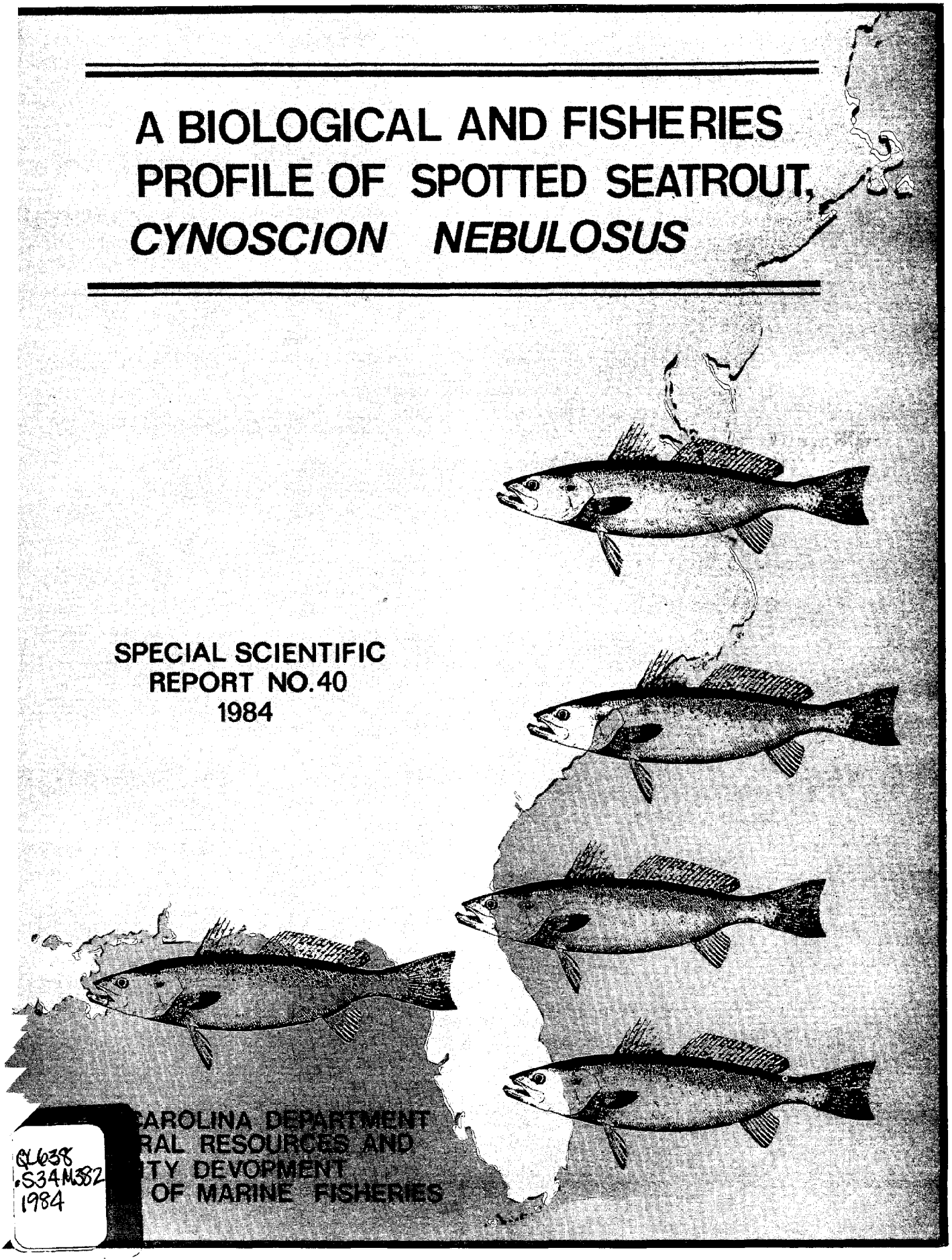
A BIOLOGICAL AND FISHERIES PROFILE OF SPOTTED SEATROUT, *CYNOSCION NEBULOSUS*



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A BIOLOGICAL AND FISHERIES PROFILE OF

SPOTTED SEATROUT, *Cynoscion nebulosus*

by

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PREFACE

In the early 1970s, state marine fisheries management agencies and the National Marine Fisheries Service (NMFS) began a cooperative program to prepare and implement fishery management plans for coastal migratory species and shared fisheries resources occurring in the Territorial Sea along the Atlantic Coast of the United States. This effort, called the State-Federal Fisheries Management Program, resulted in cooperative management plans for species such as the American lobster, surf clam, striped bass, Atlantic menhaden, penaeid (southern) shrimp, pandalid (northern) shrimp, and summer flounder, as well as development of a cooperative statistics program in the Southeast Region of the United States. Several of these plans have been adopted and implemented by regional Fisheries Management Councils under the Magnuson Fishery Conservation and Management Act of 1976 (PL 94-265). Funding for the overall program has been provided by NMFS through the Atlantic States Marine Fisheries Commission. Since 1980, this coordination has been formally conducted under the Commission's Interstate Fisheries Management Program. This spotted seatrout profile represents the initial step in preparation of profiles and plans for cooperative management of important sciaenid species occurring along the Atlantic Coast.

CONTENTS

1. IDENTITY

1.1 Nomenclature

The valid name for spotted seatrout is Cynoscion nebulosus (Cuvier) 1830 (Figure 1). The following synonymy is after Jordan and Evermann (1896):

Labrus squeteague var. maculatus, Mitchill, 1815
Otolithus nebulosus, Cuvier and Valenciennes, 1830
Otolithus carolinensis, Cuvier and Valenciennes, 1833
Otolithus drummondi, Richardson, 1836
Cestreus carolinensis, Gronow, 1854
Cynoscion carolinensis, Jordan and Gilbert, 1878
Cynoscion maculatum, Jordan and Gilbert, 1882
Cestreus nebulosus, Jordan and Eigenmann, 1889

1.2 Taxonomy

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 nebulosus

The spotted seatrout is one of 33 members of the family Sciaenidae found along the Atlantic, Gulf and Pacific coasts of the United States (Robins et al. 1980). Members of this family are commonly known as drum fishes or croakers because of the drumming or croaking sounds they produce by vibrating their swimbladders (Bigelow and Schroeder 1953). Chao (1978) assessed the phylogenetic relationships of western Atlantic Sciaenidae on the basis of swimbladder, otoliths, and external morphology. He also presented a field key to the genera and species, including meristics and species ranges. Hildebrand and Cable (1934) provided a key to eggs and young (< 35 mm TL) of Atlantic coast drums.

There are three other members of the genus Cynoscion found along the Atlantic and Gulf coasts of the United States: weakfish, C. regalis; silver seatrout, C. nothus; and sand seatrout, C. arenarius. Mohsin (1973) compared the osteology of these four species and hypothesized that there are two phyletic lines within the genus Cynoscion: one comprised of C. nebulosus and C. arenarius and the other of C. nothus and C. regalis. Results

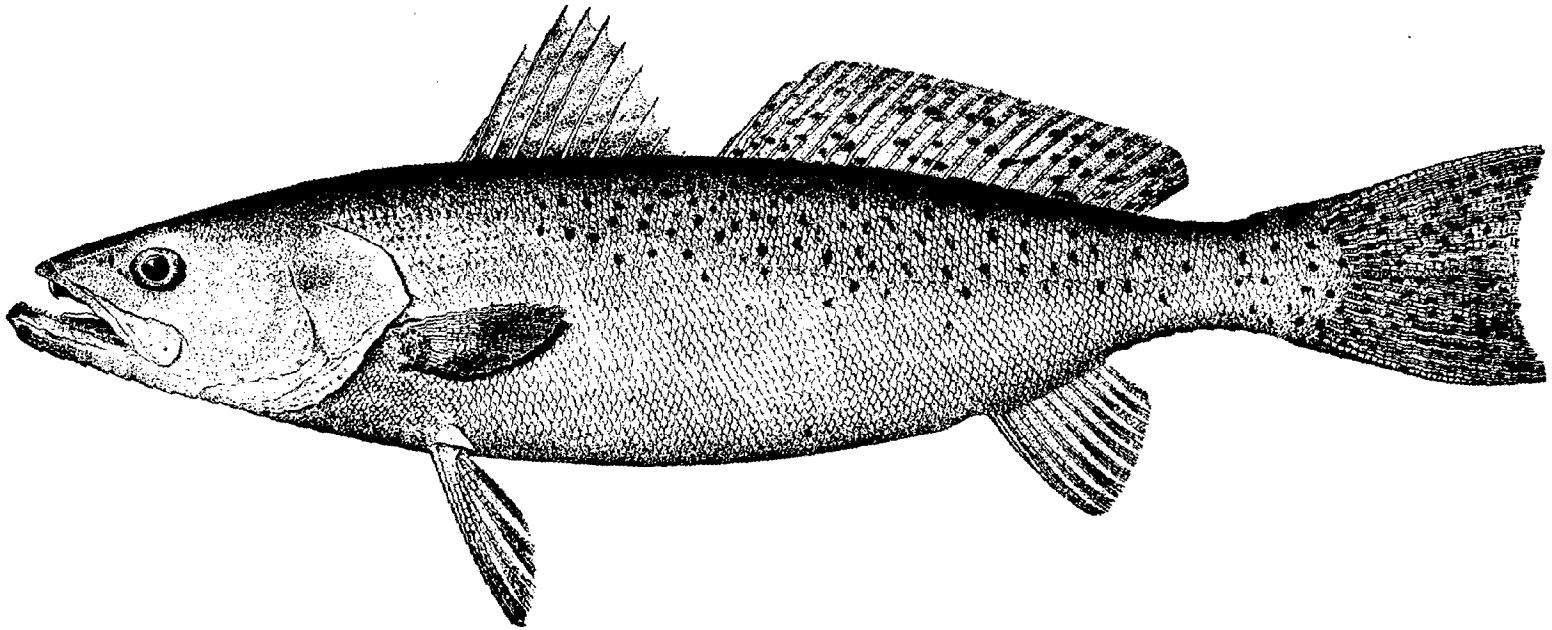

Figure 1. Spotted seatrout, Cynoscion nebulosus (Cuvier), 1830, illustrated by Goode, 1884.

of an electrophoretic investigation refuted Mohsin's conclusion and indicated that C. arenarius should be regarded as a subspecies of C. regalis (Weinstein and Yerger 1976a). These results supported conclusions of previous morphological (Ginsburg 1929) and ecological (Tabb 1966) studies that C. nebulosus is the most divergent of the four forms. An electrophoretic study of C. nebulosus from various estuaries along the Atlantic and Gulf coasts indicated that each estuary may contain a discrete subpopulation. (Weinstein and Yerger 1976b).

Spotted seatrout is the common name given Cynoscion nebulosus by the American Fisheries Society (Robins et al. 1980). Other common names are spotted weakfish, spotted squeteague, salmon trout, simon trout, spotted trout, speckles, specs, speckled trout, trout, seatrout, black trout, salmon, southern squeteague and winter trout (Smith 1907; Hildebrand and Schroeder 1928; Shiino 1976).

1.3 Morphology

The following description is that of Johnson (1978), summarized from Jordan and Evermann (1896), Welsh and Breder (1923), Hildebrand and Schroeder (1928), Hildebrand and Cable (1934), Miller and Jorgenson (1973), and Chao (1976).

D. X (rarely IX or XI)-I, 24-28, A. II, 9-12 (typically 10-11); C. 9+8, procurrent rays 6-9+5-7; V. I, 5; lateral line scales 90-102, scales between anal fin origin and lateral line 11-12; vertebrae 13+12; gill rakers 6-9 on lower limb; branchiostegals 7; a pair of large canine-like teeth at tip of upper jaw; remaining teeth small conical, set in narrow bands with outer row slightly enlarged in upper jaw and inner row distinctly enlarged in jaw; no teeth on vomer, palatines, or tongue.

Head 2.9-3.5, depth 3.4-4.5 in SL; snout 3.7-4.2, eye 4.4-5.3, interorbital 4.5-5.9, maxillary 2.2-2.3, pelvic fin 1.8-2.2 in head.

Body elongate and somewhat compressed; back a little elevated; head long; snout pointed; mouth large, oblique; lower jaw projecting; maxillary reaching to or nearly to posterior margin of eye. Scales moderate, thin, all ctenoid, fins scaleless, except for 1-10 rows of small scales at dorsal and anal fin bases. Dorsal fin continuous or slightly separate, the spines weak, flexible; anal fin small, second spine very weak, caudal fin straight to somewhat emarginate. Preopercular margin smooth, sometimes cilliated, never with strong serrations.

Pigmentation: Color dark gray above, with sky blue reflections, shading to a silvery below; upper parts of sides with numerous round black spots extending onto dorsal and caudal fins; fins pale to yellowish green.

Readily distinguished from related species by the round black spots on upper parts of body and on dorsal and caudal fins, the small scales, and the scaleless median fins.

Development of body proportions and meristic characters of larvae and juveniles (1.9-32.2 mm NL and SL) were reported by Powles and Stender (1978). Standard length-total length relationships for spotted seatrout in Georgia (Jorgenson and Miller 1968), Louisiana (Hein et al. 1980), Mississippi (Overstreet 1983), and Texas (Harrington et al. 1979) are presented in Table 1.

2. DISTRIBUTION

2.1 General distribution

Spotted seatrout occur along the Atlantic and Gulf coasts of the United States from Cape Cod, Massachusetts to Carmen Island in the lower Gulf of Campeche, Mexico (Welsh and Breder 1923; Mather 1952; Tabb 1966; Yanez-Arancibia et al. 1980). They are rare in and north of Delaware Bay (Welsh and Breder 1923), and the center of abundance is from Florida to Texas (Pearson 1929).

2.2 Differential distribution

2.21 Spawn, larvae, and juveniles

Spotted seatrout eggs have not been identified in field collections and data on the preferred spawning habitat are conflicting. Information on spawning areas in the Gulf of Mexico was summarized by Hein and Shepard (1979a) and Perret et al. (1980). The distribution of larvae and gravid and spent adults indicates that spawning occurs both within estuaries and in near-shore coastal waters along the Atlantic and Gulf coasts (Pearson 1929; Miles 1950, 1951; Stewart 1961; Tabb and Manning 1961; Tabb 1966; Jannke 1971; King 1971; Christmas and Waller 1973; Mahood 1975; Powles and Stender 1978; Houde et al. 1979; Brown 1981; Overstreet 1983).

Spotted seatrout larvae and postlarvae have been collected in channels and passes entering Florida, Louisiana, and Texas bays (Jannke 1971; King 1971; Sabins and Truesdale

Table 1. Standard length-total length relationships for spotted seatrout as reported in the literature.

Reference	Location	Size Range (mm TL)	N	Sex	Relationship	r
Jorgenson and Miller (1968)	Georgia	10-72	20	-	TL = 1.020 + 1.224 SL	-
					SL = -0.764 + 0.815 TL	-
Harrington et al. (1979)	Texas	53-858	9857	-	TL = 11.804 + 1.138 SL	0.997
Hein et al. (1980)	Louisiana	21-629	1208	-	SL = -3.883 + 0.865 TL	0.995
Overstreet (1983)	Mississippi	55-624	1680	females	TL = 10.659 + 1.128 SL	0.998
					SL = -8.354 + 0.883 TL	0.998
		55-535	1089	males	TL = 10.165 + 1.129 SL	0.997
					SL = -7.465 + 0.880 TL	0.997

1974; Robison in press) and in the eastern Gulf of Mexico within the 15 m isobath (Houde et al. 1979). Miles (1950) reported a close association between postlarvae and widgeon grass (Ruppia maritima) in Texas bays. Hildebrand and Cable (1934) collected only 17 spotted seatrout larvae (<5.0 mm) from 11 km offshore to within the Newport River estuary in several years of intensive sampling in the vicinity of Beaufort, North Carolina. All larger specimens were caught in the estuary. Williams and Deubler (1968) collected six metamorphosing spotted seatrout (16.0 mm TL) during two years of sampling in the lower Neuse and Pamlico rivers, N.C. In South Carolina larvae and postlarvae (1.9-32.2 mm SL) were collected in lower portions of the estuaries and in tidal passes (Powles and Stender 1978). Setzler (1977) sampled along a transect from 10.5 km offshore to the head of Doboy Sound, Sapelo Island, Georgia and found that spotted seatrout postlarvae were restricted to the estuary. In the Indian River lagoon system of east-central Florida young (<20 mm) were observed in moderately deep water (<3 m) over algae and muddy sand bottom (Tabb 1961). Extensive sampling there on the shallow flats failed to produce postlarvae or juveniles. The low number of specimens collected along the Atlantic coast prevents any conclusion as to the preferred habitat of larval spotted seatrout.

Young-of-the-year spotted seatrout are generally associated with seagrass beds in estuaries. Pearson (1929) collected hundreds of juveniles (20-30 mm TL) along the grassy shore lines of remote Texas bays, small restricted bayous, and creeks. In Chesapeake Bay, Virginia, juvenile spotted seatrout (24-140 mm TL) were collected in seagrass beds from July to October (Orth and Heck 1980; Brown 1981). In November young-of-the-year were caught by trawl in the channels (18-23 m) of the York and James rivers (Brown 1981). In North Carolina juveniles were collected from April to September, mainly in areas of seagrass (Spitsbergen and Wolff 1974; Wolff 1976; Purvis 1976; Miller and Dunn 1980). A few juveniles were collected in trawl surveys of South Carolina estuaries (Lunz and Schwartz 1969; Turner and Johnson 1972) and in seine and rotenone collections from an intertidal creek (Cain and Dean 1976). Spotted seatrout juveniles were trawled and seined in Georgia estuaries and along the beaches in the surf zone (Miller and Jorgenson 1969; Dahlberg 1972; Mahood 1975). More were usually taken in tidal pools and small creeks at low tide when they could not hide in the grasses along the banks (Mahood 1975). In the Indian River area of Florida, juvenile spotted seatrout were collected in areas of sand and seagrass (Tabb 1961; Jones et al. 1975). The smallest individuals (8-50 mm SL) were taken in moderately deep channels (<3 m) and appeared to disperse to shallower grassy bays with increasing size (Tabb 1961). Juveniles (13-173 mm FL) were collected over mud and sand bottom in low salinity areas (0-11.1 ppt) of the St. Johns River system, Florida (Tagatz 1967).

2.22 Adults

The spotted seatrout is primarily an estuarine species and is most abundant in the confines of semi-landlocked lagoons and quiet estuaries (Tabb 1958). Along the coasts of Florida, Alabama, Mississippi, and Texas, spotted seatrout are primarily found in large areas of shallow, quiet, brackish water with extensive submerged vegetation characterized by turtle grass (Thalassia testudinium), shoal grass (Halodule wrightii), and widgeon grass, with adjacent deep areas (3-6 m) used for refuge from high summer temperatures and winter cold (Pearson 1929; Miles 1950; Tabb 1958; Lorio and Perret 1980; Zieman 1982). They are also found in deeper bays and around oyster reefs along the Texas coast (Hoese and Moore 1977). In Louisiana spotted seatrout are associated with sandy bottoms, submerged or emergent islands, shell reefs, areas of submerged vegetation, areas where some type of structure exists (e.g., oil platforms), and deep bayous and canals (Lorio and Perret 1980). Gilmore (1977) reported that spotted seatrout are common on grassflats and sand bottom, occasional in mangroves and inlets in the Indian River lagoon, and rare in the offshore benthic-open shelf habitat in that region. The absence of seagrass beds along the coasts of South Carolina and Georgia apparently does not limit the distribution of spotted seatrout in these areas (Hoese 1973). In South Carolina spotted seatrout are usually found around shell banks in creeks, rivers, and sounds (Bearden 1961; Bearden and Farmer 1972; Hicks 1972; Shealy et al. 1974). In Georgia adults were found in all sectors of the estuaries and along ocean beaches, usually at depths of 1 to 3 m (Dahlberg 1972; Mahood 1975). In Chesapeake Bay spotted seatrout tend to stay in shallow creeks and rivers adjacent to beds of eelgrass (Zostera marina) and widgeon grass, although they will move into deep holes during midsummer (Brown 1981).

Spotted seatrout are year-round residents of estuaries along the South Atlantic coast and in the Gulf of Mexico, moving into deeper channels and holes and occasionally offshore along the beaches to avoid extreme cold (Pearson 1929; Moody 1950; Simmons 1951; Guest and Gunter 1958; Tabb 1958, 1966; Dahlberg 1972; Mahood 1975; Hein and Shepard 1979b; Music and Pafford 1984). Spotted seatrout are found year-round in the sounds and mouths of rivers in North Carolina (Smith 1907; Hildebrand and Cable 1934; Roelofs 1951).

Spotted seatrout are apparently migratory in the northern portion of their range. Hildebrand and Schroeder (1928) reported that spotted seatrout were caught by seines in the

lower part of Chesapeake Bay in early fall until cold weather arrived, at which time they left the bay and moved south. Analysis of Virginia Saltwater Fishing Tournament citation records revealed that the largest catches of spotted seatrout in Chesapeake Bay were made in May and October, corresponding to spring and fall migrations (Brown 1981). In November spotted seatrout are caught by sport fishermen in the deep channel areas of the Chesapeake Bay Bridge Tunnel, where they are often associated with weakfish. There is some indication that a portion of the North Carolina population may be migratory. Spotted seatrout are caught in trawls and gill nets off the coast of North Carolina from November through March. Whether these catches are composed of fish from northern areas or from North Carolina estuaries, or a mixture, is not known. An account of spotted seatrout habits in North Carolina in the 1800s stated that this species first made its appearance in February on its way from the south, remained in the vicinity of sounds and inlets until about May, gradually proceeded northward, and reappeared on the coast of North Carolina in September (Goode 1884).

2.3 Determinants of distribution

Tabb (1958) listed the following ecological characteristics which appeared to be of greatest importance in determining the abundance and "success" of spotted seatrout in Florida: (1) large areas of shallow, quiet, brackish waters; (2) extensive grassy areas usually dominated by turtle grass and shoal grass; (3) areas of 3-6 m depth adjacent to grass flats to be used for refuge from winter cold; (4) an abundant food supply, viz., grazing crustaceans and suitable size fish; (5) absence of predators; (6) absence of competitors; and (7) suitable temperature range of 15-27°C. The association of both juvenile and adult spotted seatrout with seagrass beds, as well as other types of habitats, is well documented (Sections 2.21 and 2.22). Temperatures below 7-10°C cause spotted seatrout in Florida to move into ocean inlets or offshore along beaches for brief periods of time (Tabb 1958). Temperature was also determined to be a factor in Georgia estuaries, with movement of spotted seatrout into deeper waters at temperatures >25°C or <16°C (Mahood 1975).

The spotted seatrout is a euryhaline species, recorded from fresh water (0.2 ppt) (Perret 1971) to hypersaline conditions of 75 ppt (Simmons 1957). Loman (1978) reported that largest catches of spotted seatrout in Mississippi were caught between 20 and 35 ppt. The optimal salinity reported from laboratory studies is 20 ppt (range: 10-45 ppt) at 28°C based on standard routine and maximum sustained respiratory metabolic rates (Wakeman and Wohlschlag 1977; Wohlschlag and Wakeman 1978). Maximum sustained swimming speeds occurred at 20-25 ppt at 28°C,

and swimming performance was reduced at salinities above or below this range. Tabb (1966) reported a normal salinity range of 5-30 ppt in Florida and that sudden changes in salinity, such as caused by tropical storms or hurricanes, may cause mass migrations or mortalities. Reported optimal salinity ranges for larvae were 20-35 ppt (Arnold et al. 1976) and 18.6-37.5 ppt (Taniguchi 1980).

There are no data relating the distribution of spotted seatrout to dissolved oxygen concentrations. Vetter (1977) reported from laboratory studies that the oxygen requirements for spotted seatrout at 28°C (a normally prevailing summer temperature in coastal Texas waters) with salinities of 10, 20, and 30 ppt were 210, 125 and 230 mg O_2/kg/hr, respectively. Seasonal metabolic compensation was compared in spotted seatrout and sand seatrout in Redfish Bay, Texas (Vetter 1982). Spotted seatrout controlled their metabolic rates within a narrower range in response to seasonal temperature change (50 mg O_2/kg/hr at 15°C, 124 mg O_2/kg/hr at 30°C) than did sand seatrout (25 mg O_2/kg/hr at 15°C, 170 mg O_2/kg/hr at 30°C). Sand seatrout migrate from the estuaries to the Gulf of Mexico in late summer and overwinter there, whereas spotted seatrout are permanent residents of estuaries. Vetter (1982) suggested that greater metabolic compensation on the part of spotted seatrout may be an adaptation to year-round exploitation of the estuarine habitat, which has more extreme temperatures than offshore waters.

3. LIFE HISTORY

Various aspects of spotted seatrout life history were reviewed by Guest and Gunter (1958), Futch (1970), Idyll and Fahy (1970), Lorio and Perret (1980), and Perret et al. (1980).

3.1 Reproduction

Spotted seatrout mature between one and three years of age and males tend to mature at a smaller size than females (Table 2). Size at maturity varies from estuary to estuary (Lorio and Perret 1980; Perret et al. 1980).

Estimates of spotted seatrout fecundity ranged from 1.4×10^4 to 1.6×10^7 (Table 3). Sundararaj and Suttkus (1962) concluded that age III fish had the greatest "spawning power", producing 40.6% of the egg supply followed by age IV (26.8%) and age II (24.5%) fish. Overstreet (1983) treated all oocytes >30 µm (other cited authors counted only large yolky eggs) because spawning occurs over several months and because vitellogenesis can proceed rapidly in small oocytes.

The spotted seatrout has a protracted spring and summer spawning season which peaks in late April-July in the Gulf of Mexico (Lorio and Perret 1980; Perret et al. 1980). Spotted seatrout spawn from April through September along the Atlantic coast. Spawning off east-central Florida occurs from mid-April to September (Tabb 1961; Gilmore et al. 1976; Mok and Gilmore 1983). In Georgia spotted seatrout spawn from April to August with a peak in May (Mahood 1975) and second smaller peak in July (Music and Pafford 1984). Limited collections of larvae along the Carolina coasts indicated an April-August spawning season (Hildebrand and Cable 1934; Powles and Stender 1978). Two spawning peaks were observed in Chesapeake Bay, mid-May to mid-June and July, corresponding to early maturing and late maturing groups of fish (Brown 1981).

Brown et al. (1983) compared reproductive strategies for spotted seatrout in Redfish Bay, Texas and Chesapeake Bay, Virginia. Spotted seatrout are year-round residents of Redfish Bay and spawn for seven months (late March-early April through October), whereas they only reside in Chesapeake Bay from May through October and spawn from May to August. In Texas all sexually mature males and 80% of mature females were ripe throughout the spawning season. In Virginia only 25% of the mature males were ripe throughout the spawning season and ripe females were only found during spawning peaks. Histological observations suggest multiple spawning in Texas. Maturity is reached one year earlier in Texas than in Virginia.

The preferred spawning habitat of spotted seatrout has not been precisely determined but may include offshore and estuarine areas. Spawning in the Gulf of Mexico is believed to occur in the deeper portions (3.0 - 4.6 m) of bays and lagoons over grassy areas (Pearson 1929; Miles 1950; Moody 1950; Stewart 1961; Tabb and Manning 1961; Tabb 1966; Overstreet 1983) and in the inshore waters of the Gulf along barrier islands, particularly in or near coastal passes (King 1971; Jannke 1971; Christmas and Waller 1973; Sabins and Truesdale 1974; Hein and Shepard 1979a; Houde et al. 1979; Overstreet 1983).

Spawning on the Atlantic coast probably occurs in coastal and estuarine waters. Tabb (1961) believed that spawning in the Indian River lagoon system, Florida took place in the deeper channels immediately adjacent to the vegetated shallows with a dispersion of young to the shallow grassy bays with increasing size. This is supported by Mok and Gilmore's (1983) study of spotted seatrout sound production in the Indian River lagoon, Florida, which found that the highest intensity of large group sounds was limited to the Intracoastal Waterway and adjacent deeper parts of the seagrass flats. Small group and individual sounds appeared on both sides of the Intracoastal Waterway and extended into shallow seagrass areas. Acoustic activity and egg numbers (indicating spawning) were positively correlated in that study. Spotted seatrout in Georgia spawn along beaches near tidal inlets and mouths of sounds, and within creeks and sounds,

Table 2. Reported size and/or age at maturity for spotted seatrout. Number in parentheses is the smallest reported size or age at maturity.

Reference	Locality	Size			Age		
		Males	Females	Both	Males	Females	Both
Pearson (1929)	Texas						2-3
Miles (1950)	Texas			200-250mm SL			
Hein and Shepard (1979a)	Louisiana	(163mm SL)	(207mm SL)				
Overstreet (1983)	Mississippi		220-299mm SL (140-219mm SL)				
Klima and Tabb (1959)	Northwest Fla.	25cm SL (18cm SL)	27cm SL				
Moody (1950)	Cedar Key, Fla.	200-240mm SL	210-250mm SL				
Stewart (1961)	Southwest Fla.			290-300mm SL (190mm SL)			
Rutherford et al. (1982)	Southwest Fla.	(237mm SL)	(230mm SL)		2-4	3-4	
Tabb (1961)	East Central Fla.	35cm SL	35cm SL		2-3	3-4	
Music and Pafford (1984)	Georgia	(342mm TL)	(229mm TL)			(2)	
Brown (1981)	Chesapeake Bay	250mm TL	290-350mm TL		2	3	

Table 3. Fecundity estimates for spotted seatrout as reported in the literature. [*Total length approximated by TL=10.6586+1.1284SL from Overstreet (1983)]

Reference	Locality	Average Size (mm TL)	N	Calculated Number of Eggs	Egg Diameter (mm)	Method
Pearson (1929)	Texas	480	1	427,819	not given	gravimetric
		620	1	1,118,000		
Moody (1950)	Cedar Key, Florida	459*	1	464,000	not given	gravimetric
Tabb (1961)	Indian River area, Florida	377*	3	15,000	not given	not given
		509*	3	150,000		
		575*	3	400,000		
		716*	3	1,100,000		
Sundararaj and Suttkus (1962)	Louisiana	283	8	140,485	.38	gravimetric (mean egg diameter)
		376	9	354,325	.52	
		450	8	660,960	.61	
		504	3	1,144,492	.63	
Overstreet (1983)	Mississippi Sound	379*	1	2,254,134	>.30	volumetric
				3,968,050	>.30	gravimetric
		595*	1	10,599,376	<.03	volumetric
				15,567,833	<.03	gravimetric

usually in water 0.9-3.0 m deep (Mahood 1975; Music and Pafford 1984). Spawning along the South Carolina coast probably takes place in the lower portions of estuaries and inlets (Powles and Stender 1978). Hildebrand and Cable (1934) were unable to determine the exact spawning ground(s) of spotted seatrout in North Carolina based on limited collections of larvae taken from 8-10 km offshore to within an estuary. Running ripe fish were caught over seagrass beds in Chesapeake Bay within several hundred feet of a channel (Brown 1981).

Spotted seatrout spawn at night (Tabb 1966; Brown 1981; Mok and Gilmore 1983). Holt et al. (1983) reported synchronous spawning near dusk in Texas. During spawning there is a constant milling and jumping of the spawning school, with side-to-side body contact among the fish (Miles 1950; Tabb 1966). Miles (1950) examined several spent males and found that they were rubbed raw around the pelvic fins, lower abdomen and vent. Spawning is accompanied by croaking sounds produced only by the males (Smith 1907; Stewart 1961; Tabb 1966). The drumming muscles of mature males (>193 mm TL) were deeper red during the spawning season than at other times of the year (Hein and Shepard 1979a). Croaking was generally heard approximately one to two hours before sunset and continued for up to six hours (Mok and Gilmore 1983). Sound production has been noted at times other than spawning, suggesting a secondary function such as defense (Stewart 1961; Hein and Shepard 1979a).

Spotted seatrout spawn at temperatures from 21-28°C. Spawning was reported to occur at 21°C or higher in Texas (Simmons 1951) and from 21-35°C in Louisiana (Fontenot and Rogillio 1970; Rogillio 1975; Hein and Shepard 1979a). Stewart (1961) stated that bimodal peaks of capture of ripe adults corresponded with the 28-30°C temperature range in southwestern Florida. Jannke (1971), however, stated that a temperature of 24°C or greater appears necessary to initiate spring spawning in southwestern Florida. Tabb (1966) reported that spawning took place between 25.5 and 28.3°C on the east-central coast of Florida.

Hein and Shepard (1979a) reported that the peak spawn in Louisiana occurred in May in 1976 and 1978 on an increasing photoperiod, while the second major peaks (July 1976 and August 1978) were recorded on a decreasing photoperiod for both years. The amount of daylight during which gravid fish were collected remained nearly the same for both years: 13 hr, 42 - 59 min, and 13 hr, 10 - 41 min (sunrise to sunset).

Fluctuating salinity is a common factor of all productive spotted seatrout grounds (Tabb 1966). Peak spawning in Florida waters occurred when salinities reached 30-35 ppt in the lagoons and estuaries during dry spring months. Hein and Shepard (1979a) collected gravid spotted seatrout at salinities of 21-26 ppt in 1976 and 17-26 ppt in 1978. No spawning occurred in the

Laguna Madre of Texas when salinity exceeded 45 ppt (Simmons 1957).

Arnold et al. (1976) found that spotted seatrout spawn in the laboratory over a salinity range of 25-30 ppt at 26°C, coupled with a constant daylight period of 15 hours.

Laboratory-spawned spotted seatrout eggs were pelagic and spherical with an average diameter of 0.77 mm and usually contained one yellow oil globule (2% had two to three globules) (Fable et al. 1978). Miles (1950, 1951) reported that eggs from ripe ovaries measured 0.70-0.98 mm in diameter and contained one to four small oil globules. Tabb (1966) stated that eggs were spherical and normally had one oil droplet, but sometimes two or three.

3.2 Pre-adult phase

Fable et al. (1978) described embryonic development of reared eggs (Figure 2). Hatching occurred 16-20 hr after fertilization at incubation temperatures of approximately 25°C. Smith (1907) reported that spotted seatrout eggs hatched in 40 hr at 25°C.

Larval and juvenile development of spotted seatrout was described and illustrated by Welsh and Breder (1923), Pearson (1929), Hildebrand and Cable (1934), and Jannke (1971) (Figure 2). These studies were recapitulated by Lippson and Moran (1974) and Johnson (1978). Daniels (1977) described and illustrated larvae 1.8-11.3 mm SL. Fable et al. (1978) described the larval development and morphometrics of laboratory-reared spotted seatrout from hatching (1.3-1.5 mm SL) to 15 days (4.5 mm SL). Descriptions and morphometrics of 25 specimens (1.9 - 32.2 mm SL) from South Carolina were presented and compared with previous studies by Powles and Stender (1978).

3.3 Adult phase

Age and growth studies of spotted seatrout indicate that longevity is greater in the northern part of the range. Brown (1981) found age XV (776 mm TL) to be the maximum age in a Chesapeake Bay study. The maximum age for east-central Florida spotted seatrout was age X (Tabb 1961). Age VIII spotted seatrout were reported from Georgia (Music and Pafford 1984) and the Gulf coast of Florida (Moffett 1961). Pearson (1929) reported several age IX fish in Texas. The largest spotted seatrout reported in the literature were two fish weighing 7.25 kg caught in Chesapeake Bay in 1922 and at Mason's Beach, Virginia in 1977 (Hildebrand and Schroeder 1928; Anonymous 1983a), and a 7.48 kg fish caught in the Neuse River in 1903 (Smith 1907). Using Brown's (1981) length-weight relationship these individuals would measure 875 and 884 mm TL, respectively.

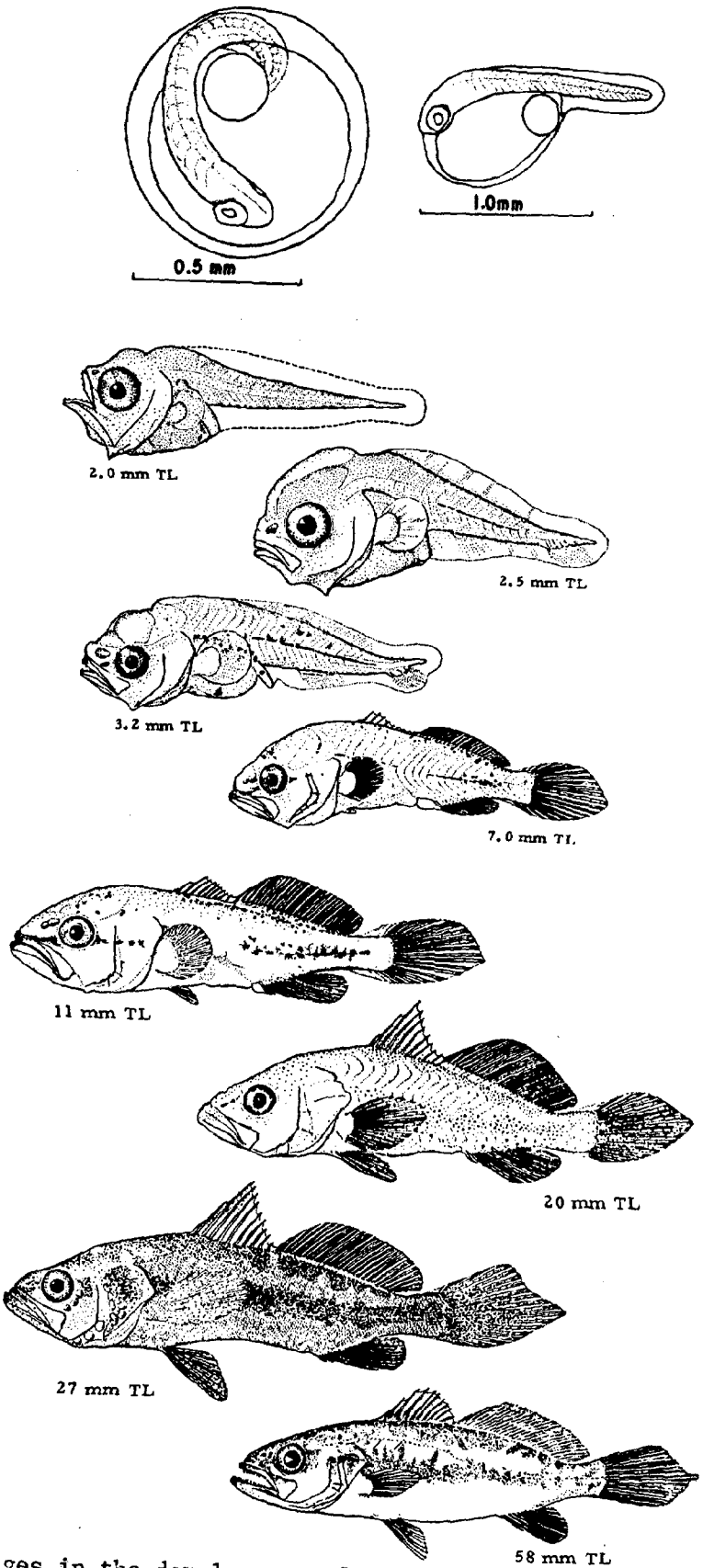

Figure 2. Stages in the development of spotted seatrout embryos, larvae, and juveniles (illustration from Lippson and Moran 1974; Fable et al. 1978).

Nine predators and six competitors of spotted seatrout were listed for Apalachee Bay in northwest Florida (Table 4), whereas only five predators, spotted seatrout, snook, gafftopsail catfish, common jack, and mangrove snapper, were listed for east-central Florida (Klima and Tabb 1959). Tabb (1961) suggested that the scarcity of predator and competitor species was a factor in the abundance and "success" of spotted seatrout in estuarine habitats.

Parasites, diseases, mortalities, and abnormal conditions of spotted seatrout were reviewed by Perret et al. (1980) and Overstreet (1983).

3.4 Nutrition and growth

Spotted seatrout are carnivorous, feeding primarily on crustaceans and fishes (Linton 1905; Hildebrand and Schroeder 1928; Pearson 1929; Gunter 1945; Kemp 1949; Knapp 1949; Miles 1949; Moody 1950; Reid 1954; Darnell 1958; Klima and Tabb 1959; Springer and Woodburn 1960; Stewart 1961; Tabb 1961; Lorio and Schafer 1966; Seagle 1969; Fontenot and Rogillio 1970; Odum 1971; Adams 1972; Carr and Adams 1973; Mahood 1975; Odum and Heald 1972; Rogillio 1975; Orth and Heck 1980; Weinstein 1981; Overstreet and Heard 1982; Rutherford et al. 1982; Matlock and Garcia 1983). The most important crustaceans were penaeid shrimp and crabs. Anchovies, menhaden, mullet, pinfish, and silversides accounted for the highest percentage of fishes in spotted seatrout stomach contents (Table 5).

Changes in food habits with growth were noted in several studies (Moody 1950; Darnell 1958; Tabb 1961; Adams 1972; Carr and Adams 1973; Colura et al. 1976). Copepods were important in the diet of fish <30 mm TL, and mysids, caridean shrimp, palaemonid shrimp, amphipods, polychaetes, and aquatic insects were important in fish <150 mm. Crustaceans (penaeid shrimp and blue crabs) were more important in fish 150-275 mm SL, whereas fish (pinfish, mullet, anchovies, and menhaden) predominated in larger fish (Moody 1950; Seagle 1969; Overstreet and Heard 1982).

Tabb (1961) suggested that food preferences are probably the result of seasonal availability of food. In Florida waters shrimp are most abundant during summer and early winter and fishes are more abundant in late winter and early spring. Lorio and Schafer (1966) also noted that shrimp were most available and eaten more frequently during summer by spotted seatrout in Louisiana. The food contents of fish obtained from Mississippi Sound included a slightly greater percentage of fish during spring and summer, when anchovies were more common. Penaeids were less prevalent in stomach contents during autumn and winter when they were also less available in the study area (Overstreet and Heard 1982).

Table 4. List of predators and competitors of spotted seatrout in Apalachee Bay in northwest Florida (from Klima and Tabb 1959).

Common name	Scientific name	Relation	Occurrence
Striped bass	Roccus saxatilis (Walbaum)	Predator (?)	Resident
Snook	Centropomus undecimalis (Bloch)	Predator	Seasonal
Tarpon	Megalops atlantica Valenciennes	Predator	Seasonal
Alligator gar	Lepisosteus spatula Lacepede	Predator (?)	Seasonal
Sea catfish	Galeichthys felis (Linnaeus)	Competitor	Resident
Barracuda	Sphyraena barracuda (Walbaum)	Predator	Occasional
Spanish mackerel	Scomberomorus maculatus (Mitchill)	Predator	Seasonal
King mackerel	Scomberomorus cavalla (Cuvier)	Predator	Seasonal
Bluefish	Pomotomus saltatrix (Linnaeus)	Predator	Resident
Grouper	Mycteroperca sp.	Competitor	Resident
Silver perch	Bairdiella chrysura (Lacepede)	Predator and competitor	Resident
Red drum	Sciaenops ocellatus (Linnaeus)	Competitor	Resident
Spot	Leiostomus xanthurus (Lacepede)	Competitor	Resident
Croaker	Micropogon undulatus (Linnaeus)	Competitor	Resident
Southern rock bass	Ambloplites rupestris ariomus Viosca	Competitor	Resident

Table 5. Stomach contents of spotted seatrout from different estuarine areas along the U.S. Atlantic and Gulf of Mexico coasts.

Author	Mahood (1975)	Tabb (1961)		Rutherford et al. (1982)		
Locality	Georgia	Indian River, Florida		Everglades National Park		
Period	Oct. 1970-Sept. 1973	Oct. 1955-June 1957		Nov. 1978-June 1980		
Source	Table 6, p. 206	Table 6, p. 20		Figure 16, p. 38		
Number of specimens	108	580		724		
Empty stomachs		410		486		
Length of specimens		2.5-15 cm SL	15-85 cm SL	< 271 mm	271-370 mm	> 370 mm
Quantitative method	% of occurrence	% total number of food items		% of occurrence		
Fishes:						
Engraulidae	5.9	-	-	[1]20.0	[1]46.0	[1]58.3
Clupeidae	10.2	-	1.3			
Mugilidae	5.9	-	22.5			
Atherinidae	7.6	-	2.6			
Cyprinodontidae	5.1	-	10.6			
Sparidae	-	-	3.3			
Sciaenidae	8.3	-	3.3			
Other	2.4	3.6	4.6			
Unidentified fish	8.5	-	-			
Crustaceans:						
Mysidacea	-	42.8	-	-	-	-
Amphipoda	-	-	-	-	-	-
Isopoda	-	-	-	-	-	-
Penaeid shrimp	33.9	53.6	37.7	88.3	720	58.3
Caridean shrimp	2.5	-	13.2	-	-	-
Brachyuran crabs	-	-	2.0	1.0	4.0	8.0
Other invertebrates:	9.3		0.1			
Polychaetes	-	-	-	-	-	-
Mollusks	-	-	-	5.0	12.0	-
Vegetation				12.0	20.0	5.0
Unidentified remains	-	-	-	2.0	5.0	5.0

[1]All fishes combined

Table 5. (continued)

Author	Overstreet and Heard (1982)			Lorio and Schafer (1966)	Seagle (1969)			
Locality	Mississippi Sound			Biloxi Marsh Area, La.	Redfish Bay, Texas			
Period				1961 - 1965	1967 - 1968			
Source	Table 2, p. 143			Table II, p. 292	Table 1			
Number of specimens	111	243	19	368	89	205	39	28
Empty stomachs	11	19	3	152	39	75	14	16
Length of specimens	73-249	250-399	400-532	25-51 cm TL	132-225	226-350	351-450	451-610 (mm SL)
Quantitative method	% of occurrence			% of occurrence	% of occurrence			
Fishes:	[1]65.0	[1]76.3	[1]75.0	[1]74.4				
Engraulidae				1.4	20.0	25.4	8.0	-
Clupeidae				1.4	-	-	-	16.7
Mugilidae				0.4	-	-	-	41.7
Atherinidae				-	8.0	2.3	4.0	-
Cyprinodontidae				-	-	-	-	-
Sparidae				-	14.0	25.4	72.0	33.3
Sciaenidae				0.9	4.0	0.8	-	-
Other				0.9	-	0.8	-	-
Unidentified				68.5	2.0	3.9	4.0	8.3
Crustaceans:	[2]47.0	[2]34.4	[2]31.3	[2]25.3				
Mysidacea				-	-	1.5	-	-
Amphipoda				0.9	2.0	3.9	-	-
Isopoda				2.3	-	1.5	4.0	-
Penaeid shrimp				11.1	40.0	23.1	12.0	-
Caridean shrimp				6.5	-	1.5	-	-
Brachyuran crabs				4.1	-	6.2	8.0	-
Other invertebrates:								
Polychaetes	2.0	9.8	6.3	-	-	-	-	-
Mollusks	2.0	1.3	0.0	-	-	-	-	-
Vegetation	3.0	6.7	18.8	2.3	-	-	-	-
Unidentified remains	-	-	-	10.2	-	-	-	-

[1]All fishes combined [2]All crustaceans combined

A high percentage of empty stomachs were reported in most of these studies (Table 5). Moody (1950) attributed this to sporadic feeding. Darnell (1958) and Seagle (1969) suggested that spotted seatrout feeding was heaviest during the early to mid-morning hours. Lascara (1981) reported movements of spotted seatrout in and out of submerged grass beds in Chesapeake Bay and found times of peak abundance corresponded to crepuscular periods (dawn and dusk). He believed that these were times of maximum feeding. Spotted seatrout have a tapeta lucida in their eyes which allows greater light penetration to the retina (Arnott et al. 1971). This adaptation allows for keener eyesight than potential prey items in dim light, and may increase feeding duration and success during periods of low light intensity. Experienced, highly successful spotted seatrout fishermen in Virginia reported that best fishing is at dusk, drifting over grass beds on a flood tide (Brown 1981).

Growth of spotted seatrout larvae in the laboratory increased significantly as prey concentrations and temperatures were raised, and decreased as stock density increased (Taniguchi 1979, 1981; Houde and Taniguchi 1982). Juvenile spotted seatrout (100-112 mm TL), stocked in ponds in Louisiana, grew 2.08 mm/day in October and 0.33 mm/day in November (Sackett et al. 1979).

Spotted seatrout growth is rapid during the first year. Pearson (1929) reported a modal length of 130 mm TL in Texas by the first winter with a range of 50-200 mm TL which reflects the prolonged spawning period. In Georgia juvenile spotted seatrout attained a mean length of 124 mm TL in November (Mahood 1975). Hildebrand and Cable (1934) reported a modal length of 170 mm TL for juvenile spotted seatrout in North Carolina at the end of 7-8 months of growth. Welsh and Breder (1923) collected five juveniles from Chesapeake Bay in December ranging in length from 110-125 mm TL. Brown (1981) reported that spotted seatrout in Chesapeake Bay attained an average of 170 mm TL by the end of their first winter. Spotted seatrout growth slows considerably by age II. Differences in age and growth between the sexes and between different populations are discussed in Section 4.1.

3.5 Behavior

Tagging studies indicated that spotted seatrout are relatively non-migratory in Georgia, Florida, and the Gulf of Mexico. Although no tagging studies have been done north of Georgia, indications are that spotted seatrout migrate seaward and southward from Chesapeake Bay and possibly from North Carolina sounds (Section 2.22). Most movement in Georgia estuaries was short range, averaging 8.9 km, although two individuals traveled 105 and 110 km, respectively (Music 1981; Music and Pafford 1984). Movement is apparently restricted to seasonal migrations in and out of the open sounds enroute to creeks and rivers in

fall and winter, and off the beaches in spring and early summer. Moffett (1961) reported that over 95% of all returned tagged fish on the west coast of Florida were recovered within 48 km of the tagging sites. The longest migration was 507 km, from Apalachicola, Florida to Grand Isle, Louisiana. Results of other tagging studies in Florida also indicated that spotted seatrout rarely move over 32-48 km (Ingle et al. 1962; Topp 1963; Beaumariage 1964, 1969; Beaumariage and Wittich 1966).

Tabb (1966) reported that spotted seatrout begin to school by the age of 6 to 8 weeks (25-50 mm). Schooling behavior remains pronounced until an age of about 5 to 6 years, at which time most males have died and the remaining large females (2.7-3.6 kg), called "sow" or "gator" trout, adopt a semi-solitary existence.

3.6 Contaminants

Trace element levels were determined for 15 elements in spotted seatrout to provide baseline data to help identify potential problems involving species, elements, or locations (Hall et al. 1978). No interpretive comments were provided.

The acute lethal effects of sodium hypochlorite, chloramine, and 5-chlorouracil on eggs and larvae of spotted seatrout were presented by Johnson et al. (1977). Forty-eight-hour median tolerance limits (TLM) for the various toxicants and age classes (2-hr old eggs, 10-hr eggs, and 1-hr posthatch larvae) were, respectively: sodium hypochlorite - 0.21±0.01, 0.21±0.01, 0.17±0.28 ppm; chloramine - 14.14±1.13, 0.57±0.28, 5.75±3.01 ppm; and 5-chlorouracil - 8.91±1.03, 100, 79.43±44.97 ppm. Results of this study indicated that considerable larval seatrout loss would be expected in areas of chlorinated effluent disposal where the toxic products of sodium hypochlorite and seawater are >0.17 ppm sodium hypochlorite.

Sublethal effects of fuel oil (water-soluble fraction) on larval spotted seatrout were investigated by Johnson et al. (1979). When larvae were subjected to sublethal concentrations of fuel oil (0.00-1.00 ppm), there was a general decrease in total body length and critical distance, while the percentage of larvae with unpigmented eyes increased with increased oil concentration.

DDT residues were measured in six generations of spotted seatrout from the Launa Madre, Texas (Butler 1969; Butler et al. 1970). Residues reached as high as 8 ppm in the gonads and breeding apparently did not occur for at least one or two years.

A survey of polychlorinated biphenyls (PCBs) in selected finfish species determined that the mean level of PCBs in 17 spotted seatrout from the Gulf of Mexico was 0.16 ppm. This level is

far below existing (5 ppm) or proposed (2 ppm) maximum permissible levels in foodfish (Gadbois and Maney 1983).

4. POPULATION

4.1 Structure

Aspects of spotted seatrout population structure have been investigated for Virginia (Brown 1981), Georgia (Mahood 1974, 1975; Music and Pafford 1984), Florida (Tabb 1958, 1961; Klima and Tabb 1959; Moffett 1961; Stewart 1961; Iversen and Tabb 1962; Rutherford 1982; Rutherford et al. 1982), Alabama (Tatum 1980; Wade in press), Louisiana (Hein and Shepard 1979a, 1980), and Texas (Pearson 1929).

Reported sex ratios for spotted seatrout populations indicate that overall, females outnumber males by as much as three to one. Pearson (1929) reported a 2:1 ratio favoring females in Texas. Female spotted seatrout outnumbered males 2.4:1 in a Louisiana study (Hein and Shepard 1979a). In western Florida females dominated at all ages and ratios increased with age to as much as 9:1 at age V (Klima and Tabb 1959; Moffett 1961). Overall sex ratios were 2:1 for both east and west coast Florida populations (Tabb 1961). Rutherford et al. (1982) found an overall sex ratio favoring females by 1.7:1, which remained constant at ages II through V in Everglades National Park, Florida. In Georgia studies the overall sex ratio of females to males were 1.7:1 (Mahood 1975) and 1.9:1 (Music and Pafford 1984). The ratio changed from 1:3 for fish <250 mm to 1:1 for fish 251-350 mm, 2.6:1 for fish 351-400 mm, and 23:1 for fish 501-550 mm TL (Music and Pafford 1984).

Older spotted seatrout were found in Chesapeake Bay (age XV) than from populations to the south (Brown 1981). Tabb (1961) reported age X fish in east-central Florida and Pearson (1929) found age IX spotted seatrout in Texas. Age VIII was the maximum reported age for Georgia (Music and Pafford 1984) and Fort Meyers, Florida (Moffett 1961). Age VII spotted seatrout were reported for southwestern Florida (Stewart 1961; Rutherford 1982) and northwest Florida (Klima and Tabb 1959). Moffett (1961) found fish through age VI in west Florida (Cedar Key), as did Tatum (1980) and Wade (in press) in Alabama.

The age distribution of the catch varied in different areas. Age groups III (27%) and IV (21%) dominated the catch in Chesapeake Bay (Brown 1981). These samples were mainly collected by haul seines which equally sample all sizes of the recruited population. Tabb (1961) found that age groups I (28%), II (27%) and III (21%) predominated in his samples from east-central Florida. In southwestern Florida dominant ages apparently shifted from age II (36%) and age III fish (42%) in

1959 (Stewart 1961) to age III (45%) and age IV (29%) in 1979 (Rutherford 1982). In west Florida age groups II (41%) and III (35%) predominated (Moffett 1961). Age group III (47%), followed by ages II (23%) and IV (22%), predominated in a northwest Florida study (Klima and Tabb 1959). Difference between the Florida studies were caused in part by differences in gear selectivity, while the lack of younger fish in these studies reflected a minimum legal size limit (30.5 cm). Only Tabb (1961) and Stewart (1961) obtained smaller spotted seatrout by trawling. Tatum (1980) reported that age groups III+ (27.7%) and II+ (17.8%) were the two most exploited age classes in Alabama fishing tournaments, 1964-1977, however, age groups V+, VI+ and > VI+ were most abundant in 1965, 1970, and 1971. Age III spotted seatrout, followed by II and IV, dominated the catch in 3-1/4 in stretched mesh gill nets in a Louisiana study (Hein and Shepard 1980).

Female spotted seatrout attain a greater maximum age than males throughout the range (Table 6). Brown (1981) found that males and females reached at least ages VIII and XII, respectively, in Chesapeake Bay. The sex of the age XV fish collected in that study was not determined. The oldest male and female spotted seatrout aged in Georgia were ages VI and VIII, respectively (Music and Pafford 1984). All Florida studies found that females lived at least one year longer than males (Klima and Tabb 1959; Moffett 1961; Stewart 1961; Tabb 1961; Rutherford 1982) except at Cedar Key, Florida (Moffett 1961). The tendency of female spotted seatrout to outlive males was also reported for Alabama (Wade in press), Louisiana (Hein and Shepard 1979a) and Texas (Pearson 1929).

Age and growth studies of spotted seatrout revealed that size at age varies between locations (Table 6). Reported mean back-calculated lengths at age were largest for east-central Florida (Tabb 1961). There appears to be a discrepency in Tabb's data, however, since his back-calculated lengths at age for combined sexes were considerably greater than lengths for either males or females, separately (Table 6). Spotted seatrout aged in Georgia were larger (combined sexes) than Chesapeake Bay fish at each age except age VI, and smaller than east-central Florida fish (Music and Pafford 1984). Calculated lengths for ages I and II spotted seatrout in Everglades National Park were greater than reported in other studies because of the back calculation formula used: $L_t - a = S_t (L - a) / S$, where L_t = length at annulus t, L = length of fish at capture, S_t = scale radius at annulus t, S = total scale radius, and a = y intercept of fish length regressed on total scale radius (Rutherford 1982). Previous investigators calculated fish lengths at annulus directly according to the formula: $L_t = S_t L/S$. The difference in length resulting from the type of back-calculation formula used becomes negligible after age II when lengths of the Park spotted seatrout population closely parallel lenths reported for other populations (Rutherford 1982). Spotted seatrout growth in Chesapeake Bay appears similar to growth at

Table 6. Mean back-calculated standard lengths (mm) at age for spotted seatrout as reported in the literature.

Study	Location	Sex	Age I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Brown (1981)*	Chesapeake Bay, Va.	Male	128 (68)	206 (66)	267 (58)	323 (26)	370 (20)	430 (7)	430 (7)	475 (2)				
		Female	161 (92)	237 (91)	296 (80)	346 (57)	385 (35)	449 (16)	449 (16)	481 (12)	504 (4)	553 (1)		
		Combined	143 (247)	221 (221)	302 (199)	354 (132)	378 (80)	447 (35)	447 (35)	482 (21)	518 (8)	557 (5)	591 (3)	620 (2)
Music and Pafford (1984)*	Georgia	Male	148 (213)	228 (210)	280 (109)	323 (26)	363 (13)	385 (9)						
		Female	161 (333)	256 (326)	328 (227)	386 (108)	425 (57)	463 (27)	523 (7)	572 (2)				
		Combined	155 (548)	244 (538)	313 (336)	373 (134)	413 (70)	443 (36)	523 (7)	572 (2)				
Tabb (1961)	East-Central, Fla.	Male	138 (281)	200 (195)	259 (109)	322 (43)	380 (14)	410 (4)	437 (1)					
		Female	145 (682)	220 (509)	300 (336)	353 (183)	408 (76)	480 (27)	520 (10)	545 (2)				
		Combined	165 (592)	248 (563)	317 (436)	384 (254)	457 (135)	533 (73)	561 (38)	624 (1)				
Stewart (1961)	Flamingo, Fla.	Male	128 (433)	210 (417)	267 (217)	313 (33)	348 (5)							
		Female	137 (562)	236 (538)	280 (372)	345 (133)	401 (50)	434 (10)	451 (2)					
Rutherford (1982)	Everglades National Park, Fla.	Male	215 (205)	260 (202)	292 (164)	327 (65)	377 (12)	403 (2)						
		Female	210 (326)	264 (325)	307 (275)	354 (134)	402 (32)	420 (12)	488 (3)					
		Combined	212 (539)	262 (535)	301 (446)	345 (201)	395 (44)	417 (12)	488 (3)					
Moffett (1961)	Fort Meyers, Fla.	Male	128 (258)	206 (255)	259 (154)	310 (39)	354 (13)	437 (1)						
		Female	131 (386)	209 (383)	266 (293)	322 (118)	371 (46)	409 (21)	431 (5)	438 (1)				
		Combined	130 (644)	208 (638)	264 (447)	320 (157)	368 (59)	430 (22)	431 (5)	438 (1)				
Moffett (1961)	Cedar Key, Fla.	Male	129 (83)	206 (83)	263 (52)	323 (19)	380 (4)	434 (1)						
		Female	130 (217)	212 (215)	269 (151)	323 (48)	383 (5)							
		Combined	130 (300)	211 (298)	268 (203)	323 (67)	382 (9)							
Klima and Tabb (1959)	Apalachicola, Fla.	Male	115 (316)	188 (312)	250 (261)	304 (71)	341 (7)	369 (1)						
		Female	117 (549)	191 (549)	258 (525)	315 (251)	372 (66)	423 (8)	437 (1)					
		Combined	116 (865)	190 (861)	255 (786)	312 (322)	369 (73)	422 (9)	437 (1)					
Pearson (1929)*	Texas	Combined	123 (396)	203 (303)	259 (230)	305 (160)	340 (94)	377 (57)	418 (36)	444 (8)	488 (3)			

*TL converted to SL using SL= -3.8832 + 0.8653TL (Hein et al. 1980)

Flamingo and Everglades National Park (excluding ages I and II). Brown (1981) reported that growth in Chesapeake Bay for the population as a whole was significantly different from growth in Texas and east-central Florida, but not from Fort Meyers, Cedar Key, or Apalachicola, Florida.

Female spotted seatrout were larger than males for all ages at each location except for age I fish at Everglades National Park and age VI fish at Fort Meyers, Florida where there was a single large age VI male (Table 6). Growth of males and females in Chesapeake Bay was significantly different from growth of Fort Meyers, Cedar Key, and Apalachicola, Florida fish, although growth for the population as a whole was not significantly different (Brown 1981).

Von Bertalanffy growth parameters were derived for spotted seatrout in Chesapeake Bay (Brown 1981) and Everglades National Park (Rutherford 1982) (Table 7). Brown's (1981) values of t_0 and K appear too low and the resulting growth curves do not describe growth as determined by back-calculated lengths. The L^{∞} values for females are higher than for males as would be expected, since females attain a greater length at age than males. Rutherford's (1982) growth parameters derived by Bayley's (1977) method, appear to closely predict spotted seatrout lengths at ages I-VI. The lower L^{∞} values for Everglades National Park fish reflect the fewer age classes and smaller sizes present in the samples.

Length-weight relationships were determined for spotted seatrout in Texas (Harrington et al. 1979), Louisiana (Adkins et al. 1979; Hein et al. 1980), Mississippi (Overstreet 1983), Alabama (Wade in press), Florida (Moffett 1961; Rutherford 1982), and Virginia (Brown 1981) (Table 8). Spotted seatrout from Chesapeake Bay appear to be heavier at a given length than those from other areas. Brown (1981), however, stated that these fish were collected only during the summer at the period of maximum feeding and sexual activity when weights would tend to be higher. No significant differences in length-weight relationships between sexes were found in Alabama or Everglades National Park, although males appeared to be heavier than females at all lengths in Alabama (Wade in press; Rutherford 1982).

Age and growth differences, the non-migratory nature of spotted seatrout and the isolation of estuarine areas along the South Atlantic and Gulf coasts suggest that there are distinct subpopulations of spotted seatrout. Iversen and Tabb (1962), concluded that there were separate populations in Florida based on growth and tagging data. Electrophoretic studies by Weinstein and Yerger (1976b) supported the concept of genetically distinct populations of spotted seatrout in the estuaries they sampled. The populations sampled west of the Mississippi River formed a group distinct from those populations east of the Mississippi. Within each of these regions were

Table 7. Von Bertanlanffy growth parameters as reported in the literature.

Area	Sex	L_∞(mm)	t_o	K
Chesapeake Bay, VA[1]	Male	760	-7.5933	.052
	Female	854	-7.9278	.052
	Combined	935	-5.6091	.059
Everglades National Park, Florida[2]	Male	591	-2.95	.12
	Female	656	-2.04	.13
	Combined	774	-2.54	.09

[1]Brown 1981

[2]Rutherford 1982

Table 8. Length-weight relationships for spotted seatrout collected from different localities.

Locality	Sex	N	Length range (mm-TL)	Equation	r	Calculated weight for a 350 mm TL fish
Chesapeake Bay, Virginia[1]	Combined	340	122-782	log W = -5.072 + 3.043 log TL	0.99	469
	Males	74	264-580	log W = -5.598 + 3.244 log TL	0.99	448
	Females	102	135-760	log W = -4.924 + 2.986 log TL	0.97	470
Georgia[2]	Combined	710		log W = -4.848 + 2.949 log L	0.95	451
	Males	277		log W = -4.182 + 2.683 log L	0.86	440
	Females	409		log W = -4.516 + 2.824 log L	0.93	466
Everglades National Park, Florida[3]	Combined	567		log W = -5.194 + 2.745 log SL	0.93	400
Fort Myers and Cedar Key, Florida[4]	Combined	307		log W = -5.333 + 3.113 log TL		386
Alabama[5]	Combined			log W = -5.305 + 3.105 log TL		392
Mississippi[6]	Males	1,087	40-465(SL)	log W = -4.947 + 3.051 log SL	0.99	404
	Females	1,683	39-544(SL)	log W = -4.947 + 3.052 log SL	0.99	406
South-Central, Louisiana[7]	Combined	1,208	21-629	log W = -5.423 + 3.154 log TL	0.99	400
Texas[8]	Combined	9,498	49-902	log W = -5.192 + 3.062 log TL	0.99	396

[1]Brown 1981
[2]Music and Pafford 1984
[3]Rutherford 1982
[4]Moffett 1961
[5]Wade (In press)
[6]Overstreet 1983
[7]Hein et al. 1980
[8]Harrington et al. 1979

separate populations, such as Corpus Christi and Galveston Bay to the west, and St. Joseph, Apalachee, Tampa, and Florida Bays in the east. Florida Bay was the most divergent of eastern Gulf populations, possibly because of the unique environmental characteristics of this estuary (shallow mud flats with higher turbidities and higher average yearly temperatures). The most widely divergent groups were those populations west of the Mississippi River and on the Atlantic coast of Florida (Indian River).

4.2 Abundance, density, mortality, and dynamics

Peaks in spotted seatrout abundance occur in spring and/or fall and winter in various estuaries throughout the range. Adults are particularly abundant in Texas and Florida in spring when they migrate from overwintering areas through passes and channels to shallow feeding and possibly spawning areas (Pearson 1929; Tabb 1958). In the lower Laguna Madre, Texas, adults averaged 2.58 kg/ha in spring in 1970-72, in contrast to 1.52 kg/ha during fall (Breuer 1973). Adult spotted seatrout are also relatively abundant during winter when they concentrate in deeper holes to escape cold (Pearson 1929; Gunter 1938; Perret 1971; Waller and Sutter 1982). Highest catch per unit effort of spotted seatrout in the shallow (0.6-1.2 m) Biloxi Marsh complex of Louisiana occurred in fall with a smaller peak in spring (Fontenot and Rogillio 1970). Adkins et al. (1979) reported that peak abundance in Louisiana occurred in spring with a second peak in late summer or fall. In Georgia spotted seatrout were most abundant in the deeper waters of the sounds and creeks in winter and in the shallows in spring (Mahood 1975). Brown (1981) reported that recreational catches of spotted seatrout in Chesapeake Bay were best in May and October, corresponding to times of spring and fall migrations.

There are no indexes of abundance available for juvenile spotted seatrout. Juveniles were not abundant in any estuarine surveys, most of which used trawls and did not sample the shallow-water habitat preferred by spotted seatrout. Juveniles were most abundant in fall in Texas (Breuer 1973), in summer in Louisiana (Adkins et al. 1979; Juneau 1975), Mississippi (Waller and Sutter 1982), Florida (Jannke 1971), Georgia (Mahood 1975), and North Carolina (Spitsbergen and Wolff 1974; Purvis 1976; Wolff 1976).

Commercial landings data have been collected by the Federal government in each state since 1880. From 1880-1927 the survey was conducted on the average of once every five years from 1927 to 1956 annual surveys were conducted and since 1956 data has been collected on a monthly basis. It should be noted that commercial statistics, when biased at all, tend to be somewhat underestimated due to reporting failures inherent in their collection. Commercial landings may reflect true abundance

trends, changes in effort, changes in gear restrictions, and/or closures of areas to commercial fishing.

Total commercial landings of spotted seatrout reached a peak at over 5,800 mt in 1945 (Table 9). From 1949-1964 landings fluctuated between 2,400 and 3,400 mt. Landings increased to over 4,000 mt in 1965, fluctuated between 3,200 and 4,400 mt until 1977, after which they declined to 1,605 mt in 1982.

Gulf of Mexico landings (west coast of Florida and Texas) have generally accounted for 60-80% of the total spotted seatrout commercial landings. Gulf landings exceeded 2,000 mt in most years from 1902 to 1976 (Table 9) (Figure 3), but have steadily declined since 1973. Highest landings in this region were reported from the west coast of Florida, followed by Texas and Louisiana. No landings were reported from Texas in 1982 since the Texas Legislature passed a bill prohibiting the commercial sale of Texas-caught spotted seatrout.

On the Atlantic coast commercial landings of spotted seatrout have been reported from Maryland to Florida (Table 9) (Figure 3). Total Atlantic coast landings were highest in 1945 (2,495 mt) and have since declined, fluctuating between 200 and 600 mt over the last two decades. Maryland landings of spotted seatrout never exceeded 12 metric tons and none have been reported since 1956. Virginia landings declined drastically from a high of 345 mt in 1944, and fluctuated from 1-89 mt from 1947-1982. North Carolina landings were highest in the 1930s (315-860 mt), declined to a low in 1968 (44 mt), increased in the early 1970s (147-304 mt), and have since declined to a low of 38 mt in 1982. Spotted seatrout landings in South Carolina peaked at 67 mt in 1945, ranged from 9 to 39 mt from 1950-1966, and fluctuated between 1 and 4 mt from 1976 to 1982. Georgia's landings peaked at 52 mt in 1936 and have not exceeded 7 mt over the past two decades except from 1972-1976 (12-14 mt). Highest commercial landings of spotted seatrout on the east coast were reported for Florida, peaking at 1,985 mt in 1945 and declining to 200-400 mt from 1957 to the present. Merriner (1980) noted that variability in annual reported catch is typical for spotted seatrout and seems to parallel the climatic conditions of the preceding spring and winter. For example, the cold winters of 1976 through 1978, during which inshore waters were less than 4.4°C for several weeks, were followed by declines in spotted seatrout landings, especially north of Florida (Table 9).

Recreational fishery statistics have not been routinely collected. Salt-water angling surveys were conducted at 5 year intervals from 1960 to 1970 (Clark 1962; Deuel and Clark 1968; Deuel 1973) and regional surveys were conducted in 1974 and 1975. The 1960-1970 surveys required fishermen to recall and report for a 1 year period the number and average weight of each species caught. The 1974-1975 surveys reduced the recall period to 2 months, but still required fishermen to report the number and average weight of each species caught. The results of these

Table 9. Commercial landings (metric tons) of spotted seatrout by state, 1887-1982.

Year	Maryland	Virginia	North Carolina	South Carolina	Georgia	East Coast Florida	Atlantic Coast Total	West Coast Florida	Alabama	Mississippi	Louisiana	Texas	Gulf Coast Total	Total
1887	-	-	-	-	-	-	-			117	238	427	782	782
1888	-	-	-	-	-	-	-	232	103	127	237	395	1,094	1,094
1889	-	-	-	-	-	-	-	234	93	168	281	488	1,264	1,264
1890	-	-	-	-	-	-	-	250	95	169	297	508	1,319	1,319
1897	-	-	-	-	-	-	-	376	134	205	257	459	1,431	1,431
1902	-	-	-	-	-	-	-	843	117	215	489	507	2,171	2,171
1908	-	-	-	-	-	-	-	547	94	234	500	478	1,853	1,853
1918	-	-	-	-	-	-	-	768	63	161	540	431	2,263	2,263
1923	-	-	414	-	-	-	414	721	22	186	355	691	1,975	2,389
1927	-	-	-	-	-	-	-	1,171	54	274	373	771	2,643	2,643
1928	-	-	-	-	-	-	-	1,216	57	221	401	526	2,421	2,421
1929	-	-	-	-	-	-	-	1,334	58	174	233	534	2,333	2,333
1930	2	90	315	5	22	36	470	1,234	51	105	322	473	2,185	2,655
1931	*	27	503	7	5	264	806	1,095	49	98	348	492	2,082	2,888
1932	2	38	850	6	21	239	1,166	975	49	103	287	443	1,857	3,023
1933	4	74	-	-	-	-	78	-	-	-	-	-	-	78
1934	4	22	839	6	25	345	1,241	1,060	66	136	688	1,117	3,067	4,308
1935	2	51	-	-	-	-	53	-	-	-	-	-	-	53
1936	2	51	635	44	52	357	1,141	1,580	54	133	470	833	3,070	4,211
1937	3	64	409	37	29	299	841	1,254	76	169	448	956	2,903	3,744
1938	4	179	385	36	28	250	882	1,323	56	129	244	945	2,697	3,570
1939	3	74	605	18	31	270	1,001	1,359	58	113	325	673	2,528	3,529
1940	*	42	525	19	14	320	920	1,481	76	59	119	342	2,077	2,997
1941	12	42	-	-	-	-	54	-	-	-	-	-	-	54
1942	2	27	-	-	-	-	29	-	-	-	-	-	-	29
1944	2	345	-	-	-	-	347	-	-	-	-	-	-	347
1945	4	203	227	67	9	1,985	2,495	1,750	263	137	416	780	3,346	5,841
1946	1	195	-	-	-	-	196	-	-	-	-	-	-	196
1947	1	49	-	-	-	-	50	-	-	-	-	-	-	50
1948	-	40	-	-	-	-	40	*	180	72	228	269	749	789
1949	-	49	-	-	-	-	49	2,067	99	89	702	286	2,943	2,992
1950	-	42	219	12	15	661	949	1,458	39	52	400	265	2,214	3,163
1951	-	29	121	21	14	568	753	1,511	47	83	273	197	2,111	2,864
1952	-	33	292	39	11	675	1,053	1,575	66	240	263	217	2,371	3,421
1953	-	39	287	23	8	252	609	1,185	60	408	243	265	2,161	2,770

Table 9. (continued)

Year	Maryland	Virginia	North Carolina	South Carolina	Georgia	East Coast Florida	Atlantic Coast Total	West Coast Florida	Alabama	Mississippi	Louisiana	Texas	Gulf Coast Total	Total
1954	-	47	365	12	9	556	989	1,042	48	666	198	304	2,258	3,247
1955	-	47	201	63	20	413	744	928	71	917	231	382	2,529	3,273
1956	*	89	177	101	5	485	857	934	51	653	278	379	2,295	3,152
1957	-	54	262	25	2	402	745	1,162	33	124	291	408	2,018	2,763
1958	-	27	80	9	1	346	463	1,375	32	152	297	525	2,371	2,834
1959	-	63	176	17	*	348	504	1,281	51	146	313	503	2,294	2,898
1960	-	25	78	13	*	404	520	1,289	28	75	212	582	2,176	2,696
1961	-	33	95	25	1	340	494	1,194	52	109	281	507	2,143	2,637
1962	-	13	93	12	*	343	461	1,216	45	80	192	449	1,982	2,443
1963	-	12	105	22	2	363	504	1,197	60	67	209	540	2,073	2,577
1964	-	11	93	27	1	347	479	1,289	59	79	161	444	2,032	2,511
1965	-	18	79	16	4	309	426	1,605	73	80	208	533	2,498	2,924
1966	-	5	53	11	1	329	398	1,439	21	66	293	684	2,504	2,902
1967	-	2	56	1	3	282	334	1,196	41	78	282	690	2,286	2,620
1968	-	3	44	5	1	289	342	1,390	46	122	281	848	2,687	3,029
1969	-	8	86	4	1	308	307	1,097	44	100	327	532	2,100	2,407
1970	-	30	183	4	5	323	545	1,199	38	116	356	525	2,233	2,778
1971	-	20	153	11	7	222	413	889	62	178	509	674	2,313	2,726
1972	-	6	228	8	12	288	542	970	100	116	771	680	2,637	3,179
1973	-	4	277	3	12	302	598	1,009	159	177	1,146	893	3,374	3,972
1974	-	12	304	4	7	299	626	1,025	165	134	964	905	3,193	3,819
1975	-	33	287	8	14	243	585	984	47	119	860	823	2,833	3,418
1976	-	18	289	3	14	241	565	1,035	20	80	731	802	2,667	3,232
1977	-	2	147	*	7	224	380	726	10	67	818	611	1,905	2,285
1978	-	3	44	*	1	183	231	914	15	48	308	527	1,812	2,043
1979	-	2	48	1	2	216	269	946	34	50	362	467	1,859	2,128
1980	-	1	78	4	2	253	338	887	12	12	274	443	1,628	1,966
1981	-	2	51	*	*	334	387	895	12	18	266	293	1,484	1,871
1982	-	2	38	1	2	330	373	844	28	31	329	-	1,232	1,605

-None reported

*Less than 1 mt

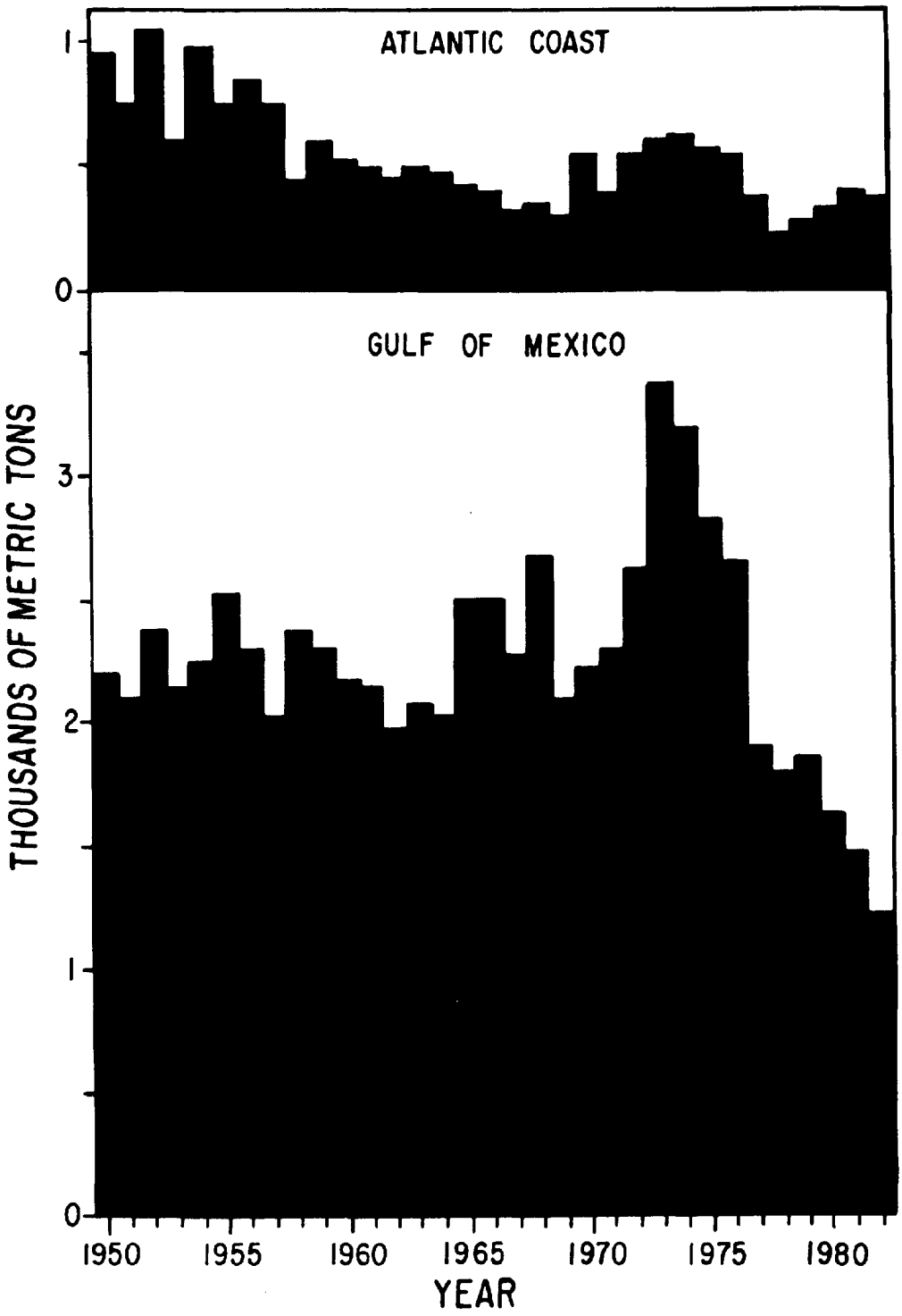

Figure 3. U. S. commercial landings of spotted seatrout by geographic region, 1950-1982.

surveys probably include some misidentified species and overestimates of the catch, although the magnitude of the overestimation is not known. Annual surveys were begun in 1979 which include a combination household survey and intercept survey (creel census). Although the results of the 1979 survey were published (Anonymous 1980), they are presently being corrected to correspond with 1980 census figures. The results of the 1980 survey (Anonymous in press) are presented, but are not directly comparable with the 1965 and 1970 surveys due to the different methodologies (Table 10). All species of seatrouts were combined in the 1960 survey.

The recreational surveys indicate that the sport fishery catch probably exceeds the commercial harvest of spotted seatrout. The total estimated recreational catches of spotted seatrout for 1965 (49,052 mt) and 1970 (48,304 mt) were 17 times greater than the reported commercial landings for those years (2,924 and 2,778 mt, respectively). The estimated 1980 recreational landings (9,448 mt) were 5 times greater than reported commercial landings (1,966 mt) for the same year. The recreational harvest of spotted seatrout in 1975 and 1976 in Texas represented about two thirds of the total catch of that species in Texas waters (Weaver 1977). Davis (1980) reported that 55% of the spotted seatrout landed in Everglades National Park, Florida from 1972 to 1977 were caught by recreational fishermen. Contrasting these data raises a question of data-set reliability (Merriner 1980). The Gulf of Mexico subregion accounted for 70% or more of the total recreational landings of spotted seatrout during all three survey years.

Although no commercial landings of spotted seatrout have been reported for Maryland in recent years, substantial quantities are caught by recreational fishermen. The 1979 and 1980 Maryland saltwater sport fishing surveys indicated that the catch of spotted seatrout in Maryland waters increased from 62 mt in 1979 to 241 mt in 1980. However, the 1980 results are probably inflated due to an error in coding some weakfish as spotted seatrout (Williams et al. 1982; Williams et al. 1983).

Age of recruitment to the recreational fishery is determined by minimum size limits in some states. In Alabama tournament rules prohibit entering fish 279 mm (11 in) which eliminates all but the faster growing age I+ fish (Tatum 1980). Age II+ fish make up about 18% of the total spotted seatrout catch and age III+ fish are the first age class fully vulnerable to the fishing tournament. Catch curve analyses from the Everglades National Park recreational fishery indicated that age at full recruitment may have changed from age III in 1959 (Stewart 1961) to age IV in 1979 (Rutherford 1982). This apparent shift in age at recruitment may be due to sample bias since Stewart (1961) made a special effort to collect small fish in the 1959 study and the minimum size limit in Florida is 30.5 cm TL (12 in).

Mortality rates were estimated for populations of spotted seatrout in Florida (Iversen and Moffett 1962; Rutherford et al. 1982) and Alabama (Tatum 1980) (Table 11). In Alabama mean annual mortality for fish older than age III, the first class fully vulnerable to the fishery, was estimated to be 49.8% and ranged from 36.2% in 1968 to 58.1% in 1975 (Tatum 1980). There was an inverse relationship between between mean size and mean number of fish caught per tournament. Iversen and Moffett (1962), in a 4-month tagging study near Pine Island, Florida, estimated that natural mortality (M) was about four times larger than fishing mortality (F). Their estimates of F and M are probably too high, especially that of M (Perret et al. 1980). Males had higher rates of total annual mortality (A=.82) than females (A=.77) in Everglades National Park, Florida (Rutherford 1982). Total annual mortality rates of fully recruited spotted seatrout (combined sexes) in Everglades National Park increased slightly from 1959 to 1979, probably because of an increase in fishing mortality. Total annual mortality of females also increased slightly from 1959 to 1979 while it decreased slightly for males. Exploitation ratios were similar for all fish during both time periods and fishing mortality coefficients were higher for males than for females.

Winter cold shock of juveniles and adults has been cited as a primary factor in local and coastwide declines in spotted seatrout (Merriner 1980). Tabb (1966) noted that the spotted seatrout is very sensitive to changes in temperature. The death of large numbers of trout following severe cold spells was documented by Smith (1907), Hildebrand and Cable (1934), Storey and Gudger (1936), Gunter (1941), Gunter and Hildebrand (1951), Tabb (1958), Tabb and Manning (1961), and Moore (1976). There is usually only one kill per season in a particular area since once driven into deeper water the fish stay there for the remainder of the winter (Tabb 1958).

Catastrophic mortalities of spotted seatrout have also been attributed to hurricanes, excessive fresh water, red tide, and supersaturated dissolved oxygen conditions (Perret et al. 1980). Tabb and Manning (1961) reported a mortality following hurricane Donna (9 September 1960) which led to fish stranding and to turbulence which stirred the marl bottom of upper Florida Bay and packed fishes' gill chambers. Tabb (1966) suggested that lower salinities caused by run-off from tropical storms may cause mortality of young fish, however, he did not find dead fish to support his hypothesis. Springer and Woodburn (1960) listed spotted seatrout as one of the species killed by a red tide (Gymnodinium breve) in the Tampa Bay area in fall 1957. A phytoplankton bloom in Galveston Bay created supersaturated dissolved oxygen conditions and resulted in the formation of gas bubbles within the bloodstream and other body areas of spotted seatrout (Renfro 1963).

Table 10. Spotted seatrout recreational catch and effort statistics from national saltwater angling surveys, 1965, 1970, and 1970.

Survey year	Catch			Number of successful anglers	Average weight		Catch per angler		
	Number	Weight					Number	Weight	
		lb	kg		lb	kg		lb	kg
	----------THOUSANDS----------								
1965[1]									
South Atl.	12,559	18,209	8,267	365	1.45	0.66	34.41	49.89	22.65
Gulf	55,108	89,837	40,786	986	1.63	0.74	55.89	91.11	41.37
TOTAL	67,667	108,046	49,052	1,351	1.60	0.72	50.09	79.97	36.31
1970[2]									
South Atl.	13,992	25,040	11,368	432	1.79	0.81	32.39	57.96	26.31
Gulf	52,779	81,356	36,936	1,012	1.54	0.70	52.15	80.39	36.50
TOTAL	66,771	106,396	48,304	1,444	1.59	0.72	46,24	73,68	33.45
1980[3]									
South Atl.	1,978	2,180	989		1.10	.50			
Gulf	16,917	18,649	8,459		1.10	.50			
TOTAL	18,895	29,729	9,448		1.10	.50			

[1]Deuel and Clark 1968.

[2]Deuel 1973.

[3]Anonymous in press.

Table 11. Annual (A) and instantaneous (F,M,Z) mortality estimates, exploitation ratios (E=F/Z) and ratios of conditional fishing ($m=1-e^{-F}$) to conditional natural mortality ($n=1-e^{-M}$) for spotted seatrout.

Location	Sex	A	F	M	Z	E	m/n
Pine Island, Florida[1]	Combined	0.99	1.44	5.80	7.24		
Alabama[2]	Combined	0.50*					
Everglades National Park, Florida[3]	Combined						
	1959	0.72	0.83	0.43	1.26	0.66	1.61
	1979	0.77	1.03	0.45	1.48	0.69	1.77
	Males						
	1959	0.85	1.36	0.54	1.90	0.72	1.78
	1979	0.82	1.26	0.46	1.72	0.73	1.94
	Females						
	1959	0.66	0.68	0.39	1.07	0.63	1.40
	1979	0.75	0.88	0.50	1.38	0.64	1.50

[1]Iversen and Moffett 1962

[2]Tatum 1980

[3]Rutherford 1982

*Mean mortality rate 1968-1975 (range: 0.36-0.58).

Yield per recruit models were generated for the Everglades National Park recreational fishery (Rutherford 1982). Separate models were generated for males and females because of differences in growth. The current yield of 249 g calculated for females was lower than that calculated for males (265 g) and was obtained at a lower fishing mortality rate. Maximum yield could be reached at the current level of fishing mortality for each sex by increasing the minimum size limit to 340 mm (age 5, 15.5 in TL) for males and 398 mm (age 5.5, 18 in TL) for females. Calculated yield per recruit was very similar for the recreational fisheries in 1959 and 1979. In both years the recreational fishery harvested females at slightly less than the maximum yield per recruit, while calculated yield of males was near maximum. Given the 300 mm (12 in) size limit, yield per recruit could have been maximized by slightly increasing the fishing mortality in both years.

4.3 Community ecology

The spotted seatrout is essentially a non-migratory, euryhaline, estuarine species. Its entire life history is spent in the estuarine habitat, particularly the nontidal portions with extensive submerged vegetation where seasonal fluctuations in temperature and salinity rather than daily fluctuations are the controlling factors. Wide tolerance to changes in estuarine conditions has allowed spotted seatrout to occupy a niche that is intolerable to most marine predators and competitors (Tabb 1966). Although spotted seatrout are estuarine-dependent, they do move seaward through tidal inlets in response to environmental extremes (Section 3.5).

Klima and Tabb (1959) noted that spotted seatrout on the east coast of Florida attained a larger mean length at each age compared with those on the northwest coast and suggested that this might be due to environmental differences between the areas. In Apalachee Bay (northwest Florida) there is a scarcity of protected calm water areas and the grass flats are composed of essentially marine species (turtle grass and manatee grass). The Indian River area (east-central Florida) consists of large areas of shallow, quiet, brackish waters supporting dense stands of shoal grass and a distinctive brackish water fauna. Nine species of spotted seatrout predators and numerous competitors were listed for Apalachee Bay (Table 4) compared with only five species of predators for the east coast. Klima and Tabb (1959) suggested that the smaller number of predators in the Indian River environment is probably a result of the inability of many marine species to invade low salinity waters for any length of time. Spotted seatrout have successfully invaded the rich feeding grounds of the euryhaline herbivores and under ideal conditions may be the top carnivore (Tabb 1958).

5. EXPLOITATION

5.1 Commercial exploitation

The commercial fisheries for spotted seatrout were reviewed by Goode (1887), Brice et al. (1898), Tabb (1958), Klima and Tabb (1959), Moffett (1961), Anderson and Gehringer (1965), Merriner (1980), and Perret et al. (1980).

5.11 Fishing equipment

The principal commercial methods used to harvest spotted seatrout include various types of gill nets (runaround, stake, anchor, set, and drift), haul seines, pound nets, hand lines, troll and trot lines, trammel nets, and otter trawls (fish and shrimp). Runaround gill nets, haul seines, and anchor, set or stake gill nets accounted for 86% of the Atlantic coast catch, whereas over 84% of the landings in the Gulf of Mexico came from runaround gill nets, trammel nets, and trot lines (Tables 12 and 13).

Gear use varies among states and is partly a function of gear efficiency in different areas, but probably is more a function of state or local laws (Perret et al. 1980). For example, no gill netting is permitted in Georgia. The commercial landings data indicate that the majority of spotted seatrout landed in Georgia are caught by hook and line. In South Carolina they are caught in drift gill nets, hand lines, and incidentally in shrimp trawls. Prior to 1971, however, most were caught in haul seines. Highest landings in Virginia and North Carolina are from haul seines followed by drift gill nets in Virginia and anchor gill nets in North Carolina. In Florida spotted seatrout are mainly caught by runaround gill nets.

Seasonal changes in use of commercial gear types occur in Florida and North Carolina. Trammel nets and haul seines are used primarily during the winter months in the rivers of northwest Florida for mullet, spotted seatrout and red drum (Klima and Tabb 1959). Hook and line fishing is productive throughout most of the year in west Florida, whereas trolling is usually best in the fall. According to local fishermen, the best gill and trammel net fishing is from mid-November to mid-February when fish congregate in deep holes, and also in the spring (Moffett 1961). In North Carolina, spotted seatrout are caught mainly by long haul seines and pound nets in spring and summer, long haul seines and gill nets in fall, and trawls and gill nets in winter.

5.12 Areas fished

The best fishing areas for spotted seatrout in Florida and throughout its range are shallow brackish bays, lagoons, mangrove-bordered estuaries with abundant submerged aquatic vegetation and adjacent deep holes or channels (Tabb 1958, 1960, 1966). In Chesapeake Bay largest catches of spotted seatrout were made in the lower bay, followed by the Rappahannock and York Rivers (Hildebrand and Schroeder 1928). Largest catches of spotted seatrout in North Carolina are made in Pamlico Sound. Commercial landings statistics indicate that the majority of spotting seatrout catches are made in the estuaries along the Atlantic Coast (82-99% in 1982) (Table 14).

5.13 Fishing seasons

In Chesapeake Bay spotted seatrout are caught from March until December with periods of peak abundance from March to May, and September to November. Spotted seatrout are caught year-round within estuaries from North Carolina southward and offshore of North Carolina in winter. Largest catches are made in the fall (October-December) in North Carolina. On the east coast of Florida largest catches are made during winter when spotted seatrout are concentrated in channels and deep holes in estuaries and also in spring at spawning time (Tabb 1960; Anderson and Gehringer 1965).

5.14 Fishing operations and results

Limited catch per unit of effort data are available for spotted seatrout commercial fisheries in the Gulf of Mexico. Davis (1980) presented commercial and recreational effort data for the Everglades National Park fisheries, 1972-77 and compared mean weights and harvests. The number of gill net sets fluctuated over the 6-year period and varied between areas within the Park. Man-hours of commercial line fishing declined in all areas. The commercial catch accounted for 45% of the total Park spotted seatrout harvest.

Matlock et al. (1979) compared catch rates of spotted seatrout in areas open and closed to commercial netting. The overall mean catch rate from areas closed to commercial netting was approximately twice as high as that from open areas. There was no difference in mean size of fish between the areas.

Klima and Tabb (1959) reported on gear selectivity in the spotted seatrout fishery in northwest Florida. The sizes of

Table 12. Atlantic coast catch of spotted seatrout by gear type, 1976 (metric tons).

Gear Type	Virginia	North Carolina	South Carolina	Georgia	Florida	Total	%
Runaround gill net	-	22.5	-	-	206.7	229.2	40.6
Haul seine	8.6	165.3	-	-	6.0	179.9	31.9
Anchor, set or stake gill net	1.7	73.3	-	0.9	0.3	76.2	13.5
Pound net	1.4	25.7	-	-	-	27.1	4.8
Hand line	-	-	0.3	2.2	19.6	22.2	3.9
Drift gill net	5.9	2.2	2.1	1.2	-	11.4	2.0
Shrimp otter trawl	-	0.3	0.2	9.3	1.3	11.0	1.9
Trammel net	-	-	-	-	4.9	4.9	0.9
Troll line	-	-	-	-	2.5	2.5	0.4
Fish otter trawl	0.2	-	-	-	-	0.2	0.0
						564.6	99.9

Source: Fishery Statistics of the United States, 1976, National Marine Fisheries Service

- None reported

Table 13. Gulf of Mexico catch of spotted seatrout by gear type, 1976 (metric tons).

Gear type	Florida	Alabama	Mississippi	Louisiana	Texas	Total	%
Runaround gill net	654.1	-	69.4	549.3	-	1,272.8	47.6
Trammel net	136.2	17.5	.1	150.6	290.6	595.0	22.3
Long (trot) line	-	-	-	0.2	387.3	387.5	14.5
Haul seine	103.2	-	-	2.1	92.4	197.7	7.4
Hand line	104.4	1.9	2.0	6.2	6.8	121.3	4.5
Anchor, set or stake gill net	-	-	-	22.8	25.6	48.4	1.8
Troll line	26.7	-	-	-	-	26.7	1.0
Drift gill net	-	-	9.1	-	-	9.1	0.3
Shrimp otter trawl	6.6	0.5	-	0.2	0.3	7.6	0.3
Fish otter trawl	4.8	-	-	-	-	4.8	0.2
Purse seine	-	-	0.9	-	-	0.9	0.0
						2,671.8	99.9

Source: Fishery Statistics of the United States, 1976, National Marine Fisheries Service.

- None reported

Table 14. Commercial catch of spotted seatrout (kg) by water area for the Atlantic coast (excluding Florida) and percent (%) caught within estuaries.

Year	Virginia Ocean	Virginia Estuary	%	North Carolina Ocean	North Carolina Estuary	%	South Carolina Ocean	South Carolina Estuary	%	Georgia Ocean	Georgia Estuary	%	Total %
1972	544	52,617	99	36,015	194,315	84	2,592	5,544	68	5,734	6,010	51	85
1973	544	3,765	87	84,368	192,779	70	1,894	729	28	6,672	5,476	45	68
1974	2,268	9,616	81	38,617	265,112	87	577	3,444	86	2,889	4,429	61	86
1975	5,216	27,669	84	37,042	249,902	87	1,846	5,852	76	6,571	7,388	53	85
1976	1,315	16,375	93	11,835	277,251	96	188	2,442	93	6,715	6,858	51	94
1977	318	1,406	82	6,297	140,399	96	61	176	74	4,903	1,903	28	93
1978	454	2,313	82	8,326	35,310	81	26	28	52	292	828	74	81
1979	318	1,270	80	9,373	38,270	80	0	2,092	100	79	2,183	97	82
1980	91	363	80	17,214	60,502	78	2,638	1,053	28	0	1,928	100	76
1981	45	1,769	97	3,502	47,892	93	38	84	69	5	281	98	93
1982	45	1,497	97	5,249	32,784	86	162	720	82	1	2,264	99	87

fish caught by commercial anglers were influenced by the size of the hook and size of bait. Spotted seatrout caught by hook and line had a smaller average size (28.5 cm SL) than those caught in gill nets (30.5 cm SL) or seines (34.5 cm SL).

An evaluation of monofilament and multifilament gill nets with 1-5/8", 1-7/8", and 2" bar mesh in Louisiana indicated that monofilament nets with 1-5/8" bar mesh were most efficient in capturing spotted seatrout (Adkins and Bourgeois 1982). The size range of 482 fish was 345-451 mm TL and the average size was 410 mm TL. Hein and Shepard (1980) reported that the mean length of all fish captured in 3 to 3-1/4" stretch monofilament gill nets in Louisiana was 377 mm TL, with a mean weight of 544 g. The mean size for females was 391 mm TL (611 g) and for males was 354 mm TL (440 g). In Georgia monofilament gill nets of 2-7/8" stretched mesh and caught spotted seatrout 238-633 mm TL, with 92% ranging from 303-428 mm TL (Mahood 1975). Tabb (1960) reported an average size of 335 mm SL and 0.6 kg for spotted seatrout taken in 3-1/8" stretched mesh gill nets in Florida.

5.15 Incidental catches

Spotted seatrout apparently do not contribute significantly to the incidental finfish catches in the South Atlantic or Gulf coast shrimp fisheries. Spotted seatrout were not reported in a study of the scrap fishery of North Carolina (Wolff 1972), in a shrimp trawling investigation along the coast of South Carolina or Florida (Anderson 1968) or in a study of shrimp fishing in Georgia's close inshore waters (Knowlton 1972). Anderson (1968) reported total catches of 54 fish from Georgia outside waters (coast to 11.1 km offshore) and 224 fish from Georgia inside waters (rivers, creeks, and sounds), both less than 0.05% of the total number of finfish caught during shrimp trawling, 1931-1935. Bearden (1969) noted that commercial shrimp trawling efforts had little effect on spotted seatrout populations in South Carolina because juveniles are found in the inshore, estuarine areas (off limits to shrimp trawling) and adults have the mobility to evade trawl gear. Spotted seatrout comprised only 0.02% by number (45,000/yr) and 0.08% by weight (5,800 kg/yr) in the South Carolina shrimp fishery, 1974-75 (Keiser 1976). Landings statistics from the National Marine Fisheries Service, however, indicated that sizeable quantities of spotted seatrout were harvested in shrimp trawls during the mid-1960s and early 1970s (Table 9). Higgins and Pearson (1928) reported that only a small percentage by number (1.8-14.0%) of spotted seatrout in North Carolina long haul seine catches were unmarketable.

5.2 Recreational exploitation

Aspects of the recreational fisheries for spotted seatrout were reviewed by Tabb (1960), Anderson and Gehringer (1965), Higman (1967), Freeman and Walford (1974, 1976a,b,c,d), Davis (1980), Merriner (1980), Perret et al. (1980) and Brown (1981).

5.21 Fishing equipment

Spotted seatrout are caught by anglers while bottom fishing, chumming, live lining, jigging and casting from shore, and trolling from boats (Freeman and Walford 1974, 1976a,b,c,d). The salt-water angling surveys indicate that the principal mode of fishing for spotted seatrout is from private or rented boats (Deuel and Clark 1968; Deuel 1973; Anonymous in press) (Table 15). Principal baits include shrimp, mullet, soft or shedder crabs, silversides and killifish. Lures such as plugs, weighted bucktails, jigs, spoons, spinners and streamer flies are also used (Freeman and Walford 1974, 1976a,b,c,d).

In Chesapeake Bay bait fishing, casting, and trolling are the most often employed fishing techniques (Brown 1981). The most effective bait is peeler crabs and the most successfull lures are stingray grubs, bucktails, and mirrolures. Bait is used mainly in spring and summer, and lures in fall. The best all-round outfit for spotted seatrout is a light spinning outfit with six-foot rod calibrated for 1/4 to 1/2-oz lures with a small reel with 8 or 10-lb mono (Osborne 1981). Lures are apparently more popular in North Carolina waters and more successful in catching citation size fish (Brown 1981).

In South Carolina anglers drift or anchor over deep holes, cast along shell banks or near pilings, troll, or surf and pier fish for spotted seatrout. Live shrimp is the most popular bait, but dead shrimp or mud minnows are also used. Many fishermen prefer to use lures such as the bucktail and stingray grub (Cupka 1972).

Spotted seatrout is the most popular sportfish in coastal Georgia and most are caught on live shrimp (Anonymous 1983b). A recent Georgia tagging study indicated that 64% of all recaptured spotted seatrout were taken using live shrimp, 27% using artificial lures, and the remainder using dead shrimp, cut bait, minnows, and fiddler crabs. During cooler weather (mid-November through March) artificial lures work just as well and often better in upper rivers and creeks. When using artificial lures, fishing tackle usually consists of light spinning or spin cast reels with rods 6 feet long or longer (12 lb line or lighter). Spotted

seatrout fishing is generally less productive for two days before and after the new and full moon phases because high tidal ranges cause muddy waters (Anonymous 1983b).

Spotted seatrout fishing in Florida includes bridge, skiff, and shoreline fishing. Live bait, including shrimp, sailors choice, pinfish, mullet, and needlefish, is generally used with greater success than lures, although experienced anglers are successful using the latter (Tabb 1960).

5.22 Areas fished

The 1965, 1970, and 1980 saltwater angling surveys indicated that the majority of spotted seatrout were caught in sounds, rivers, and bays (Deuel and Clark 1968; Deuel 1973; Anonymous in press) (Table 15). The best spotted seatrout fishing in Chesapeake Bay in summer occurs in areas with abundant grass beds, particularly on the bayside of the Eastern Shore (Brown 1981). In the fall spotted seatrout catches are best in areas with adjacent deep water such as Smith Island, Magothy Bay, Lynnhaven River, Rudee Inlet and the Chesapeake Bay Bridge Tunnel. In North Carolina spotted seatrout are most frequently caught around islands and points, over grass flats and oyster bars, at creek mouths, at jogs and bends in channels, near jetties and pilings, in marshes crisscrossed by creeks and guts, and along steeply cut banks (Osborne 1981). In late October and November spotted seatrout can be found in the surf of the Outer Banks from Corolla to Portsmouth Island (Randolph 1983). Most North Carolina citation catches have come from Pamlico Sound and Oregon Inlet (Brown 1981). The most popular areas for spotted seatrout fishing in South Carolina include Murrells Inlet, North Edisto River, Wando River and the numerous estuarine areas and tidal creeks in the southern part of the state (Cupka 1972). In Georgia they are found concentrated in areas with large quantities of dead shell, or adjacent to live oyster beds. Schools may be found in the surf zone along the beach during the warmer months. Spotted seatrout are also caught at night from lighted piers and docks. (Anonymous 1983b). On the east coast of Florida the greatest numbers of spotted seatrout are landed in the Indian River lagoon system (Tabb 1960).

5.23 Fishing seasons

The catch per unit effort for spotted seatrout in Maryland was highest in September-October (Williams et al. 1982; Williams et al. 1983). In Chesapeake Bay spotted seatrout are caught by anglers from May-October; the best month is October, followed by May (Brown 1981). In North Carolina

Table 15. Number of spotted seatrout caught by U.S. anglers in each region in 1965, 1970, and 1980 by principal area and method of fishing.

Survey year	Region	Principal area of fishing		Principal method of fishing			
		Ocean	Sounds rivers and bays	Private or rented boat	Party or charter boat	Bridge pier or jetty	Beach or bank
		(THOUSANDS)					
1965[1]	South Atlantic	2,343	10,216	10,173	180	1,412	794
	Gulf of Mexico	8,597	46,511	41,245	2,448	8,325	3,090
1970[2]	South Atlantic	4,374	9,618	7,686	2,187	3,433	686
	Gulf of Mexico	16,322	36,457	38,499	2,818	5,694	5,768
1980[3]	South Atlantic	72	1,675	254	-	193	91
	Gulf of Mexico	4,169	8,802	13,990	986	1,029	912

[1]Deuel and Clark 1968

[2]Deuel 1973

[3]Anonymous in press

(-) denotes less than thirty thousand reported

best fishing begins in July, peaks in October, and continues to December or well into January in a mild year. The prime fishing months for spotted seatrout in South Carolina are September-December and May-June (Cupka 1972). Spotted seatrout fishing takes place year-round in Florida waters (Tabb 1960). Anderson and Gehringer (1965) reported highest recreational catches in spring in the Cape Canaveral area but did not sample during winter.

5.24 Fishing operations and results

Recreational catch per unit effort data for spotted seatrout are not available for the Atlantic coast. Catch rates for Everglades National Park, Florida, from 1958 through 1978 were presented by Higman (1967) and Davis (1980). Catch per unit effort data for the Gulf states was summarized by Perret et al. (1980).

6. SOCIAL AND ECONOMIC IMPLICATIONS

6.1 Values

Spotted seatrout contributed more to the total value of U.S. sciaenid landings between 1960 and 1974 than any other species (Cato 1981). Total value of spotted seatrout landings have ranked third behind croaker and weakfish since 1977 ($3.0 million in 1982).

The total value of Gulf of Mexico landings generally increased from 1950 to 1982 (Figure 4). Atlantic coast values of spotted seatrout landings have fluctuated, but increased from 1979 to 1982. Overall price movements have been fairly consistent in both regions with Gulf of Mexico prices usually slightly below prices in the South Atlantic prior to 1975 (Table 16). Adjusting prices for inflation indicates that the real (deflated) price of spotted seatrout declined from 1967 to 1977 along the Atlantic coast. Gulf of Mexico prices have increased since 1974 (Cato 1981).

Cato (1981) analyzed spotted seatrout monthly price movements for Florida. Monthly prices were lowest in the winter months when landings were heaviest. The effect on price of a one-million-lb (454 mt) increase in monthly Florida landings was a $.086 decrease, or slightly less than a 1-cent decrease for each increase of one hundred thousand pounds (45.4 mt). A 1% increase in landings explains a .04% decrease in price. Other factors important in explaining spotted seatrout price variation were previous months' landings, total personal income, and quantities of other species landed thought to substitute in the

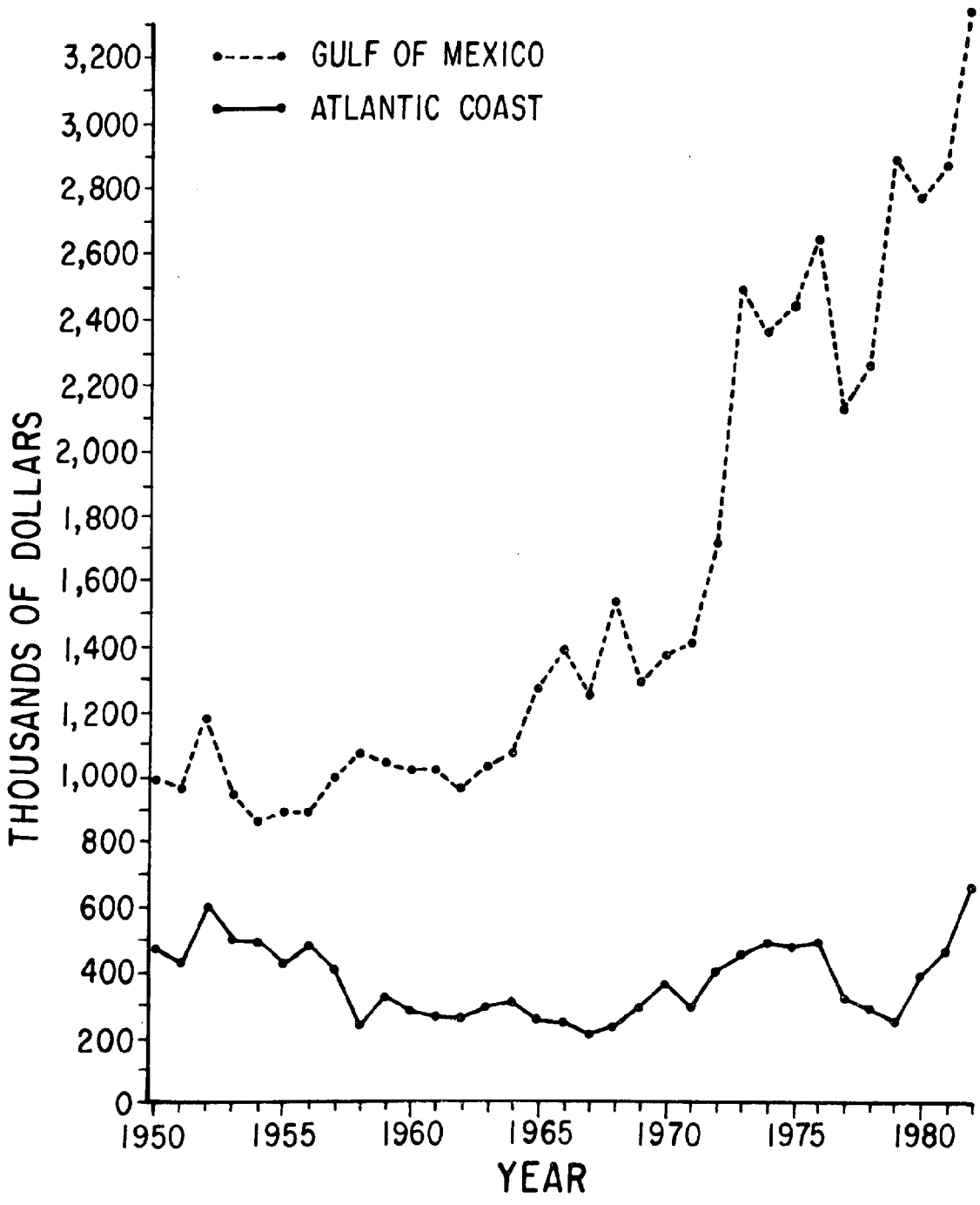

Figure 4. Dockside value of U. S. commercial landings for spotted seatrout, 1950-1982.

Table 16. Spotted seatrout ex-vessel prices, 1967-1977 (cents per pound).

Year	Atlantic Coast		Gulf of Mexico	
	Reported[1]	Adjusted[2]	Reported[1]	Adjusted[2]
1967	28.8	28.8	24.9	24.9
1968	30.1	29.4	26.0	25.4
1969	32.6	30.6	27.9	26.2
1970	30.2	27.4	27.9	25.3
1971	31.6	27.7	27.6	24.2
1972	34.6	29.1	29.6	24.9
1973	33.8	25.1	33.7	25.0
1974	35.3	22.0	33.7	21.0
1975	37.6	21.5	39.2	22.4
1976	39.6	21.6	45.2	24.7
1977	43.2	22.1	50.7	26.1

[1]Value divided by landings

[2]Reported price adjusted by wholesale price index

market for spotted seatrout. A one-million-lb (454 mt) increase in the landings of mullet, sheepshead, flounder, croaker, and red drum in Florida was seen to explain almost one-half of a 1-cent decrease in spotted seatrout prices. This indicates that these fish may be good substitutes for each other in the marketplace.

6.2 Employment

There are no data available on employment in the various spotted seatrout fisheries. Tabb (1960) stated that commercial fishing effort was declining along Florida's east coast because of closed commercial netting in some inshore waters and due to rapid urbanization and industrialization of this area.

6.3 Participation

The spotted seatrout is one of the most sought after and most often caught species of sportfish in its range (Tabb 1960; Cupka 1972). Its wide geographic range, desirable food value, and angling qualities contribute to this popularity. Participants in the spotted seatrout fishery include commercial fishermen, processors and dealers, food consumers, and recreational fishermen.

Few data are available on commercial fishing investment, total effort, efficiency, productivity, and costs for the spotted seatrout fishery, which is a mixed species fishery. Anderson and McNutt (1973) reported that spotted seatrout and red drum represented 8% of $20,000 in total returns for a small boat gill net fisherman on Florida's west coast.

Sport fishermen in the Indian River area of Florida were divided into three categories by Tabb (1960) based on disposition of the catch: fishermen who fish for recreation and home consumption only; those who consider themselves sportsmen, but who market some fish to defray trip expenses; and those who fish for sport, but who always market their catch. The South Carolina gill net fishery is primarily a noncommercial fishery; fishermen utilize small nets (<30 m), to supply fish for home consumption. Only 6% of the gill net fishermen who fished in 1978 sold a portion of their catch. Spotted seatrout comprised about 4% of the catch (7,500 kg) (Moore 1980). Hammond and Cupka (1977) made an economic evaluation of the South Carolina pier fishery and found that spotted seatrout was a relatively minor component in this fishery (<1% of total catch).

6.4 Processors and product forms

Spotted seatrout are marketed primarily along the coastal states of the Gulf of Mexico and in adjoining states (Cato 1981). In 1956 approximately 58% of all the spotted seatrout landed in the states of North Carolina, South Carolina, Georgia, Alabama, Mississippi, Texas, Louisiana, and Florida came from Florida waters (Rosen and Ellis 1958). A survey of 142 retail and wholesale markets in Georgia, Florida, and Alabama revealed that spotted seatrout sales were fairly consistent all year. Spotted seatrout were offered by 96% of the markets and average market sales per week ranged from 175 to 227 kg (384-501 lb). The predominant sales form was fresh and the average price per pound (per 0.45 kg) paid during abundant supply seasons was $1.01 (Anonymous 1979). Most seafood retailers in South Carolina reported selling about 11 kg of spotted seatrout or less per year although a few reported as much as 1,360 to 1,800 kg per year. Hook and line and gill net fishermen are the primary source of supply (Smith and Moore 1979). Perret et al. (1980) reported that virtually all of the commercial landings in the Gulf are sold in local markets as fresh in the round or gutted. A small percentage is sold as frozen and gutted or as fresh or frozen fillets.

6.5 Import/export

Perret et al. (1980) stated that imports of spotted seatrout from Mexico are substantial, and have occasionally exceeded 454 mt (Table 17). These imports have an impact in Texas, Louisiana, Oklahoma, and perhaps other markets supplied from Texas and Louisiana landings. The net impact of imports is not known.

6.6 Gear conflicts

Gear conflicts may occur between the long haul seine fishermen and the pound net, crab and eel pot fishermen in North Carolina. Abandoned, broken-off pound net stakes and pound net stakes left in place from season to season exclude long haulers from large areas, especially in Core Sound. A very large increase in the number of crab and eel pot fishermen has resulted in ever increasing friction with haul seiners, who cannot haul in areas filled with pots. Potters are mainly interested in shoal waters, which long haulers need only to bunt or harden up their seine (DeVries 1981).

Table 17. Imports of spotted seatrout, 1950-1977. (from Perret et al. 1980)

Year	Metric tons
1950	562.7
1951	465.4
1952	553.2
1953	558.4
1954	593.1
1955	589.1
1956	642.8
1957	726.5
1958	714.1
1959	773.4
1960	679.0
1961	121.7
1962	146.5
1963	164.8
1964	153.8
1965	121.2
1966	103.9
1967	58.5
1968	62.4
1969	375.1
1970	589.1
1971	466.0
1972	317.6
1973	317.5
1974	429.3
1975	379.7
1976	365.7
1977	631.1

Source: U. S. Bureau of Customs Records Transcribed by National Marine Fisheries Personnel.

6.7 Commercial-recreational conflicts

In Florida there is some contention that bait shrimp trawlers and commercial netting (gill, trammel, and seines) negatively impact spotted seatrout fishing by killing vast quantities of juveniles in the estuaries as well as damaging seagrass beds (Futch 1970). There has been legislation introduced in Florida to ban gill netting for spotted seatrout; however, none of it has passed. Commercial-recreational conflicts in Everglades National Park were discussed by Davis (1982). The National Park Service has imposed bag limits on recreational fishermen and proposed to eliminate commercial fishing in the Park by December 31, 1985. In North Carolina there is a growing conflict between recreational anglers and long haul fishermen (DeVries 1981). Conflicts and controversies in the Texas spotted seatrout fisheries were reviewed by Heffernan and Kemp (1982) and Matlock (1982). Regulations to close Texas bays to commercial fishing were adopted in the early 1900s and legislative action was taken from the 1930s to the 1970s to reduce commercial fishing pressure on the stocks, which included size limits, opened and closed waters, and gear restrictions. In 1981 legislation was passed which prohibited the sale of Texas-caught spotted seatrout. In January 1983 a task force of administrators and biologists from the Louisiana Department of Wildlife and Fisheries issued a report recommending creation of a Finfish Research/Management Section. The task force was created in late 1982 as the direct result of a controversy between commercial and recreational fishermen over laws governing spotted seatrout and red drum.

7. MANAGEMENT AND PROTECTION

7.1 Regulatory measures

The fisheries for spotted seatrout have been conducted almost entirely within the internal waters of the states and in the territorial sea which extends 5.6 km (3 n mi) offshore on the Atlantic coast. Therefore, management has been by individual state regulation. Regulations and methods of promulgating them vary among states and are summarized in Table 18. The only regulations specifically dealing with spotted seatrout are minimum size limits of 23 cm (9 in) in Maryland and 30 cm (12 in) in Florida.

The Atlantic State Marine Fisheries Commission (ASMFC) administers a cooperative program with the National Marine Fisheries Service (NMFS) entitled the Interstate Fisheries Management Program (ISFMP). This program provides funding to the Atlantic coastal states to coordinate interjurisdictional fisheries management and develop fishery management plans (FMPs) for species occuring in the territorial sea. Plans for coastal migratory species such as Atlantic menhaden, summer flounder, and striped bass have been developed under the ASMFC program and

several states have implemented regulations in compliance with these plans.

The Magnuson Fishery Conservation and Management Act (MFCMA) provides for the conservation and exclusive management by the Federal government of all fishery resources within the United States Fishery Conservation Zone (FCZ). The FCZ extends from the territorial sea to 370 km (200 n mi) from shore. Fishery management in the FCZ is based on fishery management plans developed by regional Fishery Management Councils (FMC). Spotted seatrout rarely occur in the FCZ, except off North Carolina in winter.

The National Park Service retains the authority to manage fish primarily through the establishment of coastal and nearshore national parks and national monuments such as Everglades National Park in Florida.

7.2 Habitat protection

The spotted seatrout is essentially a nonmigratory estuarine species, except perhaps at the northern extreme of its range. Nearly the entire commercial and recreational catch of spotted seatrout comes from estuaries (Tables 14 and 15). The habitat value of saltmarshes, mangroves, and seagrasses for aquatic organisms, including spotted seatrout was discussed by Thayer et al. (1978). Man's activities in these areas may negatively affect the suitability of the habitat for spotted seatrout and thereby reduce the natural production of this species (Merriner 1980).

Estuarine habitats have deteriorated rapidly since approximately 1940, mostly as a result of industrial and human population growth. The National Estuary Study, completed in 1970, indicated that 73% of the Nation's estuaries had been moderately or severely degraded (Gusey 1978, 1981). Damage and/or destruction of estuaries has largely been by dredging and filling for waterfront property, dredging of navigation channels, construction of causeways and bridges, installation of ports and marinas, alteration of freshwater flow, and pollution. Unfortunately the effects of habitat alterations have rarely been quantified.

The association of juvenile and adult spotted seatrout with seagrass beds is well documented (Pearson 1929; Miles 1950; Moody 1950; Reid 1954; Tabb 1958). Seagrass beds along the coast of Mississippi were virtually destroyed during Hurricane Camille in August 1969 (Lorio and Perret 1980); however, it is not known what effects this had on spotted seatrout populations in Mississippi Sound. An unprecedented decline in submerged aquatic vegetation has occurred in Chesapeake Bay in the last 15 to 20 years (Orth and Moore 1983). Major changes in vegetation patterns began in 1972, the year of Tropical Storm Agnes, which lowered salinities for periods of up to 4 weeks and transported

Table 18. Synoptic overview of present state management systems.

State	Rhode Island	Connecticut
Administrative organization	Rhode Island Department of Environmental Management	Connecticut Department of Environmental Protection
Legislative organization	Rhode Island Marine Fisheries Council	Connecticut Commissioner Environmental Protection
Licenses	Commercial	Commercial
Size restrictions	None	None
Limits	None	None
Gear restrictions	None	None
Conservation regulations	None	None

Table 18. Continued

State	New York
Administrative organization	New York State Department of Environmental Conservation
Legislative organization	New York Fish and Game Laws, Article 13 Marine and Coastal Resources
Licenses	Commercial non-resident beam and otter trawl
Size restrictions	None
Limits	None
Gear restrictions	Trawl prohibited from Great South Bay, Moriches Bay, Shinnecock Bay; seasonally in Peconic Bays. Gill nets restricted from Peconic Bays; haul seines limited in lengths in these same bays and cannot be fished from midnight Thursday to 6:00 p.m. Sunday. Nets and trawls may not be set in western Long Island Sound Apr. 1 - Nov. 1. Gill nets prohibited in central and western Long Island Sound.
Conservation regulations	None

Table 18. Continued

State	New Jersey	Delaware
Administrative organization	New Jersey Department of Environmental Protection, Division of Fish, Game and Wildlife, Marine Fisheries Administration, Bureau of Marine Fisheries	Division of Fish and Wildlife Department of Natural Resources and Environmental Control
Legislative organization	New Jersey Statutes, Title 23, Chapter 28	Delaware State Legislature
Licenses	Fyke nets - $1, $4, $30 Haul seines - $25 Bait seines - $3 (50' - 150') Gill nets - anchored - $13 drift - $20 run around - $20 Pound nets - $ 25 - $ 50 - $100 Otter trawl - $100 Beam trawl - $100 Purse seine - $100	None
Size restrictions	None	None
Limits	None	None
Gear restrictions	Trawls and purse seines restricted from within 2 miles of coastline. Seasons for gill nets, fyke nets, haul seines.	Trawls prohibited in Delaware Bay. Gill nets, fyke nets and seines allowed. Purse seines prohibited within 3 miles of coast.
Conservation regulations	None	None

Table 18. Continued.

State	Maryland	Virginia
Administrative organization	Maryland Department of Natural Resources	Virginia Marine Resources Commission
Legislative organization	Natural Resources Article, Annotated Code of Maryland Title 4, Subtitle 1, Title 08, Subtitle 02, Chapter 05 Fish	Marine Resources of the Commonwealth Code of Virginia of 1950, Title 28.1
Licenses	Otter trawl - $100 Beam trawl - $100 Fyke or hoop nets - $50 Gill nets- ≤200 yds $100 >200 yds $200	Commercial
Size restrictions	9" minimum	None
Limits	None	None
Gear restrictions	Trawling prohibited within 1 mile of Maryland shoreline in Atlantic Ocean. Numerous gear and area restrictions.	Trawling prohibited in Chesapeake Bay. Pound net mesh smaller than 2" (s.m.) prohibited. 3" mesh (s.m.) requirement for haul seines.
Conservation regulations	Secretary of Natural Resources has authority to adopt rules and regulations relating to taking, possession, transportation, exporting, processing, sale or shipment necessary to conservation.	None

Table 18. Continued

State	North Carolina
Administrative organization	North Carolina Department of Natural Resources and Community Development, Division of Marine Fisheries
Legislative organization	North Carolina Administrative Code, Title 15, Chapter 3.
Licenses	Vessels without motors, any length, when used with other licensed vessel - no license Vessels, not over 18' - $1/foot Vessels, over 18' to 38' - $1.50/foot Vessels, over 38' - $3/foot Non-resident vessels - $200 in addition to above fee requirement Finfish processor - $100 Unprocessed finfish dealer - $50
Size restrictions	None
Limits	None
Gear restrictions	Trawling for finfish prohibited in internal coastal waters. No purse seine for food fish. Many specific net regulations for areas and seasons.
Conservation regulations	Secretary, acting upon advise of Director of Marine Fisheries, may close area to trawling if in coastal fishing waters, samples become composed primarily of juvenile finfish of major economic important.

Table 18. Continued

State	South Carolina	Georgia
Administrative organization	South Carolina Wildlife and Marine Resources	Georgia Department of Natural Resources
Legislative organization	Section 50-5-20	Georgia Code 27-4-110
Licenses	Land and sell $25 Commercial boat license < 18' - $20 > 18' - $25 Gill nets haul seines - $10/100 yds	Commercial fishing license (personal) - $15 for any sales of catch Nontrawler license < 18' - $5 > 18' - $5 + $.50/foot Trawler license - $50 for 18' + $3/additional foot No license for seines > 300' unless catch is sold.
Size restriction	None	None
Limits	None	None
Gear restrictions	Seine mesh less than 2½" prohibited Purse seining for food fish permitted in ocean greater than 300 yds from beach.	Gill netting prohibited in Georgia waters. Seine mesh restrictions: minimum of 1¼" for seines less than 100'; minimum mesh size of 2½" (stretched mesh) for 100' - 300' maximum length.
Conservation regulations	None	None

Table 18. Continued

State	Florida
Administrative organization	Marine Fisheries Commission
Legislative organization	Chapter 370, Florida Statutes; additional 220 state laws that apply on a local level; all local laws will become Rules of the Marine Fisheries Commission by July 1, 1985.
Licenses	License to sell: Resident - $25 annually Non-resident - $100 annually Alien - $150 annually Wholesale seafood dealer Resident - $300 annually Non-resident - $500 annually Alien - $750 annually Retail seafood dealer Resident - $25 annually Non-resident - $200 annually Alien - $250 annually
Size restrictions	12" FL minimum except in Franklin and Wakulla counties
Limits	None
Gear restrictions	Purse seining and stop netting prohibited. Numerous local gear and area restrictions.
Conservation regulations	None

large quantities of suspended sediment into the estuarine system. The causes that have led to the Chesapeake Bay decline are not known but may be related to nutrient enrichment affecting the quantity and quality of light reaching the plant surface. Implications for species inhabiting grass beds have not been determined but could be considerable.

In Pinellas County and Hillsborough County, Florida, the two counties surrounding most of Tampa Bay, commercial spotted seatrout landings declined 65% from a 1951-55 average of 175 mt (386,000 lbs) to a 1976-80 average of 61 mt (135,000 lbs).[1] It has not been quantitively demonstrated how these fish yields were affected by environmental changes, fishing pressure, or socio-economic changes. However, the environmental degradation in this area has been substantial (Taylor and Saloman 1968; Lewis 1977; Lewis and Phillips 1980). By comparing old and recent aerial photographs, Lewis and Phillips (1980) calculated that seagrass acreage on the Hillsborough County side of Tampa Bay declined 73% from 4,637 ha (11,458 acres) in 1948 to 1,251 ha (3,091 acres) in 1980. Concomitantly, commercial spotted seatrout landings in Hillsborough County declined 77% from a 93 mt (204,000 lbs) average during 1951-55 to 50 mt (110,000 lbs) during 1976-80.[2] On the Pinellas County (St. Petersburg) side of the Bay, commercial spotted seatrout landings declined 59% from a 1951-56 average of 117 mt (257,000 lbs) to 48 mt (105,000 lbs) in 1976-80. No quantitative estimate of the habitat decline on the Pinellas County side of Tampa Bay is presently available. However, Taylor and Saloman (1968) estimated that in Boca Ciega Bay (a smaller bay off Tampa Bay within Pinellas County), 1,400 ha (3,500 acres) of bay bottom had been filled to create waterfront property for real estate development. This reduced the area of the bay by 20% and destroyed 1,133 mt of annual standing crop of seagrasses, resulting in an annual production loss of at least 73 mt (161,000 lbs) of fishery products.

In recent years the coastal states have enacted coastal zone management laws to regulate dredge and fill activities and shoreline development (Table 19). The Federal government also has some jurisdiction over the estuarine-marine habitat. The Office of Coastal Zone Management (OCZM) has authority through National Marine Sanctuaries, pursuant to Title III of the Marine Protection, Research, and Sanctuaries Act (MPRSA). The OCZM Estuarine Sanctuary program has designated Rookery Bay in Collier County, Florida, and the Apalachicola River and Bay in Franklin County, Florida, as estuarine sanctuaries. The OCZM also sets standards for approving and funding state coastal zone management programs. The Environmental Protection Agency may provide protection to fish communities through the granting of National Pollutant Discharge Elimination System (NPDES) permits

[1,2]Pers. commun. Roy O. Williams, Florida Department of Natural Resources, St. Petersburg, Florida.

for the discharge of pollutants into ocean waters, and the conditioning of those permits so as to protect valuable resources. The U. S. Army Corps of Engineers has jurisdiction over the disposal of dredged material, pursuant to both the Clean Water Act and the MPRSA. The Fish and Wildlife Service, under the Fish and Wildlife Coordination Act, reviews and comments on proposals for work and activities in or affecting navigable waters that are sanctioned, permitted, assisted, or conducted by Federal agencies. The review focuses mainly on potential damage to fish and wildlife, and their habitat.

The Environmental Assessment Branch of the NMFS is required to assess potential impacts on fishery resources of projects submitted to the Corps of Engineers for permits, and to recommend whether a project should be approved, denied, or modified. Fiscal year 1981 (October 1980 - September 1981) was the first year NMFS quantified the cumulative acreage of habitat involved in the Corps of Engineers permit program in the Southeast Region of the United States. NMFS made recommendations on 1,380 permit applications involving 7,272 ha (17,969 acres); 18% were proposed for dredging, 36% for filling, and 46% for impounding. NMFS did not object to alteration of 1,861 ha (4,598 acres), recommended against altering 5,411 ha (13,371 acres), and recommended that 1,345 ha (3,324 acres) either be restored or modified from upland habitat to mitigate the losses that were permitted. Thus, the NMFS efforts conserved 6,756 ha (16,695 acres) of habitat (Lindall and Thayer 1982). NMFS is also involved in the review of Congressionally authorized Federal projects. NMFS has adopted a new habitat conservation policy which will enhance its overall role in habitat conservation from a previously advisory role based primarily on the policies developed in response to the Fish and Wildlife Coordination Act and the National Environmental Policy Act.[3] The new policy will: (1) ensure that habitat is fully considered in all of NMFS' programs and activities; (2) focus NMFS' habitat conservation activities on species for which the agency has management or protection responsibilities under the MFCMA, the Marine Mammal Protection Act, and the Endangered Species Act; (3) lay the foundation for management and research cooperation on habitat issues; and (4) strengthen NMFS' partnerships with the states and the regional FMCs on habitat issues.

7.3 Stocking

Uses of artificially propagated sciaenids as a management tool include: (1) description of early life history stages; (2) bioassay; and (3) introduction of tagged known-age stocks to

[3] Federal Register 48(228):53142-53148, November 25, 1983.

Table 19. Summary of state habitat protection regulations.

State	Administrative organization	Legislative authorization	Regulations
Rhode Island	Rhode Island Department of Environmental Management and Coastal Resources Management Council	Chapter 279, Public Laws of 1971, Sect. 1, Title 46, General Laws of Water and Navigation. Chapter 23 Coastal Resources Management Council.	Permits required for coastal zone development, aquaculture, dredge and fill operations.
Connecticut	Connecticut Department of Environmental Protection	"The Coastal Management Act" Section 22-a-90 to 22a-96	Permits required to dredge fill or construct structures in both fresh and salt water. Permit required to work in regulated wetland areas.
New York	Department of Environmental Conservation, Bureau of Tidal Wetlands	Environmental Conservation Law Article 25, Tidal Wetlands Act, Part 661. Land use regulations of tidal wetlands.	Regulates activities in and adjacent to tidal wetlands and requires permits for such activities.
New Jersey	Department of Environmental Protection, Division of Coastal Resources	Wetlands Act of 1970 NJSA 13:9A-1 et seq., Coastal Area Facilities Review Act NJSA 13:19-1 et seq., Waterfront Development Law, NJSA 12:5-3, Beaches and Harbors Bond Act of 1977 PL 77-208, Shore Protection Legislation NJSA 12:6A-1	Regulates activities in the coastal zone and requires permits for such activities.

Table 19. (continued)

State	Administrative organization	Legislative authorization	Regulations
Delaware	Delaware Department of Natural Resources and Environmental Control, Division of Environmental Control, Wetlands Section	Sect. 1, Title 7, Delaware Code, Chapter 66. Wetlands.	Regulates use of wetlands and their upland border and provide penalties for violations.
Maryland	Maryland Department of Natural Resources, Tidewater Administration; Maryland Department of Health and Mental Hygiene, Office of Environmental Programs	Natural Resources Article, Code of Maryland	Regulates activities in tidal wetlands areas.
Virginia	Virginia Marine Resources Commission; County wetlands boards	Section 62.1-13.4, Code of Virginia, Wetlands Act	Regulates alterations to tidal marshes, sand and mud flats, subaqueous bottoms, and sand dunes.
North Carolina	North Carolina Department of Natural Resources and Community Development, Office of Coastal Management; Coastal Resources Commission; Coastal Resources Advisory Council	NC Dredge and Fill Law (GS 113-229), Coastal Area Management Act (CAMA) (GS 113A100)	Requires permits to dredge or fill in or about estuarine waters. Establishes areas of environmental concern. Permits required for coastal zone development.
South Carolina	South Carolina Coastal Zone Managment Council	Coastal Zone Management and Planning Act	Directs permit activities in areas of wetlands, beaches, and dunes.

Table 19. (continued)

State	Administrative organization	Legislative authorization	Regulations
Georgia	Georgia Department of Natural Resources, Coastal Resources Division, Coastal Protection Section	Coastal Marshlands Protection Act of 1970 (Gs. L. 1970, p. 939, 1.)	Requires permits to dredge, fill, remove drain, or otherwise alter any marshlands.
		Shore Assistance Act of 1979 (Gs. L. 1979, 1.)	Requires permits for a structure, shoreline engineering activity, or land alteration in beaches, sand bars, and sand dunes in Georgia.
Florida	Florida Department of Natural Resources	Chapter 253, Florida Statutes	Regulates dredge, fill, and structures on state submerged lands (below mean high water). Provides for acquisition of conservation lands and tidally influenced areas.
		Chapter 258, F.S.	Establishes aquatic preserves and regulates activities within preserves.
	Florida Department of Environmental Regulation	Chapter 403, F.S.	Permitting of activities (including dredge and fill) which affect water quality.
	Florida Department of Community Affairs	Chapter 380, F.S.	Administer and set standards for "Development of Regional Impact". Protects regional or statewide resources from poorly conceived development activities.

determine growth, migratory patterns, and exploitation rate (Tatum 1981). Biologists with the Texas Parks and Wildlife Department successfully induced spotted seatrout to spawn and pictorially documented recently hatched and developing larvae (Colura 1974). Arnold et al. (1976) developed and described methods and techniques to maintain adult spotted seatrout in captivity, to induce them to spawn repeatedly, and to culture the young in order to have eggs, larvae, and juveniles of known history for experimental purposes. Larvae were reared to an age of 3 days with a 75-80% survival and to 30 days with a 30% survival. Cannibalism and lack of proper food appeared to be the major problems in the mass production of spotted seatrout. Growth of spotted seatrout larvae in the laboratory in relation to temperature, prey species and abundance, and stocking densities in the laboratory were reported by Taniguchi (1979, 1981) and Houde and Taniguchi (1982). Juvenile spotted seatrout have been stocked in ponds in Louisiana (Sackett et al. 1979) and in Texas (Colura et al. 1976).

8. CURRENT RESEARCH

There is litle ongoing research on spotted seatrout on the Atlantic coast. The Maryland Tidewater Administration, the Virginia Institute of Marine Science, and the North Carolina Division of Marine Fisheries (NCDMF) conduct juvenile fish surveys in the estuaries to monitor numerous species. The NCDMF also samples the commercial fisheries in order to monitor adult finfish stocks and will begin an adult estuarine fish survey in 1984. A tagging and biological study of spotted seatrout was recently completed by the Georgia Coastal Resources Division. The Florida Department of Natural Resources is examining habitat loss in three Florida estuaries and changes in the fisheries of those estuaries. The National Park Service samples juvenile fishes in Everglades National Park and conducts a creel survey of the recreational fishery. The Fish and Wildlife Service is tagging spotted seatrout in Everglades National Park. NMFS Southeast Fisheries Center has initiated a habitat utilization study of seagrass beds in Everglades National Park. NMFS conducts an annual marine recreational fishery statistics survey. Commercial landings statistics are collected by state and Federal port agents.

9. IDENTIFICATION OF PROBLEMS

The ISFMP Sciaenid Technical Committee has agreed that spotted seatrout research needs are: (1) yield modeling; (2) habitat requirements; (3) effects of environmental factors on stock density;

and (4) delineation of Atlantic coast stocks. Improved catch and effort statistics for both the commercial and recreational fisheries are needed to measure stock density. The usefulness of controlling fishing mortality and minimum size need to be examined.

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