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A BIOLOGICAL AND FISHERIES PROFILE FOR LOUISIANA SPOTTED SEATROUT, *Cynoscion nebulosus*

by

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1.0 INTRODUCTION

The spotted seatrout (Cynoscion nebulosus) is one of the most important recreational and commercial marine species in Louisiana. Spotted seatrout are highly prized by commercial fishermen and consumers as a valuable food fish, and by recreational fishermen for their fighting ability on light tackle and their delectable flavor. Under current regulations, a seasonal, commercial harvest quota of 1 million lb is in effect. In a 1984 coastwide creel survey, Adkins et al. (1990) reported that spotted seatrout were targeted by more recreational fishermen in coastal Louisiana than were any other species.

This document summarizes the current literature and data on the biology and ecology of spotted seatrout and describes the commercial and recreational fisheries.

Most spotted seatrout publications are since 1970, but some of the earlier works are classics. Some of the later include studies of seatrout life history and ecology by Welsh and Breder (1924), Pearson (1929), Hildebrand and Cable (1934), Miles (1950), Moody (1950), Tabb (1958,1961,1966), Klima and Tabb (1959), Moffett (1961), Iversen and Moffett (1962), Iversen and Tabb (1962), Sundararaj and Suttkus (1962), and Lorio and Schafer (1966). Ginsburg (1929) reviewed the systematic status of the genus Cynoscion. Guest and Gunter (1958) compiled available data and information on the genus Cynoscion in the Gulf of Mexico.

Initial research on spotted seatrout in the Gulf of Mexico was conducted in Florida and Texas. However, considerable life history and ecological data have been collected in Louisiana, particularly during the 1970s and 1980s. These data include those collected in in surveys of marine recreational fisheries in the following areas: Biloxi Marsh (Stern and Schafer 1966); Vermilion Bay (Juneau and Pollard 1981); Coastal Study Area IV (Bertrand 1984); Southeast Louisiana (Titre et al. 1988); Barataria Bay (Guillory and Hutton 1990); around offshore oil platforms (Stanley and Wilson 1990); and coastwide (Clark 1962; Deuel and Clark 1968; Deuel 1973; U. S. Fish and Wildlife Service 1989, 1993; Adkins et al. 1990; Kelso et al. 1991, 1992, 1994). In addition, the Marine Recreational Fishing Statistics Survey (MRFSS) has compiled information on fishing effort, and harvest of Louisiana marine recreational fishermen. The commercial fishery or gear selectivity was described or charecterized by Bowman et al. (1977), Adkins et al. (1979), Hein and Shepard (1980a), Adkins and Bourgeois (1982), and Helser et al. (1991). The following studies described the seasonal occurrence of larvae or juveniles, or either the reproduction, age and growth, food habits, movements and migrations, ecology, size, or length-weight relationships of spotted seatrout: Darnell (1958); Lorio and Schafer (1966); Sundararaj and Suttkus (1962); Fontenot and Rogillio (1970); Rogillio (1975, 1980, 1982); Daniels (1977); Adkins et al. (1979); Hein and Shepard (1979a, 1979b, 1980a, 1980b, 1984, 1986); Sackett et al. (1979); Hein et al. (1980); Adkins and Bourgeois (1982); Arnoldi (1982, 1984, 1985); Herke et al. (1984); Peterson (1986); Shepard (1986); Wieting (1989); Helser et al. (1993); Baltz et al. (1993); and Saucier and Baltz (1993). Population dynamics of Louisiana spotted seatrout were examined by Condrey et al. (1985), Wakeman and Ramsey (1985), Ramsey and Wakeman (1987), and Helser et al. (1991 and 1993). Many other fishery surveys have provided ancillary data on general ecology, abundance, and habitats of spotted seatrout in Louisiana.

In addition to an increased proliferation of individual research studies on spotted seatrout during the late 1970s and early 1980s, several species profiles and compilations were published. A colloquium sponsored by the Gulf States Marine Fisheries Commission (GSFMC) in 1978 was devoted to the biology and management of red drum and seatrout (Williams et al. 1980). Soon after, the red drum - spotted seatrout subcommittee of the GSMFC published a fishery profile of spotted seatrout and red drum (Perret et al. 1980). A marine recreational fisheries symposium on sciaenid resources was also sponsored by the Sport Fishing Institute (Clepper 1981). A species profile and management plan was developed for the Atlantic States Marine Fisheries Commission by Mercer (1984). Additionally, GSMFC is developing a fisheries management plan for spotted seatrout. Species profiles of spotted seatrout for the Gulf of Mexico (Lassuy 1983) and south Florida (Johnson and Seaman 1986) were compiled for the U. S. Fish and Wildlife Service. An overview of spotted seatrout and red drum in Louisiana was assembled by a Fish/Seafood Division Task Force (1983). A habitat suitability index model for spotted seatrout was developed by Kostecki (1984). Darovec (1983) summarized published information on sciaenid fishes of western peninsular Florida. Peeler et al. (1976) reviewed the life history, population dynamics, fishery, user group conflicts, and management of spotted seatrout.

1.1 Status of the Fishery

Spotted seatrout have been commercially exploited since at least the late 1880s, when documented landings were first recorded. The fishery was initially a bycatch component of the shrimp-seine fishery. But, even into the early 1900s, all finfish resources in Louisiana were generally considered to be of relatively minor importance as compared to oysters and shrimp (Russell, unpublished). Although both the volume and value of Louisiana's commercial finfish landings have significantly increased since the 1950s, finfish landings in Louisiana, with the exception of gulf menhaden, still remain overshadowed in terms of dockside value by shellfish landings.

Commercial landings averaged approximately .895 million lb annually and seldom exceeded 1 million lb prior to 1971. From 1880 through the late 1960s, commercial landings of spotted seatrout were from shrimp-seine bycatch, hook-and-line, and trammel nets used during cooler fall months after shrimp seasons. During the early 1970s, the Louisiana commercial fishery for spotted seatrout rapidly expanded in both effort and volume of landings due to a rise in the general demand for finfish food sources, higher market values, and increased harvest restrictions on spotted seatrout in other Gulf states. Landings increased steadily through the mid-1970s and peaked at over 2 million lb in 1973 and 1974. An influx in 1971 of non-resident commercial fishermen using monofilament gillnets contributed to this peak (Bowman et al. 1977). Commercial landings declined after 1974 and averaged 1.2 million lb from 1975 to 1987. After 1987, a 1.25 million lb-annual (later reduced to 1.0 million lb) seasonal quota was implemented and landings ranged from .648 to 1.489 million lb, and averaged 1.15 million lb.

Little historical data exist on the recreational fishery for spotted seatrout in Louisiana. However, recreational effort, and probably harvest, has increased substantially in the last 25 years because of the availability of fast, seaworthy vessels; increased boat launch sites; increases in leisure time and discretionary income; and increased coastal populations. Wieting (1989) estimated that spotted seatrout make up 15-25% of the total recreational finfish landings in the northern Gulf coast region. Atkins et al. (1990) reported that spotted seatrout were the preferred species of 63.8% of Louisiana saltwater anglers who expressed a species preference, and that spotted seatrout made up 16.3% of the total sportfish harvest.

Recreational catches reportedly exceed commercial catches by a substantial margin. Adkins et al. (1979) estimated that in Louisiana the recreational harvest of spotted seatrout was 88%, 92%, 93%, and 86% of total harvest for 1964, 1965, 1970, and 1975, respectively. Depending upon the source, there may have been an average of .4-.485 million marine recreational anglers in Louisiana during the 1990s with approximately half targeting spotted seatrout. An average of 1.3 million fishing trips were made to harvest a total of 5.272 million spotted seatrout weighing 5.725 million lb; total annual expenditures by spotted seatrout anglers may have been in the $90-95 million range.

2.0 SPECIES BIOLOGY

2.1 Taxonomy and Nomenclature

The classification of Greenwood et al. (1966) follows.

Superorder: Acanthopterygii
Order: Perciformes
Suborder: Percoidei
Family: Sciaenidae
Genus: Cynoscion
Species: C. nebulosus

The spotted seatrout is a member of the family Sciaenidae, which contains 21 genera with 57 species in the western Atlantic Ocean (Chao 1978). Sciaenid fishes are characterized by large otoliths and, with few exceptions, by enlarged lateral line canals on the head, and pores on the snout and lower jaw; by extension of the lateral line to the tip of the caudal fin; by a large and often complex swim bladder; and by the presence of well developed drumming muscles. Sciaenids are commonly known as drum fishes or croakers, due to the drumming sounds produced by many of them, including the spotted seatrout.

The valid name for the spotted seatrout is Cynoscion nebulosus (Cuvier, 1830). The following synonymy is abbreviated from Jordan and Evermann (1898):

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

Spotted seatrout is the common name endorsed by the American Fisheries Society (Robins et al. 1991). Other common names include speckled trout, speck, speckles, spec, truite gris (Louisiana French), trucha de mar (Spanish), spotted weakfish, spotted squeateague, southern squeateague, salmon, salmon trout, simon trout, winter trout, seatrout, and black trout (Smith 1907; Hildebrand and Schroeder 1928; Shiino 1976; Hoese and Moore 1977).

Relationships of various sciaenids were reviewed by Chao (1978). Using external morphology and characteristics of the swim bladder and otoliths he grouped genera into suprageneric categories, placing the genus Cynoscion, along with Isopisthus, Macrodon, and Plagioscion, into the suprageneric group Cynoscion. This suprageneric group, Cynoscion, is characterized by a) a swim bladder with a pair of well developed horns; b) an elongate oval sagitta with smooth or notched margins; c) a snout with only two (or no) marginal pores and without upper pores; and d) a lower jaw without obvious pores or barbels.

Mohsin (1973) compared osteology in the specimens of the genus Cynoscion from along the Atlantic and Gulf coasts and hypothesized that there were two phyletic lines: one comprised of Cynoscion nebulosus and C. arenarius (sand seatrout) and the other of C. nothus (silver seatrout) and C. regalis (weakfish).

Weinstein and Yerger (1976a) used electrophoresis and Fitzsimons et al. (1985) used electrophoresis and karyology to study relationships within Gulf of Mexico representatives of the genus Cynoscion. Both studies found spotted seatrout to be the most divergent of the four species (spotted seatrout, weakfish, silver seatrout, sand seatrout), supporting conclusions of previous morphological (Ginsburg 1929) and ecological (Tabb 1966) studies.

Spotted seatrout can be distinguished from other species of Cynoscion of the northwestern Atlantic by the following characters (Chao 1976): a) ctenoid scales; b) less than 20 gill rakers on first arch; c) dorsal fin ray with 24-28 soft rays and anal fin with 9-12 soft rays; and d) posterior (soft) portion of dorsal fin with only one or two rows of small scales at base.

2.2 Distribution and Abundance

Spotted seatrout range from Cape Cod, Massachusetts, southward to Caymen Island in the lower Gulf of Campeche, Mexico (Tabb 1966). They are rare in and north of Delaware Bay, abundant along the eastern seaboard from Virginia southward to Florida, and most numerous in the Gulf of Mexico from the west coast of Florida to Texas (Iversen and Moffett 1962; Tabb 1966; Merriner 1980).

In Louisiana, large spotted seatrout are generally found in lower, more saline bays and in nearshore Gulf waters during spring and summer months, with smaller individuals found year-round in upper portions of the estuary. In the Terrebonne Bay system, Czapla et al. (1991) reported that abundance of adult spotted seatrout was greater in the marine salinity zone (>25 ppt salinity) than in either the tidal fresh (0.0-0.5 ppt salinity) or mixing zones (0.5-25 ppt salinity). In a 1984 coastwide creel survey of Louisiana anglers, Adkins et al. (1990) reported highest catches of spotted seatrout occurred in beach fishing areas, followed by pass, lake-bay, marsh, and open gulf fishing areas.

According to marine recreational surveys of the Biloxi Marsh (Stern and Schafer 1966), Vermilion Bay (Juneau and Pollard 1981), Barataria Bay (Guillory and Hutton 1990), and coastal Louisiana (Adkins et al. 1990), spotted seatrout were the most or second most abundant sport fish in creel catches. Spotted seatrout were also the most numerous fish in combined results from two gillnet surveys in coastal Louisiana (Adkins et al. 1979; Adkins and Bourgeois 1982).

In contrast, juvenile spotted seatrout have never been taken in large numbers. Numerous surveys which utilized trawls to sample Louisiana estuaries have found that spotted seatrout are rarely caught (Gunter 1938a, 1938b; Davis et al. 1970; Perret et al. 1971; Herke 1971; Perret and Caillouet 1974; Dugas 1975; Juneau 1975; Adkins and Bowman 1976; Tarver and Savoie 1976; Barrett et al. 1978; Perry 1978; Chambers 1980; Herke et al. 1984; Rogers and Herke 1985). The largest catches usually consisted of large juveniles caught during the winter months. The relative abundance of spotted seatrout in these studies was generally less than 0.10% of the total number of fishes collected. However, spotted seatrout collected by Peterson (1986) with seines and by Sabins (1973) with a hand-pulled beam trawl made up 0.54% and 0.74%, respectively, of the total number of fishes in these studies. More juvenile spotted seatrout were caught in seines than in trawls by Perret et al. (1971) and Laska (1973). Spotted seatrout juveniles collected in 1.2 m^2 drop samples ranked 11th in abundance in the summer (Rakocinski et al. 1992).

Peterson (1986) postulated that several factors may contribute to the relatively low numbers of juvenile spotted seatrout collected in fishery surveys in Louisiana despite the high annual production of adults. First, otter trawls, which do not effectively sample the marsh edges frequented by juvenile spotted seatrout were used in most surveys. Second, there is probably a high turnover of juveniles in the abundant edge habitat because of the protracted spawning season and rapid growth of juveniles.

The relatively low numerical abundance of spotted seatrout, compared to the total fish community, is not unexpected for a "top carnivore." The most abundant juvenile fish collected by Peterson (1986) in the Caminada Bay estuary were from lower trophic levels and are classified as herbivores, primary carnivores, or mid-carnivores (Odum 1971; Day et al. 1973). However, spotted seatrout, along with red drum (Sciaenops ocellatus), were the most numerous top carnivores (Odum 1971; Day et al. 1973) in the Caminada Bay estuary (Peterson 1986).

2.3 Stock Identification

Effective management of fisheries resources requires an extensive knowledge of population structure, particularly the identification of stocks and estimates of gene exchange between stocks (Weinstein and Yerger 1976b). Data from tagging and life history studies indicate that subpopulations of spotted seatrout exhibit distinct life history characteristics, suggesting genetic differences among subpopulations, perhaps due to the species' non-migratory nature and the relative isolation of their estuarine habitats (Iversen and Tabb 1962). Spotted seatrout do not migrate far from the estuaries where they are spawned (Overstreet 1983), and few have been recaptured more than 50 km from tagging locations (Moffett 1961; Iversen and Tabb 1962; Beaumariage 1969; Overstreet 1983; Baker and Matlock 1993). Subpopulations may remain distinct due to the relative isolation of estuaries along the northeastern Gulf of Mexico (Iversen and Tabb 1962; Perret et al. 1971; Weinstein and Yerger 1976b).

Several studies have evaluated the formation of subpopulations of spotted seatrout along the Gulf of Mexico. Wakeman and Ramsey (1985) found significant differences in condition factors for spotted seatrout from seven areas along the Louisiana coast, but no significant differences in condition for fish from three localities with different salinity regimes within one area. They suggested that condition factors may be useful in comparing the relative well-being of subpopulations. Wieting (1989) found significant differences in length-weight relationships, in body length to otolith radius regression, and in mean total length of spotted seatrout from three study zones. She suggested that discrete populations probably have evolved in different areas in Louisiana due to variations among coastal habitats. Although population structures were similar, there may be a trend for mean length and possibly for growth rate to increase westward in Louisiana (Wieting 1989).

Based upon growth and tagging studies, Iversen and Tabb (1962) speculated that nearly independent populations of spotted seatrout existed in Florida estuaries. Weinstein and Yerger (1976b) electrophoretically analyzed proteins in spotted seatrout in the Gulf of Mexico and inferred that independent, genetically distinct subpopulations existed in seven of the major bays from Texas to eastern Florida. Ramsey and Wakeman (1987) evaluated the biochemical variation and genetic subdivision of spotted seatrout from 15 localities from Port Aransas, Texas to northeast Florida. They reported spatial heterogeneity in allele frequencies for Adh-A, Aat-I, and Gpi-B, and indicated the presence of regional differentiation between the eastern and western Gulf of Mexico, but not to the extent suggested by Weinstein and Yerger (1976a). Ramsey and Wakeman (1987) also found no evidence of subpopulations among Florida bay systems. Murphy and Taylor (1994) indicated no evidence of distinct subpopulations in Florida spotted seatrout.

Baker et al. (1986) suggested that based upon the low recovery rate of tagged recaptures made in tributaries adjacent to Bastrop Bayou, Texas, where spotted seatrout are known to be frequently harvested, that a subpopulation within Galveston Bay may exist. Although high levels of mixing in Florida populations may not occur, local fishing pressure may be independently responsible for differences in age structure observed between populations sampled in Apalachicola Bay and the Indian River Lagoon (Murphy and Taylor 1994). King and Pate (1988) examined allelic variation in enzymes and structural proteins in spotted seatrout from four localities on the Texas coast, and found low levels of genetic variation and little differentiation into subpopulations. Colura and King (1989) attempted to separate spotted seatrout stocks along the Texas coast using scales and otoliths. They showed that fish could be assigned to the correct bay system with greater probability than would be expected if placement was random and concluded that analyses of scale and otolith shape and growth characteristics have potential for identifying Texas spotted seatrout stocks.

2.4 Morphology

Miles (1950, 1951) described spotted seatrout eggs as ranging from 0.70 - 0.98 mm in diameter and containing from one to four oil globules. Fable et al. (1978) reported that live eggs ranged from 0.73 - 0.82 mm in diameter and that oil globules ranged from 0.22 - 0.27 mm in diameter. Tabb (1966) further described eggs as: spherical; normally containing one oil droplet, but sometimes two or three; clear and unsculptured chorion; narrow privitellene space occupying only 4% of the egg diameter; and homogeneous yolk. Eggs have been reported to be demersal (Tabb 1966) as well as pelagic (Fable et al. 1978) depending upon salinity (Perret et al. 1980).

The following description of early, middle, and late stages of fertilized eggs was taken from Fable et al. (1978), who used the staging method described by Ahlstrom and Ball (1954). Early stage eggs are about 4 h or less. Eggs float with the oil globule(s) on top and the developing cells on the bottom. Development proceeds to the 16 or 32 cell stage at 1.5 h, morula stage in 2 h, and blastula stage in 3 h. At 4 h, gastrulation begins, initiating the middle stage, and by 6 h the gastrula has encircled 66% of the yolk and the primitive streak is evident. By 8 h the blastopore closes and the optic vesicles are visible in most eggs while the notochord may be occasionally present. Pigmentation has not yet developed on the egg or embryo. At 9 h after fertilization, the forebrain and notochord begin development. Small, random melanophores begin to appear around the optic vesicles. Six to eight myomeres become barely visible near the posterior one-third of the embryo at 10 h and the embryo extends over about 50% of the egg circumference by 12 h. During late stage egg development (13 h), the tip of the embryonic tail has separated from the yolk and a finfold appears on both the posterior dorsal and ventral caudal regions. Melanophores (18-20) are present over the entire embryo but are concentrated around the finfold base, dorsal surfaces of the eyes, and either side of the notochord.

Stages of embryonic, larval, and juvenile development are illustrated in Figure 2.1. At 15 h, the embryonic tail has grown well past the oil globule and developed a distinct curve. Differentiation of internal organs begins, and the eyes and hind brain become pronounced. The embryo occupies 75% of the egg circumference and 25 myomeres become apparent. Hatching occurs 16 to 20 h after fertilization. At hatching the oil globule is located at the posterior end of the yolk sac, and no pigment is visible in the yolk sac or on the oil globule.

Reviews of spotted seatrout early life history include Welsh and Breder (1924), Hildebrand and Schroeder (1928), Pearson (1929), Hildebrand and Cable (1934), Jannke (1971), Lippson and Moran (1974), Daniels (1977), Fable et al. (1978), Johnson (1978), Powles and Stender (1978), and Ditty (1989). Ditty (1989) also distinquished larvae of spotted seatrout from those of other sciaenids.

Larval specimens measuring 1.8 mm standard length (SL) were described by Hildebrand and Cable (1934) as having a deep head and trunk and slender caudal portion of the body (Figure 2.1). The caudal portion is scarcely greater than the eye diameter with an abrupt break in the ventral contour of the body at the vent. The mouth is moderately large and strongly oblique with the gape anteriorly falling approximately below the eye. The vertical finfold is uninterrupted and lacks any fin ray rudiments. Fin membranes are prominent only on the pectorals. The ventral outline of the chest and abdomen contains dark markings and a dark spot appears immediately in advance of the vent. Laboratory-reared larvae from 1.89-2.10 mm SL exhibit pectoral fin buds and body pigments forming four vertical bands located above the abdomen, above the anus and posteriorly toward the tip of the notochord (Fable et al. 1978).

Fable et al. (1978) noted the virtual disappearance of the yolk sac and described mouth formation in laboratory-reared larvae averaging 2.10 mm SL. The size and development of internal organs increase and the four vertical bands coalesce into one wide diffuse band forward of the half-way point between the anus and the notochord tip. The head and trunk is rather deep in larvae 2.5 mm SL, but the caudal portion of the body remains moderately slender, although proportionally deeper than in specimens 1.8 mm SL (Hildebrand and Cable 1934). The tissue below the distal portion of the notochord thickens, forming the primitive bases of the caudal and anal fins and the vent at near mid-body length. A black lateral stripe, consisting of closely connected dashes beginning at the vent and extending nearly half the distance to the tail, forms and the prominence of the pectoral fin membranes become prominent; however, the ventral fin membranes have not appeared.

Spotted seatrout larvae (6-8 d posthatching) measuring 2.12 mm SL have a well developed mouth with a prominent maxillary (Fable et al. 1978). Differing numbers of melanophores on the tail finfold extending to both the dorsal and ventral body margins, and dendritic melanophores reaching from the upper surface of the abdomen posteriorly toward the tail along the ventral midline are present. Large melanophores, one found immediately ahead of the anus, two to three below and anterior to the abdomen, one located at the angle of the lower jaw, with one to two more along the dorsal surface above the abdomen, are also present.

At 2.92 mm SL (11 d posthatching), larvae have six small teeth present on the upper jaw with four on the lower jaw, a more evident preopercule with a visible spine, and branchiostigal rays (Fable et al. 1978). Little change in pigmentation occurs with the principal body pigment appearing as a dark stripe extending from the mouth to the tail and melanophores now evident, giving the impression of a series of dashes along the lateral line.

A prominent preopercular spine appears at 12 d posthatching at a length of 3.35 mm SL (Fable et al. 1978). After 14 d, the numbers of caudal fin, dorsal fin, and anal fin rays are 18, 25, and 10, respectively. Wild-caught larvae, however, from 3.0-3.6 mm SL did not have fin rays (Hildebrand and Cable 1934). Little change occurs in the appearance of the dark lateral stripe (Fable et al. 1978); however, dendritic melanophores become more heavily concentrated along the lateral line and ventral margin of the tail and a single large dark melanophore is found on the caudal fin base.

Hildebrand and Cable (1934) provided the following description of 7 mm SL larvae. The body has become quite elongate and compressed with the vent situated much nearer to the caudal fin base than to the snout. The snout is pointed and longer than the eye, the mouth enlarges and becomes less strongly oblique, and both lips are black. The caudal fin has become well developed and sharply rounded and the anal and soft dorsal fins have become fully developed and the pectorals have differentiated rays; however, the spinous dorsal and the ventrals are still rudimentary. The upward curved tip of the notochord remains visible. The black lateral stripe is still evident, but becomes less distinct. Subsurface dark markings over the abdominal mass remain visible and a row of definite black spots are present along the base of the dorsal fins.

Larvae 10-12 mm SL (Hildebrand and Cable 1934) have a low and pointed head and a large, moderately oblique mouth with the lower jaw projecting quite prominently. Small spines have become evident over the preopercule and interopercule margins, and the fins have become well-developed. The caudal fin becomes moderately long and pointed, but the ventral fins and spinous dorsal remain short. Little change in pigmentation occurs although additional dusky markings appear along the black lateral stripe, and dusky markings on the head and back increase in number and intensity.

The body shape of larvae 16-20 mm SL (Hildebrand and Cable 1934) is similar to that of the adult, having become quite slender and moderately compressed. The mouth has acquired the shape and position of the adult and scales have become evident on the middle of the side from the shoulder nearly to the base of the caudal fin.

At 20 mm SL the body is nearly fully scaled; the spinous dorsal has increased in height, with the longest spine becoming proportionally as long as in the adult; and the caudal fin has become pointed (Hildebrand and Cable 1934). The ventral fins are now 2 times the length of the eye.

No major changes in body proportions occur in 25-30 mm larvae. Gill rakers have become well developed, with 8 found on the lower limb of the first arch. The body has become fully scaled with a sheath of scales found on the base of the dorsal and anal fins. The shape of the caudal fin does not change; the longest rays are equal to head length. The height of the spinous dorsal increases to the height of the soft dorsal, and ventral fins are equal in length to the pectorals. A few dark dots are present on the dorsal fins, especially on the anterior margin of the spinous dorsal fin, and scattered dark points are also present on the anal fin.

The dark longitudinal band begins to break up into spots at 30 mm SL, and at lengths of 35-40 mm the band divides into quadrate blotches while the lateral band remains almost continuous (Hildebrand and Cable 1934) .

At 60-70 mm SL, the lateral band divides into spots; the caudal fin base becomes spotted; and spots begin to develop between bands. At 70-80 mm SL, the entire upper-half of the side bears irregular spots, now more brown than in younger fish. By 110-120 mm SL, the roundish black spots typical of the adult occupy the upper two-thirds of the sides with the spots on the dorsal and caudal fins becoming fully developed. The slightly concave upper lobe and rounded lower lobe of the caudal fin does not acquire the characteristic broadly concave outline until an adult length of 300 mm SL.

The following description of adult spotted seatrout was taken from Johnson (1978), who compiled it from Jordan and Everman (1898), Hildebrand and Schroeder (1928), Miller and Jorgenson (1973), Lippson and Moran (1974) and Chao (1976).

> "Dorsal fin rays X (rarely IX or XI)-1, 24-28; anal fin rays II, 9-12 (typically 10-11); C. 9+8, procurrent rays 6-9+5-7; ventral fin rays I, 5; lateral lines 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 (L.N. Chao personal communincation, cited in Johnson 1978); no teeth on vomer, palatines, or tongue.

> Head 2.9-3.5 and depth 3.4-4.5 in standard length; 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 length.
>
> 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 (L. N. Chao personal communication, cited in Johnson 1978). 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 ciliated, never with strong serrations (L. N. Chao personal communication, cited in Johnson 1978).
>
> Pigmentation: Color dark-gray above, with sky-blue reflections, shading to silvery below; upper parts of sides with numerous round black spots extending onto dorsal and caudal fins; fins pale to yellowish-green."

Spotted seatrout is readily distinguishable from related species by the characteristic small scales and the scaleless median fins (Mercer 1984). An illustration of an adult spotted seatrout is shown in Figure 2.2.

2.5 Reproduction

Spotted seatrout in the Gulf of Mexico has a protracted spawning season, generally February through October, with peaks in late April through July (Lorio and Perret 1980; Perret et al. 1980). Latitude tempers the spawning cycle -- longer spawning seasons generally occur at more southern latitudes. Observations on spotted seatrout spawning seasons are summarized in Table 2.1.

Life history studies conducted in Louisiana indicate that the spawning season usually extends from April to September with various spawning peaks. Sundararaj and Suttkus (1962) observed peak spawning in Lake Borgne in July and August. Fontenot and Rogillio (1970) found ripe females in the Biloxi Marsh from March through October, with most spawning occurring from May through August. In southeast Louisiana, spawning took place from April to October, with a peak in May (Rogillio 1975). Using gonadosomatic indices, Arnoldi (1982) demonstrated a May to August spawning season, with a peak in July. Reproduction of spotted seatrout in Terrebonne-Timbalier Bay was documented by Adkins et al. (1979) and Adkins and Bourgeois (1982). Adkins et al. (1979) found beginning stages of gonadal development from January to March, further development during March, and spawning and spent fish from April through October, in 1976 and 1977. A similar pattern was observed during 1979 and 1980 (Adkins and Bourgeois 1982), except that a peak catch of mature (but not spawning) fish occurred in March 1981, possibly due to a mild winter.

Based upon histological observations and gonadosomatic indices, Wieting (1989) concluded that spawning in Louisiana began in April and ceased abruptly in September, rather than declining slowly. The onset of vitellogenesis began in April, with hydrated oocytes occurring from April through September with a peak in July. Oocytes in multiple histological stages of development were present throughout the spawning season, indicating multiple spawning (Wieting 1989). Bimodal (May and July) spawning peaks, as determined with gonadosomatic indices, were found in spotted seatrout from Barataria Bay by Hein and Shepard (1979a). Arnoldi (1982) noted annual variations in spawning cycles in Calcasieu Lake, with some years having spawning peaks in July and others having bimodal (May and August) spawning peaks. Bimodal spawning peaks have been observed or suggested for Florida (Tabb 1961; Stewart 1961).

Time of spawning is controlled largely by water temperature and salinity (Lorio and Perret 1980; Perret et al. 1980), but other factors such as photoperiod are also important (Arnold et al. 1976; Colura et al. 1988). Spawning occurred 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). Bimodal peaks of ripe adults in southwestern Florida corresponded with the 28-30 °C temperature range (Stewart 1961). Jannke (1971), however, stated that a minimum temperature of 24 °C initiated spring spawning in southwestern Florida. Spawning took place between 25.5 and 28.3 °C on the east-central coast of Florida (Tabb 1966). In Louisiana, Rogillio (1975) found gonadal development directly proportional to increasing water temperature and suggested that spawning began at about 20 °C and ended by the time waters exceeded 30 °C. Fontenot and Rogillio (1970) predicted spawning over a range of 26-35 °C. Sabins (1973) noted that water temperatures usually ranged between 25-30 °C during the primary spawning months (June-August). The range in average water temperatures in Barataria Bay associated with the capture of gravid fish was 24.6-30.1 °C in 1976 and 24.1-27.9 °C in 1978 (Hein and Shepard 1979a).

Fluctuating salinity is a common factor of all productive spawning grounds for spotted seatrout (Tabb 1966). Peak spawning in Florida waters occurred when spring estuarine salinities reached 30-35 ppt. Hein and Shepard (1979a) collected gravid spotted seatrout at salinities from 21-26 ppt in 1976 and from 17-26 ppt in 1978. No spawning occurred in the Laguna Madre of Texas when salinity exceeded 45 ppt (Simmons 1957). Spotted seatrout spawn in the laboratory over a salinity range of 25-30 ppt at 26 °C (Arnold et al. 1976).

Using data from laboratory-cultured eggs and larvae, Arnold et al. (1976) suggested optimal spawning salinities and temperatures of between 20-35 ppt and 20-30 °C, respectively. Hatching success of eggs was highest at 23 °C when salinities were below 40 ppt and at 26 °C when salinities exceeded 40 ppt (Gray et al. 1991). For hatching of eggs and survival of yolk-sac larvae, Taniguchi (1980) determined an optimum temperature of 28 °C and optimum salinity of 28.1 ppt, but predicted 100% survival of eggs and yolk-sac larvae between 23.1 and 32.9 °C over a salinity range of 18.6-37.5 ppt.

Photoperiod may also influence seasonal spawning activities of spotted seatrout. According to Overstreet (1983), Tucker and Faulkner (1987), and Brown-Peterson et al. (1988), photoperiod is the single most important factor in the onset or cessation of the spawning season. Peak spawning in Louisiana occurred in May on an increasing photoperiod, while secondary peaks

(July 1976 and August 1978) occurred on a decreasing photoperiod for both years (Hein and Shepard 1979a). The amount of daylight during which gravid fish were collected remained nearly the same for both years: 13 h, 42-59 minutes, and 13 h, 10-41 minutes (sunrise to sunset). Arnold et al. (1976) spawned spotted seatrout in the laboratory with a constant daylight period of 15 h.

Spotted seatrout spawn in the evening or early night (Tabb 1966; Brown 1981; Mok and Gilmore 1983; Saucier et al. 1992; Saucier and Baltz 1993). In Texas, Holt et al. (1985), however, reported synchronous spawning near dusk. Spawning of spotted seatrout in Louisiana and in Tampa Bay, Florida, occurred in conjunction with the full moon (Adkins et al. 1979; Adkins and Bourgeois 1982; McMichael and Peters 1989). Monthly spawning pulses were also documented in Georgia (Mahood 1974).

Male sciaenids aggregate in suitable spawning habitat and attract ripe females in the evening by making drumming sounds (Mok and Gilmore 1983); this activity requires substantial time and energy expenditures, and reduces available foraging time. During spawning there is a constant milling and jumping of the spawning school and side-to-side body contact between fish (Miles 1950; Tabb 1966). Spent males examined by Miles (1950) were rubbed raw around the pelvic fins, lower abdomen, and vent. Spawning is accompanied by croaking sounds produced only by the males (Smith 1907; Pearson 1929; Stewart 1961; Tabb 1966). With the use of hydrophones, Saucier et al. (1992) identified four distinctive sounds: 1) a grunt followed by a series of knocks; 2) aggregated grunts; 3) a long grunt; and, 4) a stacato. 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 1-2 h before sunset and continued for up to 6 h (Mok and Gilmore 1983). Saucier and Baltz (1993) located large drumming aggregations from 1800-2400 hours and reported that drumming increased from 1800-2100 hours and then declined. Sound production has been noted at times other than spawning, suggesting a secondary function such as defense (Stewart 1961; Hein and Shepard 1979a).

There is no consensus on the preferred spawning habitat of spotted seatrout. Published accounts of preferred spawning habitat are often contradictory and usually not supported by collection of eggs or small larvae (Lorio and Perret 1980; Perret et al. 1980).

In Louisiana, Hein and Shepard (1979a) collected gravid spotted seatrout in a variety of habitats in Barataria Bay, including shallow water, along sandy beaches; in turbulent passes; and on natural sand and shell reefs. Most ripe females were taken from stations in Terrebonne Bay that were close to the Gulf, and the number of gravid fish decreased in a northerly (inland) direction (Adkins et al. 1979). Arnoldi (1982) indicated that spawning took place in the lower Calcasieu Ship Channel and in nearshore waters adjacent to Calcasieu Pass. Tarbox (1974) suggested that spawning occurred within Vermilion Bay and the surrounding marsh rather than farther offshore as hypothesized by Herke (1971). Spotted seatrout may utilize large drifting masses of detritus as a spawning site in the absence of submerged vegetation (Sabins 1973; Tarbox 1974; Arnoldi 1982).

Saucier and Baltz (1993) observed that spawning locations over temporal spans of 1-2 weeks shifted as much as 30 km (19 miles) with changing environmental conditions and concluded that dramatic fluctuations between wet and dry years may shift site selection from inshore to offshore. Saucier (1991) utilized hydrophone recordings to locate highest spawning aggregations of spotted seatrout during summer in high-salinity waters, particularly near barrier islands and in passes. Spawning aggregations were significantly correlated with an interaction of salinity and current velocity that may have represented environmental conditions that promote survival and dispersal of eggs. Spawning locations in Barataria, Caminada, and Timbalier bays were frequently found in areas of substantial tidal movement such as between barrier islands and in open water channels where deep moving waters ranged in depth from 3-50 - m; however, 91% of moderate to large drumming aggregations were observed between depths of 2 and 10 m (Saucier and Baltz 1993).

Preferred spawning habitat of spotted seatrout in the Gulf of Mexico may include offshore and estuarine areas (Pearson 1929; Miles 1950; Miles 1951; Stewart 1961; Tabb 1966; Norden 1966; Jannke 1971; King 1971; Christmas and Waller 1973; Sabins 1973; Tarbox 1974; Rogillio 1975; Hein and Shepard 1979a; Houde et al. 1979; Arnoldi 1982; Overstreet 1983; Ditty 1984; Herke et al. 1984). Spawning is believed to occur in the deeper portions (3.0 - 4.6 m) of bays and lagoons over grassy areas (Pearson 1929; Miles 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 1975; Hein and Shepard 1979a; Houde et al. 1979; Overstreet 1983). Stewart (1961), Tabb and Manning (1961), Jannke (1971), and King (1971) presented evidence indicating spawning outside estuaries. Significant numbers of young larvae (<3 mm notochord length, NL) have been taken in plankton samples 5 km (3 miles) off the southeast Louisiana coast (LDWF unpublished data).

Spawning on the Atlantic coast probably occurs in coastal and estuarine waters. Spawning in the Indian River lagoon system, Florida, took place in the deeper channels immediately adjacent to vegetated shallows (Tabb 1961) or in the Intracoastal Waterway and adjacent deeper parts of the seagrass flats (Mok and Gilmore 1983). McMichael and Peters (1989) reported that based on the presence of small larvae spawning probably took place from mid-Tampa Bay to nearshore Gulf waters. Spotted seatrout in Georgia spawn along beaches near tidal inlets and mouths of sounds, and within creeks and sounds, 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).

Spawning locations may be influenced by salinity fluctuations. An optimal spawning salinity of 20-35 ppt was suggested by Arnold et al. (1976). Taniguchi (1980) stated that the optimal salinity for survival of eggs and larvae was 28.1 ppt and predicted that 100% survival would occur between 18.6 and 37.5 ppt.

Spotted seatrout usually become sexually mature between 1 and 3 years (Lorio and Perret 1980; Perret et al. 1980; Wieting 1989). Summary data on age-at-maturity by state and study are given in Table 2.2. Approximately 10% of spotted seatrout reached sexual maturity at the end of the first year, 50% were sexually mature by the end of the second year, and sexual maturity is generally obtained for all, at least by the end of the third year in Texas (Miles 1950). Pearson

(1929) showed that Texas spotted seatrout matured at the end of their second year but did not spawn until the third year. Age-1 fish in Louisiana contributed a small proportion of eggs to the total spawn while ages 2, 3, and 4 contributed most of the eggs (Sundararaj and Suttkus 1962). In Apalachicola and Apalachee bays, Florida, some males reached sexual maturity by age- 1, some females at age-2, and all fish appeared to have spawned by age-3 (Klima and Tabb 1959). At Cedar Key, Florida, most spotted seatrout did not spawn until their second or third summer (Moody 1950).

Size-at-sexual maturity varies from estuary to estuary, with males maturing at a smaller size than females (Lorio and Perret 1980; Perret et al. 1980). Data from various studies are listed in Table 2.2. Minimum sizes at sexual maturity for spotted seatrout in Barataria Bay were 163 mm SL for males and 207 mm SL for females (Hein and Shepard 1979a). Females at Cedar Key, Florida, matured at 210-250 mm SL, with only 1.0% of ripe females less than 220 mm SL (Moody 1950); most females did not spawn until they reached 240 -250 mm SL. Klima and Tabb (1959) concluded that all females were mature by 270 mm SL, and all males by 250 mm SL. In Texas, Brown-Peterson and Thomas (1988) reported that female spotted seatrout became sexually mature at 232 mm SL; all males they collected were sexually mature. Although Wieting (1989) did not report on size- at-maturity, she did use otolith validation and verification, back-calculation, and the von Bertalanffy growth equation to determine lengths-at-age for both male and female spotted seatrout. Back-calculated lengths-at-age and growth rates were greater than in most other Gulf of Mexico studies of spotted seatrout; these differences may result from use of scales, rather than otoliths, for age analysis in most previous studies or from sampling methods that did not allow accurate measure of growth of older age classes. Spotted seatrout may thus exhibit different growth rates at different life stages and a single equation for all classes may be biased.

Spotted seatrout are classified as "multiple, serial, or heterochronal spawners" (Wieting 1989) that continuously mature sequential batches of eggs through a prolonged spawning season (Hunter et al. 1985). In laboratory studies of small groups of spotted seatrout, spawning occurred 82 times in 13 months (Arnold et al. 1976) and 41 times from June 8 to September 13 (Tucker and Faulkner 1987). In South Carolina, spawning occurred once every 16-21 d from April through September (Saucier et al. 1992). On the average, individuals probably produce one batch every 21 d (Tucker and Faulkner 1987; Brown-Peterson et al. 1988). Based upon the daily proportion of females showing evidence of spawning by the presence of post ovulatory follicles, Wieting (1989) estimated that Louisiana spotted seatrout spawned eight times each year.

Estimates of spotted seatrout fecundity from the literature are summarized in Table 2.3. Lassuy (1983) postulated that differences in fecundity estimates among the studies may either be real or due to differences in laboratory techniques. The fecundities reported by Tabb (1961) and Sundararaj and Suttkus (1962) were probably underestimated because only large yolky eggs were counted (Overstreet 1983).

In Lake Borgne, Louisiana, Sundararaj and Suttkus (1962) calculated that female spotted seatrout of ages 2, 3, and 4 contributed about 91.9% of the total population's supply of eggs, and age-2 fish had the greatest "spawning power" with 40%-60% of the egg supply. Arnoldi (1984) demonstrated that in Calcasieu Lake, Louisiana, age-3 fish had a greater spawning potential than ages 4 and 5 combined. Age-3 fish were nearly all sexually mature and larger in size, thus providing the bulk of the spawn. Age-2 fish contributed a smaller degree of spawn because of smaller individual fish sizes and the presence of sexually immature fish. Age-3+ females tend to have fewer viable eggs than younger, more vigorous females. In Everglades National Park, female spotted seatrout of ages 3 and 4 contributed most of the eggs, whereas most male spawners were ages 2, 3, and 4 (Rutherford et al. 1982).

In general, fish fecundity increases with age and size. However, few regression equations relating length or weight of spotted seatrout with fecundity were found in the literature. Regression equations estimating fecundity were calculated by Arnoldi (1982) and Wieting (1989), using the following formula:

$$Y = -1814.32 + 6.46 \text{ TL (in.)}$$
$$\log Y = -23.65 + 3.77 \log \text{TL (mm)},$$
where Y = number of eggs.

Wieting (1989) emphasized the difficulty of estimating reproductive potential of a heterochronal spawner such as spotted seatrout. In a heterochronal spawner, counting only ripening (large) oocytes may greatly underestimate potential fecundity (Mackay and Mann 1969; Macer 1974; Conover 1985; Hunter et al. 1985). To realistically estimate annual fecundity, the number of eggs spawned in a batch and the number of batches spawned per season must be known (Hunter and Leong 1981; Conover 1985).

Batch fecundity of Louisiana spotted seatrout ranged from .03-2.1 million oocytes, with a mean of .52 million oocytes; batch fecundity peaked in July, with a smaller peak in April-May (Wieting 1989). In Texas, Colura et al. (1984) also found a July peak in batch fecundity of spotted seatrout. Wieting (1989) further calculated annual fecundity (batch fecundity X spawning frequency) to range from .28-16.9 million oocytes and average 4.15 million oocytes. The mean annual fecundity was 1.8 million oocytes; 5.2 million oocytes; 7.5 million oocytes; and 8.3 million oocytes for ages 1 through 4, respectively. Wieting stated that her estimates of spotted seatrout fecundity were higher than others reported in the literature.

Eggs of spotted seatrout have been described as both demersal (Tabb 1966) and pelagic (Fable et al. 1978) depending upon salinity (Perret et al. 1980). At salinities greater than 30 ppt, eggs are buoyant, but at 25 ppt eggs sink. This phenomenon could be an effective mechanism for keeping eggs from being transported far into estuaries where salinities may be too low for survival. Optimum salinity for the survival of eggs and larvae is about 28 ppt (Taniguchi 1980).

Spotted seatrout eggs collected near Beaufort, North Carolina, hatched in 40 h when the water temperature was 25 °C (Smith 1907). Under laboratory conditions, larvae hatched 18 h after fertilization, and ranged from 1.3-1.6 mm SL (Fable et al. 1978). Field data on newly hatched spotted seatrout larvae are meager because of the difficulty of collecting such small individuals.

Larvae (3-6 mm SL) were collected in Everglades National Park (Jannke 1971) and in Texas at tidal passes during flood tides (King 1971).

2.6 Age and Growth

Few topics are of more fundamental importance to fishery scientists than age and growth. The growth of fishes, which is generally indeterminate and affected by food availability, influences age at first reproduction, survivorship, and fecundity (Nikolskii 1963).

The age distribution of spotted seatrout differs with area. The percentages of spotted seatrout by age group for various locations are presented in Table 2.4. Except for Alabama (Wade 1984), the populations were predominated, in declining order, by ages 1, 2, and 3. In Louisiana, Arnoldi (1985) found that age-1 fish (34.8%) predominated, with age-2 (22.0%) and age-3 (22.0%) individuals uniformly abundant, and that fish of ages 4 and 6 ranged from 5% to 10% of the total, while those of ages 7 and 8 were rare.

Older spotted seatrout, along both the Atlantic and Gulf coasts, apparently occur more often in the northern part of their range. Individuals aged at 8 years were reported from Chesapeake Bay (Brown 1981); those at 10 years from east-central Florida (Tabb 1961) and those at 15 years from Georgia (Music and Pafford 1984). In the Gulf of Mexico, spotted seatrout attained 8 years in Louisiana (Arnoldi 1984) and southwest Florida (Moffett 1961) and up to 9 years in Texas (Pearson 1929). Reports of older fish, however, are uncommon (Table 2.4). Age-7 spotted seatrout were found in southwestern Florida (Stewart 1961; Rutherford 1982) and northwest Florida (Klima and Tabb 1959). Moffett (1961) recorded fish of age-6 in west Florida (Cedar Key), as did Tatum (1980) and Wade (1984) in Alabama.

Female spotted seatrout usually reach a greater maximum age than males throughout their range. Females are also generally larger at age than males (Murphy and Taylor 1994); however, males are generally heavier than females of the same length. Males and females reached at least ages 8 and 12, respectively, in Chesapeake Bay (Brown 1981). The oldest male and female spotted seatrout in a Georgia study were ages 6 and 8, respectively (Music and Pafford 1984). All Florida studies, except that of Moffett (1961), at Cedar Key, have shown that females lived at least 1 year longer than males (Klima and Tabb 1959; Moffett 1961; Stewart 1961; Tabb 1961; Rutherford 1982). In Florida estuaries, the maximum observed ages for male spotted seatrout ranged from 5-9 years, and from 6- 8 years for females. The tendency of female spotted seatrout to outlive males was also reported from Alabama (Wade 1984), Louisiana (Hein and Shepard 1979a), and Texas (Pearson 1929). Murphy and Taylor (1994) found male spotted seatrout from ages 0-9, and females from ages 0-8 in samples collected from Apalachicola Bay, Charlotte Harbor, and Indian River Lagoon, Florida.

Growth rates of larval and juvenile spotted seatrout are rapid. Peebles and Tolley (1988) reported larval growth rates of 0.4 mm/d in southwest Florida estuaries. In Texas, larval spotted seatrout held under controlled conditions at temperatures of 24-26 °C grew from 1.5 mm SL at the time of hatching to 4.5 mm SL in 15 d (Fable et al. 1978). This growth was exceeded by spotted seatrout raised in the laboratory and fed wild copepods (Taniguchi 1980); these larvae gained weight at an average rate of 76.5%/d. A modal length of 130 mm TL was obtained in Texas by the first winter (Pearson 1929). In Georgia, juvenile spotted seatrout attained a mean length of 124 mm TL in November (Mahood 1975). Hildebrand and Cable (1934) found a modal length of 170 mm TL for juvenile spotted seatrout in North Carolina at the end of 7-8 months of growth. In Texas, Bumguardner and Maciorowski (1989) observed maximum specific growth rates (2.39%/d) in juvenile spotted seatrout held at 28 °C. Based upon mean back-calculated lengths, spotted seatrout size at time of first annulus formation ranged from 220-242 mm TL, and from 301-337 mm TL at age-1, in Florida (Murphy and Taylor 1994). Juvenile spotted seatrout (100-112 mm TL) stocked in ponds in Louisiana grew 2.08 mm/d in October and 0.33 mm/d in November (Sackett et al. 1979). Juvenile spotted seatrout in Calcasieu Lake, Louisiana, grew rapidly throughout the summer, with most fish reaching a length of 120-200 mm TL by November; there was apparently little growth throughout the winter (Arnoldi 1982).

Reading annuli of scales and otoliths is the preferred method of determining age and growth of larger spotted seatrout (Perret et al. 1980). Tabb (1961) reading scales and Maceina et al. (1987) reading otoliths reported that an annulus usually forms in March when growth rates accelerate. In thin sections of sagittae, Murphy and Taylor (1994) found that opaque band formation occurred once a year in November-May for fish of ages 1-3, with no observed differences between sexes; spotted seatrout were probably 8-10 months old at time of first annulus formation. Matlock (1992) also quantitatively described growth in spotted seatrout based upon tagging studies conducted in Texas bays. Green et al. (1990) also used tag and recapture data from Texas bays to estimate time-specific survival rates and von Bertalanffy growth parameters. Length-frequency data are generally unreliable for calculating growth rates and age structure of a population because of the protracted spawning season of spotted seatrout and the differential growth rates between sexes, which result in overlap of length ranges of the various age groups (Pearson 1929; Guest and Gunter 1958; Wakeman and Ramsey 1985). Murphy and Taylor (1994) also found age assignment complicated by the protracted spawning season. The range in sizes of spotted seatrout by age (Table 2.5) further illustrates this overlap.

Mean back-calculated length-at-age, by study, is summarized in Table 2.6 for both sexes combined. Mercer (1984) noted that there appeared to be a discrepancy in Tabb's (1961) data, and that calculated lengths for ages 1 and 2 spotted seatrout in Everglades National Park (Rutherford 1982) were greater than in other studies because of the formula used in back-calculations. Length-at-age differs considerably between Gulf of Mexico and Atlantic Coast estuaries. Among Gulf sites, lengths-at-age for spotted seatrout in southwest Louisiana (Arnoldi 1984) were much smaller than in Matagorda Bay, Texas (Colura et al. 1984), and Alabama (Wade 1984), but were larger than in mid-coastal Texas (Pearson 1929) and in northwest to southwest Florida (Welsh and Breder 1924; Klima and Tabb 1959; Moffett 1961). Murphy and Taylor's (1994) estimates of average length at time of first annulus formation and of lengths at ages 1-3 were greater than reported for spotted seatrout in previous Florida studies. For older fishes (Murphy and Taylor 1994), lengths-at-age when compared with those from other studies were not marked. Back-calculated lengths-at-age for both sexes across coastal Louisiana (Wieting 1989) displayed the same relationship as did similar data from other Gulf sites, with the exception of those recent data of Murphy and Taylor (1994).

Variations in size-at-age among locations may be explained by genetics, but differing habitats, and salinity and temperature regimens are probably also important (Tabb 1958, 1966). Growth rates of spotted seatrout are also density dependent and may vary within and between populations, depending upon food availability and physical, chemical, and meteorological factors within the environment of a given population (Lorio and Perret 1980). Klima and Tabb (1959) attributed differences in growth rates of spotted seatrout between Apalachee Bay and Indian River, Florida, stocks to lack of quiet protected areas free from marine predators and competitors in Apalachee Bay and the presence of such areas at Indian River. Murphy and Taylor (1994) reported significant differences between age-1 male and female spotted seatrout, mean back-calculated lengths, and observed lengths among different areas. Year-to-year variations also cannot be ruled out as the primary source of discrepancies in growth in different areas (Lassuy 1983).

Growth rates may also vary seasonally. Spotted seatrout growth slowed or stopped in the winter because of decreased metabolism and reduced feeding (Guest and Gunter 1958; Tabb 1961). Growth rates were highest in July and August (Welsh and Breder 1924; Pearson 1929). In Louisiana, Wieting (1989) noted that rapid growth occurred from June through November, and that annuli were formed on otoliths from December through April.

Back-calculated lengths-at-age, by sex, are listed from several representative studies in the Gulf of Mexico (Table 2.7). Female spotted seatrout were larger than males for all ages in each study except for age-5 of Moffett (1961) and age-8 of Arnoldi (1984); these exceptions were in age groups represented by relatively few individuals.

Average annual growth increments by age group for spotted seatrout in different locations are shown in Table 2.8. Without exception, greatest growth occurred prior to age-1. Annual growth increments generally were above 40 mm through age group-5; however, overall growth gradually decreased with age. Fish of age-1 grew only 7 and 11 mm. Murphy and Taylor (1994) provided growth estimates made from average observed, back-calculated, and model-predicted sizes-at-age. Estimated male growth rates were significantly different between areas. Generally, males were heavier than females at a given length and differences in weight at given lengths for both males and females were observed among areas.

Annual growth increments by age group by sex are presented in Table 2.9. Females exhibited greater growth between age classes than males.

Von Bertalanffy growth curves were derived for spotted seatrout in Chesapeake Bay (Brown 1981); Everglades National Park, Florida (Rutherford 1982); Louisiana (Wakeman and Ramsey 1985; Wieting 1989); and the Gulf of Mexico (Condrey et al. 1985). Gompertz and linear growth models for both female and male spotted seatrout were used in modeling adult spotted seatrout growth in Florida (Murphy and Taylor 1994).

Sex ratios for spotted seatrout indicate that, overall, females outnumbered males. By location, the following female:male ratios were found: Texas (Pearson 1929) - 2:1; Everglades National Park, Florida (Rutherford et al. 1982) - 1.7:1.0; Florida (Murphy and Taylor 1994) - 2.14:1.0; Georgia (Music and Pafford 1984) - 1.9:1.0; Georgia (Mahood 1975) - 1.7:1.0; Barataria Bay, Louisiana (Hein and Shepard 1979a) - 2.4:1.0; Louisiana (Wieting 1989) - 1.6:1.0; and, Mississippi Sound, Mississippi (Overstreet 1983) - 1.5:1.0.

The overall sex ratio observed across coastal Louisiana was similar to that in other areas of the Gulf of Mexico (Wieting 1989). Sex ratios vary with length. Length-specific differences in growth rates, or changes in vulnerability of males to fishing or other mortality factors may account for observed trends of sex ratio with length. In Louisiana, the sex ratios ranged from a low of 1.1:1.0 for age-3, to 2.2:1.0 for age-2 fish (Wieting 1989). Percentages of females by age group in Calcasieu Lake, Louisiana, (Arnoldi 1985) were different from those in other Louisiana coastal areas: Area I - 66.2%; Area II - 79.5%; Area III - 28.4%; Area IV - 23.0%; Area V - 11.8%; Area VI - 4.1%; and Areas VII and VIII - 0%. By size group the percentages of females were: <13 in - 24%; 14 to 15 in - 75%; 16 to 18 in - 54%; 18 to 20 in - 68%; and >20 in - 100%. The percentages of female spotted seatrout in Mississippi Sound by length groups (SL) were determined by Overstreet (1983): <140 mm - 55%; 140 to 219 mm - 49.2%; 220 to 299 mm - 55.4%; 300 to 399 mm - 69.4%; and, >400 mm - 85.7%.

Similar trends were usually evident for spotted seatrout in other areas. Several studies have reported a preponderance of males among younger year classes, a near 1:1 ratio at age-2 to 3, and all or nearly all females by age-5 to 6 or older (Klima and Tabb 1959; Moffett 1961; Tabb 1961). In Georgia, the sex 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). Tabb (1961) found that 19% of age-1 fish, 47% of age-2 fish, 82% of age-5 fish, and 100% of age-8 and older were female. Stewart (1961) found approximately equal sex ratios of Florida Bay fish through age-3, followed by a predominance of females from ages 4 through 7. Klima and Tabb (1959) showed that at 175-195 mm males were 3-4 times more numerous than females, but at 295 mm females were more numerous, and by 395 mm all fish were female. In Everglades National Park, females made up 28% of age group 1, 63% of age groups 2-5, and 78% of age group 6 and older (Rutherford et al. 1982). However, Murphy and Taylor (1994) found similar abundances of male and female spotted seatrout at older ages contradictory to earlier Florida studies.

Length-weight relationships were determined for spotted seatrout in Louisiana by Hein et al. (1980) and Wieting (1989). The regressions are as follows:

1. Hein et al. (1980) $\log W = -5.423 + 3.154 \log TL$
2. Wieting (1989) $\log W = -4.00 + 2.59 \log TL$ (males)
   $\log W = -4.63 + 2.97 \log TL$ (females)
   $\log W = -4.89 + 2.95 \log TL$ (both sexes combined)

Length-weight regressions for areas outside Louisiana are listed in Table 2.10.

Condition factors for spotted seatrout have been calculated in Mississippi (Overstreet 1983) and Louisiana (Hein and Shepard 1979b; Wakeman and Ramsey 1985).

2.7 Movements and Migrations

Tagging studies in Louisiana, other Gulf states, and Georgia indicate that adult spotted seatrout are relatively non-migratory, although they may move in and out of an estuary (Moffett 1961; Ingle et al. 1962; Topp 1963; Beaumariage 1964 and 1969; Beaumariage and Wittich 1966; Fontenot and Rogillio 1970; Mahood 1974; Rogillio 1975; Adkins, et al. 1979; Rogillio 1980; Arnoldi 1982; Rogillio 1982; Baker et al. 1986; Bryant et al. 1989; Marwitz 1989; Woodward et al. 1990; Baker and Matlock 1993). Most researchers generally agree that spotted seatrout have relatively small home ranges, remain within 5 miles (8 km) of the release site, and seldom travel more than 30 miles (48 km); however, some individuals are "wanderers" and may travel considerable distances.

Two spotted seatrout were tagged in Calcasieu Lake, Louisiana, and recovered 100 miles (170 km) east in Atchafalaya Bay, Louisiana (Arnoldi 1982). All but 3 of 93 returns from Louisiana were of fish recaptured <2 miles (3.2 km) from their tagging sites; 1 of the 3 was caught 24 miles (38 km) from the release site (Adkins et al. 1979). One spotted seatrout tagged in Apalachicola Bay was recovered, 233 d later, 315 miles (500 km) away at Grand Isle, Louisiana (Moffett 1961). In Texas, tagging data collected by Bryan (1971), Simmons and Breur (1976), and summarized by McEachron and Matlock (1980), do not support long range migration of spotted seatrout. Marwitz (1989) summarized fish tagging in Texas bays between 1975 and 1988 and reported that the intra-bay recovery rate for spotted seatrout was 84%, based on a 7% return rate. Tagged spotted seatrout showed little tendency to migrate greater distances with increased time at liberty, and no correlation between fish size and distance moved was noted by Moffett (1961) and Woodward et al. (1990). About 95% of 470 recaptures were within 29 miles (46 km) of their tagging location. Of the 16 fish that were recaptured farther than 81 miles (130 km) from the tagging site, 4 moved at least 233 miles (373 km), and 1 moved 304 miles (486 km). In Georgia, only 3% of tagged spotted seatrout were recaptured in waters outside the state (Woodward et al. 1990).

Vogelbein and Overstreet (1987) studied the histopathology of internal anchor tags in spotted seatrout up to 4 months following tagging. Few complications and no tag expulsions were observed, but with time tags became encapsulated.

Movements of spotted seatrout may be associated with temperature fluctuations, freshets, spawning, feeding, and protection (Lorio and Perret 1980; Overstreet 1983; Woodward et al. 1990). Temperature was identified by most authors as the most important single factor causing movement of spotted seatrout.

During late fall, spotted seatrout begin to move from shallow lagoons to deeper bayous, canals, or Gulf waters to escape low water temperatures. High water temperatures (35 °C) have also been associated with limited movement. Texas Parks and Wildlife Department (1973) reported gradual movements to deep water and to the Gulf in winter, with much more rapid movement following passage of a cold front. Baker et al. (1986) documented an exit of spotted seatrout from Bastrop Bayou, Texas, in winter months; a return in the spring; a summer exit ; and a subsequent fall return. In Trinity Bayou, Texas, tagged fish moved toward the Gulf of Mexico in late spring and summer, and returned in the fall (Baker and Matlock 1993). Arnoldi (1984) suggested that movement and migration of spotted seatrout in southwest Louisiana was related to availability of forage species, while Rogillio (1982) indicated that presence of a food source may equal, if not exceed, influence of temperature on movement of spotted seatrout. Helser et al. (1993), however, using LDWF data, analyzed catches of spotted seatrout from experimental gillnets. They suggested that fish may actively seek areas of preferred salinity for optimal growth and survival, however other factors (biotic or abiotic) that are associated with salinity can not be ruled out. Helser et al. (1993) further reasoned that "during the spawning season, the spotted seatrout population as a whole (recruits and spawners) is oriented toward higher salinity waters of lower bays and beaches in response to favorable environmental conditions for spawning...these individuals may also be taking advantage of greater food availability in the lower coastal zone during this time." Deegan and Thompson (1985) suggested that up-estuary movement of subadult spotted seatrout in fall coincides with inshore migrations of juvenile gulf menhaden (Brevoortia patronous) and bay anchovy (Anchoa mitchelli).

Spotted seatrout begin to school at 6-8 weeks, at sizes of 25-50 ml TL, and continued to school until about 5-6 years, when most males have died and the remaining large females, called "sow" or "gator" trout, have adopted a semi-solitary existence (Tabb 1966). The swimming behavior of these old fish is slow and deliberate, except when frightened or capturing prey. Spotted seatrout swim into the current when startled and in the same direction as sudden strong winds (Texas Parks and Wildlife Department 1973).

2.8 Pathology/Parasitology

Spotted seatrout are potential hosts to numerous ecto- and endo-parasites (Lorio and Perret 1980). Records of parasites and diseases of spotted seatrout are widely scattered in the parasitological literature. Overstreet (1983) tabulated a partial annotated list of parasites of sand and spotted seatrout, and concluded that the parasites of seatrout deserve considerably more attention than they have received. No attempt is made here to itemize all parasites and diseases found in spotted seatrout; however, the most prevalent and conspicious ones are mentioned.

The most conspicuous parasite of spotted seatrout in Louisiana, is the metacestode stage of the parasitic tapeworm (Poecilancistrium caryophyllum), sometimes referenced as P. robustum (Overstreet 1983). Tapeworm larvae are elongated with a terminal bulbous enlargement, appear whitish-opaque in color, and encyst in the fleshy musculature of the upper back of the fish on either side of the vertebral column. Collins et al. (1984) found a maximum infection intensity of 10 P. caryophyllum plerocercoids per spotted seatrout. Means of transmittal and host-parasite relationships are poorly understood; however, these parasites are probably transmitted to fish by ingestion of food such as penaeid shrimp, which harbor tapeworm larvae. Sharks such as bull shark (Carcharhinus leucas) and lemon shark (Negaprion brevirostris) have been identified as definitive hosts of this parasite.

P. caryophyllum does not affect the condition coefficients of adult spotted seatrout (Overstreet 1977). One cestode was noted encysted in the musculature of a 250 mm spotted seatrout, suggesting that most individuals probably live in spotted seatrout at least 3 years before degenerating (Overstreet 1983). Numerous authors (Guest and Gunter 1958; Overstreet 1978; Adkins et al. 1979; Lorio and Perret 1980) have stated that fishermen often discard fish infected with tapeworm larvae because of a perceived danger. Overstreet (1983) questioned fishermen participating in Mississippi fishing rodeos and reported that 43.8% saw the cestode and did not mind eating infected fish, although some culled the worms, and 24.8% of those fishermen who caught infected fish did not eat them. Infected fish less than 140 mm SL probably die while those greater than 140 mm SL may develop an immunological response (Overstreet 1983). Tarver (1972) noted a greater occurrence of the parasite in spotted seatrout older than 1-year. The prevalence and intensity of infection was greater during years of high salinity because of the probable increased availability of infected intermediate hosts (Overstreet 1977).

The hemurid digenean Stomachiola magna is another parasite of spotted seatrout. This pink-colored worm is surrounded by a dark colored pigment and is found encapsulated, or wandering, in the peritoneum, flesh, or viscera (Overstreet 1983). Higher levels of prevalence and intensity of infection were found to occur more often in sand seatrout than in spotted seatrout (Corkum 1966; Sinclair et al. 1972).

A protozoan parasite was found in leucocytes of spotted seatrout by Saunders (1954). Various trematodes were reported from spotted seatrout by Manter (1938), Hargis (1956), Hopkins (1956), and Sparks and Thatcher (1958). Overstreet (1977) surveyed cestodes in spotted seatrout.

Larval spotted seatrout fed wild plankton became infested with the chalimus stage of Caligus sp., which usually attached to the dorsum near the developing dorsal fin (Houde 1972 personal communication, cited in Overstreet 1983). Larval herring reared with wild plankton became infected with the larval stage of an ascaridoid nematode, tetraphyllidean cestode, lernaeocerid copepod, and Caligus rapax (Rosenthal 1967); and these larval parasites, especially the nematode and lernaeocerid, killed about 10% of the actively feeding fish. Related species infect the spotted seatrout (Overstreet 1983).

The isopod Lironeca ovalis, the most common external metazoan parasite of spotted seatrout in Mississippi, is capable of inflicting extensive damage to gill filaments and may result in juvenile mortalities (Overstreet 1983). Pearson (1929) noted that in Texas L. ovalis commonly occurred on spotted seatrout of less than 3-years, but was rarely found on older individuals; he suggested that growth of infected fish was reduced compared to uninfested fish of the same year class and that these fish would gradually be eliminated from the population. Calligid copepods were found to infest the gills of spotted seatrout in Texas (Pearse 1952; Guest and Gunter 1958).

Overstreet (1983) collected spotted seatrout of 10-17 cm TL from November through May and found that one or two of these parasites per fish were common yet larger fish rarely demonstrated infestation.

Bere (1936) and Causey (1953) recorded several Lernanthropes gisleri on the gills of spotted seatrout. Pearse (1952) found 45 specimens of L. grisleri from 29 spotted seatrout. This species seems to have more of an affinity for spotted seatrout than any other parasitic copepod.

Overstreet (1983) also listed the dinoflagellate Amyloodinium ocellatum, peritrich ciliates, and monogeans as parasites of cultured spotted seatrout. Harmless parasites such as Scolex polymorphus, a phyllobothriid tetraphyllidean metacestode, occur in large numbers in the cystic duct, gall bladder, and intestine of its host; though the cystic duct may enlarge several fold, metabolism, condition coefficients, and food in the intestine appeared normal. Small numbers of larval helminths that have no adverse effects on spotted seatrout were also observed.

Several pathogens have been documented in spotted seatrout. The viral disease lymphocystis, which infects connective tissue cells in the fins and body proper and results in hypertrophy, have been observed in spotted seatrout in Mississippi Sound (Howse and Christmas 1970). Vibrio parahaemolyticus, a bacterium known to cause food poisoning, was found in samples of Mississippi oysters, shrimp and fish by Keel and Cook (1975). Hysterothylacium type MB larvae, which may cause mucosal hemorrhaging and focal eosinophilia in humans, has been verified in spotted seatrout (Overstreet and Meyer 1981).

Spotted seatrout are also susceptible to fungal and bacterial infections. Spotted seatrout and weakfish have a predisposition for "fin rot syndrome," a term for describing certain nonspecific lesions (Mahoney et al. 1973; Overstreet and Howse 1977; Sindermann 1979). In Louisiana, spotted seatrout killed during prolonged low temperatures during February 1978 were found to have lesions and abrasions contaminated with fungi and bacteria (Adkins et al. 1979). Decreased activity of spotted seatrout in association with low water temperature results in increased susceptibility to fungal and bacterial infections.

Algae occasionally cause disease or infection in freshwater fishes but their presence in marine fishes is rare (Blasiola and Turnier 1979). Unicellular algae were found in the flesh of a spotted seatrout in Mississippi during 1973 (Overstreet 1983).

An abnormality in spotted seatrout known as "pugheadedness" was reported by Rose and Harris (1968) and Hein and Shepard (1980b). Rose and Harris (1968) found that pugheaded spotted seatrout had a slower growth rate than did normal individuals, perhaps due to the condition affecting feeding efficiency. Mansueti (1960) suggested that pugheadedness in fishes was due to environmental conditions or heredity rather than to physical injury.

2.9 Food Habits and Trophic Relationships

The spotted seatrout is a carnivorous and opportunistic predator, feeding primarily on crustaceans and fishes (Pearson 1929; Gunter 1945; Miles 1950; Moody 1950; Klima and Tabb 1959; Tabb 1961; Lorio and Schafer 1966; Tabb 1966; Fontenot and Rogillio 1970; Rogillio 1975; Peeler et al. 1976; Lorio and Perret 1980; Adkins and Bourgeois 1982; Hettler 1989). In many estuarine areas, spotted seatrout are the only carnivores present in any numbers (Tabb 1966; Lassuy 1983) and are near the top of the estuarine food web (Johnson and Seaman 1986). Spotted seatrout have successfully invaded the rich feeding grounds of euryhaline herbivorous fishes and under ideal conditions may be the top carnivore (Tabb 1958). Odum (1971) and Day et al. (1973) discussed food webs and trophic levels in fish communities in south Florida and Barataria Bay, Louisiana, respectively, and classified spotted seatrout as a "top carnivore" (i.e., highly predaceous fishes feeding mostly on smaller fishes as adults, although larval and juvenile stages may function as mid-carnivores).

The diet of spotted seatrout varies with size. Postlarvae feed on larval shrimp, copepods, small fish and crabs (Lorio and Perrett 1980) and have been described as highly cannibalistic at this stage (Arnold et al. 1976). Copepods, mysids, penaeids, and carideans were the most common food items of juvenile spotted seatrout (Moody 1950; Springer and Woodburn 1960). Fish ranging from 12-30 mm SL fed on copepods (Crustacea), those 40-150 mm SL fed on caridea (Crustacea, Decapoda), and those >150 mm SL fed on penaeid shrimp and fish (usually Anchoa spp. or pinfish, Lagodon rhomboides) (Moody 1950). In Redfish Bay, Texas, Seagle (1969) reported spotted seatrout of 132-255 mm SL fed mainly on invertebrates, those 226-350 mm SL fed equally on invertebrates and fishes, those 351-430 mm SL fed mostly on fishes, and those of 450 mm SL, fed exclusively on fishes. In western Florida Bay, Hettler (1989) found that a) small non-decapod crustaceans, copepods, amphipods, and mysids were most abundant in stomachs (percent occurrence) of juvenile (<50 mm SL) spotted seatrout; b) penaeid and caridean shrimps increased in percent occurrence as fish increased in size; and c) fishes increased in percent occurrence in stomachs of spotted seatrout > 150 mm (SL). Young spotted seatrout in Lake Pontchartrain, Louisiana, fed on schizopods and bottom dwelling amphipods (Darnell 1958) rather than on shrimp as reported by Moody (1950) for young spotted seatrout at Cedar Key, Florida. Also, in Lake Pontchartrain, spotted seatrout began to feed on anchovies and larval fishes at an early age, achieving an adult diet (primarily bay anchovies, and other fishes) by 100 mm SL rather than 150 mm SL as reported for Cedar Key specimens (Moody 1950). In general, fishes become more important food items as size of spotted spotted seatrout increases (Lorio and Perret 1980).

Forage fishes, primarily croaker (Micropogonias undulatus), spot (Leiostomus xanthurus), and striped mullet (Mugil cephalus), were the most important foods of spotted seatrout in Louisiana (Lorio and Schafer 1966); however, crustaceans, primarily penaeid and palaemonid shrimps, were equally important to fish from May to July. Although a number of fishes were eaten by adult spotted seatrout in Mississippi (Overstreet 1983), gulf menhaden was the most often ingested fish, with bay anchovy also an important part of the diet. Penaeids, primarily brown (Penaeus aztecus) and white (P. setiferus) shrimps, were the only commonly ingested crustaceans. Other invertebrates, such as polychaete worms, were also ingested in limited amounts, but when seasonally abundant. Pink shrimp (Penaeus duorarum) was the principal food of adult spotted seatrout in Florida Bay (Stewart 1961).

Darnell (1958), in Lake Pontchartrain, occasionally observed food regurgitated by spotted seatrout; this observation was characterized by a mass of partially digested food surrounded by an oil slick on the water's surface.

Tabb (1961) concluded that apparent selectivity for food items by adult spotted seatrout was more a function of food availability than preference. However, Pearson (1929), Kemp (1949), and Moody (1950) listed shrimp the preferred food. In tank studies, without substrates for shrimp burrowing, spotted seatrout selected juvenile brown shrimp over juvenile spot and pinfish (Minello and Zimmerman 1984).

Spotted seatrout have very few competitors (Tabb 1966); even the closely related, but habitat segregated, sand seatrout and silver seatrout offer little interspecific competition. Gunter (1945) pointed out that juvenile spotted seatrout can apparently penetrate farther into low salinity areas than larger individuals, enabling them to escape competition and predation by larger individuals of their own as well as of other species. Conversely, increased susceptibility to predation and competition may result when spotted seatrout, in response to environmental extremes, move seaward through tidal inlets.

Klima and Tabb (1959) listed striped bass (Morone saxatilis), snook (Centropus undecimalis), tarpon (Megalops atlantica), alligator gar (Lepisosteus spatula), barracuda (Sphyraena barracuda), Spanish mackerel (Scomberomorus maculatus), king mackerel (S. cavalla), bluefish (Pomotomus saltatrix), and silver perch (Bairdiella chrysura) as predators of spotted seatrout in Apalachee Bay, Florida. They suggested that hardhead catfish (Arius felis), grouper (Mycteroperca sp.), red drum, spot, Atlantic croaker and southern rock bass (Amblopites rupestris ariomus) were competitors of spotted seatrout. In Lake Pontchartrain, Louisiana, spotted seatrout, silver perch, and tarpon of comparable lengths had similar food habits (Darnell 1958).

Miscellaneous predators of spotted seatrout include larger spotted seatrout and birds. Most studies (Moody 1950; Darnell 1958; Lorio and Schafer 1966; Adams et al. 1973; Rutherford et al. 1982) indicated that spotted seatrout are occasionally cannibalized; however, spotted seatrout have been reported to be frequently cannibalistic (Game, Fish, and Oyster Commission 1932). Spotted seatrout tagged by Rogillio (1982) had to be transported to adjacent areas for release to avoid predators such as cormorants (Phalacrocorax auritus), and brown pelicans (Pelecanus occidentalis), as well as as porpoises (Tursiops truncatus). Spotted seatrout were second only to sea catfish and mullet in the diet of ospreys in Florida Bay (Tabb, Bio Tropical Industries 1983 personal communication, cited in Johnson and Seaman 1986).

Larvae and juvenile stages of spotted seatrout are most susceptible to predation and competition (Johnson and Seaman 1986). Probable competitors for food and space in the early planktonic stages of the spotted seatrout are larvae of other sciaenids, pinfish, and hardhead catfish; juveniles of menhaden, anchovies, and silversides (Menidia audens); and adult menhaden and anchovies (Darnell 1958). Invertebrate larvae and adults of crustaceans, coelenterates, molluscs, ctenophores, and polychaetes may also compete with larval spotted seatrout for food.

Diel spawning of spotted seatrout at dusk may reduce egg loss by predation because eggs will be dispersed under cover of darkness (Holt et al. 1985).

Although spotted seatrout may play a significant role in the structure and function of estuarine communities (Lassuy 1983), no published experimental studies of competition, community level interactions, or quantitative studies of the role of spotted seatrout in estuarine trophic dynamics were found.

2.10 Habitat Requirements

Spotted seatrout are primarily an estuarine-dependent species (Tabb 1961) found in varied estuarine environments along the U.S. Atlantic coast and the northern coast of the Gulf of Mexico (Mahood 1974). Spotted seatrout are euryhaline and found in salinity ranges of 0.2 ppt (Perret et al. 1971) to 75 ppt (Simmons 1957).

The habitat of larvae 1.5-10.0 mm SL is generally unknown (Perret et al. 1980) because of the paucity of collection data. Jannke (1971) and King (1971) captured 5-6 mm SL larvae in tidal inlets. Tabb (1961) felt that spotted seatrout spend their first weeks of life in deep channels adjacent to grass flats. In Texas, postlarvae seek the shelter of grass beds (Pearson 1929; Miles 1950). Sabins (1973) collected larvae in areas of detrital deposition. Larval spotted seatrout were regularly collected in ichthyoplankton surveys in Florida Bay and adjacent waters (Powell et al. 1989). Larvae were found in channels, passes, and creeks bordering Florida Bay (Rutherford et al. 1989).

The seasonal occurrence, abundance, and habitat of juvenile spotted seatrout in Louisiana was described by Laska (1973), Herke et al. (1984), Arnoldi (1982, 1984), Peterson (1986), Rakocinski et al. (1992) and Baltz et al. (1993).

Peak abundance of juvenile spotted seatrout at Marsh Island, Louisiana, was in spring and summer in salinities ranging from 10.6 -13.3 ppt and water temperatures ranging from 18.8-32.0 °C (Tarbox 1974). Shallow protected lakes with detrital bottoms within the interior of Marsh Island were the prime nursery areas for spotted seatrout, although juveniles also used shoreline habitats as nursery areas (Tarbox 1974).

Juvenile spotted seatrout in Calcasieu Lake exhibited a "boom and bust" cycle during the late 1970s and early 1980s (Arnoldi 1982, 1984). Spotted seatrout utilized shoreline areas only after salinities exceeded 15 ppt. Shoreline areas with significant amounts of detritus were the preferred nursery habitat. Arnoldi (1984) suggested that Gulf beach areas may serve as nursery areas until inshore salinities increase. Perry and Carter (1979), however, only collected two spotted seatrout during a 6-year survey of three beach sites in southwest Louisiana in which a total of 27,911 fishes were collected.

Most juvenile spotted seatrout entered the marsh of Sabine National Wildlife Refuge in late August through September at 15-45 mm SL, with peak catches in canals and bayous rather than shallow marsh habitats (Herke et al. 1984). While juveniles exhibited limited use of low salinity, shallow marsh habitats, and may prefer edge habitat, they concluded that the major nursery areas were higher salinity bays or more likely nearshore Gulf waters. The juveniles found in the marsh were probably stragglers from the major nursery areas (Herke et al. 1984).

A survey of the seasonal occurrence, abundance, and habitat of juvenile spotted seatrout along a north-south transect in the Caminada Bay estuary was conducted by Peterson (1986). A peak abundance of juvenile spotted seatrout was observed in September with a minor peak in June; 95% of spotted seatrout were taken at salinities of 8-25 ppt. Sampling stations were classified by five habitat variables (water body type, edge vegetation, edge depth, bottom type, and salinity) to determine habitat preferences of juvenile spotted seatrout. The preferred habitat of 10-15 mm TL spotted seatrout was relatively shallow marsh edges of small, saline water bodies (10-25 ppt salinity), with soft to medium-soft, mud-detritus substrate, and located in a Spartina alterniflora predominated marsh (Peterson 1986); this habitat is widespread throughout the coastal deltaic marshlands of southeastern Louisiana. Peterson (1986) further suggested that juvenile spotted seatrout can tolerate a wide range of habitat conditions as long as food, cover (edge vegetation), and salinity are adequate, and that individuals larger than 50 mm TL begin to form schools and venture into more open waters. Peterson (1986) concluded that there may be differences between habitats of juvenile spotted seatrout in chenier-plain estuaries and those in deltaic marshes of southeast Louisiana. The chenier estuaries tend to be less saline and are less broken-up than the deltaic marshes. Consequently, there would be less marsh-water interface habitat available within the desirable salinity regimen, in chenier-plain esturaries.

Rakocinski et al. (1992) utilized 1.2 m^2 drop samplers in the Barataria basin and found juvenile spotted seatrout common only in summer, with distribution centered in the mid-estuary at depths up to 1 m and associated with emergent vegetation. Baltz et al. (1993) also confirmed greatest abundance of junvenile spotted seatrout in spring and summer, at high water temperatures. These authors also reported that "marsh edge is critical habitat for many species especially during intermediate and low tidal stages when adjacent salt marsh is not flooded."

The occurrence of juvenile spotted seatrout by habitat type in the Chandeleur Islands was tabulated by Laska (1973): beach - 7; channels - 1; pools - 83; lagoons - 11; and seagrass beds - 31. The Chandeleur Islands are unique because of their sea grass beds which include turtle grass (Thalassea testudinium), manatee grass (Cymodocea manatorum), and Diplanthera wrightii.

Sudden changes in environmental conditions such as abrupt declines in salinity following tropical storms may cause mortalities among young-of-the-year spotted seatrout because of their inability to escape to higher salinity areas (Tabb 1966). Tarbox (1974) collected juveniles of spotted seatrout at Marsh Island on 4 September, 1971, but after Hurricane Edith passed on 16 September, 1971, he collected none again until 15 October, 1971, three collecting trips later.

In general, outside of Louisiana, spotted seatrout of 10-15 mm SL are found in or adjacent to submergent vegetation in bays and lagoons during the warm months, but in winter apparently move into deep water (Pearson 1929; Miles 1950; Moody 1950; Reid 1954; Guest and Gunter 1958; Springer and Woodburn 1960) .

Utilization of Atlantic Coast estuaries by juvenile spotted seatrout has been documented in numerous studies. In Chesapeake Bay, Orth and Heck (1980) and Brown (1981) collected juvenile spotted seatrout (24-140 mm TL) in seagrass beds from July to October. In November, young-of-the-year (18-23 mm TL) were taken in trawls in the channels of the York and James rivers, Virginia (Brown 1981). Juveniles in North Carolina were found mainly in areas of seagrass (Spitsbergen and Wolff 1974; Wolff 1976; Purvis 1976; Miller and Dunn 1980). Few juveniles were collected in South Carolina in trawl surveys (Turner and Johnson 1972) or in seine and rotenone samples from an intertidal creek (Cain and Dean 1976). Dahlberg (1972) and Mahood (1975) collected juveniles in Georgia estuaries and beach zones but found largest numbers in tidal pools and small creeks at low tide when grasses and shorelines were exposed. Juvenile spotted seatrout in Indian River, Florida, were found in areas of sand and seagrass (Tabb 1961; Jones et al. 1975); individuals 8-50 mm SL were found in moderately deep channels (<3 m) but dispersed to shallower grassy bays with increasing size (Tabb 1961).

In Tampa Bay, Florida, the major habitat of juvenile spotted seatrout was seagrass beds, although juveniles were also found in unvegetated backwaters (McMichael and Peters 1989). Spotted seatrout juveniles in Florida Bay were most prevalent in habitats of deep, organic sediment with high densities and biomass of seagrass (Syrinogodium filiforme) and manatee grass (Chester and Thayer 1990). Rutherford et al. (1989) found juveniles in mangrove creeks, channels, shorelines, banks, basins, and bays. In Mississippi, over 70% of juvenile spotted seatrout less than 50 mm SL were collected in shallow areas with grassy bottoms (Loman 1978).

Several reports of surveys in Texas estuaries emphasized the importance of vegetated shorelines as nursery habitat. Pearson (1929) collected juveniles (20-30 mm TL) along grassy shorelines of Texas bays, small bayous, and creeks. Juvenile spotted seatrout in Lavaca Bay, Texas, were more abundant on marsh surfaces than in non-vegetated habitat at the marsh edge and were significantly more abundant during fall in all marsh habitats (Zimmerman et al. 1990b) In a related study Zimmerman et al (1990a) reported short-term lowering of salinity following freshwater floods did not prevent spotted seatrout juveniles from using deltaic marshes, but suggested that long-term changes might be detrimental to nursery habitats of spotted seatrout. Juvenile spotted seatrout in Galveston Bay, Texas, had peak abundances in summer and fall at mid-bay sites, in marsh habitats, at salinities of 15.1 and 15.4 ppt (Zimmerman et al. 1990b).

The preferred habitat of adult spotted seatrout in Louisiana is "near or over sandy bottoms, around 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 within inshore areas of the Gulf." (Lorio and Perret 1980). Spotted seatrout are taken throughout the water column with no apparent preference for any level and may be found throughout their range in clear to very turbid waters (Lorio and Perret 1980). The offshore habitat of adults is poorly known. However, Stanley and Wilson (1990) reported that spotted seatrout, along with red snapper (Lutjanus campechanus) were the most commonly caught species around oil and gas structures off Louisiana. Perret et al. (1980) generalized that "spotted seatrout are probably found in any area offering suitable salinity and temperature regimes combined with sufficient primary productivity to support a food web suitable to their needs."

In Florida, Alabama, and Mississippi, spotted seatrout are most common in large areas of shallow, brackish waters with extensive submerged vegetation and adjacent deep areas that can be used as refuge from extreme summer and winter temperatures (Pearson 1929; Tabb 1958; Lorio and Perret 1980; Zieman 1982). Submerged vegetation, however, is not a factor in the life history of spotted seatrout in Louisiana (Lorio and Perret 1980). Spotted seatrout in Florida are rare in offshore habitats, occasionally found in mangroves and inlets, but common on grass flats and sand bottoms (Gilmore 1977). Tabb (1966) reported that spotted seatrout in Florida prefer brackish non-tidal estuarine areas over outer beach and nearshore waters of the open ocean and Gulf.

Spotted seatrout in Texas are found in deeper bays, around oyster reefs (Hoese and Moore 1977), and in submerged beds of widgeon grass (Ruppia maratima) and shoal grass (Miles 1950), but preferring clear bays and lagoons, and stretches of beach near passes (Pearson 1929).

Adult spotted seatrout in southeastern Atlantic coast estuaries occur from outer bars and ocean beaches, at depths of 1-3 m, to upper tidal marshes, but prefer shallow waters--along banks of tidal creeks and rivers, along inlet beaches, and near oyster beds in sounds (Bearden 1961; Bearden and Farmer 1972; Dahlberg 1972; Hicks 1972; Mahood 1974; Shealy et al. 1974). Spotted seatrout in Georgia and South Carolina are not limited in distribution by the absence of seagrass beds (Hoese 1973).

In Chesapeake Bay, spotted seatrout usually are found in shallow creeks and rivers adjacent to eelgrass (Zostera marina) and widgeon grass beds, although they move to deeper holes during mid-summer (Brown 1981).

Kostecki (1984) constructed a habitat suitability index (HSI) for spotted seatrout in estuaries of the Atlantic and Gulf of Mexico. The HSI model considers habitat suitability for egg, larval, and juvenile stages and is based on two life requisite components -- water quality (salinity and temperature), and food and cover. The HSI equals the water quality (WQ) or food and cover (FC) component, whichever is lower. Formulae for each component follows:

WQ = $(SI_{V1} \times SI_{V2})^{1/2}$ or $(SI_{V3} \times SI_{V4})^{1/2}$, whichever is lower; SI = suitability index, V_1 = lowest monthly mean winter/spring salinity; V_2 = highest monthly mean summer salinity; V_3 = lowest monthly mean winter water temperature; V_4 = highest monthly mean summer water temperature.

FC = SI_{V5}; V_5 = percentage of area with submerged and/or emergent vegetation, submerged islands, or shell reefs.

Assumptions for optimum habitat variables included in the HSI model are:

V_1 and V_2 = stable and moderate salinity (19-38 ppt);
V_3 and V_4 = stable and moderate temperatures (20-32 °C);
V_5 = approximately 50% of the total area is suitable cover.

2.11 Environmental Tolerances

Juvenile and adult spotted seatrout seem to be equally tolerant to environmental variations typical of their particular area; however, abrupt changes in the environment affect them (Tabb 1966).

The largest catches of spotted seatrout in Mississippi occurred between temperatures of 25 and 30 °C (Loman 1978), while optimum temperature for adults ranged from 15-27 °C in Florida (Tabb 1958). Simmons (1957) found that spotted seatrout live and feed actively at temperatures between 4 and 33 °C, if they are gradually acclimated to the extremes of this range; however, sudden and extreme temperature decreases accompanying cold fronts often result in mass mortalities (Gunter 1941; Gunter and Hildebrand 1951; Moore 1976; Wochlschlag and Wakeman 1978; Adkins et al. 1979). The rate of temperature reduction as well as salinity probably influence the tolerance of spotted seatrout to low temperatures (Overstreet 1974, 1983).

Florida estuaries have a normal salinity range of 5-30 ppt, but sudden changes in salinity associated with tropical storms or hurricanes may cause mass migrations or mortalities of spotted seatrout (Tabb 1966). Wakeman and Wochlschlag (1977), in laboratory studies of spotted seatrout, used maximum sustained swimming performance as an indicator of salinity stress and reported maximum sustained swimming speeds at salinities of 20-25 ppt and (28 °C), with reduced performance at levels above or below that range. They added that several years of field observations in south Texas, indicated that spotted seatrout were essentially unavailable at salinities greater than 45 ppt and less than 10 ppt.

Optimum salinity ranges for larvae of spotted seatrout were 20-35 ppt (Arnold et al. 1976) and 18.6-37.5 ppt (Taniguchi 1980). Johnson and Seaman (1986) suggested 5 ppt salinity as the minimum tolerance level for both larval and juvenile spotted seatrout.

No reports were found relating the distribution of spotted seatrout to dissolved oxygen concentrations. Vetter (1982), however, stated that metabolic rates of spotted seatrout ranged from a high of 123 mg/O_2/kg/hr at 30 °C to a low of 49 mg/O_2/kg/hr during winter at 15 °C.

Toxic chemicals may impact spotted seatrout. The acute lethal effects of sodium hypochlorite chloramine and 5-chlorouracil on eggs and larvae of spotted seatrout were investigated by Johnson et al. (1977). They concluded that in areas subjected to discharges of chlorinated effluent, considerable mortality of spotted seatrout larvae would occur when the level of sodium hypochlorite reached 0.17 ppm. Johnson et al. (1979) exposed spotted seatrout larvae to sublethal concentrations (0.00-1.00 ppm) of fuel oil (water soluble fraction) and found a general decrease in total body length, and as oil concentrations increased, the percentage of larvae with unpigmented eyes also increased. Butler (1969) and Butler et al. (1970) measured DDT residues as high as 8 ppm in the gonads of six generations of spotted seatrout from Laguna Madre, Texas. They postulated that breeding ceased for at least 1-2 years. Daniels et al. (1987) determined median lethal concentrations (LC_{50}) of nitrite and ammonia for spotted seatrout eggs, larvae, and juveniles.

Spotted seatrout mortalities associated with natural perturbations were documented by several authors. Tabb and Manning (1961) and Tabb et al. (1962) observed spotted seatrout strandings due to rapidly receding waters following hurricanes and subsequent mortalities due to suffocation in excessively turbid waters. Springer and Woodburn (1960) listed spotted seatrout as one of the species of fish killed by red tide (Gymnodinium breve) in Tampa Bay, Florida, in 1957. Mortalities of spotted seatrout from gas bubble disease were reported for Galveston Bay by Renfro (1963). Gas bubbles formed in the bloodstream of the fish during a period when waters were supersaturated with dissolved oxygen from a phytoplankton bloom (Renfro 1963). Spotted seatrout mortalities associated with hypoxic waters have been reported at Grand Isle, Louisiana, and Mobile Bay, Alabama.

Table 2.1. Observations on spotted seatrout spawning activities.

AUTHOR(S)	LOCALITY	SPAWNING ACTIVITY
Brown (1981)	VA	May-Aug, with two peaks (May to mid-Jun and July)
Hildebrand and Cable (1934); Powles and Stender (1978)	NC & SC	Apr to Aug
Mahood (1975); Music and Pafford (1984)	GA	Apr to Aug, with a major peak in May and a smaller one in July
Tabb (1961); Gilmore et al. (1976); Mok and Gilmore (1983)	E Cent FL	Mid-Apr to Sep
Stewart (1961); Roessler (1967); Rutherford et al. (1982)	S FL	Year round, peaking in spring and again in late Jannke (1971); summer/fall
Moody (1950); Moffett (1961)	W Cent FL	Late May to Sep, peaking in Jun-Aug
Klima and Tabb (1959)	NW FL	Late Apr to Sep with a late May-early Jun peak
Overstreet (1983)	MS	Apr to Sep usually, but may occur as early as Mar and as late as Nov
Pearson (1929); Gunter (1945); Miles (1950 and 1951); King (1971); Maceina et al. (1987); Colura et al. (1988)	TX	Late May to mid Nov, with a Apr-May peak

Table 2.2. Literature derived minimum size (mm TL) and age (yrs.) at maturity for male and female spotted seatrout (Mercer 1984).

STUDY	AREA	SIZE/AGE MALES	SIZE/AGE FEMALES
Hein and Shepard (1979a)	LA	200	249
Klima and Tabb (1959)	FL	219	321
Moody (1950)	FL	242	253
Rutherford et al. (1982)	FL	283/2-4	275/3-4
Tabb (1961)	FL	411/2-3	411/3-4
Music and Pafford (1984)	GA	342	229/2
Brown (1981)	MD	250/2	290/3

Table 2.3. Fecundity estimates for spotted seatrout as reported in the literature (size = TL).

Reference	Locality	Avg. Size (Age Group)	Fecundity
Pearson (1929)	Texas	480 mm	427,819
		620 mm	1,118,000
Moody (1950)	Cedar Key, FL	459 mm	464,000
Tabb (1961)	Indian River, FL	377 mm	15,000
		509 mm	150,000
		575 mm	400,000
		716 mm	1,100,000
Overstreet (1983)	Miss. Sound, MS	379 mm	2.25-3.77 million
		595 mm	10.60-15.57 million
Miles (1951)	Texas	(1)	100,000
		(3)	300,000
		(4)	560,000
Colura et al. (1984)	Matagorda Bay, TX	321 mm/(1)	126,060
		353 mm/(2)	118,428
		414 mm/(3)	273,042
		466 mm/(4)	580,140
		514 mm/(5)	834,500
		526 mm/(6)	247,970
		699 mm/(7)	4,677,920
Sundararaj and Suttkus (1962)	Breton Sound, LA	283 mm/(1)	140,485
		376 mm/(2)	354,325
		450 mm/(3)	660,960
		504 mm/(4)	1,144,492
Arnoldi (1982)	Calcasieu Lake, LA	12 in	155,200
		13 in	316,600
		14 in	484,500
		15 in	645,900
		16 in	807,400
		17 in	975,200
		18 in	1,136,700
		19 in	1,304,600
		20 in	1,466,000
		21 in	1,627,400
		22 in	1,795,300
		23 in	1,956,800
		24 in	2,174,600
		25 in	2,286,100
		26 in	2,447,500
		27 in	2,615,400

Table 2.4. Percent of spotted seatrout (both sexes combined) of the sampled population by age group from studies along the northern Gulf of Mexico and Atlantic Ocean.

Age	A	B	C	D	E	F	G	H	I	J	K	L
0	--	--	--	--	--	--	--	--	--	--	--	5.6
1	25.0	32.8	28.3	30.2	33.7	32.6	34.2	29.7	34.8	31.4	30.8	46.1
2	22.3	32.1	26.9	30.0	32.3	32.3	34.0	29.5	36.9	23.0	23.5	29.1
3	20.1	20.1	20.8	25.0	22.3	22.6	23.1	26.9	15.0	20.0	17.9	11.3
4	13.3	8.0	12.1	11.3	8.0	7.9	7.6	11.0	9.0	9.6	12.4	5.4
5	8.0	4.2	6.4	2.5	3.0	3.0	1.0	2.4	3.0	8.3	7.3	1.6
6	3.5	2.1	3.5	0.6	0.6	1.1	--	0.3	1.3	6.2	4.4	0.6
7	3.5	0.4	1.8	0.1	0.1	0.2	--	<0.1	--	1.2	2.8	0.1
8	2.1	0.1	<0.1	--	--	<0.1	--	--	--	0.2	0.6	0.06
9	0.8	--	--	--	--	--	--	--	--	--	0.2	0.02
11	0.3	--	--	--	--	--	--	--	--	--	--	--
12	0.2	--	--	--	--	--	--	--	--	--	--	--

A = Chesapeake Bay, VA (Brown 1981)
B = GA (Music and Pafford 1984)
C = East-central FL (Tabb 1961)
D = South FL (Rutherford et al. 1982)
E = South FL (Stewart 1961)
F = Southwest FL (Moffett 1961)
G = Central FL (Moffett 1961)
H = Northwest FL (Klima and Tabb 1959)
I = AL (Wade 1984)
J = Southwest LA (Arnoldi 1984)
K = TX (Pearson 1929)
L = FL (Murphy and Taylor 1994)

Table 2.5. Ranges in size (TL) of spotted seatrout in eight year classes collected at various Gulf of Mexico and Atlantic coastal areas (Lorio and Perret 1980).

Age group	Size (mm)
1	140 - 201
2	232 - 302
3	309 - 378
4	378 - 468
5	449 - 558
6	510 - 650
7	526 - 684
8	534 - 761

Table 2.6.Back-calculated lengths (mm SL) at age for spotted seatrout (both sexes combined) from studies along the Gulf of Mexico and Atlantic Ocean.

Age	A	B	C	D	E	F	G	H	I	J	K	L	M
1	143	155	165	212	133	130	91	130	116	270	119	259	158
2	221	244	248	262	224	208	192	211	190	354	200	343	241
3	302	313	317	301	275	264	262	268	255	439	257	417	311
4	354	373	384	345	339	320	306	323	312	496	299	467	356
5	378	413	457	395	397	368	341	382	369	551	338	524	393
6	447	443	533	417	434	430	367	-	422	624	376	541	436
7	447	523	561	488	451	431	-	-	437	-	418	608	466
8	482	572	624	-	-	438	-	-	-	-	445	-	477
9	518	-	-	-	-	-	-	-	-	-	-	-	-
10	557	-	-	-	-	-	-	-	-	-	-	-	-
11	591	-	-	-	-	-	-	-	-	-	-	-	-
12	620	-	-	-	-	-	-	-	-	-	-	-	-

A = Chesapeake Bay, VA (Brown 1981)
B = GA (Music and Pafford 1984)
C = Indian River, FL (Tabb 1981)
D = Everglades National Park, FL (Rutherford et al. 1982)
E = Florida Bay, FL (Stewart 1961)
F = Fort Myers, FL (Moffett 1961)
G = Charlotte Harbor, FL (Welsh and Breder 1924)
H = Cedar Key, FL (Moffett 1961)
I = Apalachicola Bay, FL (Klima and Tabb 1959)
J = AL (Wade 1984)
K = Central TX (Pearson 1929)
L = TX (Colura et al. 1984)
M = Calcasieu Lake, LA (Arnoldi 1985)

Table 2.7. Back-calculated lengths (mm SL) at age for male (M) and female (F) spotted seatrout for selected areas in the Gulf of Mexico.

	A		B		C		D		E		F		G		H		I	
Age	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1	213	220	153	163	146	148	161	163	160	164	160	170	200	204	201	185	189	197
2	302	380	237	244	228	231	248	255	248	252	253	282	259	305	282	324	269	322
3	370	469	310	312	298	307	313	319	308	316	317	332	294	372	330	422	315	411
4	435	509	352	360	359	371	380	380	366	379	369	405	329	426	372	492	365	486
5	401	515	384	401	401	436	445	448	415	435	409	469	357	466	405	553	421	545
6	-	-	420	452	432	493	506	-	509	478	-	506	413	493	446	595	-	545
7	-	-	448	483	-	509	-	-	-	502	-	525	430	504	487	628	-	-
8	-	-	481	472	-	-	-	-	-	510	-	-	475	508	512	624	-	-

A = Coastal LA (Wieting 1989)
B = Calcasieu Lake, LA (Arnoldi 1985)
C = Apalachicola, FL (Klima and Tabb 1959)
D = Cedar Key, FL (Moffett 1961)
E = Fort Meyers, FL (Moffett 1961)
F = Flamingo, FL (Stewart 1961)
G = Charlotte Harbor, FL (Murphy and Taylor 1994)
H = Indian River Lagoon, Fl (Murphy and Taylor 1994)
I = Apalachicola Bay, FL (Murphy and Taylor 1994)

Table 2.8. Growth increments (mm SL) by age for spotted seatrout (both sexes combined) from selected studies along the Gulf of Mexico.

Age	A	B	C	D	E	F	G	H	I
1	133	212	130	130	116	270	119	251	158
2	91	50	78	81	74	84	81	84	83
3	51	49	56	57	65	85	57	74	70
4	64	44	56	55	57	57	42	50	45
5	58	50	48	59	57	55	39	57	39
6	37	22	62	--	53	73	38	17	43
7	17	61	1	--	15	--	42	68	30
8	--	--	7	--	--	--	--	--	11

A = Florida Bay, FL (Stewart 1961)
B = Everglades National Park, FL (Rutherford et al. 1982)
C = Fort Myers, FL (Moffett 1961)
D = Cedar Key, FL (Moffett 1961)
E = Apalachicola Bay, FL (Klima and Tabb 1959)
F = AL (Wade 1984)
G = Central TX (Pearson 1929)
H = TX (Colura et al. 1984)
I = Southwest LA (Arnoldi 1985)

Table 2.9. Growth increments (mm SL) by age group for male and female spotted seatrout for selected studies in the Gulf of Mexico.

	A		B		C		D		E		F		G		H		I	
Age	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1	213	220	153	163	146	148	161	163	160	164	160	170	276	309	303	343	278	326
2	89	120	84	81	82	83	87	92	88	88	93	112	24	64	34	88	48	84
3	68	109	73	68	70	76	65	64	60	64	64	50	29	66	40	68	28	61
4	65	40	42	48	61	64	67	61	58	63	52	73	32	36	37	64	32	91
5	-34	6	32	41	42	65	65	68	49	56	40	64	14	19	21	67	64	43
6	--	--	36	51	31	57	61	--	94	43	--	37	42	39	51	0	--	-13
7	--	--	--	31	--	16	--	--	--	24	--	19	24	21	50	19	--	--
8	--	--	--	-9	--	--	--	--	--	8	--	--	--	-24	5	--	--	--

A = Coastal LA (Wieting 1989)
B = Calcasieu Lake, LA (Arnoldi 1984)
C = Apalachicola, FL (Klima and Tabb 1959)
D = Cedar Key, FL (Moffett 1961)
E = Fort Meyers, FL (Moffett 1961)
F = Flamingo, FL (Stewart 1961)
G = Charlotte Harbor, FL (Murphy and Taylor 1994)
H = Indian River Lagoon, FL (Murphy and Taylor 1994)
I = Apalachicola Bay, FL (Murphy and Taylor 1994)

Table 2.10. Length-weight regressions for spotted seatrout in different localities.

Author	Locality	Sex	Equation
Brown (1981)	Chesapeake Bay, VA	Combined Males Females	log W = -5.072 + 3.043 log TL log W = -5.598 + 3.244 log TL log W = -4.924 + 2.980 log TL
Music and Pafford (1984)	GA	Combined Males Females	log W = -4.848 + 2.949 log L log W = -4.182 + 2.683 log L log W = -4.516 + 2.824 log L
Rutherford et al. (1982)	Southwest FL	Combined	log W = -5.194 + 2.745 log SL
Moffett (1961)	West FL	Combined	log W = -5.333 + 3.113 log TL
Wade (1984)	AL	Combined	log W = -5.305 + 3.105 log TL
Overstreet (1983)	MS	Males Females	log W = -4.947 + 3.051 log SL log W = -4.947 + 3.052 log SL
Harrington et al. (1978)	TX	Combined	log W = -5.192 + 3.062 log SL
Matlock and Strawn (1976)	TX	Combined	log W = -4.628 + 2.917 log SL

Figure 2.1

Figure 2.2.

3.0 DESCRIPTION OF THE FISHERY

3.1 History of Exploitation

Numerous short-term surveys of marine recreational anglers have been conducted along the Louisiana coast since the mid-1960s and the Marine Recreational Fishery Statistics Survey (MRFSS) has been in operation since 1979; however, little or no documentation exists for the earliest recreational harvesting of spotted seatrout or of quantitative, long-term trends and changes in the recreational fishery. Recent MRFSS survey data indicate that spotted seatrout has become the most commonly targeted species by coastal recreational fishermen, and effort and harvest has increased since the early 1980s. Effort has increased because personal leisure time and discretionary income has increased, more boat launching sites are available, and the coastal population itself has increased.

Commercial landings have been recorded for the Gulf since 1880 and for Louisiana since 1887 (Table 3.1). Landings of sand seatrout (Cynoscion arenarius) and silver seatrout (Cynoscion nothus) were combined with those of spotted seatrout through 1965. Louisiana commercial landings through the 1880s averaged .555 million lb annually. Reported commercial landings in Louisiana averaged approximately .690 million lb annually from 1880 to 1970. Landings peaked at 2.5 million lb in 1973 and averaged 1.4 million lb from 1971 to 1987. After 1987, an annual quota, later followed by a seasonal harvest quota, was implemented, and landings have since ranged from .648 to 1.489 million lb annually.

Although trends cannot be quantified from license records, generalizations can be made concerning historical use of commercial fishing gears for spotted seatrout. Before the introduction of management regulations, the commercial spotted seatrout fishery within Louisiana was initially a bycatch fishery. In the 1880s and early 1900s, the fishery was based largely on shrimp-seine bycatch or on a secondary hook-and-line effort. The adoption of the shrimp trawl around 1920 and the resulting decrease in use of shrimp seines led to the introduction of trammel nets and the evolution of the fishery into a directed winter fishery, conducted between shrimp seasons. The spotted seatrout fishery further matured into a year-round fishery when gillnets were introduced in the 1960s. While many commercial fishermen still preferred the hook-and-line method in the early 1970s (Pesson 1974), by the mid-1970s gillnets were the primary method of harvest followed by seines and trammel nets (Bowman et al. 1977). There was an influx in 1971 of nonresident fishermen using monofilament gillnets (Bowman et al. 1977). Gillnets remain the primary method of harvest, although trammel nets have since displaced seines as the second most popular gear type.

3.2 Commercial Fishery

3.2.1 Description of Fishing Activities

In Louisiana and adjacent coastal waters, a variety of gears have been used to target spotted seatrout (gillnets, trammel nets, handlines) or incidentally catch them (purse seines, shrimp trawls, haul seines, butterfly and skimmer nets). Commercial landings by gear type by year (Table 3.2) and by month (Table 3.3) for the 1980-89 period depict temporal and seasonal trends in landings.

Gillnets are the predominant gear used by commercial fishermen and accounted for approximately 50.5 % of 1980-89 commercial landings (Table 3.2). Prior to introduction of monofilament gillnets in Louisiana during the early 1970s, gillnets were made of treated nylon webbing. After the monofilament gillnet ban in 1977, the use of webbing composed of three or more twisted strands of monofilament became widespread. The two primary types of gillnets are strike-nets and set-nets.

Strike-net fishermen seek fish actively feeding at the surface, "bait fish," feeding gulls, or oil slicks on the water created by the regurgitation of stomach contents from feeding spotted seatrout. At night, fishermen locate fish by searching for phosphorescent trails created by the fish's darting or swimming action. During winter months fishermen generally set-nets in warmer, deeper bodies of water such as oil and gas access canals, pipeline canals, and deeper bayous and bays. Strike-nets are deployed by anchoring one end near a suspected school or concentration of fish, preferably adjacent to the shoreline, and then deploying the net from a skiff in a circle or half-circle back to the shoreline. The skiff is then used to "beat down," or run inside the enclosed net, causing fish to startle and eventually to strike the net. In turbid waters, fishermen will retrieve the net from the down-wind or down-current end and strip fish from the webbing as the net is brought aboard. However, in clear water, fishermen may "drag the net down" to make fish strike the net. The net is dragged down by towing the up-wind or up-current end of the net toward the opposite end. The free end of the net is then brought aboard, and the fish are stripped from the webbing as the diameter of the circle becomes increasingly smaller. Another variation of this method commonly used in clear waters is "cork-screwing," in which the up-wind end of the net is tied to the boat and a series of tight turns or "cork-screws" made while dragging the net down.

Set-nets are gillnets, generally 100-300 ft in length, usually staked perpendicular to a shoreline, preferably a point of land. Such nets were traditionally only periodically checked throughout the day and night. Use of set-nets has decreased with 1984 and 1995 legislation which mandates that no nets in the fishery be unattended.

Gillnet vessels are typically outboard-powered wooden or fiberglass skiffs ranging in size from 14-25 ft. For easy deployment and retrieval of the net, these skiffs have an outboard motor mounted in a well forward, and a net box aft. Crews range from one to three depending upon net size and fish availability.

Research in Louisiana on selectivity of gillnet mesh was conducted by Hein and Shepard (1980a), Arnoldi (1982), Adkins and Bourgeois (1982), and Helser et al. (1991). Spotted seatrout caught in commercial nets of 1 and 5/8-in bar mesh averaged 15.1 in TL in Barataria Bay (Hein and Shepard 1980a) and 15.7 in TL in Calcasieu Lake (Arnoldi 1984). In south-central Louisiana, Adkins and Bourgeois (1982) caught spotted seatrout averaging 16.4, 17.9, and 18.3 in TL in monofilament gillnets of 1 5/8-in, 1 7/8-in, and 2-in bar mesh, respectively, while multifilament gillnets of corresponding sizes took seatrout averaging 15.8, 18.2, and 18.1 in. Helser et al. (1991)

developed methods for the simultaneous estimation of size selectivity of gillnet mesh and relative abundance of the various size-classes of fish in the spotted seatrout population.

During 1980-89, trammel nets yielded 23.3% of the total landings (Table 3.2). Trammel nets consist of three layers of webbing sandwiched together. Two outer layers typically have a much larger mesh size than the single inner layer. Trammel nets are designed to entangle or pocket larger fish such as red drum, black drum (Pogonias cromis), and sheepshead (Archosargus probatocephalus), and are rarely used to target spotted seatrout. However, the smaller mesh inner layer of webbing is quite effective in gilling or entangling spotted seatrout. Trammel nets are generally used inshore during the cooler fall and winter months (Table 3.3) when abundances of "nontargeted" nuisance species such as hardhead catfish and blue crabs (Callinectus sapidus) are low.

Handlines have been sporadically used in Louisiana's spotted seatrout fishery (Table 3.2). Handlines are often used from small boats with one- or two-man crews. This gear is relatively nonselective and captures various sizes of fish.

Haul seines are generally used in inshore and nearshore waters by black drum fishermen. Spotted seatrout are only caught incidentally because of the current bar-mesh size restriction of 1 and 3/4-in. Spotted seatrout landings by haul seines usually accounted for less than 1% of the total annual catch (Table 3.2) from 1980 to 1989 and peaked seasonally from December through May (Table 3.3).

Shrimp trawls yield incidental catches of spotted seatrout primarily during early spring, mid-summer, and fall. Less than 1% of the total spotted seatrout harvest during 1980-89 came from shrimp trawls (Table 3.2).

Limited landings of spotted seatrout are attributed to butterfly and skimmer nets. These gears are primarily used in the shrimp fishery, and spotted seatrout of marketable size are taken infrequently as incidental bycatch.

Very limited landings of spotted seatrout have come from purse seines; the only reported landings were 42 lb reported for July and August 1981. Harvesting spotted seatrout with purse seines is now illegal.

3.2.2 Effort and Harvest

The numbers of commercial gear licenses issued annually (Table 3.4) are rough approximations of the number of commercial finfishermen. However, total number of licenses may not reflect the number of fishermen targeting or incidentally landing spotted seatrout on a seasonal basis, or the number of gear units. Specific gear licenses, previously designated as saltwater gear licenses, were changed by legislative statute in 1986 to general gear licenses. Subsequently, 1992 legislation designated saltwater gillnets as a new and separate license class. Except for saltwater gillnets, net licenses became valid in both fresh or saline waters. Licenses for individual nets were no longer necessary, and fishermen were allowed to fish any number of nets with one gear license. Additional gear restrictions were enacted following 1995 legislation which prohibited the use of saltwater trammel nets and fish seines and established qualifying criteria for gillnet licenses and spotted seatrout permit holders. Although trends cannot be quantified from license records, generalizations can be made concerning historical utilization of commercial fishing gear for spotted seatrout. Before the introduction of management regulations, the Louisiana fishery was initially a bycatch fishery. In the 1880s and early 1900s, the commercial spotted seatrout fishery was based largely on shrimp- seine bycatch or a secondary hook-and-line effort. The adoption of the shrimp trawl around 1920 and the resulting decrease in shrimp seines led to the introduction of the trammel net in Louisiana and the development of a directed winter fishery, in between shrimp seasons. The fishery further matured into a year-round fishery with the introduction of gillnets in the 1960s; peak catches occurred in spring and summer followed by occasional peaks in winter months. While many commercial fishermen still preferred the hook-and-line method in the early 1970s (Pesson 1974), by the mid-1970s gillnets were the primary method of harvest followed by seines and trammel nets (Bowman et al. 1977). There was an influx in 1971 of nonresident fishermen utilizing monofilament gillnets (Bowman et al. 1977). Recent landings data (Table 3.2) indicate that gillnets remain the primary method of harvest although trammel nets have since displaced seines as the second most popular gear type used in the fishery. Purse seine permits for use in inshore Louisiana waters were not available after 1986.

Full-time commercial finfishermen (i.e., deriving 30% of their income from finfishing) made up only 9.3% of the total in the mid-1970s. Each of these fishermen averaged 1580 ft of net and fished for 166.8 d per year.

The Gulf of Mexico fishery has historically accounted for 60-80% of the total U. S. commercial spotted seatrout landings. Landings of sand seatrout and white seatrout were combined with spotted seatrout through 1970. Gulf of Mexico annual landings have increased from 2.4 million lb in 1888 to highs of 7.4 million lb in 1945 and again in 1973 (Table 3.1). In the 1980s, landings declined because of designation of spotted seatrout as a game fish in Texas (1982) and Alabama (1987). Highest landings have historically occurred in western Florida, Louisiana, and Texas.

Louisiana landings increased from less than 1 million lb in the late 1800s to a high of 2.5 million lb in 1973 (Table 3.1). Reported annual landings in Louisiana have averaged approximately 0.85 million lb since 1887 and seldom exceeded 1 million lb prior to 1971. Landings increased steadily through the early 1970s, and peaked at 2.5 million lb in 1973. Landings averaged 1.37 million lb from 1971 to 1987. After 1988, landings ranged from 0.65 million to 1.49 million lb and averaged 1.15 million lb.

Several factors contributed to fluctuations in spotted seatrout landings during the 1970s and 1980s, and to stabilization in the 1990s. First, the sudden influx in 1971 of non-resident fishermen, using monofilament gillnets, resulted in a sharp increase in landings during the mid-1970s, particularly in Lafourche and Terrebonne parishes (Bowman et al. 1977). Second, the Arab oil embargo of the early 1970s forced more fishermen to comply with mandated reporting of landings so that they could secure maximum fuel allotments (Orville Allen, NMFS, pers. comm. cited in Adkins and Bourgeois 1982). Third, effort expanded due to a general rise in demand for finfish food sources, higher market values, and increased harvest restrictions in other Gulf states. Fourth, decreased landings from 1973 through 1982 were largely attributable to several successive years of adverse environmental conditions (i.e., freshwater flooding during 1973, 1974, and 1975, and severe winters in 1975 and 1976), but also to restrictions placed upon the commercial fishery (Adkins and Bourgeois 1982). Finally, landings were stabilized by the establishment of a 1 million lb annual harvest quota in 1988, later increased to a 1.25 million lb seasonal harvest quota, then reduced to a 1 million lb seasonal harvest quota.

Prior to 1977, the commercial fishery was regulated by a minimum size limit of 10-in TL for fish, a bar-mesh minimum size of 1 and 1/2-in for saltwater gillnets, a 1-in mesh minimum size for the inside wall of saltwater trammel nets, and a 7/8-in minimum mesh size for saltwater fish seines. Also, all nets in the fishery were restricted to a maximum length of 2000 ft.

Because of the effects on commercial spotted seatrout landings, changes in gear and license requirements after 1976 are listed chronologically:

1977 -- -- Monofilament webbing banned in all saltwater nets except those on properly permitted vessels engaged in the pompano and black drum underutilized species program. Maximum net lengths of 1200 ft established. Established a minimum mesh size of 2-in bar for saltwater gillnets, and minimum bar-meshes of 1-in for the inside wall of saltwater trammel nets and 1-in for saltwater fish seines. Created a $250 Commercial Angler's License.

1980 -- Established a minimum mesh size of 3-in bar on the outer layer of saltwater trammel nets.

1983 --All saltwater trammel nets to consist of three layers. Implemented a minimum mesh size of 1-in bar for saltwater fish seines. Created a $105 Seller's License to sell finfish.

1984 --Established a 12-in minimum size limit. Required minimum bar-mesh sizes of 1 and 3/4-in for saltwater gillnets and 1 and 5/8-in for the inside wall of saltwater trammel nets and a maximum mesh size of 12-in bar for the outside wall of trammel nets. Mandated a mesh size of 1-in bar for saltwater fish seines. Discontinued Commercial Angler's License and increased license fees.

1986 --Discontinued Saltwater Seller's License.

1987 --Implemented a 14-in TL minimum size limit. Established a minimum bar-mesh size of 1 and 3/4-in for the inside wall of saltwater trammel nets and 1 and 3/4-in for saltwater fish seines. Set an annual harvest quota of 1 million lb.

1988 --Prohibited unattended nets. Established a seasonal 1.25 million lb quota running from 1 Septemer until the quota has been filled.

1992 --Set seasonal harvest quota at 1 million lb. Season established from 15 September to 30 April, or until quota has been filled. Commercial harvest of spotted seatrout prohibited between sunset Friday through sunrise Monday.

1995 --Set season from the third Monday in November through 30 April of the following year or untill quota has been filled. Commercial harvest prohibited after sunset and before sunrise as well as between sunset Friday through sunrise Monday. Commercial taking prohibited except by special non-transferrable spotted seatrout permit with qualifying criteria. Established commercial rod-and-reel license with qualifying criteria and restricted the commercial harvest with the use of mullet strike-nets and all other legal gears to a seasonal framework and eventual prohibition with the exclusive exception of commercial rod-and-reel.

Annual landings data from 1980 to 1989, by gear type, are given in Table 3.2. In the late 1980s, the proportion of gillnet landings increased while trammel net landings rapidly declined. Monitoring of landings by gear type ended in 1989.

Commercial landings by area fished, from 1973 to 1989, are listed in Table 3.5. Inshore landings averaged 99.4 % of the total. In 1988, a higher percentage (5.3%) of landings came from offshore waters.

Differences in spotted seatrout landings by shrimp management zones for the 1987-88 to 1994-95 quota years are depicted in Figure 3.1. Landings from Zone 1 were over 115,00 lb and made up over 10% of annual landings for both the 1987-88 and 1988-89 quota years but declined in the last 3 quota years to an average of 40,739 lb, or 4.2% of the total. Zone II spotted seatrout landings made up the majority of annual landings and contributed no less than 74% of the annual total for any quota year. Spotted seatrout landings from Zone III increased since the early quota years and averaged 15.7% of the total for the last 3 quota years.

Average monthly landings from pre-quota (1981-1987) and post-quota (1988-1995) years are plotted in Figure 3.2. Average monthly landings during pre-quota years peaked in spring and summer months followed by a secondary peak during early winter. Post-quota monthly landings peaked during the fall and early winter months. The establishment of 15 September and currently the third Monday in November as the beginning of the quota year has strongly influenced seasonal peaks in landings. Harvest quotas were reached by 6 May 1988, 9 April 1989, 6 May 1990, 2 August 1991, 1 May 1992, 16 April 1993, 6 March 1994, 9 March 1995 and 30 April 1996.

3.2.3 Mariculture

Use of artificially propagated spotted seatrout for aquaculture is probably not economically feasible at present. However, the rapid growth, high market values, and limited commercial availability of spotted seatrout justifies further mariculture investigations.

Research on mariculture of spotted seatrout has been conducted since the mid-1970s. Arnold et al. (1976) developed methods and techniques to maintain adult spotted seatrout in captivity, to induce them to spawn repeatedly, and to culture early life history stages for experimental purposes. Colura (1974), Arnold et al. (1976), Gray and Colura (1988), Thomas and Boyd (1988, 1989), Colura et al. (1990b) and Thomas and Arnold (1993) successfully induced spotted seatrout to spawn in the laboratory using hormone induced techniques. Arnold et al. (1978) induced spawning by manipulating photoperiod and temperature. Tucker (1988) raised spotted seatrout juveniles on a dietary sequence of rotifers, brine shrimp nauplii, and dry feeds, and obtained feed conversions of 0.78 to 1.55. McGeachin and Stickney (1977) and Porter and Maciorowski (1984) experimented with algae-fed brine shrimp nauplii as a food source for larval and fingerling spotted seatrout.

Survival, growth, and production of larval and juvenile spotted seatrout have been evaluated in reference to different factors. Taniguchi (1980, 1981) and Houde and Taniguchi (1982) documented growth of spotted seatrout larvae in relation to temperature, prey species, and abundance, and with stocking densities in the laboratory. Arnold et al. (1976) noted that brood fish were often injured or killed because of handling and injections, but that the major limiting factor in mass production of spotted seatrout was the low larval survival rates caused by cannibalism and lack of a proper food supply. In pond culture trials, Colura et al. (1990a) obtained an overall return rate of 32 % and suggested that spotted seatrout culture methods are sufficiently advanced to allow hatchery scale fingerling culture. Colura et al. (1992) examined 28 independent variables associated with stocking density, water quality, length of culture period, fertilization, zooplankton densities, and production, and determined that polychaete larvae density was the most important statistical factor associated with the production of spotted seatrout from larvae to 30 mm TL fingerlings. Lasswell and Garza (1977) were unable to successfully rear spotted seatrout larvae for freshwater acclimation and later introduction into heated Texas reservoirs. Colura et al. (1990a) recommended that spotted seatrout pond culture be limited to periods when salinity is above 16 ppt, and that identification of optimum stocking rates should provide overall fingerling yields and production values comparable to those for red drum. Sacket et al. (1979) reported a natural spawn in a 0.25 acre pond and an average growth rate of 75.6 mm in 65 d, before freezing temperatures caused a complete mortality. Age-linked patterns of salinity acclimation were demonstrated in spotted seatrout larvae from eggs spawned in brackish and hypersaline waters (Banks et al. 1991).

Procarione et al. (1988) developed morphometric techniques for identifying stocked fingerlings of spotted seatrout, orangemouth corvina (Cynoscion xanthulus), and their hybrids.

3.2.4 Economics

Dockside values are usually used in economic analyses of commercial fisheries. However, using dockside values for analysis of the spotted seatrout fishery will not measure its total benefit to society. Anderson (1980) stressed the relevance of increased job satisfaction that commercial fishermen might receive from fishing as compared to them pursuing other occupations. Commercial fishermen may accept lower pay and more uncertain benefits to remain within their chosen occupation.

Most gears used in the commercial spotted seatrout fishery can be utilized for harvest of other inshore species. While most commercial fishermen are probably involved in harvesting several different inshore species throughout the year, income derived from spotted seatrout fishing may be important in keeping these same fishermen in the industry (Williams et al. 1980).

Economic data associated with Louisiana's commercial landings of spotted seatrout for 1975-93 is contained in Table 3.6. Dockside price-per-pound has increased under $0.50 per pound before 1977, to more than $0.80 since 1981, and to more than $1.00 since 1989. Except for 1990, deflated prices have decreased from 1984 and 1985 levels. Several factors may have influenced dockside prices. First, the commercial spotted seatrout fishery was placed under a quota in September 1987. Second, the expansion of other fisheries, such as red drum, black drum, tuna, and swordfish may have increased competition within the fresh fish outlets (i.e., restaurants and retail dealers) through which spotted seatrout have historically been marketed.

Landings generally fluctuated in the 0.6 - 1.9 million lb range. The value of annual landings increased from the mid-1970s to highs of over $1.6 million in 1986 and 1987 (Table 3.6). Increases in price and resulting total values were probably due to inflation in early years. However, implementation of the quota system in 1987 reduced the deflated total value of the fishery because of decreased landings.

Since spotted seatrout is only one component of Louisiana's inshore commercial fisheries, it is important to identify what losses in commercial harvesting revenues would result from a decline in commercial catches of spotted seatrout. Overall industry revenues may not decline proportionately with declining spotted seatrout landings because commercial inshore fishermen can redirect effort to other species. Thunberg et al. (1990) concluded that restrictions on red drum harvest led to only a moderate decline in revenues from Florida's nearshore fishery because fishermen were able to redirect effort to other nearshore species. Caution should be exercised in extrapolating these results to Louisiana. Furthermore, the ability to redirect commercial effort will become increasingly limited as additional restrictions are placed on a greater array of species.

3.3 Recreational Fishery

3.3.1 Description of Fishing Activities

The spotted seatrout is the most frequently targeted species of recreational anglers in the Gulf coast region and has contributed a substantial percentage (8%-15%) of the recreational landings in the northern Gulf of Mexico (Current Fishery Statistics 1987). Spotted seatrout makes up 15%-25% and 15%-60% of the total recreational catch in Louisiana and the northern Gulf coast region, respectively (Wieting 1989). Spotted seatrout was the most targeted species from May to

August while red drum was most popular the remainder of the year (Adkins et al. 1990). By area fished, percentages of fishermen who expressed a preference for spotted seatrout were 77.6% (beach), lake and bay (54.6%), pass (51.9%), gulf (35.4%), and marsh (30%).

Adkins et al. (1990) found that spotted seatrout was the preferred species of 63.8% of Louisiana saltwater anglers. From mail surveys in 1989, 1990, and 1993, Kelso et al. (1991, 1992, 1994) indicated that 76%, 87% and 60% of Louisiana saltwater anglers fished for a particular species during their fishing trips, with spotted seatrout accounting for 50%, 52%, and 56% of first-choice responses.

Surveys characterizing Louisiana marine recreational fishermen include those of Stern and Schafer (1966), Juneau and Pollard (1981), Bertrand (1984), Adkins et al. (1990), Guillory and Hutton (1990), Stanley and Wilson (1990), Kelso et al. (1991, 1992, 1994), and the MRFSS from 1979 to the present.

Fishermen targeting spotted seatrout utilize a variety of baits, tackle, techniques, and fishing modes. Spotted seatrout are caught while bottom fishing, jigging, trolling, or casting from beaches, banks, piers, and boats, during day and night. Most fishermen use a variety of artificial jigs, spoons, and plugs, while natural baits including live and dead penaeid shrimp, Atlantic croaker, gulf menhaden, and cyprinodonts (Fundulus spp.) are also used. Both rod-and-reel combinations and cane-poles are used. Spotted seatrout were also harvested by fishermen using licensed recreational saltwater gillnets, trammel nets, and seines from 1 January, 1987, through 7 July, 1988 (personal communication; Debbie Thornton, LDWF License Section), although no harvest figures are available.

The primary mode of fishing for spotted seatrout is by boat, although surf fishing is seasonally important; and bank and pier fishermen are fairly common in localized areas. Bank and pier fishing is less common in Louisiana than in other states due to the difficulties involved in reaching fishing areas in the coastal marshes. According to the MRFSS, no less than 83% of the total recreational catch in any given year from 1979 to 1989 was from boat fishermen. Kelso et al. (1991) indicated that 82% of Louisiana saltwater anglers used boats. The U.S. Fish and Wildlife Service (1989), however, found that catches from the surf, shore, bridges, and piers made up 43.8% of the total saltwater catch. There are also some indications of geographic differences, with bank fishermen most numerous in the central and western parts of the state, while boat fishing was most popular in the central and southeastern part (Gulf South Research Institute 1986).

Fishermen that targeted spotted seatrout, overwhelmingly preferred fishing beach habitats, followed by lake - bay, pass, gulf, and marsh habitats; however, charter-boat fishermen fished primarily around petroleum platforms or barrier island beaches (Adkins et al. 1990). Highest catches were made in beach habitats, followed by catches from pass, lake - bay, marsh and gulf habitats (Adkins et al. 1990). Stanley and Wilson (1990) found that red snapper and spotted seatrout had the highest catch rates around offshore petroleum platforms. Catches of spotted seatrout, according to the MRFSS, were approximately equal from "inshore" and "less than 3 miles out" areas. Although no single area dominated consistently, the area "less than 3 miles out" usually had the largest percentage of catch.

Overall catch rates of spotted seatrout per hour, by area, are lower Barataria Bay -- 1.08 (Guillory and Hutton 1990); Vermilion Bay -- 0.38 (Juneau and Pollard 1981); Lake Borgne estuary and Chandeleur Sound -- 0.53; Breton Sound and estuary -- 0.37; Barataria Bay -- 0.21; Terrebonne and Timbalier bays -- 0.51; Bayou Sale to Point au Fer Island -- 0.28; Point au Fer Island to Freshwater Bayou -- 0.11; and, Freshwater Bayou to Sabine Lake -- 0.04 (Adkins et al. 1990).

Seasonally, highest catch rates of spotted seatrout were recorded during summer and fall (Perret et al. 1980; Guillory and Hutton 1990). In a survey conducted the year after a substantial freeze (1984), Adkins et al. (1990) found catch rates for spotted seatrout between 0.07-0.16 per hour during January to May, 0.29-0.43 per hour during June to September, and 0.46-0.58 per hour during October to December. Largest spotted seatrout were taken in spring, followed by those in winter, fall, and summer, and the largest were from gulf habitats, followed by those from beach, lake - bay, and marsh habitats. Kelso et al. (1992) reported that May through September were the most popular months for saltwater fishing, accounting for 57% of the effort. Overall catch was highest in afternoons and on weekends (Adkins et al. 1990). Catches of spotted seatrout from the MRFSS were greatest during the spring, summer, and fall. The bimonthly percentages of total annual catch of spotted seatrout were 2.5%, January-February; 6.4%, March-April; 24.0%, May-June; 30.2%, July-August; 14.4%, September-October; and 22.4%, November-December.

Some information is available on the demographics of marine recreation fishermen in Louisiana. Gulf South Research Institute (1986) described the typical boat-fishermen as male, white, relatively affluent, and better-educated than the overall sample interviewed, while bank fishermen were less likely to be male, with an increased proportion of non-whites and with lower income levels. Data from Bertrand (1984), Kelso et al. (1992), and U. S. Fish and Wildlife Service (1993) supports the above generalizations. The percentage of anglers by age-group was tabulated by Kelso et al. (1992): 10-19, 1.6%; 20-29, 18.3%; 30-39, 33%; 40-49, 29.9%; 50-59, 14.3%; and over 60, 3.0%.

The Grand Isle area ranked as the most popular inshore fishing spot for Louisiana fishermen, accounting for 8% of first choice responses followed by the Terrebonne area (6%), Plaquemines (6%), Cameron (6%) and Jefferson (4%) (Kelso et al. 1992). Adkins et al. (1990) found that the greatest amount of fishing effort was east of the Mississippi River (46%), lowest in the central coast from Bayou Sale to Freshwater Bayou (9.1%), and intermediate in Barataria Bay, Terrebonne and Timbalier bays, and west Louisiana. These variations in fishing pressure were attributed to the relative size of each area, and proximity and population of major metropolitian areas such as New Orleans, Baton Rouge, Lafayette, and Lake Charles.

The all-tackle world record spotted seatrout is a 16-lb fish taken at Mason's Beach, Virginia, on 28 May, 1977 (International Game Fish Association 1987). Although larger spotted seatrout have been taken in some Gulf states, these records have not officially been noted for various reasons. The Louisiana state record is a 12-lb, 6 oz, fish taken in Lake Hermitage in May 1950 (Louisiana Outdoor Writers Association 1989).

Kelso et al. (1994) reported that of anglers who expressed an opinion regarding management alternatives, 75.1% preferred current regulations, but 15.9% preferred higher creel limits and a smaller minimum size, and 9.0% preferred reduced creel limits and a larger minimum size. Since the introduction in Louisiana of a minimum size for spotted seatrout those alleging catch-and-release results in high hooking-mortalities have attempted to have the minimum size reduced or removed entirely or to have legislated a special daily allowance of undersized fish. In Barataria Bay, Thomas et al. (1995) caught spotted seatrout over an 18-month period using a variety of methods. Methods included single hook with live bait (SHB), single hook with artificial lure (SHA), treble hook with live bait (THB) and treble hook with artificial lure (THA). Overall spotted seatrout survival while held in tanks over a 3-7 d period was 82.5% with survival dependent on fishing method: 74% (SHB), 83% (THB), 91% (SHA) and 97% (THA). Spotted seatrout smaller than the 12-in minimum recreational size limit had higher survival rates (87%) than larger fish (81%).

Additionally, earlier studies designed to estimate short-term survival of hook-caught spotted seatrout have been conducted in Florida (Ludwig et al. 1989) and Texas (Hegen et al. 1984; Matlock et al. 1993). Ludwig et al. (1989) found mortality rates of 45% for fish caught in nets and 5% for fish caught by angling. Spotted seatrout in Texas had survival rates of 62.8% ± 10% in the summer and 84.2% ± 5% in the winter (Hegen et al. 1984). Matlock et al. (1993) found an overall mortality rate of 7.3% and no significant differences among hook types or bait types.

3.3.2 Effort and Harvest

A historic review of implementation of size, possession, creel limits, and license requirements is provided for background information because these regulatory changes have influenced catches. Prior to 1976, the recreational fishery was largely unregulated except for a basic fishing license requirement. In chronological order, the following regulations were adopted:

1977 --Daily limit of a combined total of 50 red drum and spotted seatrout with an allowable two-day catch in possession.

1984 --Daily limit of a combined total of 50 red drum and spotted seatrout with a one-day catch in possession. Possession of a saltwater fishing license required for all anglers fishing south of the officially established "saltwater line" for saltwater species.

1987 --A 12-in minimum (total length) size limit.

1988 --Daily limit of 25 spotted seatrout with an allowable one-day catch in possession.

Several one-time marine recreational fishery surveys that include data on effort and harvest have been completed within Louisiana (Clark 1962; Stern and Schafer 1966; Deuel and Clark 1968;

Deuel 1973; Juneau and Pollard 1981, Bertrand 1984; Gulf South Research Institute 1986; U. S. Fish and Wildlife Service 1988; Titre et al. 1988; Adkins et al. 1990; Guillory and Hutton 1990; Stanley and Wilson 1990; Kelso et al. 1991, 1992, 1994; Rogers, unpublished). Although these data can be useful to characterize the recreational fishery, long term trend analysis is not possible for several reasons. First, some studies were restricted in scope and geographic area. Second, differences in methodology and statistical approach were present. Third, earlier statewide surveys (Clark 1962; Deuel and Clark 1968; Deuel 1973) tended to overestimate harvest and effort due to methods used to expand the estimates from the intercept part of their surveys. Data from the MRFSS survey conducted from 1981 to the present will be emphasized to characterize effort and harvest over time.

Another shortcoming of some recreational surveys is that telephone or mail surveys depend on the angler's ability to recall the number of trips and catch over a one-year period; angler recall errors tend to bias values in an upward direction (Westat 1989). The species targeted or caught, if based on recall, tends to be biased toward the high-profile species such as spotted seatrout or red drum, and away from such species as black drum, Atlantic croaker, and sea catfish. These biases increase with the length of time for recall increases. More recent creel surveys, utilize shorter periods for their basis for expansion of effort to reduce these sources of bias (Ron Essig, NMFS, pers. comm.).

Annual Louisiana fishing effort directed toward spotted seatrout is a function of the total number of marine recreational anglers, number of fishing trips per angler, average length of fishing trip, average party size, and percentage of fishing trips dedicated to spotted seatrout.

Estimates of the numbers of saltwater fishermen differ, depending upon the source. Resident recreational license sales by the LDWF increased from 102,125 in 1984 (the first year) to 280,360 during the 1994-1995 license year (Table 3.7). Sales for the first year were low because purchase was not required until September of the first year, by which time the summer fishing season was completed. Sales also lagged in the second year. Resident license sales from 1990-91 through 1994-95 averaged approximately 245,000. If it is assumed that fishermen not required to purchase a license (ie., those less than 16 or over 59 years of age, or disabled) comprise 50% of the total, then the estimated total number of resident salt-water fishermen would presently be approximately 350,000. In addition, the number of non-resident saltwater licenses have averaged about 34,750 during the 1990's (Table 3.7); the total number of non-resident saltwater anglers would be greater because individuals under sixteen years of age are exempt. The total number of licensed and unlicensed resident and non-resident saltwater anglers may be close to 400,000.

MRFSS estimates of resident and non-resident Lousiana marine recreational anglers from 1987-1994 ranged from 442,000 in 1993 to 664,000 in 1987 and averaged 485,000 in the 1990s (Table 3.7). Differences in the number of licenses sold versus MRFSS estimates of angler numbers is not only due to license exemptions but also to methodological problems in angler estimations. Estimates of numbers of anglers by the MRFSS survey are derived from the reciprocal of the estimates of the numbers of trips and the avidity estimates, based on an annual participation question. Other published estimates of the number of saltwater fishermen include 150,000 in 1984 (Adkins et al. 1990); 179,512 in 1982 and 1983 (Bertrand 1984); 351,000 in 1985 (U. S. Fish and Wildlife Service 1989); 681,509 in 1985 (Gulf South Research Institute 1986); and 240,000 in 1991 (U. S. Fish and Wildlife Service 1993) (Table 3.8).

The estimated number of annual fishing trips or days fished per fishermen ranged from 9-22.3 trips and from 8.3-22.6 d (Table 3.8). Estimates from Bertrand (1984) and Gulf South Research Institute (1986), are especially high, and may indicate that some mail or phone surveys that are based on recall do not accurately reflect past fishing effort. The number of fishing trips per year is probably in the range of 7-10 trips, with the number of days somewhat higher at 8-12 d.

Average party size was estimated at 3.3 (Bertrand 1984), 2.5 (Titre et al. 1988), and 2.5 (Adkins et al. 1990) (Table 3.8). Average trip durations for marine anglers were 1.2 d (U. S. Fish and Wildlife Service 1993), 1.4 d (Bertrand 1984; U. S. Fish and Wildlife Service 1989), and 1.6 d (Titre et al. 1988) while the hours fished per day were estimated at 5.4 h (U. S. Fish and Wildlife Service 1989) and 5.3 h (Adkins et al. 1990) (Table 3.8).

Estimates of saltwater recreational fishing effort in Louisiana have been measured by number of fishing trips or number of days fished (Table 3.8). Estimates of the total number of saltwater fishing trips ranged from 2.08 (Bertrand 1984) to 2.12 millon d (U. S. Fish and Wildlife Service 1993) while MRFSS data indicates that the number of fishing trips ranged from 1.358 million in 1981 to 3.029 million in 1986 and averaged 2.386 million during the 1990s. The number of trip estimates from Bertrand (1984) for a small portion of the coast and Gulf South Research Institute (1986) statewide are probably overestimated. Titre et al. (1988) estimated that about .7 million saltwater fishing trips were taken in the delta marsh region of south Louisiana during the December 1985 to December 1986 period; extrapolation of this value over the entire state would not approach the 3 million trips estimated by MRFSS for the same time. The 1984 LDWF access point creel survey (Adkins et al. 1990) estimated an adjusted effort estimate of 1.35 million user days; they cautioned that their estimate was probably low because a severe coastwide fish kill in late 1983 reduced fishing effort, and the creel design did not include or underestimated fishermen from camps, private launches, and banks and shore. [standardization of numbers presentation is needed]

Estimates of the total number of days spent fishing in saltwater in Louisiana included 0.27 million d (Adkins et al. 1990), 2.93 million d (U. S. Fish and Wildlife Service 1989), and 2.01 million d (U. S. Fish and Wildlife Service 1993).

Most targeted angling by Louisiana saltwater anglers is directed toward spotted seatrout and red drum, but many anglers target no specific species. According to the MRFSS, fishermen who targeted no specific species made up the highest annual percentages (43.4%-58.7%) of all anglers, each year from 1980 through 1985. Percentage of fishermen targeting spotted seatrout ranged from 12.8% in 1983 to 59.1% in 1991 and averaged 18.6% from 1980 through 1989, but 54.1% from 1990-1994. Other studies have shown that spotted seatrout is the primary target species -- 63.8% of anglers according to Adkins et al. (1990) and 50% according to Kelso et al. (1991).

Bertrand (1984) showed that 9.3% of anglers preferred spotted seatrout only, 53.8% both spotted seatrout and red drum, and an additional 10.9% also included black drum. The U. S. Fish and Wildlife Service (1993) estimated that 123,900 anglers, or 51.6% of total anglers, fished for seatrout in Louisiana in 1991.

The MRFSS estimates of species preferences are derived directly from the intercept portion of the data set and may be biased for several reasons: a) the increased chance of interception experienced by frequent anglers, which would bias the estimate in an upward direction; b) the tendency for anglers to report target species as that which was caught, and to report "prestige" species as targets; and, c) the intercept design is biased toward frequency of use, so that larger numbers of interviews are taken during times of greater fishing pressure.

The number of "seatrout" fishermen in Louisiana for 1991 was estimated at 123,900 (U. S. Fish and Wildlife and Service 1993). A rough estimate of 200,000-240,000 Louisiana spotted seatrout fishermen can also be derived by assuming that half of the previously estimated 400,000 (LDWF license sales) and 485,000 (MRFSS) saltwater anglers fish for spotted seatrout.

The U. S. Fish and Wildlife Service (1993) found that 52.1% of the Louisiana fishing effort, or 1.36 million d were devoted to "seatrout" in 1991. Fishing trips that targeted spotted seatrout, according to the MRFSS, increased from 380,326 in 1981 to 1,427,318 in 1994 (Table 3.9). This increase can be attributed to both an increase in numbers of saltwater anglers and in percentage of anglers targeting spotted seatrout. Targeted effort averaged 1.3 million trips during the 1990s.

Several sources substantiated that the recreational catch of spotted seatrout in Louisiana yielded up to 93% of the total harvest (Table 3.10). Annual estimates of recreational harvest ranged between 2.1 and 23.5 million lb with the greatest harvest in 1975. Louisiana recreational spotted seatrout catch, harvest, and effort data according to the MRFSS from 1981 to 1994 are tabulated in Table 3.9. Recreational harvest of spotted seatrout by number of fish ranged from 1.99 million in 1981 to 9.55 million in 1986. Harvest of spotted seatrout during the 1990s averaged 5.272 million fish weighing 5.725 million lb.

Annual spotted seatrout catch per trip from 1981 to 1994 is given in (Table 3.9). Highest annual catch rates were obtained in 1982 and 1983, when 11.0 fish per trip were harvested. If these 2 years are disregarded, then no long term trend is discernable.

Length frequency histograms of spotted seatrout were compared for the 1980-87 and 1988-94 periods to contrast recreational catch before and after implementation of a 12-in TL minimum size limit in 1987 (Figure 3.3). The percentage of spotted seatrout smaller than 13-in TL was 56% prior to 1988 and 31% after 1987. For the pre-regulation and post-regulation years, 32% and 44% of the total catch, respectively, were 13-in or larger.

Average weight of recreationally caught spotted seatrout in Louisiana is given in Table 3.9. Average weight declined during the 1985-1987 period, but increased after implementation of the minimum size limit.

3.3.3 Economics

Measures of species specific effort and expenditures by spotted seatrout recreational fishermen are central to the estimation of the economic value of the fishery. Available data on total numbers of recreational fishermen, percentage of fishermen targeting the species, average number of fishing trips per year, and expenditures per trip are highly variable between studies, even over the same time period. Conclusions drawn from these data should therefore be viewed as tentative.

Recreational fishing effort depends primarily upon the number of fishermen and number of trips per fisherman. Individual fishing effort is largely a function of the expenses incurred in the activity and the perceived benefits of the activity. As costs rise and benefits remain the same, effort tends to decrease. Anglers can receive both tangible and intangible benefits from fishing activities. Tangible benefits include the number or quality of fish caught. Intangible benefits can include enjoyment of the outdoors, change in routine, and companionship.

Fishing effort will continue as long as the economic costs are not greater than the angling satisfaction (or what economists call utility). Fishing net benefits (satisfication minus cost) may decline due to satiation, declining catch per angler, congestion in favored fishing locations, degradation of aesthetic value of wetland areas, or from increased fishing costs.

Direct expenditures per trip for marine recreational anglers in Louisiana were estimated at $53 (Kelso et al. 1992), $64 (Bertrand 1984), $75 (Kelso et al. 1991), and $133 (Titre et al. 1988) (Table 3.8). Direct expenditures include automotive and boat fuel, lodging, food and drinks, ice, boat launch fee, bait, and other expenses directly related to the trip. In addition to trip expenses, anglers purchase equipment (boats, motors, trailers, vehicles) and speciality gear that can be used for more than one trip or even for several years; costs of the latter gear need to be allocated over time. Published annual estimates of these expenses vary widely depending on what is included: $698 (U. S. Fish and Wildlife Service 1993), and $824 (Kelso et al. 1991), and $1108 (Kelso et al. 1992). All estimates were based on the ability of the respondents to recall average costs over the previous year. Consequently, these estimates may have been biased by the inadvertent overestimation or underestimation of expenses over the previous year.

Total expenditures by saltwater anglers in Louisiana was estimated at $180.6 million by Bertrand (1984) and can also be calculated from data provided by other surveys. From a 1985 survey, the U.S. Fish and Wildlife Service (1989) estimated that state residents spent a total of $197 million on saltwater fishing expenses, including equipment and trip-related expenses; non-resident anglers spent an estimated $37.6 million in trip-related expenses in Louisiana. If non-resident expenditures are partitioned in the same proportions as they are for residents, this yields total saltwater fishing expenses of $210 million. From the next survey in 1991, the U.S. Fish and Wildlife Service (1993) estimated expenditures of $158.8 million by state residents on saltwater angling. If the ratio of non-resident to resident expenditures is the same as in 1985, then the total saltwater fishing expenditures in 1991 would have been $167.7 million.

Saltwater expenditures can be allocated to spotted seatrout by using the percentage of fishing trips devoted to the species. According to the MRFSS, 54% of marine fishing effort in Louisiana from 1990 to 1994 targeted spotted seatrout. If approximately $170 to $175 million are expended annually on marine recreational fishing, then direct expenditures among those anglers targeting spotted seatrout would be approximately $90 to $95 million.

While direct expenditures represent an important facet in evaluation of recreational saltwater fishing, they have limited economic importance in policy analysis. Using direct expenditures does not fully describe the perceived value of recreational activities. Anglers who take a recreational fishing trip to Louisiana's wetlands receive more recreational benefits than just the fishing. For instance, they observe wildlife, and enjoy the time outside with companions.

Direct expenditures for the fishing trip may be less than the angler would be willing-to-pay for the whole experience. The difference between direct expenditures and what the angler is willing-to-pay is called the consumer's surplus, which is a measure of the value that the angler receives for benefits other than the fishing activity. Titre et al. (1988) found that the average recreational user would be willing-to-pay approximately $320 to $360 annually for the right to recreate in Louisiana wetlands under current conditions of harvest, catch, and amenity situations. This $320 to $360 represents an estimate of the consumer's surplus and when added to direct expenditures, provides a total economic value for an angler's trip.

Willingness-to-pay may be best estimated from participation changes occurring with cost and harvest changes (Dr. Trellis Green, University of Southern Mississippi, personal communication). While such analysis is beyond the scope of this report and data required for the assessment may not be available, such an estimation would be extremely valuable to personnel involved in management of the fishery. According to MRFSS data, there were direct relationships between the percentage of saltwater anglers targeting spotted seatrout, and both harvest (retained catch) and total catch of the species. In addition, the correlation coefficient is greater when catch rather than harvest is considered. The increase in correlation is mainly due to increased release rates in the 1987- 1989 period, after adoption of a minimum size regulation. These relationships should be viewed with caution because of the abnormally high catch and harvest rates for this period. However, they suggest that harvest rates alone may or may not be sufficient to explain angler satisfaction if catch rates remain within some acceptable range.

Estimated reduction in annual willingness-to-pay for wetland use in Louisiana associated with a reduction in daily saltwater catch was relatively small, even with relatively large reductions in catch (Titre et al. 1988). For instance, 50% and 75% reduction in catch rates led to reductions in annual willingness-to-pay rates of $38 and $56, respectively. Saltwater fishermen reported that their decision to fish or not was not affected greatly by a reduction in mean daily catch. There was a reduction of approximately 2 d from the 10.8 d per year (6.78 trips at 1.59 d per trip) when the mean daily saltwater fish catch was reduced by 75%. Data, however, from the MRFSS survey suggests a much higher reduction. In 1984, when the freeze of 1983 made fish scarce, the MRFSS reported a 40% reduction in number of trips from the prior four-year average, a value much higher than predicted by Titre et al. (1988). Fish catch in 1984 was reduced by 58% over the average of the previous 4 years.

Findings from Titre et al. (1988) can be directly applied to spotted seatrout catch scenarios only if spotted seatrout anglers behave similarly to the "average" fisherman described in their study. The findings do suggest, however, that the harvest level of a species may not completely determine the magnitude of economic activities associated with that species. The relatively low reduction in willingness-to-pay, if valid, implies that activity would continue at a rate only somewhat lower than at high harvest rates even with a substantial reduction in harvest.

Table 3.1.Gulf of Mexico commercial spotted seatrout landings in 1000 lbs, 1880 to 1995. (Source=National Marine Fisheries Service; includes white and sand seatrout from 1880 to 1965)

Year	Florida West Coast	Alabama	Mississippi	Louisiana	Texas	Total
1880	(*)	(*)	(*)	(*)	(*)	(*)
1887	(*)	(*)	258	524	941	(*)
1888	511	228	280	522	872	2,413
1889	517	205	370	619	1,077	2,788
1890	551	209	372	656	1,120	2,908
1897	830	296	453	567	1,012	3,158
1902	1,859	259	473	1,078	1,119	4,788
1908	1,207	208	517	1,103	1,055	4,090
1918	1,694	139	356	1,190	1,613	4,992
1923	1,590	49	410	783	1,524	4,356
1927	2,583	118	605	822	1,700	5,823
1928	2,682	125	487	885	1,160	5,339
1929	2,942	128	384	513	1,178	5,145
1930	2,722	113	232	710	1,043	4,820
1931	2,414	109	216	767	1,084	4,590
1932	2,150	109	227	633	976	4,095
1934	2,337	145	300	1,518	2,462	6,762
1936	3,483	118	293	1,037	1,836	6,767
1937	2,765	168	373	987	2,109	6,402
1938	2,917	124	284	539	2,083	5,947
1939	2,997	128	249	716	1,485	5,575
1940	3,263	167	131	262	755	4,580
1945	3,859	581	301	917	1,720	7,378
1948	(*)	396	158	503	593	(*)
1949	4,558	218	197	886	630	6,489
1950	3,214	87	115	882	584	4,882
1951	3,332	104	182	602	434	4,654
1952	3,472	146	529	602	479	5,228
1953	2,614	133	900	535	585	4,767
1954	2,298	106	1,480	437	670	4,991
1955	2,046	156	2,021	510	843	5,576
1956	2,059	113	1,441	612	835	5,060
1957	2,562	72	274	641	899	4,448
1958	3,010	70	336	654	1,158	5,228
1959	2,825	112	322	691	1,109	5,059
1960	2,643	62	143	467	1,283	4,798
1961	2,633	115	241	619	1,117	4,725
1962	2,682	100	176	424	989	4,371
1963	2,639	132	148	460	1,190	4,569
1964	2,842	130	174	356	978	4,480
1965	3,539	162	175	458	1,176	5,511
1966	3,174	47	145	647	1,508	5,521

Table 3.1. Cont'd.

Year	Florida West Coast	Alabama	Mississippi	Louisiana	Texas	Total
1967	2,637	91	171	621	1,521	5,041
1968	3,065	101	268	619	1,871	5,924
1969	2,419	98	221	720	1,173	4,631
1970	2,643	84	255	786	1,157	4,925
1971	1,961	137	393	1,122	1,487	5,100
1972	2,140	220	255	1,700	1,499	5,814
1973	2,226	351	366	2,528	1,969	7,440
1974	2,260	364	295	2,125	1,996	7,040
1975	2,169	104	263	1,697	1,814	6,247
1976	2,282	43	177	1,611	1,769	5,882
1977	1,600	22	147	1,804	1,347	4,200
1978	1,800	32	106	682	1,162	3,782
1979	2,086	74	109	798	1,030	4,097
1980	1,956	26	27	604	978	3,591
1981	1,963	27	90	587	646	3,232
1982	2,099	62	17	728	*	2,906
1983	1,870	59	54	1,341	*	3,324
1984	1,550	21	55	973	*	2,599
1985	1,731	4	47	1,161	*	2,943
1986	1,261	3	38	1,978	*	3,280
1987	1,345	3	57	1,802	*	3,207
1988	1,341	*	66	1,433	*	2,840
1989	1,361	*	78	1,489	*	2,928
1990	761	*	30	648	*	1,451
1991	829	*	31	1,220	*	2,132
1992	634	*	32	971	*	1,637
1993	545	*	NA	1,138	*	NA
1994	NA	*	NA	1,023	*	NA
1995	NA	*	NA	658	*	NA

(*) - None reported

* - Commercial sale prohibited

NA - Not available

Table 3.2. Louisiana commercial spotted seatrout landings (1000 lbs) by gear type (GN = gillnet; TN = trammel net; HS = haul seine; ST = shrimp trawl; OT = other, or handlines, purse seines, and butterfly nets), 1980 to 1989. (Source=National Marine Fisheries Service)

Years	GN	TN	HS	ST	OT
1980	224.6	377.0	0	0.2	2.3
1981	424.0	157.8	0	13.3	3.2
1982	471.8	218.8	9.6	2.4	26.4
1983	842.0	440.3	21.2	0.6	36.5
1984	454.6	496.3	0	0.3	22.0
1985	577.7	539.0	0.4	5.2	39.3
1986	1,189.3	680.0	24.4	6.2	77.0
1987	1,209.8	496.0	8.5	22.3	65.3
1988	1,196.5	170.0	2.0	61.1	13.6
1989	1,376.0	93.3	1.7	17.8	<0.1

Table 3.3. Louisiana commercial spotted seatrout landings (1000 lbs) by gear type (GN = gillnet, TN = trammel net, HS = haul seine; ST = shrimp trawl; OT = other, or handlines, purse seines, and butterfly nets) by month, 1980-1989. (Source = National Marine Fisheries Service)

Month	GN	TN	HS	ST	OT
Jan	98.3	46.6	2.5	1.1	2.9
Feb	61.8	32.2	1.0	0.1	0.7
Mar	52.3	25.6	0.8	0.4	1.3
Apr	74.8	34.5	0.4	0.1	2.4
May	92.2	44.9	0.3	0.3	3.8
Jun	59.2	27.8	<0.1	0.4	2.9
Jul	52.2	29.4	<0.1	1.7	2.7
Aug	27.4	15.3	<0.1	0.6	2.1
Sep	36.9	8.6	<0.1	1.0	0.6
Oct	60.2	20.2	0.1	2.4	1.5
Nov	73.7	26.8	<0.1	2.1	2.9
Dec	100.6	53.7	0.3	2.8	4.9

Table 3.4.Number of Louisiana resident commercial gear licenses, 1980 to 1994. (Source = Louisiana Department of Wildlife and Fisheries)

Year	Haul Seine	Trammel Net	Purse Seine	Gill Net	Handline/ Bottom Longline
1980	445	319	0	1,602	NA
1981	425	334	4	1,786	NA
1982	472	429	18	2,552	NA
1983	40	483	40	2,780	NA
1984	609	414	33	2,252	NA
1985	442	423	34	2,031	NA
1986	345	377	26	2,118	NA
1987	281	826	NA	3,271	NA
1988	236	605	NA	2,476	NA
1989	265	619	73	2,717	180
1990	257	594	71	2,565	NA
1991	249	536	63	2,645	NA
1992*	218	493	53	831	NA
1993	184	486	53	900	NA
1994	196	489	58	1,017	NA

* - Indicates first full year saltwater gillnet licenses issued (new license class)

NA - Not available

Table 3.5.Louisiana commercial spotted seatrout landings by area, 1973 to 1989. (Source = National Marine Fisheries Service)

YEAR	INSHORE TO BEACH POUNDS	INSHORE TO BEACH PERCENT	BEACH TO 3 MILES POUNDS	BEACH TO 3 MILES PERCENT	OUTSIDE 3 MILES POUNDS	OUTSIDE 3 MILES PERCENT
1973	2,524,764	99.1	2,259	.09	0	0.0
1974	2,122,076	99.1	2,400	0.1	0	0.0
1975	1,861,536	98.2	35,150	1.8	0	0.0
1976	1,598,800	99.2	12,405	0.8	0	0.0
1977	1,073,478	99.0	10,472	1.0	0	0.0
1978	682,016	100.0	0	0.0	0	0.0
1979	797,528	99.9	800	0.1	0	0.0
1980	604,255	100.0	0	0.0	0	0.0
1981	586,859	100.0	0	0.0	0	0.0
1982	727,606	100.0	0	0.0	0	0.0
1983	1,339,894	99.9	281	.02	0	0.0
1984	973,150	99.9	100	.01	0	0.0
1985	1,160,616	99.9	936	.08	46	.004
1986	1,978,038	100.0	0	0.0	0	0.0
1987	1,801,874	100.0	0	0.0	0	0.0
1988	1,366,877	94.7	42,829	3.0	33,702	2.3
1989	1,486,165	99.8	2,000	.13	713	.05

Table 3.6. Louisiana commercial spotted seatrout landings, values, and prices, 1975-1993. (Source = National Marine Fisheries Service; values deflated by dividing by 1982-84 base period Consumer Price Index)

Year	Landings (Pounds)	Current Value (Dollars)	Deflated Value (Dollars)	Current Price ($/lb.)	Deflated Price ($/lb.)
1975	1,896,686	695,978	1,293,639	0.37	0.69
1976	1,611,205	713,789	1,254,462	0.44	0.77
1977	1,083,950	527,712	870,812	0.49	0.81
1978	682,016	392,466	601,020	0.58	0.89
1979	798,328	566,470	781,338	0.71	0.98
1980	604,255	474,479	576,524	0.78	0.95
1981	586,859	567,795	623,265	0.97	1.06
1982	727,606	652,985	675,968	0.90	0.93
1983	1,340,625	1,219,915	1,223,586	0.91	0.91
1984	973,250	1,062,136	1,020,303	1.09	1.05
1985	1,161,598	1,255,982	1,165,104	1.08	1.00
1986	1,978,038	1,675,936	1,530,535	0.85	0.78
1987	1,801,874	1,604,978	1,180,131	0.89	0.78
1988	1,433,408	1,498,464	1,319,070	1.04	0.88
1989	1,488,878	1,389,716	1,175,733	0.93	0.75
1990	648,645	996,730	763,778	1.54	1.18
1991	1,220,231	1,511,935	1,110,084	1.24	0.91
1992	971,481	1,075,260	766,400	1.11	0.79
1993	1,138,070	1,274,101	881,731	1.12	0.78

Table 3.7. Number of Louisiana saltwater fishermen according to Louisiana Department of Wildlife and Fisheries license sales (1984-1985 to 1994-95 and Marine Recreational Fishermen Statistics Survey (MRFSS) estimates (1987 to 1994). (RES=residents, NR=non-residents, NA=not available)

License	Number of Licenses				MRFSS Estimates		
Year	RES	NR	TOTAL	Year	RES	NR	TOTAL
1984-1985	102,125	NA	102,125				
1985-1986	169,149	NA	169,149				
1986-1987	198,852	NA	198,852				
1987-1988	195,099	20,627	215,726	1987	608,000	56,000	664,000
1988-1989	204,686	14,107	218,793	1988	497,000	87,000	584,000
1989-1990	208,292	19,396	227,688	1989	393,000	52,000	445,000
1990-1991	206,088	27,900	233,988	1990	413,000	88,000	501,000
1991-1992	229,805	33,587	263,392	1991	471,000	80,000	551,000
1992-1993	245,942	39,591	285,543	1992	418,000	54,000	472,000
1993-1994	265,759	33,896	299,655	1993	387,000	55,000	442,000
1994-1995	280,360	35,397	315,757	1994	411,000	55,000	466,000

Table 3.8. Selected Louisiana marine recreational surveys providing summary data for statewide estimates of effort, harvest, and expenditures for marine anglers. [A=Bertrand (1984); B=Adkins et al. (1990); C=U. S. Fish and Wildlife Service (1989); D=Gulf South Research Institute (1986): E=Titre et al. (1988); G=U. S. Fish and Wildlife Service (1993); H=Kelso et al. (1991); I=Kelso et al. (1992); J=Marine Recreational Fishery Statistics Survey]

Survey Methodology

A=Telephone survey of saltwater anglers in Lafourche and Terrebonne Parishes in 1982 and 1983.
B=Coastwide access point creel survey in 1984.
C=Statewide telephone survey of anglers for 1985 data.
D=Statewide telephone survey of anglers for 1985 data.
E=Combination access point creel survey and mail survey of recreational users from Shell Beach to Cypremort Point.
G=Statewide telephone survey in 1991.
H=Statewide mail survey (9,602 mail-outs) of fishermen for 1989 data.
I=Statewide mail survey (7,362 mail-outs) of fishermen for 1990 data.
J=Statewide combination access point/telephone survey from 1990-1994.

Party Size

A=3.3; B=2.5; E=2.5.

Trips per Fishermen

A=16.8; C=5.9; D=22.3; E=6.8; G=8.8; J=4.9.

Trip (day) Duration

A=1.4 days; B=(5.3 hours); C=1.4 days and (5.4 hours); E=1.6 days; G=1.2 days.

Number of Fishermen

A=179,512; B=150,000; C=351,700; D=681,509; G=240,000; J=486,400.

Number of Spotted Seatrout Fishermen

G=123,900.

Total Fishing Trips/Year (Millions)

A=2.63; C=2.08; G=2.12; J=2.39.

Table 3.8. Cont'd.

Total Fishing Time (Hours or million days)

B=1,448,312 hours or 0.27 days; C=2.93 days; G=2.61 days.

Spotted Seatrout Effort/Year (Million of Trips or Days)

G=1.36 days; J=1.30 trips.

Expenditures

A=$64/trip; C=$680/year; E=$133/trip; G=$698/year; H=$75/trip, plus $824/year for gear and equipment; I=$53/trip, plus $1108/year for gear and equipment.

Total Expenditures (Million dollars)

A=$180.6; C=$210.0; G=$167.7.

Table. 3.9.Louisiana spotted seatrout recreational statistics, 1979-1994. (Source = Marine Recreational Fishery Statistics Survey; average weight in pounds=Avg Wt)

YEAR	Catch (1000's)	Harvest (1000's)	Harvest (1000 lbs)	Trip (1000's)	Number/ Trip	Avg. Wt.
1981	2,262	1,991	2,571	380	5.2	1.28
1982	7,882	6,799	6,923	617	11.0	1.02
1983	5,804	4,770	5,911	433	11.0	1.24
1984	1,528	1,404	2,344	368	3.8	1.67
1985	4,533	3,440	3,229	654	5.2	0.94
1986	11,938	9,555	9,066	1,482	6.4	0.95
1987	11,553	7,558	7,518	1,302	5.8	0.99
1988	8,716	4,906	6,271	1,472	3.3	1.28
1989	6,966	4,159	5,705	1,090	3.8	1.37
1990	4,211	2,286	2,668	876	2.6	1.17
1991	13,541	6,854	7,537	1,430	4.8	1.10
1992	11,075	6,008	6,389	1,462	4.1	1.06
1993	9,410	4,847	4,999	1,262	3.8	1.03
1994	11,372	6,366	7,034	1,472	4.3	1.10

Table 3.10. Comparison of recreational and commercial harvests of spotted seatrout from various survey sources (Adapted from Adkins et al., 1979; LWFC = Louisiana Wildlife and Fisheries Commission, NMFS = National Marine Fisheries Service, USFWS = U. S. Fish and Wildlife Service, LDWF = Louisiana Department of Wildlife and Fisheries)

Year		Harvest (pounds)	Percent	Source
1964	Recreational	2,131,738	88	LWFC
	Commercial	290,500	12	NMFS
1965	Recreational	4,865,115	92	USFWS
	Commercial	398,200	8	NMFS
1970	Recreational	10,410,585	93	NMFS
	Recreational	7,827,688	91	USFWS
	Commercial	786,300	7/9	NMFS
1975	Recreational	12,127,500	86	LWFC
	Recreational	23,545,119	93	NMFS
	Commercial	1,896,686	14/7	NMFS
	Commercial	1,621,348	---	LWFC
1984	Recreational	2,265,820		Adkins et al. (1990)
1990	Recreational	1,903,037*	66	NMFS
	Commercial	973,300	30/34	NMFS

* Estimated weight of type A (available for identification) fish only.

Figure 3.1. Commercial landings by zone

Figure 3.2. Commercial pre- and post-quota landings

Figure 3.3. Recreational length frequency histograms

(Pages 76-78)

4.0 RESEARCH NEEDS

The general biology and ecology of spotted seatrout is fairly well described in the literature. However, there are some specific areas that are not well known in Louisiana. Additional information on size at age of fish over 4-years and those less than 1-year are critical for the development of accurate sex-specific growth curves. A maturity schedule is necessary to develop more accurate estimates of spawning stock biomass.

Needed fishery dependent data includes more accurate estimates of harvest, sex ratios of the catch, and annual gear-specific length-frequency data. The inclusion of data on sex ratio of the catch would allow better estimation of spawning biomass and sex-specific mortality rates. Other harvest data are necessary to identify factors influencing recruitment and survival, and to predict future fishing success. Prediction of fishing success may not be required for management purposes, but it is ancillary to the information on survival, which may be very important in estimating the effects of environmental or habitat perturbations on the stocks. Such information is also essential to verify estimates of population parameters derived from fishery-dependant sources.

Information on the economic structure of the fisheries is either not available, or has broad confidence limits. Milon (1989) describes the information necessary to properly describe the economics of a recreational fishery. A broader base of socioeconomic information on the fishermen would allow a better description of the user groups. Critical information on response of fishermen to variation in catch, both species-specific and overall (elasticity of demand), is still sparse and inconsistent. Estimates of costs associated with various modes of fishing, and the socio-economic profiles of fishermen within these modes are needed. A comparison of predictions of economic models with actual reaction of the fishermen to changes in regulation or stock abundance would be valuable. The importance of non-tangible factors on the recreational angler should be evaluated by type of fisherman. Willingness-to-pay and trip and equipment cost estimates for these angler groups should be a high priority.

Economic surveys of the commercial fishery should concentrate on the importance of various income sources to fishermen, and the flexibility of the fishermen in various areas and various fisheries to shift to other income sources with changes in the availability of a species. Such measures are necessary in order to properly evaluate the effects of regulation on these fisheries. Fine-scale data such as catch per effort by trip, gear, trip length, prices, costs, are needed.

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