreational fishing regulations for weakfish, *Cynoscion regalis*.

State	Commercial Fishing	Recreational Fishing
Maine	None	None
New Hampshire	None	None
Massachusetts	None	None
Rhode Island	None	None
Connecticut	None	None
New York	Only weakfish measuring 12 inches may be retained[1]	Only weakfish measuring 12 inches may be retained[1]
New Jersey	None	None
Delaware	Only weakfish measuring 10 inches may be retained and only nets measuring 2 inches may be used	Only weakfish measuring 10 inches may be retained
Maryland	Only weakfish measuring 10 inches may be retained	Only weakfish measuring 10 inches may be retained
Virginia	Only weakfish measuring 10 inches may be retained	Only weakfish measuring 10 inches may be retained
North Carolina	None	None
South Carolina	None	None
Georgia	None	None
Florida	None	None
Alabama	None	None
Mississippi	None	None
Louisiana	None	None
Texas	None	None

[1]This recent 12-inch size limitation for weakfish was touted by recreational fishermeno as a technique to insure successful year classes; however, it was endorsed by commercial fishermen because they saw the size limitation as a measure to keep an acceptable market size (Poole, New York State Department of Environmental Conservation, pers. comm.).

6.2 Control or Alteration of the Physical Features of the Environment

No data available.

6.3 Control or Alteration of the Chemical Features of the Environment

Joseph (1972) hypothesized that the widespread use of DDT along the Atlantic coast, beginning in 1945 and 1946 and its continued heavy use for the next years, might be related to the dramatic decline in weakfish stocks during the 1950's and 1960's. He further supports his views by noting that Butler (1969) found no breeding for two spawning seasons in spotted seatrout (*Cynoscion nebulosus*) from an area of Texas with consistently high pesticide residues.

Recently, Hall et al. (1978) analyzed weakfish muscle, liver, and whole tissue samples for 15 trace element levels. The results of their study are summarized in Table 6.

6.4 Control or Alteration of the Biological Features of the Environment

No data available.

6.5 Artificial Stocking

No data available.

7.e AQUACULTUREe

No data available.e

TABLE 6. Trace element levels in weakfish, *Cynoscion regalis*, muscle, liver, and whole tissue samples (from: Hall et al., 1978).

Element	Tissue	Total No. of samples	No. of samples in mean	RANGE OF MEAN ELEMENT CONTENT (ppm) <0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1.0	1.0-2.0	2.0-3.0	3.0-4.0	4.0-5.0	5.0-6.0	6.0-7.0	7.0-8.0	8.0-9.0	9.0-10.0	10.0-20.0	20.0-30.0
Antimony	Muscle	72	55							X														
	Liver	3	3						X															
	Whole	10	10											X										
Arsenic	Muscle	72	71											X										
	Liver	2	2											X										
	Whole	10	10												X									
Cadmium	Muscle	72	68	X																				
	Liver	3	3			X																		
	Whole	10	10		X																			
Chromium	Muscle	71	70		X																			
	Liver	3	3		X																			
	Whole	10	10				X																	
Copper	Muscle	72	72				X																	
	Liver	3	3															X						
	Whole	10	10					X																
Lead	Muscle	70	69					X																
	Liver	3	3					X																
	Whole	10	10											X										
Manganese	Muscle	72	72		X																			
	Liver	3	3										X											
	Whole	10	10											X										
Mercury	Muscle	71	70		X																			
	Liver	3	3	X																				
	Whole	10	6	X																				
Molybdemum	Muscle	72	22		X																			
	Liver	3	2		X																			
	Whole	10	10			X																		
Nickel	Muscle	72	71			X																		
	Liver	3	3				X																	
	Whole	10	10				X																	
Selenium	Muscle	71	71						X															
	Liver	2	2								X													
	Whole	10	10											X										
Silver	Muscle	72	59	X																				
	Liver	3	3	X																				
	Whole	10	10		X																			
Tin	Muscle	72	72						X															
	Liver	3	3				X																	
	Whole	10	10											X										
Vanadium	Muscle	72	21				X																	
	Liver	3	1	X																				
	Whole	10	10					X																
Zinc	Muscle	71	71														X							
	Liver	3	3																					X
	Whole	10	10																				X	

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